Red Hat

Red Hat Data Grid 7.3

Red Hat Data Grid User Guide

For use with Red Hat Data Grid 7.3

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For use with Red Hat Data Grid 7.3

Abstract

This guide describes the administration and configuration of Red Hat Data Grid 7.3.

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CHAPTER 1. INTRODUCTION

Welcome to the official Red Hat Data Grid User Guide. This comprehensive document will guide you through every last detail of Red Hat Data Grid.

1.1. WHAT IS RED HAT DATA GRID ?

Red Hat Data Grid is a distributed in-memory key/value data store with optional schema. It can be used both as an embedded Java library and as a language-independent service accessed remotely over a variety of protocols (Hot Rod, REST, and Memcached). It offers advanced functionality such as transactions, events, querying and distributed processing as well as numerous integrations with frameworks such as the JCache API standard, CDI, Hibernate, WildFly, Spring Cache, Spring Session, Lucene, Spark and Hadoop.

1.2. WHY USE RED HAT DATA GRID ?

1.2.1. As a local cache

The primary use for Red Hat Data Grid is to provide a fast in-memory cache of frequently accessed data. Suppose you have a slow data source (database, web service, text file, etc): you could load some or all of that data in memory so that it’s just a memory access away from your code. Using Red Hat Data Grid is better than using a simple ConcurrentHashMap, since it has additional useful features such as expiration and eviction.

1.2.2. As a clustered cache

If your data doesn’t fit in a single node, or you want to invalidate entries across multiple instances of your application, Red Hat Data Grid can scale horizontally to several hundred nodes.

1.2.3. As a clustering building block for your applications

If you need to make your application cluster-aware, integrate Red Hat Data Grid and get access to features like topology change notifications, cluster communication and clustered execution.

1.2.4. As a remote cache

If you want to be able to scale your caching layer independently from your application, or you need to make your data available to different applications, possibly even using different languages / platforms, use Red Hat Data Grid Server and its various clients.

1.2.5. As a data grid

Data you place in Red Hat Data Grid doesn’t have to be temporary: use Red Hat Data Grid as your primary store and use its powerful features such as transactions, notifications, queries, distributed execution, distributed streams, analytics to process data quickly.

1.2.6. As a geographical backup for your data

Red Hat Data Grid supports replication between clusters, allowing you to backup your data across geographically remote sites.

CHAPTER 2. THE EMBEDDED CACHEMANAGER

The CacheManager is Red Hat Data Grid's main entry point. You use a CacheManager to

- configure and obtain caches
- manage and monitor your nodes
- execute code across a cluster
- more...

Depending on whether you are embedding Red Hat Data Grid in your application or you are using it remotely, you will be dealing with either an **EmbeddedCacheManager** or a **RemoteCacheManager**. While they share some methods and properties, be aware that there are semantic differences between them. The following chapters focus mostly on the *embedded* implementation. For details on the *remote* implementation refer to Hot Rod Java Client .

CacheManagers are heavyweight objects, and we foresee no more than one CacheManager being used per JVM (unless specific setups require more than one; but either way, this would be a minimal and finite number of instances).

The simplest way to create a CacheManager is:

```
EmbeddedCacheManager manager = new DefaultCacheManager();
```

which starts the most basic, local mode, non-clustered cache manager with no caches. CacheManagers have a lifecycle and the default constructors also call start(). Overloaded versions of the constructors are available, that do not start the CacheManager, although keep in mind that CacheManagers need to be started before they can be used to create Cache instances.

Once constructed, CacheManagers should be made available to any component that require to interact with it via some form of application-wide scope such as JNDI, a ServletContext or via some other mechanism such as an IoC container.

When you are done with a CacheManager, you must stop it so that it can release its resources:

```
manager.stop();
```

This will ensure all caches within its scope are properly stopped, thread pools are shutdown. If the CacheManager was clustered it will also leave the cluster gracefully.

2.1. CONFIGURATION

Red Hat Data Grid offers both declarative and programmatic configuration.

2.1.1. Configuring caches declaratively

Declarative configuration comes in a form of XML document that adheres to a provided Red Hat Data Grid configuration XML schema.

Every aspect of Red Hat Data Grid that can be configured declaratively can also be configured programmatically. In fact, declarative configuration, behind the scenes, invokes the programmatic configuration API as the XML configuration file is being processed. One can even use a combination of these approaches. For example, you can read static XML configuration files and at runtime programmatically tune that same configuration. Or you can use a certain static configuration defined in XML as a starting point or template for defining additional configurations in runtime.

There are two main configuration abstractions in Red Hat Data Grid: **global** and **cache**.

Global configuration

Global configuration defines global settings shared among all cache instances created by a single EmbeddedCacheManager. Shared resources like thread pools, serialization/marshalling settings, transport and network settings, JMX domains are all part of global configuration.

Cache configuration

Cache configuration is specific to the actual caching domain itself: it specifies eviction, locking, transaction, clustering, persistence etc. You can specify as many named cache configurations as you need. One of these caches can be indicated as the **default** cache, which is the cache returned by the **CacheManager.getCache()** API, whereas other named caches are retrieved via the **CacheManager.getCache(String name)** API.

Whenever they are specified, named caches inherit settings from the default cache while additional behavior can be specified or overridden. Red Hat Data Grid also provides a very flexible inheritance mechanism, where you can define a hierarchy of configuration templates, allowing multiple caches to share the same settings, or overriding specific parameters as necessary.

NOTE

Embedded and Server configuration use different schemas, but we strive to maintain them as compatible as possible so that you can easily migrate between the two.

One of the major goals of Red Hat Data Grid is to aim for zero configuration. A simple XML configuration file containing nothing more than a single infinispan element is enough to get you started. The configuration file listed below provides sensible defaults and is perfectly valid.

infinispan.xml

```
<infinispan />
```

However, that would only give you the most basic, local mode, non-clustered cache manager with no caches. Non-basic configurations are very likely to use customized global and default cache elements.

Declarative configuration is the most common approach to configuring Red Hat Data Grid cache instances. In order to read XML configuration files one would typically construct an instance of DefaultCacheManager by pointing to an XML file containing Red Hat Data Grid configuration. Once the configuration file is read you can obtain reference to the default cache instance.

```
EmbeddedCacheManager manager = new DefaultCacheManager("my-config-file.xml");
Cache defaultCache = manager.getCache();
```

or any other named instance specified in **my-config-file.xml**.

```
Cache someNamedCache = manager.getCache("someNamedCache");
```

The name of the default cache is defined in the **<cache-container>** element of the XML configuration file, and additional caches can be configured using the **<local-cache>**,**<distributed-cache>**,**<invalidation-cache>** or **<replicated-cache>** elements.

The following example shows the simplest possible configuration for each of the cache types supported by Red Hat Data Grid:

```xml
<infinispan>
  <cache-container default-cache="local">
    <transport cluster="mycluster"/>
    <local-cache name="local"/>
    <invalidation-cache name="invalidation" mode="SYNC"/>
    <replicated-cache name="repl-sync" mode="SYNC"/>
    <distributed-cache name="dist-sync" mode="SYNC"/>
  </cache-container>
</infinispan>
```

2.1.1.1. Cache configuration templates

As mentioned above, Red Hat Data Grid supports the notion of *configuration templates*. These are full or partial configuration declarations which can be shared among multiple caches or as the basis for more complex configurations.

The following example shows how a configuration named **local-template** is used to define a cache named **local**.

```xml
<infinispan>
  <cache-container default-cache="local">
    <!-- template configurations -->
    <local-cache-configuration name="local-template">
      <expiration interval="10000" lifespan="10" max-idle="10"/>
    </local-cache-configuration>

    <!-- cache definitions -->
    <local-cache name="local" configuration="local-template" />
  </cache-container>
</infinispan>
```

Templates can inherit from previously defined templates, augmenting and/or overriding some or all of the configuration elements:

```xml
<infinispan>
  <cache-container default-cache="local">
    <!-- template configurations -->
    <local-cache-configuration name="base-template">
      <expiration interval="10000" lifespan="10" max-idle="10"/>
    </local-cache-configuration>

    <local-cache-configuration name="extended-template" configuration="base-template">
      <expiration lifespan="20"/>
      <memory>
        <object size="2000"/>
      </memory>
    </local-cache-configuration>

    <!-- cache definitions -->
    <local-cache name="local" configuration="base-template" />
    <local-cache name="local-bounded" configuration="extended-template" />
  </cache-container>
</infinispan>
```

In the above example, **base-template** defines a local cache with a specific *expiration* configuration. The **extended-template** configuration inherits from **base-template**, overriding just a single parameter of the *expiration* element (all other attributes are inherited) and adds a *memory* element. Finally, two caches are defined: **local** which uses the **base-template** configuration and **local-bounded** which uses the **extended-template** configuration.

WARNING

Be aware that for multi-valued elements (such as **properties**) the inheritance is additive, i.e. the child configuration will be the result of merging the properties from the parent and its own.

2.1.1.2. Cache configuration wildcards

An alternative way to apply templates to caches is to use wildcards in the template name, e.g. **basecache***. Any cache whose name matches the template wildcard will inherit that configuration.

```
<infinispan>
    <cache-container>
        <local-cache-configuration name="basecache*">
            <expiration interval="10500" lifespan="11" max-idle="11"/>
        </local-cache-configuration>
        <local-cache name="basecache-1"/>
        <local-cache name="basecache-2"/>
    </cache-container>
</infinispan>
```

Above, caches **basecache-1** and **basecache-2** will use the **basecache*** configuration. The configuration will also be applied when retrieving undefined caches programmatically.

NOTE

If a cache name matches multiple wildcards, i.e. it is ambiguous, an exception will be thrown.

2.1.1.3. Declarative configuration reference

For more details on the declarative configuration schema, refer to the configuration reference. If you are using XML editing tools for configuration writing you can use the provided Red Hat Data Grid schema to assist you.

2.1.2. Configuring caches programmatically

Programmatic Red Hat Data Grid configuration is centered around the CacheManager and ConfigurationBuilder API. Although every single aspect of Red Hat Data Grid configuration could be set programmatically, the most usual approach is to create a starting point in a form of XML configuration file and then in runtime, if needed, programmatically tune a specific configuration to suit the use case best.

```
EmbeddedCacheManager manager = new DefaultCacheManager("my-config-file.xml");
Cache defaultCache = manager.getCache();
```

Let’s assume that a new synchronously replicated cache is to be configured programmatically. First, a fresh instance of Configuration object is created using ConfigurationBuilder helper object, and the cache mode is set to synchronous replication. Finally, the configuration is defined/registered with a manager.

```
Configuration c = new
ConfigurationBuilder().clustering().cacheMode(CacheMode.REPL_SYNC).build();

String newCacheName = "repl";
manager.defineConfiguration(newCacheName, c);
Cache<String, String> cache = manager.getCache(newCacheName);
```

The default cache configuration (or any other cache configuration) can be used as a starting point for creation of a new cache. For example, lets say that **infinispan-config-file.xml** specifies a replicated cache as a default and that a distributed cache is desired with a specific L1 lifespan while at the same time retaining all other aspects of a default cache. Therefore, the starting point would be to read an instance of a default Configuration object and use **ConfigurationBuilder** to construct and modify cache mode and L1 lifespan on a new **Configuration** object. As a final step the configuration is defined/registered with a manager.

```
EmbeddedCacheManager manager = new DefaultCacheManager("infinispan-config-file.xml");
Configuration dcc = manager.getDefaultCacheConfiguration();
Configuration c = new
ConfigurationBuilder().read(dcc).clustering().cacheMode(CacheMode.DIST_SYNC).l1().lifespan(6000
0L).build();

String newCacheName = "distributedWithL1";
manager.defineConfiguration(newCacheName, c);
Cache<String, String> cache = manager.getCache(newCacheName);
```

As long as the base configuration is the default named cache, the previous code works perfectly fine. However, other times the base configuration might be another named cache. So, how can new configurations be defined based on other defined caches? Take the previous example and imagine that instead of taking the default cache as base, a named cache called "replicatedCache" is used as base. The code would look something like this:

```
EmbeddedCacheManager manager = new DefaultCacheManager("infinispan-config-file.xml");
Configuration rc = manager.getCacheConfiguration("replicatedCache");
Configuration c = new
ConfigurationBuilder().read(rc).clustering().cacheMode(CacheMode.DIST_SYNC).l1().lifespan(60000
L).build();

String newCacheName = "distributedWithL1";
manager.defineConfiguration(newCacheName, c);
Cache<String, String> cache = manager.getCache(newCacheName);
```

Refer to CacheManager , ConfigurationBuilder , Configuration , and GlobalConfiguration javadocs for more details.

2.1.2.1. ConfigurationBuilder Programmatic Configuration API

While the above paragraph shows how to combine declarative and programmatic configuration, starting from an XML configuration is completely optional. The ConfigurationBuilder fluent interface style allows for easier to write and more readable programmatic configuration. This approach can be used for both the global and the cache level configuration. GlobalConfiguration objects are constructed using GlobalConfigurationBuilder while Configuration objects are built using ConfigurationBuilder. Let's look at some examples on configuring both global and cache level options with this API:

2.1.2.2. Configuring the transport

One of the most commonly configured global option is the transport layer, where you indicate how an Red Hat Data Grid node will discover the others:

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder().transport()
        .defaultTransport()
        .clusterName("qa-cluster")
        .addProperty("configurationFile", "jgroups-tcp.xml")
        .machineId("qa-machine").rackId("qa-rack")
      .build();
```

2.1.2.3. Using a custom JChannel

If you want to construct the JGroups JChannel by yourself, you can do so.

NOTE

The JChannel must not be already connected.

```
GlobalConfigurationBuilder global = new GlobalConfigurationBuilder();
JChannel jchannel = new JChannel();
// Configure the jchannel to your needs.
JGroupsTransport transport = new JGroupsTransport(jchannel);
global.transport().transport(transport);
new DefaultCacheManager(global.build());
```

2.1.2.4. Enabling JMX MBeans and statistics

Sometimes you might also want to enable collection of global JMX statistics at cache manager level or get information about the transport. To enable global JMX statistics simply do:

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .globalJmxStatistics()
  .enable()
  .build();
```

Please note that by not enabling (or by explicitly disabling) global JMX statistics your are just turning off statistics collection. The corresponding MBean is still registered and can be used to manage the cache manager in general, but the statistics attributes do not return meaningful values.

Further options at the global JMX statistics level allows you to configure the cache manager name which comes handy when you have multiple cache managers running on the same system, or how to locate the JMX MBean Server:

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .globalJmxStatistics()
    .cacheManagerName("SalesCacheManager")
    .mBeanServerLookup(new JBossMBeanServerLookup())
  .build();
```

2.1.2.5. Configuring the thread pools

Some of the Red Hat Data Grid features are powered by a group of the thread pool executors which can also be tweaked at this global level. For example:

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
   .replicationQueueThreadPool()
     .threadPoolFactory(ScheduledThreadPoolExecutorFactory.create())
  .build();
```

You can not only configure global, cache manager level, options, but you can also configure cache level options such as the cluster mode:

```
Configuration config = new ConfigurationBuilder()
  .clustering()
    .cacheMode(CacheMode.DIST_SYNC)
    .sync()
    .l1().lifespan(25000L)
    .hash().numOwners(3)
  .build();
```

Or you can configure eviction and expiration settings:

```
Configuration config = new ConfigurationBuilder()
           .memory()
             .size(20000)
          .expiration()
             .wakeUpInterval(5000L)
             .maxIdle(120000L)
           .build();
```

2.1.2.6. Configuring transactions and locking

An application might also want to interact with an Red Hat Data Grid cache within the boundaries of JTA and to do that you need to configure the transaction layer and optionally tweak the locking settings. When interacting with transactional caches, you might want to enable recovery to deal with transactions that finished with an heuristic outcome and if you do that, you will often want to enable JMX management and statistics gathering too:

```
Configuration config = new ConfigurationBuilder()
  .locking()
    .concurrencyLevel(10000).isolationLevel(IsolationLevel.REPEATABLE_READ)
    .lockAcquisitionTimeout(12000L).useLockStriping(false).writeSkewCheck(true)
    .versioning().enable().scheme(VersioningScheme.SIMPLE)
  .transaction()
    .transactionManagerLookup(new GenericTransactionManagerLookup())
    .recovery()
  .jmxStatistics()
  .build();
```

2.1.2.7. Configuring cache stores

Configuring Red Hat Data Grid with chained cache stores is simple too:

```
Configuration config = new ConfigurationBuilder()
   .persistence().passivation(false)
   .addSingleFileStore().location("/tmp").async().enable()
   .preload(false).shared(false).threadPoolSize(20).build();
```

2.1.2.8. Advanced programmatic configuration

The fluent configuration can also be used to configure more advanced or exotic options, such as advanced externalizers:

```
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
  .serialization()
    .addAdvancedExternalizer(998, new PersonExternalizer())
    .addAdvancedExternalizer(999, new AddressExternalizer())
  .build();
```

Or, add custom interceptors:

```
Configuration config = new ConfigurationBuilder()
  .customInterceptors().addInterceptor()
    .interceptor(new FirstInterceptor()).position(InterceptorConfiguration.Position.FIRST)
    .interceptor(new LastInterceptor()).position(InterceptorConfiguration.Position.LAST)
    .interceptor(new FixPositionInterceptor()).index(8)
    .interceptor(new AfterInterceptor()).after(NonTransactionalLockingInterceptor.class)
    .interceptor(new BeforeInterceptor()).before(CallInterceptor.class)
  .build();
```

For information on the individual configuration options, please check the configuration guide.

2.1.3. Configuration Migration Tools

The configuration format of Red Hat Data Grid has changed since schema version 6.0 in order to align the embedded schema with the one used by the server. For this reason, when upgrading to schema 7.x or later, you should use the configuration converter included in the *all* distribution. Simply invoke it from the command-line passing the old configuration file as the first parameter and the name of the converted file as the second parameter.

To convert on Unix/Linux/macOS:

```
bin/config-converter.sh oldconfig.xml newconfig.xml
```

on Windows:

```
bin\config-converter.bat oldconfig.xml newconfig.xml
```

TIP

If you wish to help write conversion tools from other caching systems, please contact infinispan-dev.

2.1.4. Clustered Configuration

Red Hat Data Grid uses JGroups for network communications when in clustered mode. Red Hat Data Grid ships with *pre-configured* JGroups stacks that make it easy for you to jump-start a clustered configuration.

2.1.4.1. Using an external JGroups file

If you are configuring your cache programmatically, all you need to do is:

```
GlobalConfiguration gc = new GlobalConfigurationBuilder()
   .transport().defaultTransport()
   .addProperty("configurationFile", "jgroups.xml")
   .build();
```

and if you happen to use an XML file to configure Red Hat Data Grid, just use:

```
<infinispan>
  <jgroups>
     <stack-file name="external-file" path="jgroups.xml"/>
  </jgroups>
  <cache-container default-cache="replicatedCache">
    <transport stack="external-file" />
    <replicated-cache name="replicatedCache"/>
  </cache-container>

  ...

</infinispan>
```

In both cases above, Red Hat Data Grid looks for *jgroups.xml* first in your classpath, and then for an absolute path name if not found in the classpath.

2.1.4.2. Use one of the pre-configured JGroups files

Red Hat Data Grid ships with a few different JGroups files (packaged in infinispan-core.jar) which means they will already be on your classpath by default. All you need to do is specify the file name, e.g., instead of **jgroups.xml** above, specify **/default-configs/default-jgroups-tcp.xml**.

The configurations available are:

- default-jgroups-udp.xml - Uses UDP as a transport, and UDP multicast for discovery. Usually suitable for larger (over 100 nodes) clusters *or* if you are using replication or invalidation. Minimises opening too many sockets.
- default-jgroups-tcp.xml - Uses TCP as a transport and UDP multicast for discovery. Better for smaller clusters (under 100 nodes) *only if* you are using distribution, as TCP is more efficient as a point-to-point protocol

- default-jgroups-ec2.xml - Uses TCP as a transport and S3_PING for discovery. Suitable on Amazon EC2 nodes where UDP multicast isn't available.
- default-jgroups-kubernetes.xml - Uses TCP as a transport and KUBE_PING for discovery. Suitable on Kubernetes and OpenShift nodes where UDP multicast is not always available.

2.1.4.2.1. Tuning JGroups settings

The settings above can be further tuned without editing the XML files themselves. Passing in certain system properties to your JVM at startup can affect the behaviour of some of these settings. The table below shows you which settings can be configured in this way. E.g.,

```
$ java -cp ... -Djgroups.tcp.port=1234 -Djgroups.tcp.address=10.11.12.13
```

Table 2.1. default-jgroups-udp.xml

System Property	*Description*	*Default*	*Required?*
jgroups.udp.mcast_addr	IP address to use for multicast (both for communications and discovery). Must be a valid Class D IP address, suitable for IP multicast.	228.6.7.8	No
jgroups.udp.mcast_port	Port to use for multicast socket	46655	No
jgroups.udp.ip_ttl	Specifies the time-to-live (TTL) for IP multicast packets. The value here refers to the number of network hops a packet is allowed to make before it is dropped	2	No

Table 2.2. default-jgroups-tcp.xml

System Property	*Description*	*Default*	*Required?*
jgroups.tcp.address	IP address to use for the TCP transport.	127.0.0.1	No
jgroups.tcp.port	Port to use for TCP socket	7800	No

jgroups.udp.mcast_addr	IP address to use for multicast (for discovery). Must be a valid Class D IP address, suitable for IP multicast.	228.6.7.8	No
jgroups.udp.mcast_port	Port to use for multicast socket	46655	No
jgroups.udp.ip_ttl	Specifies the time-to-live (TTL) for IP multicast packets. The value here refers to the number of network hops a packet is allowed to make before it is dropped	2	No

Table 2.3. default-jgroups-ec2.xml

System Property	*Description*	*Default*	*Required?*
jgroups.tcp.address	IP address to use for the TCP transport.	127.0.0.1	No
jgroups.tcp.port	Port to use for TCP socket	7800	No
jgroups.s3.access_key	The Amazon S3 access key used to access an S3 bucket		No
jgroups.s3.secret_access_key	The Amazon S3 secret key used to access an S3 bucket		No
jgroups.s3.bucket	Name of the Amazon S3 bucket to use. Must be unique and must already exist		No

Table 2.4. default-jgroups-kubernetes.xml

System Property	*Description*	*Default*	*Required?*
jgroups.tcp.address	IP address to use for the TCP transport.	eth0	No

jgroups.tcp.port	Port to use for TCP socket	7800	No

2.1.4.3. Further reading

JGroups also supports more system property overrides, details of which can be found on this page: SystemProps

In addition, the JGroups configuration files shipped with Red Hat Data Grid are intended as a jumping off point to getting something up and running, and working. More often than not though, you will want to fine-tune your JGroups stack further to extract every ounce of performance from your network equipment. For this, your next stop should be the JGroups manual which has a detailed section on configuring each of the protocols you see in a JGroups configuration file.

2.2. OBTAINING CACHES

After you configure the **CacheManager**, you can obtain and control caches.

Invoke the **getCache()** method to obtain caches, as follows:

```
Cache<String, String> myCache = manager.getCache("myCache");
```

The preceding operation creates a cache named **myCache**, if it does not already exist, and returns it.

Using the **getCache()** method creates the cache only on the node where you invoke the method. In other words, it performs a local operation that must be invoked on each node across the cluster. Typically, applications deployed across multiple nodes obtain caches during initialization to ensure that caches are *symmetric* and exist on each node.

Invoke the **createCache()** method to create caches dynamically across the entire cluster, as follows:

```
Cache<String, String> myCache = manager.administration().createCache("myCache",
"myTemplate");
```

The preceding operation also automatically creates caches on any nodes that subsequently join the cluster.

Caches that you create with the **createCache()** method are ephemeral by default. If the entire cluster shuts down, the cache is not automatically created again when it restarts.

Use the PERMANENT flag to ensure that caches can survive restarts, as follows:

```
Cache<String, String> myCache =
manager.administration().withFlags(AdminFlag.PERMANENT).createCache("myCache",
"myTemplate");
```

For the PERMANENT flag to take effect, you must enable global state and set a configuration storage provider.

For more information about configuration storage providers, see GlobalStateConfigurationBuilder#configurationStorage().

2.3. CLUSTERING INFORMATION

The **EmbeddedCacheManager** has quite a few methods to provide information as to how the cluster is operating. The following methods only really make sense when being used in a clustered environment (that is when a Transport is configured).

2.3.1. Member Information

When you are using a cluster it is very important to be able to find information about membership in the cluster including who is the owner of the cluster.

getMembers()

The getMembers() method returns all of the nodes in the current cluster.

getCoordinator()

The getCoordinator() method will tell you which one of the members is the coordinator of the cluster. For most intents you shouldn't need to care who the coordinator is. You can use isCoordinator() method directly to see if the local node is the coordinator as well.

2.3.2. Other methods

getTransport()

This method provides you access to the underlying Transport that is used to send messages to other nodes. In most cases a user wouldn't ever need to go to this level, but if you want to get Transport specific information (in this case JGroups) you can use this mechanism.

getStats()

The stats provided here are coalesced from all of the active caches in this manager. These stats can be useful to see if there is something wrong going on with your cluster overall.

CHAPTER 3. THE CACHE API

3.1. THE CACHE INTERFACE

Red Hat Data Grid's Caches are manipulated through the Cache interface.

A Cache exposes simple methods for adding, retrieving and removing entries, including atomic mechanisms exposed by the JDK's ConcurrentMap interface. Based on the cache mode used, invoking these methods will trigger a number of things to happen, potentially even including replicating an entry to a remote node or looking up an entry from a remote node, or potentially a cache store.

NOTE

For simple usage, using the Cache API should be no different from using the JDK Map API, and hence migrating from simple in-memory caches based on a Map to Red Hat Data Grid's Cache should be trivial.

3.1.1. Performance Concerns of Certain Map Methods

Certain methods exposed in Map have certain performance consequences when used with Red Hat Data Grid, such as size() , values() , keySet() and entrySet() . Specific methods on the **keySet**, **values** and **entrySet** are fine for use please see their Javadoc for further details.

Attempting to perform these operations globally would have large performance impact as well as become a scalability bottleneck. As such, these methods should only be used for informational or debugging purposes only.

It should be noted that using certain flags with the withFlags method can mitigate some of these concerns, please check each method's documentation for more details.

3.1.2. Mortal and Immortal Data

Further to simply storing entries, Red Hat Data Grid's cache API allows you to attach mortality information to data. For example, simply using put(key, value) would create an *immortal* entry, i.e., an entry that lives in the cache forever, until it is removed (or evicted from memory to prevent running out of memory). If, however, you put data in the cache using put(key, value, lifespan, timeunit) , this creates a *mortal* entry, i.e., an entry that has a fixed lifespan and expires after that lifespan.

In addition to *lifespan* , Red Hat Data Grid also supports *maxIdle* as an additional metric with which to determine expiration. Any combination of lifespans or maxIdles can be used.

3.1.3. Expiration and Mortal Data

See Expiration for more information about using mortal data with Red Hat Data Grid.

3.1.4. putForExternalRead operation

Red Hat Data Grid's Cache class contains a different 'put' operation called putForExternalRead . This operation is particularly useful when Red Hat Data Grid is used as a temporary cache for data that is persisted elsewhere. Under heavy read scenarios, contention in the cache should not delay the real transactions at hand, since caching should just be an optimization and not something that gets in the way.

To achieve this, putForExternalRead acts as a put call that only operates if the key is not present in the cache, and fails fast and silently if another thread is trying to store the same key at the same time. In this particular scenario, caching data is a way to optimise the system and it's not desirable that a failure in caching affects the on-going transaction, hence why failure is handled differently. putForExternalRead is considered to be a fast operation because regardless of whether it's successful or not, it doesn't wait for any locks, and so returns to the caller promptly.

To understand how to use this operation, let's look at basic example. Imagine a cache of Person instances, each keyed by a PersonId , whose data originates in a separate data store. The following code shows the most common pattern of using putForExternalRead within the context of this example:

```
// Id of the person to look up, provided by the application
PersonId id = ...;

// Get a reference to the cache where person instances will be stored
Cache<PersonId, Person> cache = ...;

// First, check whether the cache contains the person instance
// associated with with the given id
Person cachedPerson = cache.get(id);

if (cachedPerson == null) {
  // The person is not cached yet, so query the data store with the id
  Person person = dataStore.lookup(id);

  // Cache the person along with the id so that future requests can
  // retrieve it from memory rather than going to the data store
  cache.putForExternalRead(id, person);
} else {
  // The person was found in the cache, so return it to the application
  return cachedPerson;
}
```

Please note that putForExternalRead should never be used as a mechanism to update the cache with a new Person instance originating from application execution (i.e. from a transaction that modifies a Person's address). When updating cached values, please use the standard put operation, otherwise the possibility of caching corrupt data is likely.

3.2. THE ADVANCEDCACHE INTERFACE

In addition to the simple Cache interface, Red Hat Data Grid offers an AdvancedCache interface, geared towards extension authors. The AdvancedCache offers the ability to inject custom interceptors, access certain internal components and to apply flags to alter the default behavior of certain cache methods. The following code snippet depicts how an AdvancedCache can be obtained:

```
AdvancedCache advancedCache = cache.getAdvancedCache();
```

3.2.1. Flags

Flags are applied to regular cache methods to alter the behavior of certain methods. For a list of all available flags, and their effects, see the Flag enumeration. Flags are applied using AdvancedCache.withFlags() . This builder method can be used to apply any number of flags to a cache invocation, for example:

```
advancedCache.withFlags(Flag.CACHE_MODE_LOCAL, Flag.SKIP_LOCKING)
  .withFlags(Flag.FORCE_SYNCHRONOUS)
  .put("hello", "world");
```

3.2.2. Custom Interceptors

The AdvancedCache interface also offers advanced developers a mechanism with which to attach custom interceptors. Custom interceptors allow developers to alter the behavior of the cache API methods, and the AdvancedCache interface allows developers to attach these interceptors programmatically, at run-time. See the AdvancedCache Javadocs for more details.

For more information on writing custom interceptors, see Custom Interceptors.

3.3. LISTENERS AND NOTIFICATIONS

Red Hat Data Grid offers a listener API, where clients can register for and get notified when events take place. This annotation-driven API applies to 2 different levels: cache level events and cache manager level events.

Events trigger a notification which is dispatched to listeners. Listeners are simple POJO s annotated with @Listener and registered using the methods defined in the Listenable interface.

NOTE

Both Cache and CacheManager implement Listenable, which means you can attach listeners to either a cache or a cache manager, to receive either cache-level or cache manager-level notifications.

For example, the following class defines a listener to print out some information every time a new entry is added to the cache:

```
@Listener
public class PrintWhenAdded {

  @CacheEntryCreated
  public void print(CacheEntryCreatedEvent event) {
    System.out.println("New entry " + event.getKey() + " created in the cache");
  }

}
```

For more comprehensive examples, please see the Javadocs for @Listener.

3.3.1. Cache-level notifications

Cache-level events occur on a per-cache basis, and by default are only raised on nodes where the events occur. Note in a distributed cache these events are only raised on the owners of data being affected. Examples of cache-level events are entries being added, removed, modified, etc. These events trigger notifications to listeners registered to a specific cache.

Please see the Javadocs on the org.infinispan.notifications.cachelistener.annotation package for a comprehensive list of all cache-level notifications, and their respective method-level annotations.

NOTE

Please refer to the Javadocs on the org.infinispan.notifications.cachelistener.annotation package for the list of cache-level notifications available in Red Hat Data Grid.

3.3.1.1. Cluster Listeners

The cluster listeners should be used when it is desirable to listen to the cache events on a single node.

To do so all that is required is set to annotate your listener as being clustered.

```
@Listener (clustered = true)
public class MyClusterListener { .... }
```

There are some limitations to cluster listeners from a non clustered listener.

1. A cluster listener can only listen to **@CacheEntryModified**, **@CacheEntryCreated**, **@CacheEntryRemoved** and **@CacheEntryExpired** events. Note this means any other type of event will not be listened to for this listener.
2. Only the post event is sent to a cluster listener, the pre event is ignored.

3.3.1.2. Event filtering and conversion

All applicable events on the node where the listener is installed will be raised to the listener. It is possible to dynamically filter what events are raised by using a KeyFilter (only allows filtering on keys) or CacheEventFilter (used to filter for keys, old value, old metadata, new value, new metadata, whether command was retried, if the event is before the event (ie. isPre) and also the command type).

The example here shows a simple **KeyFilter** that will only allow events to be raised when an event modified the entry for the key **Only Me**.

```
public class SpecificKeyFilter implements KeyFilter<String> {
    private final String keyToAccept;

    public SpecificKeyFilter(String keyToAccept) {
      if (keyToAccept == null) {
        throw new NullPointerException();
      }
      this.keyToAccept = keyToAccept;
    }

    boolean accept(String key) {
      return keyToAccept.equals(key);
    }
}

...
cache.addListener(listener, new SpecificKeyFilter("Only Me"));
...
```

This can be useful when you want to limit what events you receive in a more efficient manner.

There is also a CacheEventConverter that can be supplied that allows for converting a value to another before raising the event. This can be nice to modularize any code that does value conversions.

NOTE

The mentioned filters and converters are especially beneficial when used in conjunction with a Cluster Listener. This is because the filtering and conversion is done on the node where the event originated and not on the node where event is listened to. This can provide benefits of not having to replicate events across the cluster (filter) or even have reduced payloads (converter).

3.3.1.3. Initial State Events

When a listener is installed it will only be notified of events after it is fully installed.

It may be desirable to get the current state of the cache contents upon first registration of listener by having an event generated of type **@CacheEntryCreated** for each element in the cache. Any additionally generated events during this initial phase will be queued until appropriate events have been raised.

NOTE

This only works for clustered listeners at this time. ISPN-4608 covers adding this for non clustered listeners.

3.3.1.4. Duplicate Events

It is possible in a non transactional cache to receive duplicate events. This is possible when the primary owner of a key goes down while trying to perform a write operation such as a put.

Red Hat Data Grid internally will rectify the put operation by sending it to the new primary owner for the given key automatically, however there are no guarantees in regards to if the write was first replicated to backups. Thus more than 1 of the following write events (**CacheEntryCreatedEvent**, **CacheEntryModifiedEvent** & **CacheEntryRemovedEvent**) may be sent on a single operation.

If more than one event is generated Red Hat Data Grid will mark the event that it was generated by a retried command to help the user to know when this occurs without having to pay attention to view changes.

```
@Listener
public class MyRetryListener {
  @CacheEntryModified
  public void entryModified(CacheEntryModifiedEvent event) {
    if (event.isCommandRetried()) {
      // Do something
    }
  }
}
```

Also when using a **CacheEventFilter** or **CacheEventConverter** the EventType contains a method **isRetry** to tell if the event was generated due to retry.

3.3.2. Cache manager-level notifications

Cache manager-level events occur on a cache manager. These too are global and cluster-wide, but involve events that affect all caches created by a single cache manager. Examples of cache manager-level events are nodes joining or leaving a cluster, or caches starting or stopping.

Please see the Javadocs on the org.infinispan.notifications.cachemanagerlistener.annotation package for a comprehensive list of all cache manager-level notifications, and their respective method-level annotations.

3.3.3. Synchronicity of events

By default, all notifications are dispatched in the same thread that generates the event. This means that you *must* write your listener such that it does not block or do anything that takes too long, as it would prevent the thread from progressing. Alternatively, you could annotate your listener as *asynchronous* , in which case a separate thread pool will be used to dispatch the notification and prevent blocking the event originating thread. To do this, simply annotate your listener such:

```
@Listener (sync = false)
public class MyAsyncListener { .... }
```

3.3.3.1. Asynchronous thread pool

To tune the thread pool used to dispatch such asynchronous notifications, use the **<listener-executor />** XML element in your configuration file.

3.4. ASYNCHRONOUS API

In addition to synchronous API methods like Cache.put() , Cache.remove() , etc., Red Hat Data Grid also has an asynchronous, non-blocking API where you can achieve the same results in a non-blocking fashion.

These methods are named in a similar fashion to their blocking counterparts, with "Async" appended. E.g., Cache.putAsync() , Cache.removeAsync() , etc. These asynchronous counterparts return a Future containing the actual result of the operation.

For example, in a cache parameterized as **Cache<String, String>**, **Cache.put(String key, String value)** returns a **String**. **Cache.putAsync(String key, String value)** would return a **Future<String>**.

3.4.1. Why use such an API?

Non-blocking APIs are powerful in that they provide all of the guarantees of synchronous communications - with the ability to handle communication failures and exceptions - with the ease of not having to block until a call completes. This allows you to better harness parallelism in your system. For example:

```
Set<Future<?>> futures = new HashSet<Future<?>>();
futures.add(cache.putAsync(key1, value1)); // does not block
futures.add(cache.putAsync(key2, value2)); // does not block
futures.add(cache.putAsync(key3, value3)); // does not block

// the remote calls for the 3 puts will effectively be executed
// in parallel, particularly useful if running in distributed mode
// and the 3 keys would typically be pushed to 3 different nodes
// in the cluster

// check that the puts completed successfully
for (Future<?> f: futures) f.get();
```

3.4.2. Which processes actually happen asynchronously?

There are 4 things in Red Hat Data Grid that can be considered to be on the critical path of a typical write operation. These are, in order of cost:

- network calls
- marshalling
- writing to a cache store (optional)
- locking

As of Red Hat Data Grid 4.0, using the async methods will take the network calls and marshalling off the critical path. For various technical reasons, writing to a cache store and acquiring locks, however, still happens in the caller’s thread. In future, we plan to take these offline as well. See this developer mail list thread about this topic.

3.4.3. Notifying futures

Strictly, these methods do not return JDK Futures, but rather a sub-interface known as a NotifyingFuture . The main difference is that you can attach a listener to a NotifyingFuture such that you could be notified when the future completes. Here is an example of making use of a notifying future:

```
FutureListener futureListener = new FutureListener() {

  public void futureDone(Future future) {
    try {
      future.get();
    } catch (Exception e) {
      // Future did not complete successfully
      System.out.println("Help!");
    }
  }
};

cache.putAsync("key", "value").attachListener(futureListener);
```

3.4.4. Further reading

The Javadocs on the Cache interface has some examples on using the asynchronous API, as does this article by Manik Surtani introducing the API.

3.5. INVOCATION FLAGS

An important aspect of getting the most of Red Hat Data Grid is the use of per-invocation flags in order to provide specific behaviour to each particular cache call. By doing this, some important optimizations can be implemented potentially saving precious time and network resources. One of the most popular usages of flags can be found right in Cache API, underneath the putForExternalRead() method which is used to load an Red Hat Data Grid cache with data read from an external resource. In order to make this call efficient, Red Hat Data Grid basically calls a normal put operation passing the following flags: FAIL_SILENTLY , FORCE_ASYNCHRONOUS , ZERO_LOCK_ACQUISITION_TIMEOUT

What Red Hat Data Grid is doing here is effectively saying that when putting data read from external read, it will use an almost-zero lock acquisition time and that if the locks cannot be acquired, it will fail silently without throwing any exception related to lock acquisition. It also specifies that regardless of the cache mode, if the cache is clustered, it will replicate asynchronously and so won't wait for responses from other nodes. The combination of all these flags make this kind of operation very efficient, and the efficiency comes from the fact this type of *putForExternalRead* calls are used with the knowledge that client can always head back to a persistent store of some sorts to retrieve the data that should be stored in memory. So, any attempt to store the data is just a best effort and if not possible, the client should try again if there's a cache miss.

3.5.1. Examples

If you want to use these or any other flags available, which by the way are described in detail the Flag enumeration , you simply need to get hold of the advanced cache and add the flags you need via the withFlags() method call. For example:

```
Cache cache = ...
cache.getAdvancedCache()
   .withFlags(Flag.SKIP_CACHE_STORE, Flag.CACHE_MODE_LOCAL)
   .put("local", "only");
```

It's worth noting that these flags are only active for the duration of the cache operation. If the same flags need to be used in several invocations, even if they're in the same transaction, withFlags() needs to be called repeatedly. Clearly, if the cache operation is to be replicated in another node, the flags are carried over to the remote nodes as well.

3.5.1.1. Suppressing return values from a put() or remove()

Another very important use case is when you want a write operation such as put() to *not* return the previous value. To do that, you need to use two flags to make sure that in a distributed environment, no remote lookup is done to potentially get previous value, and if the cache is configured with a cache loader, to avoid loading the previous value from the cache store. You can see these two flags in action in the following example:

```
Cache cache = ...
cache.getAdvancedCache()
   .withFlags(Flag.SKIP_REMOTE_LOOKUP, Flag.SKIP_CACHE_LOAD)
   .put("local", "only")
```

For more information, please check the Flag enumeration javadoc.

3.6. TREE API MODULE

Red Hat Data Grid's tree API module offers clients the possibility of storing data using a tree-structure like API. This API is similar to the one provided by JBoss Cache , hence the tree module is perfect for those users wanting to migrate their applications from JBoss Cache to Red Hat Data Grid, who want to limit changes their codebase as part of the migration. Besides, it's important to understand that Red Hat Data Grid provides this tree API much more efficiently than JBoss Cache did, so if you're a user of the tree API in JBoss Cache, you should consider migrating to Red Hat Data Grid.

3.6.1. What is Tree API about?

The aim of this API is to store information in a hierarchical way. The hierarchy is defined using paths represented as Fqn or fully qualified names , for example: */this/is/a/fqn/path* or */another/path* . In the hierarchy, there's a special path called root which represents the starting point of all paths and it's represented as: */*

Each FQN path is represented as a node where users can store data using a key/value pair style API (i.e. a Map). For example, in */persons/john* , you could store information belonging to John, for example: surname=Smith, birthdate=05/02/1980…etc.

Please remember that users should not use root as a place to store data. Instead, users should define their own paths and store data there. The following sections will delve into the practical aspects of this API.

3.6.2. Using the Tree API

3.6.2.1. Dependencies

For your application to use the tree API, you need to import infinispan-tree.jar which can be located in the Red Hat Data Grid binary distributions, or you can simply add a dependency to this module in your pom.xml:

pom.xml

```
<dependencies>
  ...
  <dependency>
    <groupId>org.infinispan</groupId>
    <artifactId>infinispan-tree</artifactId>
    <version>${version.infinispan}</version>
  </dependency>
  ...
</dependencies>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

3.6.3. Creating a Tree Cache

The first step to use the tree API is to actually create a tree cache. To do so, you need to create an Red Hat Data Grid Cache as you'd normally do, and using the TreeCacheFactory , create an instance of TreeCache . A very important note to remember here is that the Cache instance passed to the factory must be configured with invocation batching. For example:

```
import org.infinispan.config.Configuration;
import org.infinispan.tree.TreeCacheFactory;
import org.infinispan.tree.TreeCache;
...
Configuration config = new Configuration();
config.setInvocationBatchingEnabled(true);
Cache cache = new DefaultCacheManager(config).getCache();
TreeCache treeCache = TreeCacheFactory.createTreeCache(cache);
```

3.6.4. Manipulating data in a Tree Cache

The Tree API effectively provides two ways to interact with the data:

Via TreeCache convenience methods: These methods are located within the TreeCache interface and enable users to store , retrieve , move , remove ...etc data with a single call that takes the Fqn , in String or Fqn format, and the data involved in the call. For example:

```
treeCache.put("/persons/john", "surname", "Smith");
```

Or:

```
import org.infinispan.tree.Fqn;
...
Fqn johnFqn = Fqn.fromString("persons/john");
Calendar calendar = Calendar.getInstance();
calendar.set(1980, 5, 2);
treeCache.put(johnFqn, "birthdate", calendar.getTime()));
```

Via Node API: It allows finer control over the individual nodes that form the FQN, allowing manipulation of nodes relative to a particular node. For example:

```
import org.infinispan.tree.Node;
...
TreeCache treeCache = ...
Fqn johnFqn = Fqn.fromElements("persons", "john");
Node<String, Object> john = treeCache.getRoot().addChild(johnFqn);
john.put("surname", "Smith");
```

Or:

```
Node persons = treeCache.getRoot().addChild(Fqn.fromString("persons"));
Node<String, Object> john = persons.addChild(Fqn.fromString("john"));
john.put("surname", "Smith");
```

Or even:

```
Fqn personsFqn = Fqn.fromString("persons");
Fqn johnFqn = Fqn.fromRelative(personsFqn, Fqn.fromString("john"));
Node<String, Object> john = treeCache.getRoot().addChild(johnFqn);
john.put("surname", "Smith");
```

A node also provides the ability to access its parent or children . For example:

```
Node<String, Object> john = ...
Node persons = john.getParent();
```

Or:

```
Set<Node<String, Object>> personsChildren = persons.getChildren();
```

3.6.5. Common Operations

In the previous section, some of the most used operations, such as addition and retrieval, have been shown. However, there are other important operations that are worth mentioning, such as remove:

You can for example remove an entire node, i.e. */persons/john* , using:

```
treeCache.removeNode("/persons/john");
```

Or remove a child node, i.e. persons that a child of root, via:

```
treeCache.getRoot().removeChild(Fqn.fromString("persons"));
```

You can also remove a particular key/value pair in a node:

```
Node john = treeCache.getRoot().getChild(Fqn.fromElements("persons", "john"));
john.remove("surname");
```

Or you can remove all data in a node with:

```
Node john = treeCache.getRoot().getChild(Fqn.fromElements("persons", "john"));
john.clearData();
```

Another important operation supported by Tree API is the ability to move nodes around in the tree. Imagine we have a node called "john" which is located under root node. The following example is going to show how to we can move "john" node to be under "persons" node:

Current tree structure:

```
  /persons
  /john
```

Moving trees from one FQN to another:

```
Node john = treeCache.getRoot().addChild(Fqn.fromString("john"));
Node persons = treeCache.getRoot().getChild(Fqn.fromString("persons"));
treeCache.move(john.getFqn(), persons.getFqn());
```

Final tree structure:

```
  /persons/john
```

3.6.6. Locking in the Tree API

Understanding when and how locks are acquired when manipulating the tree structure is important in order to maximise the performance of any client application interacting against the tree, while at the same time maintaining consistency.

Locking on the tree API happens on a per node basis. So, if you're putting or updating a key/value under a particular node, a write lock is acquired for that node. In such case, no write locks are acquired for parent node of the node being modified, and no locks are acquired for children nodes.

If you're adding or removing a node, the parent is not locked for writing. In JBoss Cache, this behaviour was configurable with the default being that parent was not locked for insertion or removal.

Finally, when a node is moved, the node that's been moved and any of its children are locked, but also the target node and the new location of the moved node and its children. To understand this better, let's look at an example:

Imagine you have a hierarchy like this and we want to move c/ to be underneath b/:

```
     /
   --|--
  /     \
  a     c
  |     |
  b     e
  |
  d
```

The end result would be something like this:

```
     /
     |
     a
     |
     b
   --|--
  /     \
  d     c
        |
        e
```

To make this move, locks would have been acquired on:

- */a/b* - because it's the parent underneath which the data will be put
- */c* and */c/e* - because they're the nodes that are being moved
- */a/b/c* and */a/b/c/e* - because that's new target location for the nodes being moved

3.6.7. Listeners for tree cache events

The current Red Hat Data Grid listeners have been designed with key/value store notifications in mind, and hence they do not map to tree cache events correctly. Tree cache specific listeners that map directly to tree cache events (i.e. adding a child…etc) are desirable but these are not yet available. If you're interested in this type of listeners, please follow this issue to find out about any progress in this area.

3.7. ENCODING

3.7.1. Overview

Encoding is the data conversion operation done by Red Hat Data Grid caches before storing data, and when reading back from storage.

It allows dealing with a certain data format during API calls (map, listeners, stream, etc) while the format effectively stored is different.

The data conversions are handled by instances of *org.infinispan.commons.dataconversion.Encoder* :

```
public interface Encoder {

   /**
    * Convert data in the read/write format to the storage format.
    *
    * @param content data to be converted, never null.
    * @return Object in the storage format.
    */
   Object toStorage(Object content);

   /**
    * Convert from storage format to the read/write format.
    *
    * @param content data as stored in the cache, never null.
    * @return data in the read/write format
    */
   Object fromStorage(Object content);

   /**
     * Returns the {@link MediaType} produced by this encoder or null if the storage format is not
known.
     */
   MediaType getStorageFormat();
}
```

3.7.2. Default encoders

Red Hat Data Grid automatically picks the Encoder depending on the cache configuration. The table below shows which internal Encoder is used for several configurations:

Mode	Configuration	Encoder	Description
Embedded/Server	Default	IdentityEncoder	Passthrough encoder, no conversion done
Embedded	StorageType.OFF_HEAP	GlobalMarshallerEncoder	Use the Red Hat Data Grid internal marshaller to convert to byte[]. May delegate to the configured marshaller in the cache manager.
Embedded	StorageType.BINARY	BinaryEncoder	Use the Red Hat Data Grid internal marshaller to convert to byte[], except for primitives and String.
Server	StorageType.OFF_HEAP	IdentityEncoder	Store byte[]s directly as received by remote clients

3.7.3. Overriding programmatically

Is is possible to override programmatically the encoding used for both keys and values, by calling the *.withEncoding()* method variants from *AdvancedCache*.

Example, consider the following cache configured as OFF_HEAP:

```
// Read and write POJO, storage will be byte[] since for
// OFF_HEAP the GlobalMarshallerEncoder is used internally:
cache.put(1, new Pojo())
Pojo value = cache.get(1)

// Get the content in its stored format by overriding
// the internal encoder with a no-op encoder (IdentityEncoder)
Cache<?,?> rawContent = cache.getAdvancedCache().withValueEncoding(IdentityEncoder.class)
byte[] marshalled = rawContent.get(1)
```

The override can be useful if any operation in the cache does not require decoding, such as counting number of entries, or calculating the size of byte[] of an OFF_HEAP cache.

3.7.4. Defining custom Encoders

A custom encoder can be registered in the *EncoderRegistry*.

CAUTION

Ensure that the registration is done in every node of the cluster, before starting the caches.

Consider a custom encoder used to compress/decompress with gzip:

```
public class GzipEncoder implements Encoder {

  @Override
  public Object toStorage(Object content) {
    assert content instanceof String;
    return compress(content.toString());
  }

  @Override
  public Object fromStorage(Object content) {
    assert content instanceof byte[];
    return decompress((byte[]) content);
  }

  private byte[] compress(String str) {
    try (ByteArrayOutputStream baos = new ByteArrayOutputStream();
        GZIPOutputStream gis = new GZIPOutputStream(baos)) {
      gis.write(str.getBytes("UTF-8"));
      gis.close();
      return baos.toByteArray();
    } catch (IOException e) {
      throw new RuntimeException("Unabled to compress", e);
    }
  }

  private String decompress(byte[] compressed) {
    try (GZIPInputStream gis = new GZIPInputStream(new ByteArrayInputStream(compressed));
        BufferedReader bf = new BufferedReader(new InputStreamReader(gis, "UTF-8"))) {
      StringBuilder result = new StringBuilder();
```

```
            String line;
            while ((line = bf.readLine()) != null) {
               result.append(line);
            }
            return result.toString();
         } catch (IOException e) {
            throw new RuntimeException("Unable to decompress", e);
         }
      }

      @Override
      public MediaType getStorageFormat() {
         return MediaType.parse("application/gzip");
      }

      @Override
      public boolean isStorageFormatFilterable() {
         return false;
      }

      @Override
      public short id() {
         return 10000;
      }
   }
```

It can be registered by:

```
GlobalComponentRegistry registry = cacheManager.getGlobalComponentRegistry();
EncoderRegistry encoderRegistry = registry.getComponent(EncoderRegistry.class);
encoderRegistry.registerEncoder(new GzipEncoder());
```

And then be used to write and read data from a cache:

```
AdvancedCache<String, String> cache = ...

// Decorate cache with the newly registered encoder, without encoding keys (IdentityEncoder)
// but compressing values
AdvancedCache<String, String> compressingCache = (AdvancedCache<String, String>)
cache.withEncoding(IdentityEncoder.class, GzipEncoder.class);

// All values will be stored compressed...
compressingCache.put("297931749", "0412c789a37f5086f743255cfa693dd5");

// ... but API calls deals with String
String value = compressingCache.get("297931749");

// Bypassing the value encoder to obtain the value as it is stored
Object value = compressingCache.withEncoding(IdentityEncoder.class).get("297931749");

// value is a byte[] which is the compressed value
```

3.7.5. MediaType

A Cache can optionally be configured with a **org.infinispan.commons.dataconversion.MediaType** for keys and values. By describing the data format of the cache, Red Hat Data Grid is able to convert data on the fly during cache operations.

NOTE

The MediaType configuration is more suitable when storing binary data. When using server mode, it's common to have a MediaType configured and clients such as REST or Hot Rod reading and writing in different formats.

The data conversion between MediaType formats are handled by instances of **org.infinispan.commons.dataconversion.Transcoder**

```
public interface Transcoder {

  /**
   * Transcodes content between two different {@link MediaType}.
   *
   * @param content         Content to transcode.
   * @param contentType     The {@link MediaType} of the content.
   * @param destinationType The target {@link MediaType} to convert.
   * @return the transcoded content.
   */
  Object transcode(Object content, MediaType contentType, MediaType destinationType);

  /**
   * @return all the {@link MediaType} handled by this Transcoder.
   */
  Set<MediaType> getSupportedMediaTypes();
}
```

3.7.5.1. Configuration

Declarative:

```
<cache>
  <encoding>
    <key media-type="application/x-java-object; type=java.lang.Integer"/>
    <value media-type="application/xml; charset=UTF-8"/>
  </encoding>
</cache>
```

Programmatic:

```
ConfigurationBuilder cfg = new ConfigurationBuilder();

cfg.encoding().key().mediaType("text/plain");
cfg.encoding().value().mediaType("application/json");
```

3.7.5.2. Overriding the MediaType Programmatically

It's possible to decorate the Cache with a different MediaType, allowing cache operations to be executed sending and receiving different data formats.

Example:

```
DefaultCacheManager cacheManager = new DefaultCacheManager();

// The cache will store POJO for keys and values
ConfigurationBuilder cfg = new ConfigurationBuilder();
cfg.encoding().key().mediaType("application/x-java-object");
cfg.encoding().value().mediaType("application/x-java-object");

cacheManager.defineConfiguration("mycache", cfg.build());

Cache<Integer, Person> cache = cacheManager.getCache("mycache");

cache.put(1, new Person("John","Doe"));

// Wraps cache using 'application/x-java-object' for keys but JSON for values
Cache<Integer, byte[]> jsonValuesCache = (Cache<Integer, byte[]>)
cache.getAdvancedCache().withMediaType("application/x-java-object", "application/json");

byte[] json = jsonValuesCache.get(1);
```

Will return the value in JSON format:

```
{
  "_type":"org.infinispan.sample.Person",
  "name":"John",
  "surname":"Doe"
}
```

CAUTION

Most Transcoders are installed when server mode is used; when using library mode, an extra dependency, *org.infinispan:infinispan-server-core* should be added to the project.

3.7.5.3. Transcoders and Encoders

Usually there will be none or only one data conversion involved in a cache operation:

- No conversion by default on caches using in embedded or server mode;
- *Encoder* based conversion for embedded caches without MediaType configured, but using OFF_HEAP or BINARY;
- *Transcoder* based conversion for caches used in server mode with multiple REST and Hot Rod clients sending and receiving data in different formats. Those caches will have MediaType configured describing the storage.

But it’s possible to have both encoders and transcoders being used simultaneously for advanced use cases.

Consider an example, a cache that stores marshalled objects (with jboss marshaller) content but for security reasons a transparent encryption layer should be added in order to avoid storing "plain" data to an external store. Clients should be able to read and write data in multiple formats.

This can be achieved by configuring the cache with the the MediaType that describes the storage regardless of the encoding layer:

```
ConfigurationBuilder cfg = new ConfigurationBuilder();
cfg.encoding().key().mediaType("application/x-jboss-marshalling");
cfg.encoding().key().mediaType("application/x-jboss-marshalling");
```

The transparent encryption can be added by decorating the cache with a special *Encoder* that encrypts/decrypts with storing/retrieving, for example:

```
public class Scrambler implements Encoder {

  Object toStorage(Object content) {
    // Encrypt data
  }

  Object fromStorage(Object content) {
    // Decrypt data
  }

  MediaType getStorageFormat() {
    return "application/scrambled";
  }

}
```

To make sure all data written to the cache will be stored encrypted, it's necessary to decorate the cache with the Encoder above and perform all cache operations in this decorated cache:

```
Cache<?,?> secureStorageCache =
cache.getAdvancedCache().withEncoding(Scrambler.class).put(k,v);
```

The capability of reading data in multiple formats can be added by decorating the cache with the desired MediaType:

```
// Obtain a stream of values in XML format from the secure cache
secureStorageCache.getAdvancedCache().withMediaType("application/xml","application/xml").values
().stream();
```

Internally, Red Hat Data Grid will first apply the encoder *fromStorage* operation to obtain the entries, that will be in "application/x-jboss-marshalling" format and then apply a successive conversion to "application/xml" by using the adequate Transcoder.

CHAPTER 4. EVICTION AND DATA CONTAINER

Red Hat Data Grid supports eviction of entries, such that you do not run out of memory. Eviction is typically used in conjunction with a cache store, so that entries are not permanently lost when evicted, since eviction only removes entries from memory and not from cache stores or the rest of the cluster.

Red Hat Data Grid supports storing data in a few different formats. Data can be stored as the object iself, binary as a byte[], and off-heap which stores the byte[] in native memory.

TIP

Passivation is also a popular option when using eviction, so that only a single copy of an entry is maintained - either in memory or in a cache store, but not both. The main benefit of using passivation over a regular cache store is that updates to entries which exist in memory are cheaper since the update doesn’t need to be made to the cache store as well.

IMPORTANT

Eviction occurs on a *local* basis, and is not cluster-wide. Each node runs an eviction thread to analyse the contents of its in-memory container and decide what to evict. Eviction does not take into account the amount of free memory in the JVM as threshold to starts evicting entries. You have to set **size** attribute of the eviction element to be greater than zero in order for eviction to be turned on. If size is too large you can run out of memory. The **size** attribute will probably take some tuning in each use case.

4.1. ENABLING EVICTION

Eviction is configured by adding the **<memory />** element to your **<*-cache />** configuration sections or using MemoryConfigurationBuilder API programmatic approach.

All cache entry are evicted by piggybacking on user threads that are hitting the cache.

4.1.1. Eviction strategy

Strategies control how the eviction is handled.

The possible choices are

NONE

Eviction is not enabled and it is assumed that the user will not invoke evict directly on the cache. If passivation is enabled this will cause aa warning message to be emitted. This is the default strategy.

MANUAL

This strategy is just like <b>NONE</b> except that it assumes the user will be invoking evict directly. This way if passivation is enabled no warning message is logged.

REMOVE

This strategy will actually evict "old" entries to make room for incoming ones.

Eviction is handled by Caffeine utilizing the TinyLFU algorithm with an additional admission window. This was chosen as provides high hit rate while also requiring low memory overhead. This provides a better hit ratio than LRU while also requiring less memory than LIRS.

EXCEPTION

This strategy actually prevents new entries from being created by throwing a **ContainerFullException**. This strategy only works with transactional caches that always run with 2 phase commit, that is no 1 phase commit or synchronization optimizations allowed.

4.1.2. Eviction types

Eviction type applies only when the size is set to something greater than 0. The eviction type below determines when the container will decide to remove entries.

COUNT

This type of eviction will remove entries based on how many there are in the cache. Once the count of entries has grown larger than the **size** then an entry will be removed to make room.

MEMORY

This type of eviction will estimate how much each entry will take up in memory and will remove an entry when the total size of all entries is larger than the configured **size**. This type does not work with **OBJECT** storage type below.

4.1.3. Storage type

Red Hat Data Grid allows the user to configure in what form their data is stored. Each form supports the same features of Red Hat Data Grid, however eviction can be limited for some forms. There are currently three storage formats that Red Hat Data Grid provides, they are:

OBJECT

Stores the keys and values as objects in the Java heap Only **COUNT** eviction type is supported.

BINARY

Stores the keys and values as a byte[] in the Java heap. This will use the configured marshaller for the cache if there is one. Both **COUNT** and **MEMORY** eviction types are supported.

OFF-HEAP

Stores the keys and values in native memory outside of the Java heap as bytes. The configured marshaller will be used if the cache has one. Both **COUNT** and **MEMORY** eviction types are supported.

> **WARNING**
>
> Both **BINARY** and **OFF-HEAP** violate equality and hashCode that they are dictated by the resulting byte[] they generate instead of the object instance.

4.1.4. More defaults

By default when no **<memory />** element is specified, no eviction takes place, **OBJECT** storage type is used, and a strategy of **NONE** is assumed.

In case there is an memory element, this table describes the behaviour of eviction based on information provided in the xml configuration ("-" in Supplied size or Supplied strategy column means that the attribute wasn't supplied)

Supplied size	Example	Eviction behaviour
-	**<memory />**	no eviction as an object
-	**<memory> <object strategy="MANUAL" /> </memory>**	no eviction as an object and won't log warning if passivation is enabled
> 0	**<memory> <object size="100" /> </memory>**	eviction takes place and stored as objects
> 0	**<memory> <binary size="100" eviction="MEMORY"/> </memory>**	eviction takes place and stored as a binary removing to make sure memory doens't go higher than 100
> 0	**<memory> <off-heap size="100" /> </memory>**	eviction takes place and stored in off-heap
> 0	**<memory> <off-heap size="100" strategy="EXCEPTION" /> </memory>**	entries are stored in off-heap and if 100 entries are in container exceptions will be thrown for additional
0	**<memory> <object size="0" /> </memory>**	no eviction
< 0	**<memory> <object size="-1" /> </memory>**	no eviction

4.2. EXPIRATION

Similar to, but unlike eviction, is expiration. Expiration allows you to attach lifespan and/or maximum idle times to entries. Entries that exceed these times are treated as invalid and are removed. When removed expired entries are not passivated like evicted entries (if passivation is turned on).

TIP

Unlike eviction, expired entries are removed globally - from memory, cache stores, and cluster-wide.

By default entries created are immortal and do not have a lifespan or maximum idle time. Using the cache API, mortal entries can be created with lifespans and/or maximum idle times. Further, default lifespans and/or maximum idle times can be configured by adding the <expiration /> element to your **<*-cache />** configuration sections.

When an entry expires it resides in the data container or cache store until it is accessed again by a user request. An expiration reaper is also available to check for expired entries and remove them at a configurable interval of milliseconds.

You can enable the expiration reaper declaratively with the **reaper-interval** attribute or programmatically with the **enableReaper** method in the **ExpirationConfigurationBuilder** class.

NOTE

- The expiration reaper cannot be disabled when a cache store is present.
- When using a maximum idle time in a clustered cache, you should always enable the expiration reaper. For more information, see Clustered Max Idle.

4.2.1. Difference between Eviction and Expiration

Both Eviction and Expiration are means of cleaning the cache of unused entries and thus guarding the heap against **OutOfMemory** exceptions, so now a brief explanation of the difference.

With *eviction* you set *maximal number of entries* you want to keep in the cache and if this limit is exceeded, some candidates are found to be removed according to a choosen *eviction strategy* (LRU, LIRS, etc…). Eviction can be setup to work with passivation, which is eviction to a cache store.

With *expiration* you set *time criteria* for entries to specify *how long you want to keep them* in the cache.

lifespan

Specifies how long entries can remain in the cache before they expire. The default value is **-1**, which is unlimited time.

maximum idle time

Specifies how long entries can remain idle before they expire. An entry in the cache is idle when no operation is performed with the key. The default value is **-1**, which is unlimited time.

4.3. EXPIRATION DETAILS

1. *Expiration* is a top-level construct, represented in the configuration as well as in the cache API.
2. While eviction is *local to each cache instance* , expiration is *cluster-wide* . Expiration **lifespan** and **maxIdle** values are replicated along with the cache entry.
3. Maximum idle times for cache entries require additional network messages in clustered environments. For this reason, setting **maxIdle** in clustered caches can result in slower operation times.
4. Expiration lifespan and **maxIdle** are also persisted in CacheStores, so this information survives eviction/passivation.

4.3.1. Maximum Idle Expiration

Maximum idle expiration has different behavior in local and clustered cache environments.

IMPORTANT

Maximum idle expiration, **max-idle**, does not currently work with entries stored in off-heap memory. Likewise, **max-idle** does not work if caches use cache stores as a persistence layer.

4.3.1.1. Local Max Idle

In local cache mode, Red Hat Data Grid expires entries with the **maxIdle** configuration when:

- accessed directly (**Cache.get()**).
- iterated upon (**Cache.size()**).
- the expiration reaper thread runs.

4.3.1.2. Clustered Max Idle

In clustered cache modes, when clients read entries that have **max-idle** expiration values, Red Hat Data Grid sends touch commands to all owners. This ensures that the entries have the same relative access time across the cluster.

When nodes detect that an entry reaches the maximum idle time, Red Hat Data Grid removes it from the cache and does not return the entry to the client that requested it.

Before using **max-idle** with clustered cache modes, you should review the following points:

- **Cache.get()** does not return until the touch commands complete. This synchronous behavior increases latency of client requests.
- Clustered **max-idle** also updates the "recently accessed" metadata for cache entries on all owners, which Red Hat Data Grid uses for eviction.
- Iteration across a clustered cache returns entries that might be expired with the maximum idle time. This behavior ensures performance because no remote invocations are performed during the iteration. However this does not refresh any expired entries, which are removed by the expiration reaper or when accessed directly (**Cache.get()**).

IMPORTANT

- Clustered caches should always use the expiration reaper with the **maxIdle** configuration.
- When using **maxIdle** expiration with exception-based eviction, entries that are expired but not removed from the cache count towards the size of the data container.

4.3.2. Configuration

Eviction and Expiration may be configured using the programmatic or declarative XML configuration. This configuration is on a per-cache basis. Valid eviction/expiration-related configuration elements are:

```
<!-- Eviction -->
<memory>
  <object size="2000"/>
```

```
</memory>
<!-- Expiration -->
<expiration lifespan="1000" max-idle="500" interval="1000" />
```

Programmatically, the same would be defined using:

```
Configuration c = new ConfigurationBuilder()
               .memory().size(2000)
               .expiration().wakeUpInterval(5000l).lifespan(1000l).maxIdle(500l)
               .build();
```

4.3.3. Memory Based Eviction Configuration

Memory based eviction may require some additional configuration options if you are using your own custom types (as Red Hat Data Grid is normally used). In this case Red Hat Data Grid cannot estimate the memory usage of your classes and as such you are required to use **storeAsBinary** when memory based eviction is used.

```
<!-- Enable memory based eviction with 1 GB/>
<memory>
   <binary size="1000000000" eviction="MEMORY"/>
</memory>
```

```
Configuration c = new ConfigurationBuilder()
               .memory()
               .storageType(StorageType.BINARY)
               .evictionType(EvictionType.MEMORY)
               .size(1_000_000_000)
               .build();
```

4.3.4. Default values

Eviction is disabled by default. Default values are used:

- size: -1 is used if not specified, which means unlimited entries.
- 0 means no entries, and the eviction thread will strive to keep the cache empty.

Expiration lifespan and maxIdle both default to -1, which means that entries will be created immortal by default. This can be overridden per entry with the API.

4.3.5. Using expiration

Expiration allows you to set either a lifespan or a maximum idle time on each key/value pair stored in the cache. This can either be set cache-wide using the configuration, as described above, or it can be defined per-key/value pair using the Cache interface. Any values defined per key/value pair overrides the cache-wide default for the specific entry in question.

For example, assume the following configuration:

```
<expiration lifespan="1000" />
```

```
// this entry will expire in 1000 millis
```

```
cache.put("pinot noir", pinotNoirPrice);

// this entry will expire in 2000 millis
cache.put("chardonnay", chardonnayPrice, 2, TimeUnit.SECONDS);

// this entry will expire 1000 millis after it is last accessed
cache.put("pinot grigio", pinotGrigioPrice, -1,
        TimeUnit.SECONDS, 1, TimeUnit.SECONDS);

// this entry will expire 1000 millis after it is last accessed, or
// in 5000 millis, which ever triggers first
cache.put("riesling", rieslingPrice, 5,
        TimeUnit.SECONDS, 1, TimeUnit.SECONDS);
```

4.4. EXPIRATION DESIGNS

Central to expiration is an ExpirationManager.

The purpose of the ExpirationManager is to drive the expiration thread which periodically purges items from the DataContainer. If the expiration thread is disabled (wakeupInterval set to -1) expiration can be kicked off manually using ExprationManager.processExpiration(), for example from another maintenance thread that may run periodically in your application.

The expiration manager processes expirations in the following manner:

1. Causes the data container to purge expired entries

2. Causes cache stores (if any) to purge expired entries

CHAPTER 5. PERSISTENCE

Persistence allows configuring external (persistent) storage engines complementary to the default in memory storage offered by Red Hat Data Grid. An external persistent storage might be useful for several reasons:

- Increased Durability. Memory is volatile, so a cache store could increase the life-span of the information store in the cache.
- Write-through. Interpose Red Hat Data Grid as a caching layer between an application and a (custom) external storage engine.
- Overflow Data. By using eviction and passivation, one can store only the "hot" data in memory and overflow the data that is less frequently used to disk.

The integration with the persistent store is done through the following SPI: CacheLoader, CacheWriter, AdvancedCacheLoader and AdvancedCacheWriter (discussed in the following sections).

These SPIs allow for the following features:

- Alignment with JSR-107. The CacheWriter and CacheLoader interface are similar to the the loader and writer in JSR 107. This should considerably help writing portable stores across JCache compliant vendors.
- Simplified Transaction Integration. All necessary locking is handled by Red Hat Data Grid automatically and implementations don't have to be concerned with coordinating concurrent access to the store. Even though concurrent writes on the same key are not going to happen (depending locking mode in use), implementors should expect operations on the store to happen from multiple/different threads and code the implementation accordingly.
- Parallel Iteration. It is now possible to iterate over entries in the store with multiple threads in parallel.
- Reduced Serialization. This translates in less CPU usage. The new API exposes the stored entries in serialized format. If an entry is fetched from persistent storage for the sole purpose of being sent remotely, we no longer need to deserialize it (when reading from the store) and serialize it back (when writing to the wire). Now we can write to the wire the serialized format as read from the storage directly.

5.1. CONFIGURATION

Stores (readers and/or writers) can be configured in a chain. Cache read operation looks at all of the specified **CacheLoader** s, in the order they are configured, until it finds a valid and non-null element of data. When performing writes all cache **CacheWriter** s are written to, except if the **ignoreModifications** element has been set to true for a specific cache writer.

IMPLEMENTING BOTH A CACHEWRITER AND CACHELOADER

Store providers should implement both the **CacheWriter** and the **CacheLoader** interfaces. Stores that do this are considered both for reading and writing (assuming **read-only=false**) data.

```
This is the configuration of a custom(not shipped with infinispan) store:
  <local-cache name="myCustomStore">
    <persistence passivation="false">
```

```
        <store
          class="org.acme.CustomStore"
          fetch-state="false" preload="true" shared="false"
          purge="true" read-only="false" singleton="false">

          <write-behind modification-queue-size="123" thread-pool-size="23" />

          <property name="myProp">${system.property}</property>
        </store>
      </persistence>
    </local-cache>
```

Parameters that you can use to configure persistence are as follows:

connection-attempts

Sets the maximum number of attempts to start each configured CacheWriter/CacheLoader. If the attempts to start are not successful, an exception is thrown and the cache does not start.

connection-interval

Specifies the time, in milliseconds, to wait between connection attempts on startup. A negative or zero value means no wait between connection attempts.

availability-interval

Specifies the time, in milliseconds, between availability checks to determine if the PersistenceManager is available. In other words, this interval sets how often stores/loaders are polled via their **org.infinispan.persistence.spi.CacheWriter#isAvailable** or **org.infinispan.persistence.spi.CacheLoader#isAvailable** implementation. If a single store/loader is not available, an exception is thrown during cache operations.

passivation

Enables passivation. The default value is **false** (boolean).
This property has a significant impact on Red Hat Data Grid interactions with the loaders. See Cache Passivation for more information.

class

Defines the class of the store and must implement **CacheLoader**, **CacheWriter**, or both.

fetch-state

Fetches the persistent state of a cache when joining a cluster. The default value is **false** (boolean).
The purpose of this property is to retrieve the persistent state of a cache and apply it to the local cache store of a node when it joins a cluster. Fetching the persistent state does not apply if a cache store is shared because it accesses the same data as the other stores.

This property can be **true** for one configured cache loader only. If more than one cache loader fetches the persistent state, a configuration exception is thrown when the cache service starts.

preload

Pre-loads data into memory from the cache loader when the cache starts. The default value is **false** (boolean).
This property is useful when data in the cache loader is required immediately after startup to prevent delays with cache operations when the data is loaded lazily. This property can provide a "warm cache" on startup but it impacts performance because it affects start time.

Pre-loading data is done locally, so any data loaded is stored locally in the node only. The pre-loaded data is not replicated or distributed. Likewise, Red Hat Data Grid pre-loads data only up to the maximum configured number of entries in eviction.

shared

Determines if the cache loader is shared between cache instances. The default value is **false** (boolean).
This property prevents duplicate writes of data to the cache loader by different cache instances. An example is where all cache instances in a cluster use the same JDBC settings for the same remote, shared database.

read-only

Prevents new data from being persisted to the cache store. The default value is **false** (boolean).

purge

Empties the specified cache loader at startup. The default value is **false** (boolean). This property takes effect only if the **read-only** property is set to **false**.

max-batch-size

Sets the maximum size of a batch to insert of delete from the cache store. The default value is 100. If the value is less than **1**, no upper limit applies to the number of operations in a batch.

write-behind

Asynchronously persists data to the cache store. The default value is **false** (boolean). See Asynchronous Write-Behind for more information.

singleton

Enables one node in the cluster, the coordinator, to store modifications. The default value is **false** (boolean).
Whenever data enters a node, it is replicated or distributed to keep the in-memory state of the caches synchronized. The coordinator is responsible for pushing that state to disk.

If **true** you must set this property on all nodes in the cluster. Only the coordinator of the cluster persists data. However, all nodes must have this property enabled to prevent other nodes from persisting data.

You cannot enable the **singleton** property if the cache store is shared.

NOTE

You can define additional attributes in the **properties** section to configure specific aspects of each cache loader, such as the **myProp** attribute in the previous example.

Other cache loaders with more complex configurations also include additional properties. See the following JDBC cache store configuration for examples.

The preceding configuration applies a generic cache store implementation. However, the default Red Hat Data Grid store implementation has a more complex configuration schema, in which the **properties** section is replaced with XML attributes:

```
<persistence passivation="false">
  <!-- note that class is missing and is induced by the fileStore element name -->
  <file-store
        shared="false" preload="true"
        fetch-state="true"
        read-only="false"
        purge="false"
```

```
            path="${java.io.tmpdir}">
        <write-behind thread-pool-size="5" />
    </file-store>
</persistence>
```

The same configuration can be achieved programmatically:

```
    ConfigurationBuilder builder = new ConfigurationBuilder();
    builder.persistence()
          .passivation(false)
          .addSingleFileStore()
             .preload(true)
             .shared(false)
             .fetchPersistentState(true)
             .ignoreModifications(false)
             .purgeOnStartup(false)
             .location(System.getProperty("java.io.tmpdir"))
             .async()
                .enabled(true)
                .threadPoolSize(5)
             .singleton()
                .enabled(true)
                .pushStateWhenCoordinator(true)
                .pushStateTimeout(20000);
```

5.2. CACHE PASSIVATION

A CacheWriter can be used to enforce entry passivation and activation on eviction in a cache. Cache passivation is the process of removing an object from in-memory cache and writing it to a secondary data store (e.g., file system, database) on eviction. Cache activation is the process of restoring an object from the data store into the in-memory cache when it's needed to be used. In order to fully support passivation, a store needs to be both a CacheWriter and a CacheLoader. In both cases, the configured cache store is used to read from the loader and write to the data writer.

When an eviction policy in effect evicts an entry from the cache, if passivation is enabled, a notification that the entry is being passivated will be emitted to the cache listeners and the entry will be stored. When a user attempts to retrieve a entry that was evicted earlier, the entry is (lazily) loaded from the cache loader into memory. When the entry has been loaded a notification is emitted to the cache listeners that the entry has been activated. In order to enable passivation just set passivation to true (false by default). When passivation is used, only the first cache loader configured is used and all others are ignored.

5.2.1. Limitations

Due to the unique nature of passivation, it is not supported with some other store configurations.

- Transactional store - Passivation writes/removes entries from the store outside the scope of the actual Infinispan commit boundaries.
- Shared store - Shared store requires entries always being in the store for other owners. Thus passivation makes no sense as we can't remove the entry from the store.

5.2.2. Cache Loader Behavior with Passivation Disabled vs Enabled

When passivation is disabled, whenever an element is modified, added or removed, then that modification is persisted in the backend store via the cache loader. There is no direct relationship between eviction and cache loading. If you don't use eviction, what's in the persistent store is basically a copy of what's in memory. If you do use eviction, what's in the persistent store is basically a superset of what's in memory (i.e. it includes entries that have been evicted from memory). When passivation is enabled, and with an unshared store, there is a direct relationship between eviction and the cache loader. Writes to the persistent store via the cache loader only occur as part of the eviction process. Data is deleted from the persistent store when the application reads it back into memory. In this case, what's in memory and what's in the persistent store are two subsets of the total information set, with no intersection between the subsets. With a shared store, entries which have been passivated in the past will continue to exist in the store, although they may have a stale value if this has been overwritten in memory.

The following is a simple example, showing what state is in RAM and in the persistent store after each step of a 6 step process:

Operation	Passivation Off	Passivation On, Shared Off	Passivation On, Shared On
Insert keyOne	**Memory:** keyOne **Disk:** keyOne	**Memory:** keyOne **Disk:** (none)	**Memory:** keyOne **Disk:** (none)
Insert keyTwo	**Memory:** keyOne, keyTwo **Disk:** keyOne, keyTwo	**Memory:** keyOne, keyTwo **Disk:** (none)	**Memory:** keyOne, keyTwo **Disk:** (none)
Eviction thread runs, evicts keyOne	**Memory:** keyTwo **Disk:** keyOne, keyTwo	**Memory:** keyTwo **Disk:** keyOne	**Memory:** keyTwo **Disk:** keyOne
Read keyOne	**Memory:** keyOne, keyTwo **Disk:** keyOne, keyTwo	**Memory:** keyOne, keyTwo **Disk:** (none)	**Memory:** keyOne, keyTwo **Disk:** keyOne
Eviction thread runs, evicts keyTwo	**Memory:** keyOne **Disk:** keyOne, keyTwo	**Memory:** keyOne **Disk:** keyTwo	**Memory:** keyOne **Disk:** keyOne, keyTwo
Remove keyTwo	**Memory:** keyOne **Disk:** keyOne	**Memory:** keyOne **Disk:** (none)	**Memory:** keyOne **Disk:** keyOne

5.3. CACHE LOADERS AND TRANSACTIONAL CACHES

When a cache is transactional and a cache loader is present, the cache loader won't be enlisted in the transaction in which the cache is part. That means that it is possible to have inconsistencies at cache loader level: the transaction to succeed applying the in-memory state but (partially) fail applying the changes to the store. Manual recovery would not work with caches stores.

5.4. WRITE-THROUGH AND WRITE-BEHIND CACHING

Red Hat Data Grid can optionally be configured with one or several cache stores allowing it to store data in a persistent location such as shared JDBC database, a local filesystem, etc. Red Hat Data Grid can handle updates to the cache store in two different ways:

- Write-Through (Synchronous)
- Write-Behind (Asynchronous)

5.4.1. Write-Through (Synchronous)

In this mode, which is supported in version 4.0, when clients update a cache entry, i.e. via a Cache.put() invocation, the call will not return until Red Hat Data Grid has gone to the underlying cache store and has updated it. Normally, this means that updates to the cache store are done within the boundaries of the client thread.

The main advantage of this mode is that the cache store is updated at the same time as the cache, hence the cache store is consistent with the cache contents. On the other hand, using this mode reduces performance because the latency of having to access and update the cache store directly impacts the duration of the cache operation.

Configuring a write-through or synchronous cache store does not require any particular configuration option. By default, unless marked explicitly as write-behind or asynchronous, all cache stores are write-through or synchronous. Please find below a sample configuration file of a write-through unshared local file cache store:

```
<persistence passivation="false">
  <file-store fetch-state="true"
           read-only="false"
           purge="false" path="${java.io.tmpdir}"/>
</persistence>
```

5.4.2. Write-Behind (Asynchronous)

In this mode, updates to the cache are asynchronously written to the cache store. Red Hat Data Grid puts pending changes into a modification queue so that it can quickly store changes.

The configured number of threads consume the queue and apply the modifications to the underlying cache store. If the configured number of threads cannot consume the modifications fast enough, or if the underlying store becomes unavailable, the modification queue becomes full. In this event, the cache store becomes write-through until the queue can accept new entries.

This mode provides an advantage in that cache operations are not affected by updates to the underlying store. However, because updates happen asynchronously, there is a period of time during which data in the cache store is inconsistent with data in the cache.

The write-behind strategy is suitable for cache stores with low latency and small operational cost; for example, an unshared file-based cache store that is local to the cache itself. In this case, the time during which data is inconsistent between the cache store and the cache is reduced to the lowest possible period.

The following is an example configuration for the write-behind strategy:

```
<persistence passivation="false">
  <file-store fetch-state="true"
           read-only="false"
           purge="false" path="${java.io.tmpdir}">
  <!-- start write-behind configuration -->
  <write-behind modification-queue-size="123" thread-pool-size="23" />
```

```
    <!-- end write-behind configuration -->
    </file-store>
  </persistence>
```

5.5. FILESYSTEM BASED CACHE STORES

A filesystem-based cache store is typically used when you want to have a cache with a cache store available locally which stores data that has overflowed from memory, having exceeded size and/or time restrictions.

> **WARNING**
>
> Usage of filesystem-based cache stores on shared filesystems like NFS, Windows shares, etc. should be avoided as these do not implement proper file locking and can cause data corruption. File systems are inherently not transactional, so when attempting to use your cache in a transactional context, failures when writing to the file (which happens during the commit phase) cannot be recovered.

5.5.1. Single File Store

The single file cache store keeps all data in a single file. The way it looks up data is by keeping an in-memory index of keys and the positions of their values in this file. This results in greater performance compared to old file cache store. There is one caveat though. Since the single file based cache store keeps keys in memory, it can lead to increased memory consumption, and hence it's not recommended for caches with big keys.

In certain use cases, this cache store suffers from fragmentation: if you store larger and larger values, the space is not reused and instead the entry is appended at the end of the file. The space (now empty) is reused only if you write another entry that can fit there. Also, when you remove all entries from the cache, the file won't shrink, and neither will be de-fragmented.

These are the available configuration options for the single file cache store:

- **path** is the file-system location where Red Hat Data Grid stores data.
  For embedded deployments, Red Hat Data Grid stores data to the current working directory. To store data in a different location, specify the absolute path to that directory as the value.

  For server deployments, Red Hat Data Grid stores data in **$RHDG_HOME/data**. You should not change the default location for Red Hat Data Grid server. In other words, do not set a value for **path** with server deployments.

you should create a path declaration and use the **relative-to** attribute for the file store location. If you set **relative-to** to a directory location or environment variable, Red Hat Data Grid server startup fails.

- **max-entries** specifies the maximum number of entries to keep in this file store. As mentioned before, in order to speed up lookups, the single file cache store keeps an index of keys and their corresponding position in the file. To avoid this index resulting in memory consumption problems, this cache store can bounded by a maximum number of entries that it stores. If this limit is exceeded, entries are removed permanently using the LRU algorithm both from the in-memory index and the underlying file based cache store. So, setting a maximum limit only makes sense when Red Hat Data Grid is used as a cache, whose contents can be recomputed or they can be retrieved from the authoritative data store. If this maximum limit is set when the Red Hat Data Grid is used as an authoritative data store, it could lead to data loss, and hence it’s not recommended for this use case. The default value is **-1** which means that the file store size is unlimited.

5.5.1.1. Declarative Configuration

The following examples show declarative configuration for a single file cache store.

Library Mode

```
<persistence>
  <file-store path="/tmp/myDataStore" max-entries="5000"/>
</persistence>
```

Server Mode

```
<persistence>
  <file-store max-entries="5000"/>
</persistence>
```

5.5.1.2. Programmatic Configuration

The following example shows programmatic configuration for a single file cache store:

```
ConfigurationBuilder b = new ConfigurationBuilder();
b.persistence()
    .addSingleFileStore()
    .location("/tmp/myDataStore")
    .maxEntries(5000);
```

5.5.2. Soft-Index File Store

The Soft-Index File Store is an experimental local file-based. It is a pure Java implementation that tries to get around Single File Store’s drawbacks by implementing a variant of B+ tree that is cached in-memory using Java’s soft references - here’s where the name Soft-Index File Store comes from. This B+ tree (called Index) is offloaded on filesystem to single file that does not need to be persisted - it is purged and rebuilt when the cache store restarts, its purpose is only offloading.

The data that should be persisted are stored in a set of files that are written in append-only way - that means that if you store this on conventional magnetic disk, it does not have to seek when writing a burst of entries. It is not stored in single file but set of files. When the usage of any of these files drops below 50% (the entries from the file are overwritten to another file), the file starts to be collected, moving the live entries into different file and in the end removing that file from disk.

Most of the structures in Soft Index File Store are bounded, therefore you don’t have to be afraid of OOMEs. For example, you can configure the limits for concurrently open files as well.

5.5.2.1. Configuration

Here is an example of Soft-Index File Store configuration via XML:

```
<persistence>
    <soft-index-file-store xmlns="urn:infinispan:config:store:soft-index:8.0">
        <index path="/tmp/sifs/testCache/index" />
        <data path="/tmp/sifs/testCache/data" />
    </soft-index-file-store>
</persistence>
```

Programmatic configuration would look as follows:

```
ConfigurationBuilder b = new ConfigurationBuilder();
b.persistence()
    .addStore(SoftIndexFileStoreConfigurationBuilder.class)
        .indexLocation("/tmp/sifs/testCache/index");
        .dataLocation("/tmp/sifs/testCache/data")
```

5.5.2.2. Current limitations

Size of a node in the Index is limited, by default it is 4096 bytes, though it can be configured. This size also limits the key length (or rather the length of the serialized form): you can't use keys longer than size of the node - 15 bytes. Moreover, the key length is stored as 'short', limiting it to 32767 bytes. There's no way how you can use longer keys - SIFS throws an exception when the key is longer after serialization.

When entries are stored with expiration, SIFS cannot detect that some of those entries are expired. Therefore, such old file will not be compacted (method AdvancedStore.purgeExpired() is not implemented). This can lead to excessive file-system space usage.

5.6. JDBC STRING BASED CACHE STORE

A cache store which relies on the provided JDBC driver to load/store values in the underlying database.

Each key in the cache is stored in its own row in the database. In order to store each key in its own row, this store relies on a (pluggable) bijection that maps the each key to a String object. The bijection is defined by the Key2StringMapper interface. Red Hat Data Grids ships a default implementation (smartly named DefaultTwoWayKey2StringMapper) that knows how to handle primitive types.

NOTE

By default Red Hat Data Grid shares are not stored, meaning that all nodes in the cluster will write to the underlying store upon each update. If you wish for an operation to only be written to the underlying database once, you must configure the JDBC store to be shared.

5.6.1. Connection management (pooling)

In order to obtain a connection to the database the JDBC cache store relies on a ConnectionFactory implementation. The connection factory is specified programmatically using one of the connectionPool(), dataSource() or simpleConnection() methods on the JdbcStringBasedStoreConfigurationBuilder class or declaratively using one of the **<connectionPool />**, **<dataSource />** or **<simpleConnection />** elements.

Red Hat Data Grid ships with three ConnectionFactory implementations:

- PooledConnectionFactoryConfigurationBuilder is a factory based on HikariCP. Additional properties for HikariCP can be provided by a properties file, either via placing a

hikari.properties file on the classpath or by specifying the path to the file via **PooledConnectionFactoryConfiguration.propertyFile** or **properties-file** in the connection pool's xml config. N.B. a properties file specified explicitly in the configuration is loaded instead of the **hikari.properties** file on the class path and Connection pool characteristics which are explicitly set in PooledConnectionFactoryConfiguration always override the values loaded from a properties file.

Refer to the official documentation for details of all configuration properties.

- ManagedConnectionFactoryConfigurationBuilder is a connection factory that can be used within managed environments, such as application servers. It knows how to look into the JNDI tree at a certain location (configurable) and delegate connection management to the DataSource.

- SimpleConnectionFactoryConfigurationBuilder is a factory implementation that will create database connection on a per invocation basis. Not recommended in production.

The **PooledConnectionFactory** is generally recommended for stand-alone deployments (i.e. not running within AS or servlet container). **ManagedConnectionFactory** can be used when running in a managed environment where a **DataSource** is present, so that connection pooling is performed within the **DataSource**.

5.6.2. Sample configurations

Below is a sample configuration for the JdbcStringBasedStore. For detailed description of all the parameters used refer to the JdbcStringBasedStore.

```
<persistence>
  <string-keyed-jdbc-store xmlns="urn:infinispan:config:store:jdbc:9.4" dialect="H2">
    <connection-pool connection-url="jdbc:h2:mem:infinispan_string_based;DB_CLOSE_DELAY=-1"
username="sa" driver="org.h2.Driver"/>
    <string-keyed-table drop-on-exit="true" create-on-start="true" prefix="ISPN_STRING_TABLE">
      <id-column name="ID_COLUMN" type="VARCHAR(255)" />
      <data-column name="DATA_COLUMN" type="BINARY" />
      <timestamp-column name="TIMESTAMP_COLUMN" type="BIGINT" />
    </string-keyed-table>
  </string-keyed-jdbc-store>
</persistence>
```

```
ConfigurationBuilder builder = new ConfigurationBuilder();
builder.persistence().addStore(JdbcStringBasedStoreConfigurationBuilder.class)
      .shared(true)
      .table()
        .dropOnExit(true)
        .createOnStart(true)
        .tableNamePrefix("ISPN_STRING_TABLE")
        .idColumnName("ID_COLUMN").idColumnType("VARCHAR(255)")
        .dataColumnName("DATA_COLUMN").dataColumnType("BINARY")
        .timestampColumnName("TIMESTAMP_COLUMN").timestampColumnType("BIGINT")
      .connectionPool()
        .connectionUrl("jdbc:h2:mem:infinispan_string_based;DB_CLOSE_DELAY=-1")
        .username("sa")
        .driverClass("org.h2.Driver");
```

Finally, below is an example of a JDBC cache store with a managed connection factory, which is chosen implicitly by specifying a datasource JNDI location:

```
<persistence>
  <string-keyed-jdbc-store xmlns="urn:infinispan:config:store:jdbc:9.4" shared="true" dialect="H2">
    <data-source jndi-url="java:/StringStoreWithManagedConnectionTest/DS" />
    <string-keyed-table drop-on-exit="true" create-on-start="true" prefix="ISPN_STRING_TABLE">
      <id-column name="ID_COLUMN" type="VARCHAR(255)" />
      <data-column name="DATA_COLUMN" type="BINARY" />
      <timestamp-column name="TIMESTAMP_COLUMN" type="BIGINT" />
    </string-keyed-table>
  </string-keyed-jdbc-store>
</persistence>
```

```
ConfigurationBuilder builder = new ConfigurationBuilder();
builder.persistence().addStore(JdbcStringBasedStoreConfigurationBuilder.class)
     .shared(true)
     .table()
       .dropOnExit(true)
       .createOnStart(true)
       .tableNamePrefix("ISPN_STRING_TABLE")
       .idColumnName("ID_COLUMN").idColumnType("VARCHAR(255)")
       .dataColumnName("DATA_COLUMN").dataColumnType("BINARY")
       .timestampColumnName("TIMESTAMP_COLUMN").timestampColumnType("BIGINT")
     .dataSource()
       .jndiUrl("java:/StringStoreWithManagedConnectionTest/DS");
```

5.7. REMOTE STORE

The **RemoteStore** is a cache loader and writer implementation that stores data in a remote Red Hat Data Grid cluster. In order to communicate with the remote cluster, the **RemoteStore** uses the HotRod client/server architecture. HotRod bering the load balancing and fault tolerance of calls and the possibility to fine-tune the connection between the RemoteCacheStore and the actual cluster. Please refer to Hot Rod for more information on the protocol, client and server configuration. For a list of RemoteStore configuration refer to the javadoc . Example:

5.7.1. Sample Usage

```
<persistence>
  <remote-store xmlns="urn:infinispan:config:store:remote:8.0" cache="mycache" raw-values="true">
    <remote-server host="one" port="12111" />
    <remote-server host="two" />
    <connection-pool max-active="10" exhausted-action="CREATE_NEW" />
    <write-behind />
  </remote-store>
</persistence>
```

```
ConfigurationBuilder b = new ConfigurationBuilder();
b.persistence().addStore(RemoteStoreConfigurationBuilder.class)
     .fetchPersistentState(false)
     .ignoreModifications(false)
     .purgeOnStartup(false)
     .remoteCacheName("mycache")
```

```
        .rawValues(true)
    .addServer()
        .host("one").port(12111)
        .addServer()
        .host("two")
        .connectionPool()
        .maxActive(10)
        .exhaustedAction(ExhaustedAction.CREATE_NEW)
        .async().enable();
```

In this sample configuration, the remote cache store is configured to use the remote cache named "mycache" on servers "one" and "two". It also configures connection pooling and provides a custom transport executor. Additionally the cache store is asynchronous.

5.8. CLUSTER CACHE LOADER

The ClusterCacheLoader is a cache loader implementation that retrieves data from other cluster members.

It is a cache loader only as it doesn't persist anything (it is not a Store), therefore features like *fetchPersistentState* (and like) are not applicable.

A cluster cache loader can be used as a non-blocking (partial) alternative to *stateTransfer* : keys not already available in the local node are fetched on-demand from other nodes in the cluster. This is a kind of lazy-loading of the cache content.

```
<persistence>
  <cluster-loader remote-timeout="500"/>
</persistence>
```

```
ConfigurationBuilder b = new ConfigurationBuilder();
b.persistence()
   .addClusterLoader()
   .remoteCallTimeout(500);
```

For a list of ClusterCacheLoader configuration refer to the javadoc .

NOTE

The ClusterCacheLoader does not support preloading(preload=true). It also won't provide state if fetchPersistentSate=true.

5.9. COMMAND-LINE INTERFACE CACHE LOADER

The Command-Line Interface (CLI) cache loader is a cache loader implementation that retrieves data from another Red Hat Data Grid node using the CLI. The node to which the CLI connects to could be a standalone node, or could be a node that it's part of a cluster. This cache loader is read-only, so it will only be used to retrieve data, and hence, won't be used when persisting data.

The CLI cache loader is configured with a connection URL pointing to the Red Hat Data Grid node to which connect to. Here is an example:

NOTE

Details on the format of the URL and how to make sure a node can receive invocations via the CLI can be found in the Command-Line Interface chapter.

```
<persistence>
  <cli-loader connection="jmx://1.2.3.4:4444/MyCacheManager/myCache" />
</persistence>
```

```
ConfigurationBuilder b = new ConfigurationBuilder();
b.persistence()
    .addStore(CLInterfaceLoaderConfigurationBuilder.class)
    .connectionString("jmx://1.2.3.4:4444/MyCacheManager/myCache");
```

5.10. ROCKSDB CACHE STORE

Red Hat Data Grid supports using RocksDB as a cache store.

5.10.1. Introduction

RocksDB is a fast key-value filesystem-based storage from Facebook. It started as a fork of Google's LevelDB, but provides superior performance and reliability, especially in highly concurrent scenarios.

5.10.1.1. Sample Usage

The RocksDB cache store requires 2 filesystem directories to be configured - each directory contains a RocksDB database: one location is used to store non-expired data, while the second location is used to store expired keys pending purge.

```
Configuration cacheConfig = new ConfigurationBuilder().persistence()
    .addStore(RocksDBStoreConfigurationBuilder.class)
    .build();
EmbeddedCacheManager cacheManager = new DefaultCacheManager(cacheConfig);

Cache<String, User> usersCache = cacheManager.getCache("usersCache");
usersCache.put("raytsang", new User(...));
```

5.10.2. Configuration

It is also possible to configure the underlying rocks db instance. This can be done via properties in the store configuration. Any property that is prefixed with the name **database** will configure the rocks db database. Data is now stored in column families, these can be configured independently of the database by setting a property prefixed with the name **data**.

Note that you do not have to supply properties and this is entirely optional.

5.10.2.1. Sample Programatic Configuration

```
Properties props = new Properties();
props.put("database.max_background_compactions", "2");
props.put("data.write_buffer_size", "512MB");
```

```
Configuration cacheConfig = new ConfigurationBuilder().persistence()
    .addStore(RocksDBStoreConfigurationBuilder.class)
    .location("/tmp/rocksdb/data")
    .expiredLocation("/tmp/rocksdb/expired")
        .properties(props)
    .build();
```

Parameter	Description
location	Directory to use for RocksDB to store primary cache store data. The directory will be auto-created if it does not exit.
expiredLocation	Directory to use for RocksDB to store expiring data pending to be purged permanently. The directory will be auto-created if it does not exit.
expiryQueueSize	Size of the in-memory queue to hold expiring entries before it gets flushed into expired RocksDB store
clearThreshold	There are two methods to clear all entries in RocksDB. One method is to iterate through all entries and remove each entry individually. The other method is to delete the database and re-init. For smaller databases, deleting individual entries is faster than the latter method. This configuration sets the max number of entries allowed before using the latter method
compressionType	Configuration for RocksDB for data compression, see CompressionType enum for options
blockSize	Configuration for RocksDB - see documentation for performance tuning
cacheSize	Configuration for RocksDB - see documentation for performance tuning

5.10.2.2. Sample XML Configuration

infinispan.xml

```
<local-cache name="vehicleCache">
  <persistence>
    <rocksdb-store path="/tmp/rocksdb/data">
      <expiration path="/tmp/rocksdb/expired"/>
      <property name="database.max_background_compactions">2</property>
      <property name="data.write_buffer_size">512MB</property>
    </rocksdb-store>
  </persistence>
</local-cache>
```

NOTE

Red Hat Data Grid servers log warning messages at startup when you add configuration properties that are specific to RocksDB.

For example, as in the preceding example, if you set **data.write_buffer_size** in your configuration, then the following message is written to logs:

```
WARN  [org.infinispan.configuration.parsing.XmlConfigHelper] ISPN000292:
Unrecognized attribute 'data.write_buffer_size'. Please check your
configuration. Ignoring!
```

Red Hat Data Grid applies the RocksDB properties even though the log message indicates they do not take effect. You can ignore these **WARN** messages.

5.10.3. Additional References

Refer to the test case for code samples in action.

Refer to test configurations for configuration samples.

5.11. LEVELDB CACHE STORE

WARNING

The LevelDB Cache Store has been deprecated and has been replaced with the RocksDB Cache Store. If you have existing data stored in a LevelDB Cache Store, the RocksDB Cache Store will convert it to the new SST-based format on the first run.

5.12. JPA CACHE STORE

The implementation depends on JPA 2.0 specification to access entity meta model.

In normal use cases, it’s recommended to leverage Red Hat Data Grid for JPA second level cache and/or query cache. However, if you’d like to use only Red Hat Data Grid API and you want Red Hat Data Grid to persist into a cache store using a common format (e.g., a database with well defined schema), then JPA Cache Store could be right for you.

Things to note

- When using JPA Cache Store, the key should be the ID of the entity, while the value should be the entity object.
- Only a single **@Id** or **@EmbeddedId** annotated property is allowed.
- Auto-generated ID is not supported.
- Lastly, all entries will be stored as immortal entries.

5.12.1. Sample Usage

For example, given a persistence unit "myPersistenceUnit", and a JPA entity User:

persistence.xml

```
<persistence-unit name="myPersistenceUnit">
 ...
</persistence-unit>
```

User entity class

User.java

```
@Entity
public class User implements Serializable {
 @Id
 private String username;
 private String firstName;
 private String lastName;

 ...
}
```

Then you can configure a cache "usersCache" to use JPA Cache Store, so that when you put data into the cache, the data would be persisted into the database based on JPA configuration.

```
EmbeddedCacheManager cacheManager = ...;


Configuration cacheConfig = new ConfigurationBuilder().persistence()
            .addStore(JpaStoreConfigurationBuilder.class)
            .persistenceUnitName("org.infinispan.loaders.jpa.configurationTest")
            .entityClass(User.class)
            .build();
cacheManager.defineCache("usersCache", cacheConfig);

Cache<String, User> usersCache = cacheManager.getCache("usersCache");
usersCache.put("raytsang", new User(...));
```

Normally a single Red Hat Data Grid cache can store multiple types of key/value pairs, for example:

```
Cache<String, User> usersCache = cacheManager.getCache("myCache");
usersCache.put("raytsang", new User());
Cache<Integer, Teacher> teachersCache = cacheManager.getCache("myCache");
teachersCache.put(1, new Teacher());
```

It's important to note that, when a cache is configured to use a JPA Cache Store, that cache would only be able to store ONE type of data.

```
Cache<String, User> usersCache = cacheManager.getCache("myJPACache"); // configured for User entity class
usersCache.put("raytsang", new User());
```

```
Cache<Integer, Teacher> teachersCache = cacheManager.getCache("myJPACache"); // cannot do
this when this cache is configured to use a JPA cache store
teachersCache.put(1, new Teacher());
```

Use of **@EmbeddedId** is supported so that you can also use composite keys.

```
@Entity
public class Vehicle implements Serializable {
 @EmbeddedId
 private VehicleId id;
 private String color; ...
}

@Embeddable
public class VehicleId implements Serializable
{
 private String state;
 private String licensePlate;
 ...
}
```

Lastly, auto-generated IDs (e.g., **@GeneratedValue**) is not supported. When putting things into the cache with a JPA cache store, the key should be the ID value!

5.12.2. Configuration

5.12.2.1. Sample Programatic Configuration

```
Configuration cacheConfig = new ConfigurationBuilder().persistence()
             .addStore(JpaStoreConfigurationBuilder.class)
             .persistenceUnitName("org.infinispan.loaders.jpa.configurationTest")
             .entityClass(User.class)
             .build();
```

Parameter	Description
persistenceUnitName	JPA persistence unit name in JPA configuration (persistence.xml) that contains the JPA entity class
entityClass	JPA entity class that is expected to be stored in this cache. Only one class is allowed.

5.12.2.2. Sample XML Configuration

```
<local-cache name="vehicleCache">
   <persistence passivation="false">
      <jpa-store xmlns="urn:infinispan:config:store:jpa:7.0"
         persistence-unit="org.infinispan.persistence.jpa.configurationTest"
         entity-class="org.infinispan.persistence.jpa.entity.Vehicle">
```

```
    />
    </persistence>
  </local-cache>
```

Parameter	Description
persistence-unit	JPA persistence unit name in JPA configuration (persistence.xml) that contains the JPA entity class
entity-class	Fully qualified JPA entity class name that is expected to be stored in this cache. Only one class is allowed.

5.12.3. Additional References

Refer to the test case for code samples in action.

Refer to test configurations for configuration samples.

5.13. CUSTOM CACHE STORES

If the provided cache stores do not fulfill all of your requirements, it is possible for you to implement your own store. The steps required to create your own store are as follows:

1. Write your custom store by implementing one of the following interfaces:
   - **org.infinispan.persistence.spi.AdvancedCacheWriter**
   - **org.infinispan.persistence.spi.AdvancedCacheLoader**
   - **org.infinispan.persistence.spi.CacheLoader**
   - **org.infinispan.persistence.spi.CacheWriter**
   - **org.infinispan.persistence.spi.ExternalStore**
   - **org.infinispan.persistence.spi.AdvancedLoadWriteStore**
   - **org.infinispan.persistence.spi.TransactionalCacheWriter**
2. Annotate your store class with the **@Store** annotation and specify the properties relevant to your store, e.g. is it possible for the store to be shared in Replicated or Distributed mode: **@Store(shared = true)**.
3. Create a custom cache store configuration and builder. This requires extending **AbstractStoreConfiguration** and **AbstractStoreConfigurationBuilder**. As an optional step, you should add the following annotations to your configuration - **@ConfigurationFor**, **@BuiltBy** as well as adding **@ConfiguredBy** to your store implementation class. These additional annotations will ensure that your custom configuration builder is used to parse your store configuration from xml. If these annotations are not added, then the **CustomStoreConfigurationBuilder** will be used to parse the common store attributes defined in **AbstractStoreConfiguration** and any additional elements will be ignored. If a store and its configuration do not declare the **@Store** and **@ConfigurationFor** annotations respectively, a warning message will be logged upon cache initialisation.

4. Add your custom store to your cache's configuration:

   a. Add your custom store to the ConfigurationBuilder, for example:

   ```
   Configuration config = new ConfigurationBuilder()
               .persistence()
               .addStore(CustomStoreConfigurationBuilder.class)
               .build();
   ```

   b. Define your custom store via xml:

   ```
   <local-cache name="customStoreExample">
     <persistence>
       <store class="org.infinispan.persistence.dummy.DummyInMemoryStore" />
     </persistence>
   </local-cache>
   ```

5.13.1. HotRod Deployment

A Custom Cache Store can be packaged into a separate JAR file and deployed in a HotRod server using the following steps:

1. Follow Custom Cache Stores, steps 1-3>> in the previous section and package your implementations in a JAR file (or use a Custom Cache Store Archetype).

2. In your Jar create a proper file under **META-INF/services/**, which contains the fully qualified class name of your store implementation. The name of this service file should reflect the interface that your store implements. For example, if your store implements the **AdvancedCacheWriter** interface than you need to create the following file:

   - **/META-INF/services/org.infinispan.persistence.spi.AdvancedCacheWriter**

3. Deploy the JAR file in the Red Hat Data Grid Server.

5.14. STORE MIGRATOR

Red Hat Data Grid 7.3 introduced changes to internal marshalling functionality that are not backwardly compatible with previous versions of Red Hat Data Grid. As a result, Red Hat Data Grid 7.3.x and later cannot read cache stores created in earlier versions of Red Hat Data Grid. Additionally, Red Hat Data Grid no longer provides some store implementations such as JDBC Mixed and Binary stores.

You can use **StoreMigrator.java** to migrate cache stores. This migration tool reads data from cache stores in previous versions and rewrites the content for compatibility with the current marshalling implementation.

5.14.1. Migrating Cache Stores

To perform a migration with **StoreMigrator**,

1. Put **infinispan-tools-9.4.0.jar** and dependencies for your source and target databases, such as JDBC drivers, on your classpath.

2. Create a **.properties** file that contains configuration properties for the source and target cache stores.

You can find an example properties file that contains all applicable configuration options in migrator.properties.

3. Specify **.properties** file as an argument for **StoreMigrator**.

4. Run **mvn exec:java** to execute the migrator.

See the following example Maven **pom.xml** for **StoreMigrator**:

```
<?xml version="1.0" encoding="UTF-8"?>
<project xmlns="http://maven.apache.org/POM/4.0.0"
         xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
         xsi:schemaLocation="http://maven.apache.org/POM/4.0.0 http://maven.apache.org/xsd/maven-
4.0.0.xsd">
    <modelVersion>4.0.0</modelVersion>

    <groupId>org.infinispan.example</groupId>
    <artifactId>jdbc-migrator-example</artifactId>
    <version>1.0-SNAPSHOT</version>

    <dependencies>
        <dependency>
            <groupId>org.infinispan</groupId>
            <artifactId>infinispan-tools</artifactId>
            <version>${version.infinispan}</version>
        </dependency>

        <!-- ADD YOUR REQUIRED DEPENDENCIES HERE -->
    </dependencies>

    <build>
        <plugins>
            <plugin>
                <groupId>org.codehaus.mojo</groupId>
                <artifactId>exec-maven-plugin</artifactId>
                <version>1.2.1</version>
                <executions>
                    <execution>
                        <goals>
                            <goal>java</goal>
                        </goals>
                    </execution>
                </executions>
                <configuration>
                    <mainClass>StoreMigrator</mainClass>
                    <arguments>
                        <argument><!-- PATH TO YOUR MIGRATOR.PROPERTIES FILE --></argument>
                    </arguments>
                </configuration>
            </plugin>
        </plugins>
    </build>
</project>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

5.14.2. Store Migrator Properties

All migrator properties are configured within the context of a source or target store. Each property must start with either **source.** or **target.**.

All properties in the following sections apply to both source and target stores, except for **table.binary.*** properties because it is not possible to migrate to a binary table.

5.14.2.1. Common Properties

Property	Description	Example value	Required
type	JDBC_STRING | JDBC_BINARY | JDBC_MIXED | LEVELDB | ROCKSDB | SINGLE_FILE_STORE | SOFT_INDEX_FILE_STORE	JDBC_MIXED	TRUE
cache_name	The name of the cache associated with the store	persistentMixedCache	TRUE

5.14.2.2. JDBC Properties

Property	Description	Example value	Required
dialect	The dialect of the underlying database	POSTGRES	TRUE
marshaller.type	The marshaller to use for the store. Possible values are: - **LEGACY** Red Hat Data Grid 7.2.x marshaller. Valid for source stores only. - **CURRENT** Red Hat Data Grid 7.3.x marshaller. - **CUSTOM** Custom marshaller.	CURRENT	TRUE
marshaller.class	The class of the marshaller if type=CUSTOM	org.example.CustomMarshaller	

Property	Description	Example value	Required
marshaller.externalizers	A comma-separated list of custom AdvancedExternalizer implementations to load **[id]:<Externalizer class>**	**25:Externalizer1,org.example.Externalizer2**	
connection_pool.connection_url	The JDBC connection url	**jdbc:postgresql:postgres**	TRUE
connection_pool.driver_class	The class of the JDBC driver	org.postrgesql.Driver	TRUE
connection_pool.username	Database username		TRUE
connection_pool.password	Database password		TRUE
db.major_version	Database major version	9	
db.minor_version	Database minor version	5	
db.disable_upsert	Disable db upsert	false	
db.disable_indexing	Prevent table index being created	false	
table.**<binary|string>**.table_name_prefix	Additional prefix for table name	tablePrefix	
table.**<binary|string>**.**<id|data|timestamp>**.name	Name of the column	id_column	TRUE
table.**<binary|string>**.**<id|data|timestamp>**.type	Type of the column	VARCHAR	TRUE
key_to_string_mapper	TwoWayKey2StringMapper Class	**org.infinispan.persistence.keymappers.DefaultTwoWayKey2StringMapper**	

5.14.2.3. LevelDB/RocksDB Properties

Property	Description	Example value	Required
location	The location of the db directory	/some/example/dir	TRUE
compression	The compression type to be used	SNAPPY	

5.14.2.4. SingleFileStore Properties

Property	Description	Example value	Required
location	The directory containing the store's .dat file	/some/example/dir	TRUE

5.14.2.5. SoftIndexFileStore Properties

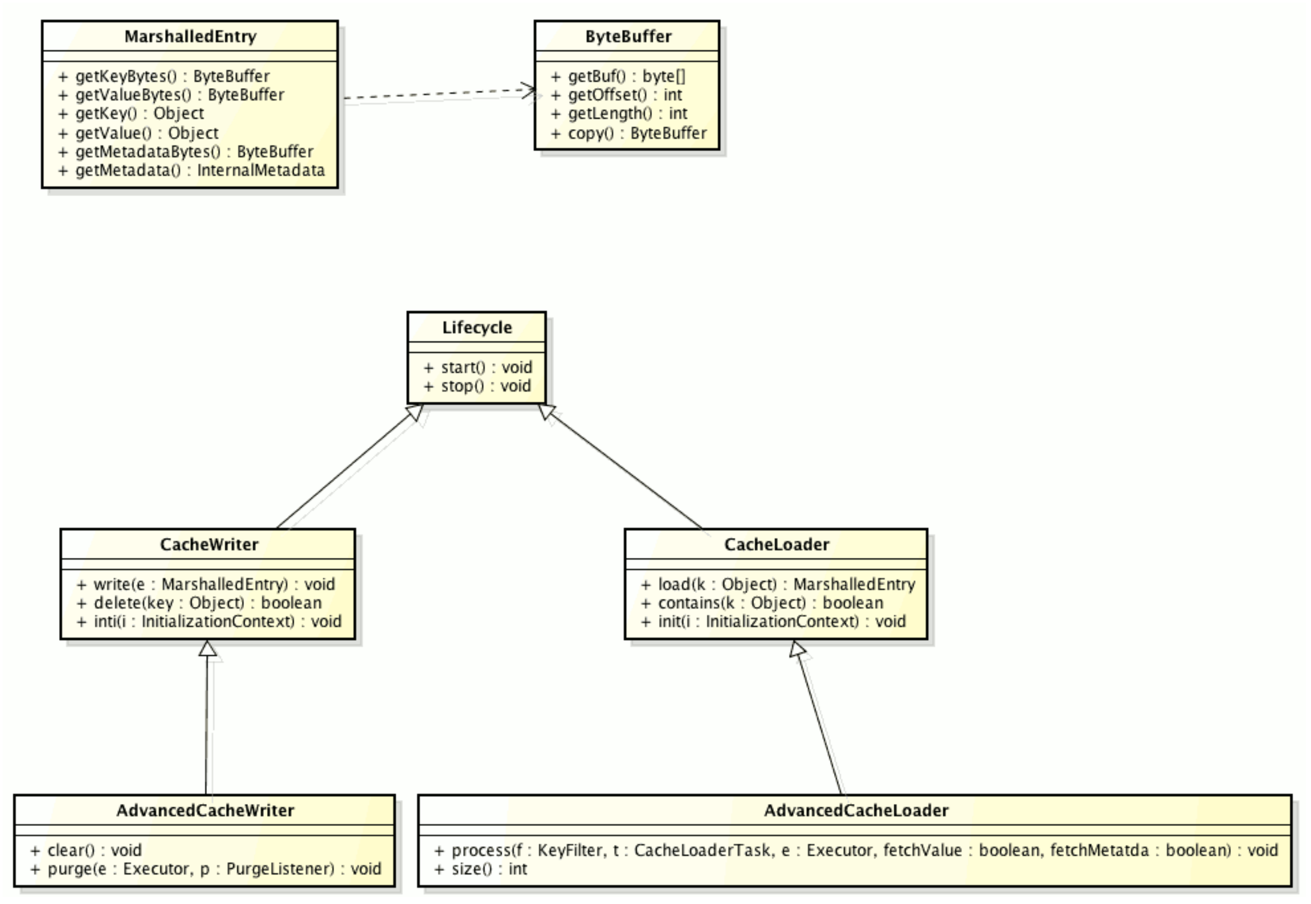
Property	Description	Example value	Required
location	The location of the db directory	/some/example/dir	TRUE
index_location	The location of the db's index	/some/example/dir-index	Target Only

Following sections describe the SPI and also discuss the SPI implementations that Red Hat Data Grid ships out of the box.

5.15. SPI

The following class diagram presents the main SPI interfaces of the persistence API:

Figure 5.1. Persistence SPI


MarshalledEntry
+ getKeyBytes() : ByteBuffer
+ getValueBytes() : ByteBuffer
+ getKey() : Object
+ getValue() : Object
+ getMetadataBytes() : ByteBuffer
+ getMetadata() : InternalMetadata
ByteBuffer
+ getBuf() : byte[]
+ getOffset() : int
+ getLength() : int
+ copy() : ByteBuffer
Lifecycle
+ start() : void
+ stop() : void
CacheWriter
+ write(e : MarshalledEntry) : void
+ delete(key : Object) : boolean
+ inti(i : InitializationContext) : void
CacheLoader
+ load(k : Object) : MarshalledEntry
+ contains(k : Object) : boolean
+ init(i : InitializationContext) : void
AdvancedCacheWriter
+ clear() : void
+ purge(e : Executor, p : PurgeListener) : void
AdvancedCacheLoader
+ process(f : KeyFilter, t : CacheLoaderTask, e : Executor, fetchValue : boolean, fetchMetatda : boolean) : void
+ size() : int

Some notes about the classes:

- ByteBuffer - abstracts the serialized form of an object
- MarshalledEntry - abstracts the information held within a persistent store corresponding to a key-value added to the cache. Provides method for reading this information both in serialized (ByteBuffer) and deserialized (Object) format. Normally data read from the store is kept in serialized format and lazily deserialized on demand, within the MarshalledEntry implementation
- CacheWriter and CacheLoader provide basic methods for reading and writing to a store
- AdvancedCacheLoader and AdvancedCacheWriter provide operations to manipulate the underlaying storage in bulk: parallel iteration and purging of expired entries, clear and size.

A provider might choose to only implement a subset of these interfaces:

- Not implementing the AdvancedCacheWriter makes the given writer not usable for purging expired entries or clear
- If a loader does not implement the AdvancedCacheLoader inteface, then it will not participate in preloading nor in cache iteration (required also for stream operations).

If you’re looking at migrating your existing store to the new API or to write a new store implementation, the SingleFileStore might be a good starting point/example.

5.16. MORE IMPLEMENTATIONS

Many more cache loader and cache store implementations exist. Visit this website for more details.

CHAPTER 6. CLUSTERING

A cache manager can be configured to be either local (standalone) or clustered. When clustered, manager instances use JGroups' discovery protocols to automatically discover neighboring instances on the same local network and form a cluster.

Creating a local-only cache manager is trivial: just use the no-argument **DefaultCacheManager** constructor, or supply the following XML configuration file.

```
<infinispan/>
```

To start a clustered cache manager, you need to create a clustered configuration.

```
GlobalConfigurationBuilder gcb = GlobalConfigurationBuilder.defaultClusteredBuilder();
DefaultCacheManager manager = new DefaultCacheManager(gcb.build());
```

```
<infinispan>
  <cache-container>
    <transport/>
  </cache-container>
</infinispan>
```

Individual caches can then be configured in different modes:

- **Local**: changes and reads are never replicated. This is the only mode available in non-clustered cache managers.
- **Invalidation**: changes are not replicated, instead the key is invalidated on all nodes; reads are local.
- **Replicated**: changes are replicated to all nodes, reads are always local.
- **Distributed**: changes are replicated to a fixed number of nodes, reads request the value from at least one of the owner nodes.

6.1. LOCAL MODE

While Red Hat Data Grid is particularly interesting in clustered mode, it also offers a very capable local mode. In this mode, it acts as a simple, in-memory data cache similar to a **ConcurrentHashMap**.

But why would one use a local cache rather than a map? Caches offer a lot of features over and above a simple map, including write-through and write-behind to a persistent store, eviction of entries to prevent running out of memory, and expiration.

Red Hat Data Grid's **Cache** interface extends JDK's **ConcurrentMap** – making migration from a map to Red Hat Data Grid trivial.

Red Hat Data Grid caches also support transactions, either integrating with an existing transaction manager or running a separate one. Local caches transactions have two choices:

1. When to lock? **Pessimistic locking** locks keys on a write operation or when the user calls **AdvancedCache.lock(keys)** explicitly. **Optimistic locking** only locks keys during the transaction commit, and instead it throws a **WriteSkewCheckException** at commit time, if another transaction modified the same keys after the current transaction read them.

2. Isolation level. We support **read-committed** and **repeatable read**.

6.1.1. Simple Cache

Traditional local caches use the same architecture as clustered caches, i.e. they use the interceptor stack. That way a lot of the implementation can be reused. However, if the advanced features are not needed and performance is more important, the interceptor stack can be stripped away and simple cache can be used.

So, which features are stripped away? From the configuration perspective, simple cache does not support:

- transactions and invocation batching
- persistence (cache stores and loaders)
- custom interceptors (there's no interceptor stack!)
- indexing
- compatibility (embedded/server mode)
- store as binary (which is hardly useful for local caches)

From the API perspective these features throw an exception:

- adding custom interceptors
- Distributed Executors Framework

So, what's left?

- basic map-like API
- cache listeners (local ones)
- expiration
- eviction
- security
- JMX access
- statistics (though for max performance it is recommended to switch this off using statistics-available=false)

6.1.1.1. Declarative configuration

```
<local-cache name="mySimpleCache" simple-cache="true">
    <!-- expiration, eviction, security... -->
</local-cache>
```

6.1.1.2. Programmatic configuration

```
CacheManager cm = getCacheManager();
ConfigurationBuilder builder = new ConfigurationBuilder().simpleCache(true);
cm.defineConfiguration("mySimpleCache", builder.build());
Cache cache = cm.getCache("mySimpleCache");
```

Simple cache checks against features it does not support, if you configure it to use e.g. transactions, configuration validation will throw an exception.

6.2. INVALIDATION MODE

In invalidation, the caches on different nodes do not actually share any data. Instead, when a key is written to, the cache only aims to remove data that may be stale from other nodes. This cache mode only makes sense if you have another, permanent store for your data such as a database and are only using Red Hat Data Grid as an optimization in a read-heavy system, to prevent hitting the database for every read. If a cache is configured for invalidation, every time data is changed in a cache, other caches in the cluster receive a message informing them that their data is now stale and should be removed from memory and from any local store.

Figure 6.1. Invalidation mode

Sometimes the application reads a value from the external store and wants to write it to the local cache, without removing it from the other nodes. To do this, it must call **Cache.putForExternalRead(key, value)** instead of **Cache.put(key, value)**.

Invalidation mode can be used with a shared cache store. A write operation will both update the shared store, and it would remove the stale values from the other nodes' memory. The benefit of this is twofold: network traffic is minimized as invalidation messages are very small compared to replicating the entire value, and also other caches in the cluster look up modified data in a lazy manner, only when needed.

NOTE

Never use invalidation mode with a **local** store. The invalidation message will not remove entries in the local store, and some nodes will keep seeing the stale value.

An invalidation cache can also be configured with a special cache loader, **ClusterLoader**. When **ClusterLoader** is enabled, read operations that do not find the key on the local node will request it from all the other nodes first, and store it in memory locally. In certain situation it will store stale values, so only use it if you have a high tolerance for stale values.

Invalidation mode can be synchronous or asynchronous. When synchronous, a write blocks until all nodes in the cluster have evicted the stale value. When asynchronous, the originator broadcasts invalidation messages but doesn’t wait for responses. That means other nodes still see the stale value for a while after the write completed on the originator.

Transactions can be used to batch the invalidation messages. Transactions acquire the key lock on the primary owner. To find more about how primary owners are assigned, please read the Key Ownership section.

- With pessimistic locking, each write triggers a lock message, which is broadcast to all the nodes. During transaction commit, the originator broadcasts a one-phase prepare message (optionally fire-and-forget) which invalidates all affected keys and releases the locks.
- With optimistic locking, the originator broadcasts a prepare message, a commit message, and an unlock message (optional). Either the one-phase prepare or the unlock message is fire-and-forget, and the last message always releases the locks.

6.3. REPLICATED MODE

Entries written to a replicated cache on any node will be replicated to all other nodes in the cluster, and can be retrieved locally from any node. Replicated mode provides a quick and easy way to share state across a cluster, however replication practically only performs well in small clusters (under 10 nodes), due to the number of messages needed for a write scaling linearly with the cluster size. Red Hat Data Grid can be configured to use UDP multicast, which mitigates this problem to some degree.

Each key has a primary owner, which serializes data container updates in order to provide consistency. To find more about how primary owners are assigned, please read the Key Ownership section.

Figure 6.2. Replicated mode

Replicated mode can be synchronous or asynchronous.

- Synchronous replication blocks the caller (e.g. on a **cache.put(key, value)**) until the modifications have been replicated successfully to all the nodes in the cluster.
- Asynchronous replication performs replication in the background, and write operations return immediately. Asynchronous replication is not recommended, because communication errors, or errors that happen on remote nodes are not reported to the caller.

If transactions are enabled, write operations are not replicated through the primary owner.

- With pessimistic locking, each write triggers a lock message, which is broadcast to all the nodes. During transaction commit, the originator broadcasts a one-phase prepare message and an unlock message (optional). Either the one-phase prepare or the unlock message is fire-and-forget.
- With optimistic locking, the originator broadcasts a prepare message, a commit message, and an unlock message (optional). Again, either the one-phase prepare or the unlock message is fire-and-forget.

6.4. DISTRIBUTION MODE

Distribution tries to keep a fixed number of copies of any entry in the cache, configured as **numOwners**. This allows the cache to scale linearly, storing more data as nodes are added to the cluster.

As nodes join and leave the cluster, there will be times when a key has more or less than **numOwners** copies. In particular, if **numOwners** nodes leave in quick succession, some entries will be lost, so we say that a distributed cache tolerates **numOwners - 1** node failures.

The number of copies represents a trade-off between performance and durability of data. The more copies you maintain, the lower performance will be, but also the lower the risk of losing data due to server or network failures. Regardless of how many copies are maintained, distribution still scales linearly, and this is key to Red Hat Data Grid's scalability.

The owners of a key are split into one **primary owner**, which coordinates writes to the key, and zero or more **backup owners**. To find more about how primary and backup owners are assigned, please read the Key Ownership section.

Figure 6.3. Distributed mode

A read operation will request the value from the primary owner, but if it doesn't respond in a reasonable amount of time, we request the value from the backup owners as well. (The **infinispan.stagger.delay** system property, in milliseconds, controls the delay between requests.) A read operation may require **0** messages if the key is present in the local cache, or up to **2 * numOwners** messages if all the owners are slow.

A write operation will also result in at most **2 * numOwners** messages: one message from the originator to the primary owner, **numOwners - 1** messages from the primary to the backups, and the corresponding ACK messages.

NOTE

Cache topology changes may cause retries and additional messages, both for reads and for writes.

Just as replicated mode, distributed mode can also be synchronous or asynchronous. And as in replicated mode, asynchronous replication is not recommended because it can lose updates. In addition to losing updates, asynchronous distributed caches can also see a stale value when a thread writes to a key and then immediately reads the same key.

Transactional distributed caches use the same kinds of messages as transactional replicated caches, except lock/prepare/commit/unlock messages are sent only to the **affected nodes** (all the nodes that own at least one key affected by the transaction) instead of being broadcast to all the nodes in the cluster. As an optimization, if the transaction writes to a single key and the originator is the primary owner of the key, lock messages are not replicated.

6.4.1. Read consistency

Even with synchronous replication, distributed caches are not linearizable. (For transactional caches, we say they do not support serialization/snapshot isolation.) We can have one thread doing a single put:

```
cache.get(k) -> v1
cache.put(k, v2)
cache.get(k) -> v2
```

But another thread might see the values in a different order:

```
cache.get(k) -> v2
cache.get(k) -> v1
```

The reason is that read can return the value from **any** owner, depending on how fast the primary owner replies. The write is not atomic across all the owners – in fact, the primary commits the update only after it receives a confirmation from the backup. While the primary is waiting for the confirmation message from the backup, reads from the backup will see the new value, but reads from the primary will see the old one.

6.4.2. Key Ownership

Distributed caches split entries into a fixed number of segments and assign each segment to a list of owner nodes. Replicated caches do the same, with the exception that every node is an owner.

The first node in the list of owners is the **primary owner**. The other nodes in the list are **backup owners**. When the cache topology changes, because a node joins or leaves the cluster, the segment ownership table is broadcast to every node. This allows nodes to locate keys without making multicast requests or maintaining metadata for each key.

The **numSegments** property configures the number of segments available. However, the number of segments cannot change unless the cluster is restarted.

Likewise the key-to-segment mapping cannot change. Keys must always map to the same segments regardless of cluster topology changes. It is important that the key-to-segment mapping evenly distributes the number of segments allocated to each node while minimizing the number of segments that must move when the cluster topology changes.

You can customize the key-to-segment mapping by configuring a KeyPartitioner or by using the Grouping API.

However, Red Hat Data Grid provides the following implementations:

SyncConsistentHashFactory

Uses an algorithm based on consistent hashing. Selected by default when server hinting is disabled. This implementation always assigns keys to the same nodes in every cache as long as the cluster is symmetric. In other words, all caches run on all nodes. This implementation does have some negative points in that the load distribution is slightly uneven. It also moves more segments than strictly necessary on a join or leave.

TopologyAwareSyncConsistentHashFactory

Similar to **SyncConsistentHashFactory**, but adapted for Server Hinting. Selected by default when server hinting is enabled.

DefaultConsistentHashFactory

Achieves a more even distribution than **SyncConsistentHashFactory**, but with one disadvantage. The order in which nodes join the cluster determines which nodes own which segments. As a result, keys might be assigned to different nodes in different caches.
Was the default from version 5.2 to version 8.1 with server hinting disabled.

TopologyAwareConsistentHashFactory

Similar to *DefaultConsistentHashFactory*, but adapted for Server Hinting.
Was the default from version 5.2 to version 8.1 with server hinting enabled.

ReplicatedConsistentHashFactory

Used internally to implement replicated caches. You should never explicitly select this algorithm in a distributed cache.

6.4.2.1. Capacity Factors

Capacity factors allocate segment-to-node mappings based on resources available to nodes.

To configure capacity factors, you specify any non-negative number and the Red Hat Data Grid hashing algorithm assigns each node a load weighted by its capacity factor (both as a primary owner and as a backup owner).

For example, nodeA has 2x the memory available than nodeB in the same Red Hat Data Grid cluster. In this case, setting **capacityFactor** to a value of **2** configures Red Hat Data Grid to allocate 2x the number of segments to nodeA.

Setting a capacity factor of **0** is possible but is recommended only in cases where nodes are not joined to the cluster long enough to be useful data owners.

6.4.2.2. Zero Capacity Node

You might need to configure a whole node where the capacity factor is **0** for every cache, user defined caches and internal caches. When defining a zero capacity node, the node won't hold any data. This is how you declare a zero capacity node:

```
<cache-container zero-capacity-node="true" />
```

```
new GlobalConfigurationBuilder().zeroCapacityNode(true);
```

However, note that this will be true for distributed caches only. If you are using replicated caches, the node will still keep a copy of the value. Use only distributed caches to make the best use of this feature.

6.4.2.3. Hashing Configuration

This is how you configure hashing declaratively, via XML:

```
<distributed-cache name="distributedCache" owners="2" segments="100" capacity-factor="2" />
```

And this is how you can configure it programmatically, in Java:

```
Configuration c = new ConfigurationBuilder()
  .clustering()
    .cacheMode(CacheMode.DIST_SYNC)
    .hash()
      .numOwners(2)
      .numSegments(100)
      .capacityFactor(2)
  .build();
```

6.4.3. Initial cluster size

Red Hat Data Grid's very dynamic nature in handling topology changes (i.e. nodes being added / removed at runtime) means that, normally, a node doesn't wait for the presence of other nodes before starting. While this is very flexible, it might not be suitable for applications which require a specific number of nodes to join the cluster before caches are started. For this reason, you can specify how many nodes should have joined the cluster before proceeding with cache initialization. To do this, use the **initialClusterSize** and **initialClusterTimeout** transport properties. The declarative XML configuration:

```
<transport initial-cluster-size="4" initial-cluster-timeout="30000" />
```

The programmatic Java configuration:

```
GlobalConfiguration global = new GlobalConfigurationBuilder()
  .transport()
     .initialClusterSize(4)
     .initialClusterTimeout(30000)
  .build();
```

The above configuration will wait for *4* nodes to join the cluster before initialization. If the initial nodes do not appear within the specified timeout, the cache manager will fail to start.

6.4.4. L1 Caching

When L1 is enabled, a node will keep the result of remote reads locally for a short period of time (configurable, 10 minutes by default), and repeated lookups will return the local L1 value instead of asking the owners again.

Figure 6.4. L1 caching

L1 caching is not free though. Enabling it comes at a cost, and this cost is that every entry update must broadcast an invalidation message to all the nodes. L1 entries can be evicted just like any other entry when the the cache is configured with a maximum size. Enabling L1 will improve performance for repeated reads of non-local keys, but it will slow down writes and it will increase memory consumption to some degree.

Is L1 caching right for you? The correct approach is to benchmark your application with and without L1 enabled and see what works best for your access pattern.

6.4.5. Server Hinting

The following topology hints can be specified:

Machine

This is probably the most useful, when multiple JVM instances run on the same node, or even when multiple virtual machines run on the same physical machine.

Rack

In larger clusters, nodes located on the same rack are more likely to experience a hardware or network failure at the same time.

Site

Some clusters may have nodes in multiple physical locations for extra resilience. Note that Cross site replication is another alternative for clusters that need to span two or more data centres.

All of the above are optional. When provided, the distribution algorithm will try to spread the ownership of each segment across as many sites, racks, and machines (in this order) as possible.

6.4.5.1. Configuration

The hints are configured at transport level:

```
<transport
    cluster="MyCluster"
    machine="LinuxServer01"
    rack="Rack01"
    site="US-WestCoast" />
```

6.4.6. Key affinity service

In a distributed cache, a key is allocated to a list of nodes with an opaque algorithm. There is no easy way to reverse the computation and generate a key that maps to a particular node. However, we can generate a sequence of (pseudo-)random keys, see what their primary owner is, and hand them out to the application when it needs a key mapping to a particular node.

6.4.6.1. API

Following code snippet depicts how a reference to this service can be obtained and used.

```
// 1. Obtain a reference to a cache
Cache cache = ...
Address address = cache.getCacheManager().getAddress();

// 2. Create the affinity service
KeyAffinityService keyAffinityService = KeyAffinityServiceFactory.newLocalKeyAffinityService(
      cache,
      new RndKeyGenerator(),
        Executors.newSingleThreadExecutor(),
        100);

// 3. Obtain a key for which the local node is the primary owner
Object localKey = keyAffinityService.getKeyForAddress(address);

// 4. Insert the key in the cache
cache.put(localKey, "yourValue");
```

The service is started at step 2: after this point it uses the supplied *Executor* to generate and queue keys. At step 3, we obtain a key from the service, and at step 4 we use it.

6.4.6.2. Lifecycle

KeyAffinityService extends **Lifecycle**, which allows stopping and (re)starting it:

```
public interface Lifecycle {
  void start();
  void stop();
}
```

The service is instantiated through **KeyAffinityServiceFactory**. All the factory methods have an **Executor** parameter, that is used for asynchronous key generation (so that it won't happen in the caller's thread). It is the user's responsibility to handle the shutdown of this **Executor**.

The **KeyAffinityService**, once started, needs to be explicitly stopped. This stops the background key generation and releases other held resources.

The only situation in which **KeyAffinityService** stops by itself is when the cache manager with which it was registered is shutdown.

6.4.6.3. Topology changes

When the cache topology changes (i.e. nodes join or leave the cluster), the ownership of the keys generated by the **KeyAffinityService** might change. The key affinity service keep tracks of these topology changes and doesn't return keys that would currently map to a different node, but it won't do anything about keys generated earlier.

As such, applications should treat **KeyAffinityService** purely as an optimization, and they should not rely on the location of a generated key for correctness.

In particular, applications should not rely on keys generated by **KeyAffinityService** for the same address to always be located together. Collocation of keys is only provided by the Grouping API.

6.4.7. The Grouping API

Complementary to Key affinity service and similar to AtomicMap, the grouping API allows you to co-locate a group of entries on the same nodes, but without being able to select the actual nodes.

6.4.7.1. How does it work?

By default, the segment of a key is computed using the key's **hashCode()**. If you use the grouping API, Red Hat Data Grid will compute the segment of the group and use that as the segment of the key. See the Key Ownership section for more details on how segments are then mapped to nodes.

When the group API is in use, it is important that every node can still compute the owners of every key without contacting other nodes. For this reason, the group cannot be specified manually. The group can either be intrinsic to the entry (generated by the key class) or extrinsic (generated by an external function).

6.4.7.2. How do I use the grouping API?

First, you must enable groups. If you are configuring Red Hat Data Grid programmatically, then call:

```
Configuration c = new ConfigurationBuilder()
   .clustering().hash().groups().enabled()
   .build();
```

Or, if you are using XML:

```
<distributed-cache>
   <groups enabled="true"/>
</distributed-cache>
```

If you have control of the key class (you can alter the class definition, it's not part of an unmodifiable library), then we recommend using an intrinsic group. The intrinsic group is specified by adding the **@Group** annotation to a method. Let's take a look at an example:

```
class User {
   ...
   String office;
   ...

   public int hashCode() {
      // Defines the hash for the key, normally used to determine location
      ...
   }

   // Override the location by specifying a group
   // All keys in the same group end up with the same owners
   @Group
   public String getOffice() {
      return office;
   }
   }
}
```

NOTE

The group method must return a **String**

If you don't have control over the key class, or the determination of the group is an orthogonal concern to the key class, we recommend using an extrinsic group. An extrinsic group is specified by implementing the **Grouper** interface.

```
public interface Grouper<T> {
    String computeGroup(T key, String group);
    Class<T> getKeyType();
}
```

If multiple **Grouper** classes are configured for the same key type, all of them will be called, receiving the value computed by the previous one. If the key class also has a **@Group** annotation, the first **Grouper** will receive the group computed by the annotated method. This allows you even greater control over the group when using an intrinsic group. Let’s take a look at an example **Grouper** implementation:

```
public class KXGrouper implements Grouper<String> {

   // The pattern requires a String key, of length 2, where the first character is
   // "k" and the second character is a digit. We take that digit, and perform
   // modular arithmetic on it to assign it to group "0" or group "1".
   private static Pattern kPattern = Pattern.compile("(^k)(<a>\\d</a>)$");

   public String computeGroup(String key, String group) {
      Matcher matcher = kPattern.matcher(key);
      if (matcher.matches()) {
         String g = Integer.parseInt(matcher.group(2)) % 2 + "";
         return g;
      } else {
         return null;
      }
   }

   public Class<String> getKeyType() {
      return String.class;
   }
}
```

Grouper implementations must be registered explicitly in the cache configuration. If you are configuring Red Hat Data Grid programmatically:

```
Configuration c = new ConfigurationBuilder()
   .clustering().hash().groups().enabled().addGrouper(new KXGrouper())
   .build();
```

Or, if you are using XML:

```
<distributed-cache>
   <groups enabled="true">
      <grouper class="com.acme.KXGrouper" />
   </groups>
</distributed-cache>
```

6.4.7.3. Advanced Interface

AdvancedCache has two group-specific methods:

getGroup(groupName)
: Retrieves all keys in the cache that belong to a group.

removeGroup(groupName)
: Removes all the keys in the cache that belong to a group.

Both methods iterate over the entire data container and store (if present), so they can be slow when a cache contains lots of small groups.

6.5. ASYNCHRONOUS OPTIONS

6.5.1. Asynchronous Communications

All clustered cache modes can be configured to use asynchronous communications with the **mode="ASYNC"** attribute on the **<replicated-cache/>**, **<distributed-cache>**, or **<invalidation-cache/>** element.

With asynchronous communications, the originator node does not receive any acknowledgement from the other nodes about the status of the operation, so there is no way to check if it succeeded on other nodes.

We do not recommend asynchronous communications in general, as they can cause inconsistencies in the data, and the results are hard to reason about. Nevertheless, sometimes speed is more important than consistency, and the option is available for those cases.

6.5.2. Asynchronous API

The Asynchronous API allows you to use synchronous communications, but without blocking the user thread.

There is one caveat: The asynchronous operations do NOT preserve the program order. If a thread calls **cache.putAsync(k, v1); cache.putAsync(k, v2)**, the final value of **k** may be either **v1** or **v2**. The advantage over using asynchronous communications is that the final value can't be **v1** on one node and **v2** on another.

NOTE

Prior to version 9.0, the asynchronous API was emulated by borrowing a thread from an internal thread pool and running a blocking operation on that thread.

6.5.3. Return Values

Because the **Cache** interface extends **java.util.Map**, write methods like **put(key, value)** and **remove(key)** return the previous value by default.

In some cases, the return value may not be correct:

1. When using **AdvancedCache.withFlags()** with **Flag.IGNORE_RETURN_VALUE**, **Flag.SKIP_REMOTE_LOOKUP**, or **Flag.SKIP_CACHE_LOAD**.
2. When the cache is configured with **unreliable-return-values="true"**.
3. When using asynchronous communications.
4. When there are multiple concurrent writes to the same key, and the cache topology changes. The topology change will make Red Hat Data Grid retry the write operations, and a retried operation's return value is not reliable.

Transactional caches return the correct previous value in cases 3 and 4. However, transactional caches also have a gotcha: in distributed mode, the read-committed isolation level is implemented as repeatable-read. That means this example of "double-checked locking" won't work:

```
Cache cache = ...
TransactionManager tm = ...

tm.begin();
try {
   Integer v1 = cache.get(k);
   // Increment the value
   Integer v2 = cache.put(k, v1 + 1);
   if (Objects.equals(v1, v2) {
      // success
   } else {
      // retry
   }
} finally {
  tm.commit();
}
```

The correct way to implement this is to use **cache.getAdvancedCache().withFlags(Flag.FORCE_WRITE_LOCK).get(k)**.

In caches with optimistic locking, writes can also return stale previous values. Write skew checks can avoid stale previous values. For more information, see Write Skews.

6.6. PARTITION HANDLING

An Red Hat Data Grid cluster is built out of a number of nodes where data is stored. In order not to lose data in the presence of node failures, Red Hat Data Grid copies the same data — cache entry in Red Hat Data Grid parlance — over multiple nodes. This level of data redundancy is configured through the **numOwners** configuration attribute and ensures that as long as fewer than **numOwners** nodes crash simultaneously, Red Hat Data Grid has a copy of the data available.

However, there might be catastrophic situations in which more than **numOwners** nodes disappear from the cluster:

Split brain

Caused e.g. by a router crash, this splits the cluster in two or more partitions, or sub-clusters that operate independently. In these circumstances, multiple clients reading/writing from different partitions see different versions of the same cache entry, which for many application is problematic. Note there are ways to alleviate the possibility for the split brain to happen, such as redundant networks or IP bonding. These only reduce the window of time for the problem to occur, though.

numOwners nodes crash in sequence

When at least **numOwners** nodes crash in rapid succession and Red Hat Data Grid does not have the time to properly rebalance its state between crashes, the result is partial data loss.

The partition handling functionality discussed in this section allows the user to configure what operations can be performed on a cache in the event of a split brain occurring. Red Hat Data Grid provides multiple partition handling strategies, which in terms of Brewer's CAP theorem determine whether availability or consistency is sacrificed in the presence of partition(s). Below is a list of the provided strategies:

Strategy	Description	CAP

Strategy	Description	CAP
DENY_READ_WRITES	If the partition does not have all owners for a given segment, both reads and writes are denied for all keys in that segment.	Consistency
ALLOW_READS	Allows reads for a given key if it exists in this partition, but only allows writes if this partition contains all owners of a segment. This is still a consistent approach because some entries are readable if available in this partition, but from a client application perspective it is not deterministic.	Consistency
ALLOW_READ_WRITES	Allow entries on each partition to diverge, with conflict resolution attempted upon the partitions merging.	Availability

The requirements of your application should determine which strategy is appropriate. For example, DENY_READ_WRITES is more appropriate for applications that have high consistency requirements; i.e. when the data read from the system must be accurate. Whereas if Red Hat Data Grid is used as a best-effort cache, partitions maybe perfectly tolerable and the ALLOW_READ_WRITES might be more appropriate as it favours availability over consistency.

The following sections describe how Red Hat Data Grid handles split brain and successive failures for each of the partition handling strategies. This is followed by a section describing how Red Hat Data Grid allows for automatic conflict resolution upon partition merges via merge policies. Finally, we provide a section describing how to configure partition handling strategies and merge policies .

6.6.1. Split brain

In a split brain situation, each network partition will install its own JGroups view, removing the nodes from the other partition(s). We don't have a direct way of determining whether the has been split into two or more partitions, since the partitions are unaware of each other. Instead, we assume the cluster has split when one or more nodes disappear from the JGroups cluster without sending an explicit leave message.

6.6.1.1. Split Strategies

In this section, we detail how each partition handling strategy behaves in the event of split brain occurring.

6.6.1.1.1. ALLOW_READ_WRITES

Each partition continues to function as an independent cluster, with all partitions remaining in AVAILABLE mode. This means that each partition may only see a part of the data, and each partition could write conflicting updates in the cache. During a partition merge these conflicts are automatically resolved by utilising the ConflictManager and the configured EntryMergePolicy.

6.6.1.1.2. DENY_READ_WRITES

When a split is detected each partition does not start a rebalance immediately, but first it checks whether it should enter **DEGRADED** mode instead:

- If at least one segment has lost all its owners (meaning at least *numOwners* nodes left since the last rebalance ended), the partition enters DEGRADED mode.
- If the partition does not contain a simple majority of the nodes (floor(numNodes/2) + 1) in the *latest stable topology*, the partition also enters DEGRADED mode.
- Otherwise the partition keeps functioning normally, and it starts a rebalance.

The *stable topology* is updated every time a rebalance operation ends and the coordinator determines that another rebalance is not necessary.

These rules ensures that at most one partition stays in AVAILABLE mode, and the other partitions enter DEGRADED mode.

When a partition is in DEGRADED mode, it only allows access to the keys that are wholly owned:

- Requests (reads and writes) for entries that have all the copies on nodes within this partition are honoured.
- Requests for entries that are partially or totally owned by nodes that disappeared are rejected with an **AvailabilityException**.

This guarantees that partitions cannot write different values for the same key (cache is consistent), and also that one partition can not read keys that have been updated in the other partitions (no stale data).

To exemplify, consider the initial cluster **M = {A, B, C, D}**, configured in distributed mode with **numOwners = 2**. Further on, consider three keys **k1**, **k2** and **k3** (that might exist in the cache or not) such that **owners(k1) = {A,B}**, **owners(k2) = {B,C}** and **owners(k3) = {C,D}**. Then the network splits in two partitions, **N1 = {A, B}** and **N2 = {C, D}**, they enter DEGRADED mode and behave like this:

- on **N1**, **k1** is available for read/write, **k2** (partially owned) and **k3** (not owned) are not available and accessing them results in an **AvailabilityException**
- on **N2**, **k1** and **k2** are not available for read/write, **k3** is available

A relevant aspect of the partition handling process is the fact that when a split brain happens, the resulting partitions rely on the original segment mapping (the one that existed before the split brain) in order to calculate key ownership. So it doesn't matter if **k1**, **k2**, or **k3** already existed cache or not, their availability is the same.

If at a further point in time the network heals and **N1** and **N2** partitions merge back together into the initial cluster **M**, then **M** exits the degraded mode and becomes fully available again. During this merge operation, because **M** has once again become fully available, the ConflictManager and the configured EntryMergePolicy are used to check for any conflicts that may have occurred in the interim period between the split brain occurring and being detected.

As another example, the cluster could split in two partitions **O1 = {A, B, C}** and **O2 = {D}**, partition **O1** will stay fully available (rebalancing cache entries on the remaining members). Partition **O2**, however, will detect a split and enter the degraded mode. Since it doesn't have any fully owned keys, it will reject any read or write operation with an **AvailabilityException**.

If afterwards partitions **O1** and **O2** merge back into **M**, then the ConflictManager attempts to resolve any conflicts and **D** once again becomes fully available.

6.6.1.1.3. ALLOW_READS

Partitions are handled in the same manner as DENY_READ_WRITES, except that when a partition is in DEGRADED mode read operations on a partially owned key WILL not throw an AvailabilityException.

6.6.1.2. Current limitations

Two partitions could start up isolated, and as long as they don't merge they can read and write inconsistent data. In the future, we will allow custom availability strategies (e.g. check that a certain node is part of the cluster, or check that an external machine is accessible) that could handle that situation as well.

6.6.2. Successive nodes stopped

As mentioned in the previous section, Red Hat Data Grid can't detect whether a node left the JGroups view because of a process/machine crash, or because of a network failure: whenever a node leaves the JGroups cluster abruptly, it is assumed to be because of a network problem.

If the configured number of copies (**numOwners**) is greater than 1, the cluster can remain available and will try to make new replicas of the data on the crashed node. However, other nodes might crash during the rebalance process. If more than **numOwners** nodes crash in a short interval of time, there is a chance that some cache entries have disappeared from the cluster altogether. In this case, with the DENY_READ_WRITES or ALLOW_READS strategy enabled, Red Hat Data Grid assumes (incorrectly) that there is a split brain and enters DEGRADED mode as described in the split-brain section.

The administrator can also shut down more than **numOwners** nodes in rapid succession, causing the loss of the data stored only on those nodes. When the administrator shuts down a node gracefully, Red Hat Data Grid knows that the node can't come back. However, the cluster doesn't keep track of how each node left, and the cache still enters DEGRADED mode as if those nodes had crashed.

At this stage there is no way for the cluster to recover its state, except stopping it and repopulating it on restart with the data from an external source. Clusters are expected to be configured with an appropriate **numOwners** in order to avoid **numOwners** successive node failures, so this situation should be pretty rare. If the application can handle losing some of the data in the cache, the administrator can force the availability mode back to AVAILABLE via JMX.

6.6.3. Conflict Manager

The conflict manager is a tool that allows users to retrieve all stored replica values for a given key. In addition to allowing users to process a stream of cache entries whose stored replicas have conflicting values. Furthermore, by utilising implementations of the EntryMergePolicy interface it is possible for said conflicts to be resolved automatically.

6.6.3.1. Detecting Conflicts

Conflicts are detected by retrieving each of the stored values for a given key. The conflict manager retrieves the value stored from each of the key's write owners defined by the current consistent hash. The .equals method of the stored values is then used to determine whether all values are equal. If all values are equal then no conflicts exist for the key, otherwise a conflict has occurred. Note that null values are returned if no entry exists on a given node, therefore we deem a conflict to have occurred if both a null and non-null value exists for a given key.

6.6.3.2. Merge Policies

In the event of conflicts arising between one or more replicas of a given CacheEntry, it is necessary for a conflict resolution algorithm to be defined, therefore we provide the EntryMergePolicy interface. This interface consists of a single method, "merge", whose returned CacheEntry is utilised as the "resolved" entry for a given key. When a non-null CacheEntry is returned, this entries value is "put" to all replicas in the cache. However when the merge implementation returns a null value, all replicas associated with the conflicting key are removed from the cache.

The merge method takes two parameters: the "preferredEntry" and "otherEntries". In the context of a partition merge, the preferredEntry is the primary replica of a CacheEntry stored in the partition that contains the most nodes or if partitions are equal the one with the largest topologyId. In the event of overlapping partitions, i.e. a node A is present in the topology of both partitions {A}, {A,B,C}, we pick {A} as the preferred partition as it will have the higher topologId as the other partition's topology is behind. When a partition merge is not occurring, the "preferredEntry" is simply the primary replica of the CacheEntry. The second parameter, "otherEntries" is simply a list of all other entries associated with the key for which a conflict was detected.

NOTE

EntryMergePolicy::merge is only called when a conflict has been detected, it is not called if all CacheEntrys are the same.

Currently Red Hat Data Grid provides the following implementations of EntryMergePolicy:

Policy	Description
MergePolicy.NONE (default)	No attempt is made to resolve conflicts. Entries hosted on the minority partition are removed and the nodes in this partition do not hold any data until the rebalance starts. Note, this behaviour is equivalent to prior Infinispan versions which did not support conflict resolution. Note, in this case all changes made to entries hosted on the minority partition are lost, but once the rebalance has finished all entries will be consistent.
MergePolicy.PREFERRED_ALWAYS	Always utilise the "preferredEntry". MergePolicy.NONE is almost equivalent to PREFERRED_ALWAYS, albeit without the performance impact of performing conflict resolution, therefore MergePolicy.NONE should be chosen unless the following scenario is a concern. When utilising the DENY_READ_WRITES or DENY_READ strategy, it is possible for a write operation to only partially complete when the partitions enter DEGRADED mode, resulting in replicas containing inconsistent values. MergePolicy.PREFERRED_ALWAYS will detect said inconsistency and resolve it, whereas with MergePolicy.NONE the CacheEntry replicas will remain inconsistent after the cluster has rebalanced.

Policy	Description
MergePolicy.PREFERRED_NON_NULL	Utilise the "preferredEntry" if it is non-null, otherwise utilise the first entry from "otherEntries".
MergePolicy.REMOVE_ALL	Always remove a key from the cache when a conflict is detected.
Fully qualified class name	The custom implementation for merge will be used Custom merge policy

6.6.4. Usage

During a partition merge the ConflictManager automatically attempts to resolve conflicts utilising the configured EntryMergePolicy, however it is also possible to manually search for/resolve conflicts as required by your application.

The code below shows how to retrieve an EmbeddedCacheManager's ConflictManager, how to retrieve all versions of a given key and how to check for conflicts across a given cache.

```
EmbeddedCacheManager manager = new DefaultCacheManager("example-config.xml");
Cache<Integer, String> cache = manager.getCache("testCache");
ConflictManager<Integer, String> crm = ConflictManagerFactory.get(cache.getAdvancedCache());

// Get All Versions of Key
Map<Address, InternalCacheValue<String>> versions = crm.getAllVersions(1);

// Process conflicts stream and perform some operation on the cache
Stream<Map<Address, InternalCacheEntry<Integer, String>>> stream = crm.getConflicts();
stream.forEach(map -> {
  CacheEntry<Object, Object> entry = map.values().iterator().next();
  Object conflictKey = entry.getKey();
  cache.remove(conflictKey);
});

// Detect and then resolve conflicts using the configured EntryMergePolicy
crm.resolveConflicts();

// Detect and then resolve conflicts using the passed EntryMergePolicy instance
crm.resolveConflicts((preferredEntry, otherEntries) -> preferredEntry);
```

NOTE

Although the **ConflictManager::getConflicts** stream is processed per entry, the underlying spliterator is in fact lazily-loading cache entries on a per segment basis.

6.6.5. Configuring partition handling

Unless the cache is distributed or replicated, partition handling configuration is ignored. The default partition handling strategy is ALLOW_READ_WRITES and the default EntryMergePolicy is MergePolicies::PREFERRED_ALWAYS.

```
<distributed-cache name="the-default-cache">
  <partition-handling when-split="ALLOW_READ_WRITES" merge-policy="PREFERRED_NON_NULL"/>
</distributed-cache>
```

The same can be achieved programmatically:

```
ConfigurationBuilder dcc = new ConfigurationBuilder();
dcc.clustering().partitionHandling()
                    .whenSplit(PartitionHandling.ALLOW_READ_WRITES)
                    .mergePolicy(MergePolicies.PREFERRED_ALWAYS);
```

6.6.5.1. Implement a custom merge policy

It's also possible to provide custom implementations of the EntryMergePolicy

```
<distributed-cache name="the-default-cache">
  <partition-handling when-split="ALLOW_READ_WRITES" merge-policy="org.example.CustomMergePolicy"/>
</distributed-cache>
```

```
ConfigurationBuilder dcc = new ConfigurationBuilder();
dcc.clustering().partitionHandling()
                    .whenSplit(PartitionHandling.ALLOW_READ_WRITES)
                    .mergePolicy(new CustomMergePolicy());
```

```
public class CustomMergePolicy implements EntryMergePolicy<String, String> {

  @Override
  public CacheEntry<String, String> merge(CacheEntry<String, String> preferredEntry, List<CacheEntry<String, String>> otherEntries) {
    // decide which entry should be used

    return the_solved_CacheEntry;
  }
```

6.6.5.2. Deploy custom merge policies to a Infinispan server instance

To utilise a custom EntryMergePolicy implementation on the server, it's necessary for the implementation class(es) to be deployed to the server. This is accomplished by utilising the java service-provider convention and packaging the class files in a jar which has a META-INF/services/org.infinispan.conflict.EntryMergePolicy file containing the fully qualified class name of the EntryMergePolicy implementation.

```
# list all necessary implementations of EntryMergePolicy with the full qualified name
org.example.CustomMergePolicy
```

In order for a Custom merge policy to be utilised on the server, you should enable object storage, if your policies semantics require access to the stored Key/Value objects. This is because cache entries in the server may be stored in a marshalled format and the Key/Value objects returned to your policy would be instances of WrappedByteArray. However, if the custom policy only depends on the metadata associated with a cache entry, then object storage is not required and should be avoided (unless needed for other reasons) due to the additional performance cost of marshalling data per request. Finally, object storage is never required if one of the provided merge policies is used.

6.6.6. Monitoring and administration

The availability mode of a cache is exposed in JMX as an attribute in the Cache MBean. The attribute is writable, allowing an administrator to forcefully migrate a cache from DEGRADED mode back to AVAILABLE (at the cost of consistency).

The availability mode is also accessible via the AdvancedCache interface:

```
AdvancedCache ac = cache.getAdvancedCache();

// Read the availability
boolean available = ac.getAvailability() == AvailabilityMode.AVAILABLE;

// Change the availability
if (!available) {
   ac.setAvailability(AvailabilityMode.AVAILABLE);
}
```

CHAPTER 7. MARSHALLING

Marshalling is the process of converting Java POJOs into something that can be written in a format that can be transferred over the wire. Unmarshalling is the reverse process whereby data read from a wire format is transformed back into Java POJOs. Red Hat Data Grid uses marshalling/unmarshalling in order to:

- Transform data so that it can be send over to other Red Hat Data Grid nodes in a cluster.
- Transform data so that it can be stored in underlying cache stores.
- Store data in Red Hat Data Grid in a wire format to provide lazy deserialization capabilities.

7.1. THE ROLE OF JBOSS MARSHALLING

Since performance is a very important factor in this process, Red Hat Data Grid uses JBoss Marshalling framework instead of standard Java Serialization in order to marshall/unmarshall Java POJOs. Amongst other things, this framework enables Red Hat Data Grid to provide highly efficient ways to marshall internal Red Hat Data Grid Java POJOs that are constantly used. Apart from providing more efficient ways to marshall Java POJOs, including internal Java classes, JBoss Marshalling uses highly performant **java.io.ObjectOutput** and **java.io.ObjectInput** implementations compared to standard **java.io.ObjectOutputStream** and **java.io.ObjectInputStream**.

7.2. SUPPORT FOR NON-SERIALIZABLE OBJECTS

From a users perspective, a very common concern is whether Red Hat Data Grid supports storing non-Serializable objects. In 4.0, an Red Hat Data Grid cache instance can only store non-Serializable key or value objects if, and only if:

- cache is configured to be a local cache *and...*
- cache is not configured with lazy serialization *and...*
- cache is not configured with any write-behind cache store

If either of these options is true, key/value pairs in the cache will need to be marshalled and currently they require to either to extend **java.io.Serializable** or **java.io.Externalizable**.

TIP

Since Red Hat Data Grid 5.0, marshalling non-Serializable key/value objects are supported as long as users can to provide meaningful Externalizer implementations for these non-Seralizable objects.

If you’re unable to retrofit Serializable or Externalizable into the classes whose instances are stored in Red Hat Data Grid, you could alternatively use something like XStream to convert your Non-Serializable objects into a String that can be stored into Red Hat Data Grid. The one caveat about using XStream is that it slows down the process of storing key/value objects due to the XML transformation that it needs to do.

7.2.1. Store As Binary

Store as binary enables data to be stored in its serialized form. This can be useful to achieve lazy deserialization, which is the mechanism by which Red Hat Data Grid by which serialization and deserialization of objects is deferred till the point in time in which they are used and needed. This typically means that any deserialization happens using the thread context class loader of the invocation that requires deserialization, and is an effective mechanism to provide classloader isolation. By default lazy deserialization is disabled but if you want to enable it, you can do it like this:

- Via XML at the Cache level, either under **<*-cache />** element:

```
<memory>
  <binary />
</memory>
```

- Programmatically:

```
ConfigurationBuilder builder = ...
builder.memory().storageType(StorageType.BINARY);
```

7.2.1.1. Equality Considerations

When using lazy deserialization/storing as binary, keys and values are wrapped as WrappedBytes. It is this wrapper class that transparently takes care of serialization and deserialization on demand, and internally may have a reference to the object itself being wrapped, or the serialized, byte array representation of this object.

This has a particular effect on the behavior of equality. The equals() method of this class will either compare binary representations (byte arrays) or delegate to the wrapped object instance's equals() method, depending on whether both instances being compared are in serialized or deserialized form at the time of comparison. If one of the instances being compared is in one form and the other in another form, then one instance is either serialized or deserialized.

This will affect the way keys stored in the cache will work, when **storeAsBinary** is used, since comparisons happen on the key which will be wrapped by a MarshalledValue. Implementers of equals() methods on their keys need to be aware of the behavior of equality comparison, when a key is wrapped as a MarshalledValue, as detailed above.

7.2.1.2. Store-by-value via defensive copying

The configuration **storeAsBinary** offers the possibility to enable defensive copying, which allows for store-by-value like behaviour.

Red Hat Data Grid marshalls objects the moment they're stored, hence changes made to object references are not stored in the cache, not even for local caches. This provides store-by-value like behaviour. Enabling **storeAsBinary** can be achieved:

- Via XML at the Cache level, either under **<*-cache />** or **<default />** elements:

```
<store-as-binary keys="true" values="true"/>
```

- Programmatically:

```
ConfigurationBuilder builder = ...
builder.storeAsBinary().enable().storeKeysAsBinary(true).storeValuesAsBinary(true);
```

7.3. ADVANCED CONFIGURATION

Internally, Red Hat Data Grid uses an implementation of this Marshaller interface in order to marshall/unmarshall Java objects so that they're sent other nodes in the grid, or so that they're stored in a cache store, or even so to transform them into byte arrays for lazy deserialization.

By default, Red Hat Data Grid uses the GlobalMarshaller. Optionally, Red Hat Data Grid users can provide their own marshaller, for example:

- Via XML at the CacheManager level, under **<cache-manager />** element:

```
<serialization marshaller="com.acme.MyMarshaller"/>
```

- Programmatically:

```
GlobalConfigurationBuilder builder = ...
builder.serialization().marshaller(myMarshaller); // needs an instance of the marshaller
```

7.3.1. Troubleshooting

Sometimes it might happen that the Red Hat Data Grid marshalling layer, and in particular JBoss Marshalling, might have issues marshalling/unmarshalling some user object. In Red Hat Data Grid 4.0, marshalling exceptions will contain further information on the objects that were being marshalled. Example:

```
java.io.NotSerializableException: java.lang.Object
at org.jboss.marshalling.river.RiverMarshaller.doWriteObject(RiverMarshaller.java:857)
at org.jboss.marshalling.AbstractMarshaller.writeObject(AbstractMarshaller.java:407)
at
org.infinispan.marshall.exts.ReplicableCommandExternalizer.writeObject(ReplicableCommandExternali
er.java:54)
at
org.infinispan.marshall.jboss.ConstantObjectTable$ExternalizerAdapter.writeObject(ConstantObjectTab
e.java:267)
at org.jboss.marshalling.river.RiverMarshaller.doWriteObject(RiverMarshaller.java:143)
at org.jboss.marshalling.AbstractMarshaller.writeObject(AbstractMarshaller.java:407)
at org.infinispan.marshall.jboss.JBossMarshaller.objectToObjectStream(JBossMarshaller.java:167)
at org.infinispan.marshall.VersionAwareMarshaller.objectToBuffer(VersionAwareMarshaller.java:92)
at
org.infinispan.marshall.VersionAwareMarshaller.objectToByteBuffer(VersionAwareMarshaller.java:170)

at
org.infinispan.marshall.DefaultMarshallerTest.testNestedNonSerializable(VersionAwareMarshallerTest.j
ava:415)
Caused by: an exception which occurred:
in object java.lang.Object@b40ec4
in object org.infinispan.commands.write.PutKeyValueCommand@df661da7
... Removed 22 stack frames
```

The way the "in object" messages are read is the same in which stacktraces are read. The highest "in object" being the most inner one and the lowest "in object" message being the most outer one. So, the above example indicates that a java.lang.Object instance contained in an instance of org.infinispan.commands.write.PutKeyValueCommand could not be serialized because java.lang.Object@b40ec4 is not serializable.

This is not all though! If you enable DEBUG or TRACE logging levels, marshalling exceptions will contain show the toString() representations of objects in the stacktrace. For example:

```
java.io.NotSerializableException: java.lang.Object
...
Caused by: an exception which occurred:
in object java.lang.Object@b40ec4
-> toString = java.lang.Object@b40ec4
in object org.infinispan.commands.write.PutKeyValueCommand@df661da7
-> toString = PutKeyValueCommand{key=k, value=java.lang.Object@b40ec4, putIfAbsent=false,
lifespanMillis=0, maxIdleTimeMillis=0}
```

With regards to unmarshalling exceptions, showing such level of information it's a lot more complicated but where possible. Red Hat Data Grid will provide class type information. For example:

```
java.io.IOException: Injected failure!
at
org.infinispan.marshall.DefaultMarshallerTest$1.readExternal(VersionAwareMarshallerTest.java:426)
at org.jboss.marshalling.river.RiverUnmarshaller.doReadNewObject(RiverUnmarshaller.java:1172)
at org.jboss.marshalling.river.RiverUnmarshaller.doReadObject(RiverUnmarshaller.java:273)
at org.jboss.marshalling.river.RiverUnmarshaller.doReadObject(RiverUnmarshaller.java:210)
at org.jboss.marshalling.AbstractUnmarshaller.readObject(AbstractUnmarshaller.java:85)
at org.infinispan.marshall.jboss.JBossMarshaller.objectFromObjectStream(JBossMarshaller.java:210)
at
org.infinispan.marshall.VersionAwareMarshaller.objectFromByteBuffer(VersionAwareMarshaller.java:10
4)
at
org.infinispan.marshall.VersionAwareMarshaller.objectFromByteBuffer(VersionAwareMarshaller.java:17
7)
at
org.infinispan.marshall.DefaultMarshallerTest.testErrorUnmarshalling(VersionAwareMarshallerTest.java
:431)
Caused by: an exception which occurred:
in object of type org.infinispan.marshall.DefaultMarshallerTest$1
```

In this example, an IOException was thrown when trying to unmarshall a instance of the inner class org.infinispan.marshall.DefaultMarshallerTest$1. In similar fashion to marshalling exceptions, when DEBUG or TRACE logging levels are enabled, classloader information of the class type is provided. For example:

```
java.io.IOException: Injected failure!
...
Caused by: an exception which occurred:
in object of type org.infinispan.marshall.DefaultMarshallerTest$1
-> classloader hierarchy:
-> type classloader = sun.misc.Launcher$AppClassLoader@198dfaf
->...file:/opt/eclipse/configuration/org.eclipse.osgi/bundles/285/1/.cp/eclipse-testng.jar
->...file:/opt/eclipse/configuration/org.eclipse.osgi/bundles/285/1/.cp/lib/testng-jdk15.jar
->...file:/home/galder/jboss/infinispan/code/trunk/core/target/test-classes/
->...file:/home/galder/jboss/infinispan/code/trunk/core/target/classes/
->...file:/home/galder/.m2/repository/org/testng/testng/5.9/testng-5.9-jdk15.jar
->...file:/home/galder/.m2/repository/net/jcip/jcip-annotations/1.0/jcip-annotations-1.0.jar
-
>...file:/home/galder/.m2/repository/org/easymock/easymockclassextension/2.4/easymockclassextensio
2.4.jar
->...file:/home/galder/.m2/repository/org/easymock/easymock/2.4/easymock-2.4.jar
->...file:/home/galder/.m2/repository/cglib/cglib-nodep/2.1_3/cglib-nodep-2.1_3.jar
->...file:/home/galder/.m2/repository/javax/xml/bind/jaxb-api/2.1/jaxb-api-2.1.jar
```

```
->...file:/home/galder/.m2/repository/javax/xml/stream/stax-api/1.0-2/stax-api-1.0-2.jar
->...file:/home/galder/.m2/repository/javax/activation/activation/1.1/activation-1.1.jar
->...file:/home/galder/.m2/repository/jgroups/jgroups/2.8.0.CR1/jgroups-2.8.0.CR1.jar
->...file:/home/galder/.m2/repository/org/jboss/javaee/jboss-transaction-api/1.0.1.GA/jboss-
transaction-api-1.0.1.GA.jar
->...file:/home/galder/.m2/repository/org/jboss/marshalling/river/1.2.0.CR4-SNAPSHOT/river-
1.2.0.CR4-SNAPSHOT.jar
->...file:/home/galder/.m2/repository/org/jboss/marshalling/marshalling-api/1.2.0.CR4-
SNAPSHOT/marshalling-api-1.2.0.CR4-SNAPSHOT.jar
->...file:/home/galder/.m2/repository/org/jboss/jboss-common-core/2.2.14.GA/jboss-common-core-
2.2.14.GA.jar
->...file:/home/galder/.m2/repository/org/jboss/logging/jboss-logging-spi/2.0.5.GA/jboss-logging-spi-
2.0.5.GA.jar
->...file:/home/galder/.m2/repository/log4j/log4j/1.2.14/log4j-1.2.14.jar
->...file:/home/galder/.m2/repository/com/thoughtworks/xstream/xstream/1.2/xstream-1.2.jar
->...file:/home/galder/.m2/repository/xpp3/xpp3_min/1.1.3.4.O/xpp3_min-1.1.3.4.O.jar
->...file:/home/galder/.m2/repository/com/sun/xml/bind/jaxb-impl/2.1.3/jaxb-impl-2.1.3.jar
-> parent classloader = sun.misc.Launcher$ExtClassLoader@1858610
->...file:/usr/java/jdk1.5.0_19/jre/lib/ext/localedata.jar
->...file:/usr/java/jdk1.5.0_19/jre/lib/ext/sunpkcs11.jar
->...file:/usr/java/jdk1.5.0_19/jre/lib/ext/sunjce_provider.jar
->...file:/usr/java/jdk1.5.0_19/jre/lib/ext/dnsns.jar
... Removed 22 stack frames
</code>
```

Finding the root cause of marshalling/unmarshalling exceptions can sometimes be really daunting but we hope that the above improvements would help get to the bottom of those in a more quicker and efficient manner.

7.4. USER DEFINED EXTERNALIZERS

One of the key aspects of Red Hat Data Grid is that it often needs to marshall/unmarshall objects in order to provide some of its functionality. For example, if it needs to store objects in a write-through or write-behind cache store, the stored objects need marshalling. If a cluster of Red Hat Data Grid nodes is formed, objects shipped around need marshalling. Even if you enable lazy deserialization, objects need to be marshalled so that they can be lazily unmarshalled with the correct classloader.

Using standard JDK serialization is slow and produces payloads that are too big and can affect bandwidth usage. On top of that, JDK serialization does not work well with objects that are supposed to be immutable. In order to avoid these issues, Red Hat Data Grid uses JBoss Marshalling for marshalling/unmarshalling objects. JBoss Marshalling is fast, produces very space efficient payloads, and on top of that during unmarshalling, it enables users to have full control over how to construct objects, hence allowing objects to carry on being immutable.

Starting with 5.0, users of Red Hat Data Grid can now benefit from this marshalling framework as well, and they can provide their own externalizer implementations, but before finding out how to provide externalizers, let's look at the benefits they bring.

7.4.1. Benefits of Externalizers

The JDK provides a simple way to serialize objects which, in its simplest form, is just a matter of extending java.io.Serializable , but as it's well known, this is known to be slow and it generates payloads that are far too big. An alternative way to do serialization, still relying on JDK serialization, is for your objects to extend java.io.Externalizable . This allows for users to provide their own ways to marshall/unmarshall classes, but has some serious issues because, on top of relying on slow JDK serialization, it forces the class that you want to serialize to extend this interface, which has two side effects: The first is that you're forced to modify the source code of the class that you want to marshall/unmarshall which you might not be able to do because you either, don't own the source, or you don't even have it. Secondly, since Externalizable implementations do not control object creation, you're forced to add set methods in order to restore the state, hence potentially forcing your immutable objects to become mutable.

Instead of relying on JDK serialization, Red Hat Data Grid uses JBoss Marshalling to serialize objects and requires any classes to be serialized to be associated with an Externalizer interface implementation that knows how to transform an object of a particular class into a serialized form and how to read an object of that class from a given input. Red Hat Data Grid does not force the objects to be serialized to implement Externalizer. In fact, it is recommended that a separate class is used to implement the Externalizer interface because, contrary to JDK serialization, Externalizer implementations control how objects of a particular class are created when trying to read an object from a stream. This means that readObject() implementations are responsible of creating object instances of the target class, hence giving users a lot of flexibility on how to create these instances (whether direct instantiation, via factory or reflection), and more importantly, allows target classes to carry on being immutable. This type of externalizer architecture promotes good OOP designs principles, such as the principle of single responsibility .

It's quite common, and in general recommended, that Externalizer implementations are stored as inner static public classes within classes that they externalize. The advantages of doing this is that related code stays together, making it easier to maintain. In Red Hat Data Grid, there are two ways in which Red Hat Data Grid can be plugged with user defined externalizers:

7.4.2. User Friendly Externalizers

In the simplest possible form, users just need to provide an Externalizer implementation for the type that they want to marshall/unmarshall, and then annotate the marshalled type class with {@link SerializeWith} annotation indicating the externalizer class to use. For example:

```
import org.infinispan.commons.marshall.Externalizer;
import org.infinispan.commons.marshall.SerializeWith;

@SerializeWith(Person.PersonExternalizer.class)
public class Person {

   final String name;
   final int age;

   public Person(String name, int age) {
      this.name = name;
      this.age = age;
   }

   public static class PersonExternalizer implements Externalizer<Person> {
      @Override
      public void writeObject(ObjectOutput output, Person person)
            throws IOException {
         output.writeObject(person.name);
         output.writeInt(person.age);
      }

      @Override
      public Person readObject(ObjectInput input)
            throws IOException, ClassNotFoundException {
```

```
         return new Person((String) input.readObject(), input.readInt());
      }
   }
}
```

At runtime JBoss Marshalling will inspect the object and discover that it is marshallable (thanks to the annotation) and so marshall it using the externalizer class passed. To make externalizer implementations easier to code and more typesafe, make sure you define type **<T>** as the type of object that's being marshalled/unmarshalled.

Even though this way of defining externalizers is very user friendly, it has some disadvantages:

- Due to several constraints of the model, such as support for different versions of the same class or the need to marshall the Externalizer class, the payload sizes generated via this method are not the most efficient.
- This model requires that the marshalled class be annotated with link:https://access.redhat.com/webassets/avalon/d/red-hat-data-grid/7.3/api/org/infinispan/commons/marshall/SerializeWith.html but a user might need to provide an Externalizer for a class for which source code is not available, or for any other constraints, it cannot be modified.
- The use of annotations by this model might be limiting for framework developers or service providers that try to abstract lower level details, such as the marshalling layer, away from the user.

If you're affected by any of these disadvantages, an alternative method to provide externalizers is available via more advanced externalizers:

7.4.3. Advanced Externalizers

AdvancedExternalizer provides an alternative way to provide externalizers for marshalling/unmarshalling user defined classes that overcome the deficiencies of the more user-friendly externalizer definition model explained in Externalizer. For example:

```
import org.infinispan.marshall.AdvancedExternalizer;

public class Person {

   final String name;
   final int age;

   public Person(String name, int age) {
      this.name = name;
      this.age = age;
   }

   public static class PersonExternalizer implements AdvancedExternalizer<Person> {
      @Override
      public void writeObject(ObjectOutput output, Person person)
            throws IOException {
         output.writeObject(person.name);
         output.writeInt(person.age);
      }

      @Override
      public Person readObject(ObjectInput input)
            throws IOException, ClassNotFoundException {
         return new Person((String) input.readObject(), input.readInt());
      }

      @Override
      public Set<Class<? extends Person>> getTypeClasses() {
         return Util.<Class<? extends Person>>asSet(Person.class);
      }

      @Override
      public Integer getId() {
         return 2345;
      }
   }
}
```

The first noticeable difference is that this method does not require user classes to be annotated in anyway, so it can be used with classes for which source code is not available or that cannot be modified. The bound between the externalizer and the classes that are marshalled/unmarshalled is set by providing an implementation for getTypeClasses() which should return the list of classes that this externalizer can marshall:

7.4.3.1. Linking Externalizers with Marshaller Classes

Once the Externalizer's readObject() and writeObject() methods have been implemented, it's time to link them up together with the type classes that they externalize. To do so, the Externalizer implementation must provide a getTypeClasses() implementation. For example:

```
import org.infinispan.commons.util.Util;
...
@Override
public Set<Class<? extends ReplicableCommand>> getTypeClasses() {
  return Util.asSet(LockControlCommand.class, RehashControlCommand.class,
      StateTransferControlCommand.class, GetKeyValueCommand.class,
      ClusteredGetCommand.class,
      SingleRpcCommand.class, CommitCommand.class,
      PrepareCommand.class, RollbackCommand.class,
      ClearCommand.class, EvictCommand.class,
      InvalidateCommand.class, InvalidateL1Command.class,
      PutKeyValueCommand.class, PutMapCommand.class,
      RemoveCommand.class, ReplaceCommand.class);
}
```

In the code above, ReplicableCommandExternalizer indicates that it can externalize several type of commands. In fact, it marshalls all commands that extend ReplicableCommand interface, but currently the framework only supports class equality comparison and so, it's not possible to indicate that the classes to marshalled are all children of a particular class/interface.

However there might sometimes when the classes to be externalized are private and hence it's not possible to reference the actual class instance. In this situations, users can attempt to look up the class with the given fully qualified class name and pass that back. For example:

```
@Override
public Set<Class<? extends List>> getTypeClasses() {
    return Util.<Class<? extends List>>asSet(
          Util.loadClass("java.util.Collections$SingletonList"));
}
```

7.4.3.2. Externalizer Identifier

Secondly, in order to save the maximum amount of space possible in the payloads generated, advanced externalizers require externalizer implementations to provide a positive identified via getId() implementations or via XML/programmatic configuration that identifies the externalizer when unmarshalling a payload. In order for this to work however, advanced externalizers require externalizers to be registered on cache manager creation time via XML or programmatic configuration which will be explained in next section. On the contrary, externalizers based on Externalizer and SerializeWith require no pre-registration whatsoever. Internally, Red Hat Data Grid uses this advanced externalizer mechanism in order to marshall/unmarshall internal classes.

So, getId() should return a positive integer that allows the externalizer to be identified at read time to figure out which Externalizer should read the contents of the incoming buffer, or it can return null. If getId() returns null, it is indicating that the id of this advanced externalizer will be defined via XML/programmatic configuration, which will be explained in next section.

Regardless of the source of the the id, using a positive integer allows for very efficient variable length encoding of numbers, and it’s much more efficient than shipping externalizer implementation class information or class name around. Red Hat Data Grid users can use any positive integer as long as it does not clash with any other identifier in the system. It’s important to understand that a user defined externalizer can even use the same numbers as the externalizers in the Red Hat Data Grid Core project because the internal Red Hat Data Grid Core externalizers are special and they use a different number space to the user defined externalizers. On the contrary, users should avoid using numbers that are within the pre-assigned identifier ranges which can be found at the end of this article. Red Hat Data Grid checks for id duplicates on startup, and if any are found, startup is halted with an error.

When it comes to maintaining which ids are in use, it’s highly recommended that this is done in a centralized way. For example, getId() implementations could reference a set of statically defined identifiers in a separate class or interface. Such class/interface would give a global view of the identifiers in use and so can make it easier to assign new ids.

7.4.3.3. Registering Advanced Externalizers

The following example shows the type of configuration required to register an advanced externalizer implementation for Person object shown earlier stored as a static inner class within it:

infinispan.xml

```
<infinispan>
  <cache-container>
    <serialization>
      <advanced-externalizer class="Person$PersonExternalizer"/>
    </serialization>
  </cache-container>
  ...
</infinispan>
```

Programmatically:

```
GlobalConfigurationBuilder builder = ...
builder.serialization()
  .addAdvancedExternalizer(new Person.PersonExternalizer());
```

As mentioned earlier, when listing these externalizer implementations, users can optionally provide the identifier of the externalizer via XML or programmatically instead of via getId() implementation. Again, this offers a centralized way to maintain the identifiers but it's important that the rules are clear: An AdvancedExternalizer implementation, either via XML/programmatic configuration or via annotation, needs to be associated with an identifier. If it isn't, Red Hat Data Grid will throw an error and abort startup. If a particular AdvancedExternalizer implementation defines an id both via XML/programmatic configuration and annotation, the value defined via XML/programmatically is the one that will be used. Here's an example of an externalizer whose id is defined at registration time:

infinispan.xml

```
<infinispan>
  <cache-container>
    <serialization>
      <advanced-externalizer id="123"
                             class="Person$PersonExternalizer"/>
    </serialization>
  </cache-container>
  ...
</infinispan>
```

Programmatically:

```
GlobalConfigurationBuilder builder = ...
builder.serialization()
  .addAdvancedExternalizer(123, new Person.PersonExternalizer());
```

Finally, a couple of notes about the programmatic configuration. GlobalConfiguration.addExternalizer() takes varargs, so it means that it is possible to register multiple externalizers in just one go, assuming that their ids have already been defined via @Marshalls annotation. For example:

```
builder.serialization()
  .addAdvancedExternalizer(new Person.PersonExternalizer(),
                           new Address.AddressExternalizer());
```

7.4.3.4. Preassigned Externalizer Id Ranges

This is the list of Externalizer identifiers that are used by Red Hat Data Grid based modules or frameworks. Red Hat Data Grid users should avoid using ids within these ranges.

Red Hat Data Grid Tree Module:	1000 - 1099
Red Hat Data Grid Server Modules:	1100 - 1199
Hibernate Red Hat Data Grid Second Level Cache:	1200 - 1299
Red Hat Data Grid Lucene Directory:	1300 - 1399

Hibernate OGM:	1400 - 1499
Hibernate Search:	1500 - 1599
Red Hat Data Grid Query Module:	1600 - 1699
Red Hat Data Grid Remote Query Module:	1700 - 1799
Red Hat Data Grid Scripting Module:	1800 - 1849
Red Hat Data Grid Server Event Logger Module:	1850 - 1899
Red Hat Data Grid Remote Store:	1900 - 1999
Red Hat Data Grid Counters:	2000 - 2049
Red Hat Data Grid Multimap:	2050 - 2099
Red Hat Data Grid Locks:	2100 - 2149

CHAPTER 8. TRANSACTIONS

Red Hat Data Grid can be configured to use and to participate in JTA compliant transactions. Alternatively, if transaction support is disabled, it is equivalent to using autocommit in JDBC calls, where modifications are potentially replicated after every change (if replication is enabled).

On every cache operation Red Hat Data Grid does the following:

1. Retrieves the current Transaction associated with the thread
2. If not already done, registers XAResource with the transaction manager to be notified when a transaction commits or is rolled back.

In order to do this, the cache has to be provided with a reference to the environment's TransactionManager. This is usually done by configuring the cache with the class name of an implementation of the TransactionManagerLookup interface. When the cache starts, it will create an instance of this class and invoke its **getTransactionManager()** method, which returns a reference to the **TransactionManager**.

Red Hat Data Grid ships with several transaction manager lookup classes:

Transaction manager lookup implementations

- EmbeddedTransactionManagerLookup: This provides with a basic transaction manager which should only be used for embedded mode when no other implementation is available. This implementation has some severe limitations to do with concurrent transactions and recovery.
- JBossStandaloneJTAManagerLookup: If you're running Red Hat Data Grid in a standalone environment, or in JBoss AS 7 and earlier, and WildFly 8, 9, and 10, this should be your default choice for transaction manager. It's a fully fledged transaction manager based on JBoss Transactions which overcomes all the deficiencies of the **EmbeddedTransactionManager**.
- WildflyTransactionManagerLookup: If you're running Red Hat Data Grid in Wildfly 11 or later, this should be your default choice for transaction manager.
- GenericTransactionManagerLookup: This is a lookup class that locate transaction managers in the most popular Java EE application servers. If no transaction manager can be found, it defaults on the **EmbeddedTransactionManager**.

WARN: **DummyTransactionManagerLookup** has been deprecated in 9.0 and it will be removed in the future. Use **EmbeddedTransactionManagerLookup** instead.

Once initialized, the **TransactionManager** can also be obtained from the **Cache** itself:

```
//the cache must have a transactionManagerLookupClass defined
Cache cache = cacheManager.getCache();

//equivalent with calling TransactionManagerLookup.getTransactionManager();
TransactionManager tm = cache.getAdvancedCache().getTransactionManager();
```

8.1. CONFIGURING TRANSACTIONS

Transactions are configured at cache level. Below is the configuration that affects a transaction behaviour and a small description of each configuration attribute.

```
<locking
  isolation="READ_COMMITTED"
  write-skew="false"/>
<transaction
  locking="OPTIMISTIC"
  auto-commit="true"
  complete-timeout="60000"
  mode="NONE"
  notifications="true"
  protocol="DEFAULT"
  reaper-interval="30000"
  recovery-cache="__recoveryInfoCacheName__"
  stop-timeout="30000"
  transaction-manager-
lookup="org.infinispan.transaction.lookup.GenericTransactionManagerLookup"/>
<versioning
  scheme="NONE"/>
```

or programmatically:

```
ConfigurationBuilder builder = new ConfigurationBuilder();
builder.locking()
    .isolationLevel(IsolationLevel.READ_COMMITTED)
    .writeSkewCheck(false);
builder.transaction()
    .lockingMode(LockingMode.OPTIMISTIC)
    .autoCommit(true)
    .completedTxTimeout(60000)
    .transactionMode(TransactionMode.NON_TRANSACTIONAL)
    .useSynchronization(false)
    .notifications(true)
    .transactionProtocol(TransactionProtocol.DEFAULT)
    .reaperWakeUpInterval(30000)
    .cacheStopTimeout(30000)
    .transactionManagerLookup(new GenericTransactionManagerLookup())
    .recovery()
    .enabled(false)
    .recoveryInfoCacheName("__recoveryInfoCacheName__");
builder.versioning()
    .enabled(false)
    .scheme(VersioningScheme.NONE);
```

- **isolation** - configures the isolation level. Check section Isolation Levels for more details. Default is **REPEATABLE_READ**.
- **write-skew** - enables write skew checks (deprecated). Red Hat Data Grid automatically sets this attribute in Library Mode. Default is **false** for **READ_COMMITTED**. Default is **true** for **REPEATABLE_READ**. See Write Skews for more details.
- **locking** - configures whether the cache uses optimistic or pessimistic locking. Check section Transaction Locking for more details. Default is **OPTIMISTIC**.
- **auto-commit** - if enable, the user does not need to start a transaction manually for a single operation. The transaction is automatically started and committed. Default is **true**.

- **complete-timeout** - the duration in milliseconds to keep information about completed transactions. Default is **60000**.
- **mode** - configures whether the cache is transactional or not. Default is **NONE**. The available options are:
  - **NONE** - non transactional cache
  - **FULL_XA** - XA transactional cache with recovery enabled. Check section Transaction recovery for more details about recovery.
  - **NON_DURABLE_XA** - XA transactional cache with recovery disabled.
  - **NON_XA** - transactional cache with integration via Synchronization instead of XA. Check section Enlisting Synchronizations for details.
  - **BATCH**- transactional cache using batch to group operations. Check section Batching for details.
- **notifications** - enables/disables triggering transactional events in cache listeners. Default is **true**.
- **protocol** - configures the protocol uses. Default is **DEFAULT**. Values available are:
  - **DEFAULT** - uses the traditional Two-Phase-Commit protocol. It is described below.
  - **TOTAL_ORDER** - uses total order ensured by the **Transport** to commit transactions. Check section Total Order based commit protocol for details.
- **reaper-interval** - the time interval in millisecond at which the thread that cleans up transaction completion information kicks in. Defaults is **30000**.
- **recovery-cache** - configures the cache name to store the recovery information. Check section Transaction recovery for more details about recovery. Default is ***recoveryInfoCacheName***.
- **stop-timeout** - the time in millisecond to wait for ongoing transaction when the cache is stopping. Default is **30000**.
- **transaction-manager-lookup** - configures the fully qualified class name of a class that looks up a reference to a **javax.transaction.TransactionManager**. Default is **org.infinispan.transaction.lookup.GenericTransactionManagerLookup**.
- Versioning **scheme** - configure the version scheme to use when write skew is enabled with optimistic or total order transactions. Check section Write Skews for more details. Default is **NONE**.

For more details on how Two-Phase-Commit (2PC) is implemented in Red Hat Data Grid and how locks are being acquired see the section below. More details about the configuration settings are available in Configuration reference.

8.2. ISOLATION LEVELS

Red Hat Data Grid offers two isolation levels - READ_COMMITTED and REPEATABLE_READ.

These isolation levels determine when readers see a concurrent write, and are internally implemented using different subclasses of **MVCCEntry**, which have different behaviour in how state is committed back to the data container.

Here’s a more detailed example that should help understand the difference between **READ_COMMITTED** and **REPEATABLE_READ** in the context of Red Hat Data Grid. With **READ_COMMITTED**, if between two consecutive read calls on the same key, the key has been updated by another transaction, the second read may return the new updated value:

```
Thread1: tx1.begin()
Thread1: cache.get(k) // returns v
Thread2:                                       tx2.begin()
Thread2:                                       cache.get(k) // returns v
Thread2:                                       cache.put(k, v2)
Thread2:                                       tx2.commit()
Thread1: cache.get(k) // returns v2!
Thread1: tx1.commit()
```

With **REPEATABLE_READ**, the final get will still return **v**. So, if you’re going to retrieve the same key multiple times within a transaction, you should use **REPEATABLE_READ**.

However, as read-locks are not acquired even for **REPEATABLE_READ**, this phenomena can occur:

```
cache.get("A") // returns 1
cache.get("B") // returns 1

Thread1: tx1.begin()
Thread1: cache.put("A", 2)
Thread1: cache.put("B", 2)
Thread2:                                       tx2.begin()
Thread2:                                       cache.get("A") // returns 1
Thread1: tx1.commit()
Thread2:                                       cache.get("B") // returns 2
Thread2:                                       tx2.commit()
```

8.3. TRANSACTION LOCKING

8.3.1. Pessimistic transactional cache

From a lock acquisition perspective, pessimistic transactions obtain locks on keys at the time the key is written.

1. A lock request is sent to the primary owner (can be an explicit lock request or an operation)
2. The primary owner tries to acquire the lock:
    a. If it succeed, it sends back a positive reply;
    b. Otherwise, a negative reply is sent and the transaction is rollback.

As an example:

```
transactionManager.begin();
cache.put(k1,v1); //k1 is locked.
cache.remove(k2); //k2 is locked when this returns
transactionManager.commit();
```

When **cache.put(k1,v1)** returns, **k1** is locked and no other transaction running anywhere in the cluster can write to it. Reading **k1** is still possible. The lock on **k1** is released when the transaction completes (commits or rollbacks).

NOTE

For conditional operations, the validation is performed in the originator.

8.3.2. Optimistic transactional cache

With optimistic transactions locks are being acquired at transaction prepare time and are only being held up to the point the transaction commits (or rollbacks). This is different from the 5.0 default locking model where local locks are being acquire on writes and cluster locks are being acquired during prepare time.

1. The prepare is sent to all the owners.
2. The primary owners try to acquire the locks needed:
    a. If locking succeeds, it performs the write skew check.
    b. If the write skew check succeeds (or is disabled), send a positive reply.
    c. Otherwise, a negative reply is sent and the transaction is rolled back.

As an example:

```
transactionManager.begin();
cache.put(k1,v1);
cache.remove(k2);
transactionManager.commit(); //at prepare time, K1 and K2 is locked until committed/rolled back.
```

NOTE

For conditional commands, the validation still happens on the originator.

8.3.3. What do I need - pessimistic or optimistic transactions?

From a use case perspective, optimistic transactions should be used when there is *not* a lot of contention between multiple transactions running at the same time. That is because the optimistic transactions rollback if data has changed between the time it was read and the time it was committed (with write skew check enabled).

On the other hand, pessimistic transactions might be a better fit when there is high contention on the keys and transaction rollbacks are less desirable. Pessimistic transactions are more costly by their nature: each write operation potentially involves a RPC for lock acquisition.

8.4. WRITE SKEWS

Write skews occur when two transactions independently and simultaneously read and write to the same key. The result of a write skew is that both transactions successfully commit updates to the same key but with different values.

In Library Mode, Red Hat Data Grid automatically performs write skew checks to ensure data consistency for **REPEATABLE_READ** isolation levels in optimistic transactions. This allows Red Hat Data Grid to detect and roll back one of the transactions.

NOTE

The **write-skew** attribute is deprecated for Library Mode. In Remote Client/Server Mode, this attribute is not a valid declaration.

When operating in **LOCAL** mode, write skew checks rely on Java object references to compare differences, which provides a reliable technique for checking for write skews.

In clustered environments, you should configure data versioning to ensure reliable write skew checks. Red Hat Data Grid provides an implementation of the **EntryVersion** interface called **SIMPLE** versioning, which is backed by a long that is incremented each time the entry is updated.

```
<versioning scheme="SIMPLE|NONE" />
```

Or

```
new ConfigurationBuilder().versioning().scheme(SIMPLE);
```

8.4.1. Forcing write locks on keys in pessimitic transactions

To avoid write-skews with pessimistic transactions, lock keys at read-time with **Flag.FORCE_WRITE_LOCK**.

NOTE

- In non-transactional caches, **Flag.FORCE_WRITE_LOCK** does not work. The **get()** call reads the key value but does not acquire locks remotely.
- You should use **Flag.FORCE_WRITE_LOCK** with transactions in which the entity is updated later in the same transaction.

Compare the following code snippets for an example of **Flag.FORCE_WRITE_LOCK**:

```
// begin the transaction
if (!cache.getAdvancedCache().lock(key)) {
   // abort the transaction because the key was not locked
} else {
   cache.get(key);
   cache.put(key, value);
   // commit the transaction
}
```

```
// begin the transaction
try {
   // throws an exception if the key is not locked.
   cache.getAdvancedCache().withFlags(Flag.FORCE_WRITE_LOCK).get(key);
   cache.put(key, value);
} catch (CacheException e) {
   // mark the transaction rollback-only
}
// commit or rollback the transaction
```

8.5. DEALING WITH EXCEPTIONS

If a CacheException (or a subclass of it) is thrown by a cache method within the scope of a JTA transaction, then the transaction is automatically marked for rollback.

8.6. ENLISTING SYNCHRONIZATIONS

By default Red Hat Data Grid registers itself as a first class participant in distributed transactions through XAResource. There are situations where Red Hat Data Grid is not required to be a participant in the transaction, but only to be notified by its lifecycle (prepare, complete): e.g. in the case Red Hat Data Grid is used as a 2nd level cache in Hibernate.

Red Hat Data Grid allows transaction enlistment through Synchronization. To enable it just use **NON_XA** transaction mode.

Synchronizations have the advantage that they allow **TransactionManager** to optimize 2PC with a 1PC where only one other resource is enlisted with that transaction (last resource commit optimization). E.g. Hibernate second level cache: if Red Hat Data Grid registers itself with the **TransactionManager** as a **XAResource** than at commit time, the **TransactionManager** sees two **XAResource** (cache and database) and does not make this optimization. Having to coordinate between two resources it needs to write the tx log to disk. On the other hand, registering Red Hat Data Grid as a **Synchronisation** makes the **TransactionManager** skip writing the log to the disk (performance improvement).

8.7. BATCHING

Batching allows atomicity and some characteristics of a transaction, but not full-blown JTA or XA capabilities. Batching is often a lot lighter and cheaper than a full-blown transaction.

TIP

Generally speaking, one should use batching API whenever the only participant in the transaction is an Red Hat Data Grid cluster. On the other hand, JTA transactions (involving **TransactionManager**) should be used whenever the transactions involves multiple systems. E.g. considering the "Hello world!" of transactions: transferring money from one bank account to the other. If both accounts are stored within Red Hat Data Grid, then batching can be used. If one account is in a database and the other is Red Hat Data Grid, then distributed transactions are required.

NOTE

You *do not* have to have a transaction manager defined to use batching.

8.7.1. API

Once you have configured your cache to use batching, you use it by calling **startBatch()** and **endBatch()** on **Cache**. E.g.,

```
Cache cache = cacheManager.getCache();
// not using a batch
cache.put("key", "value"); // will replicate immediately
```

```
// using a batch
cache.startBatch();
cache.put("k1", "value");
cache.put("k2", "value");
cache.put("k2", "value");
cache.endBatch(true); // This will now replicate the modifications since the batch was started.

// a new batch
cache.startBatch();
cache.put("k1", "value");
cache.put("k2", "value");
cache.put("k3", "value");
cache.endBatch(false); // This will "discard" changes made in the batch
```

8.7.2. Batching and JTA

Behind the scenes, the batching functionality starts a JTA transaction, and all the invocations in that scope are associated with it. For this it uses a very simple (e.g. no recovery) internal **TransactionManager** implementation. With batching, you get:

1. Locks you acquire during an invocation are held until the batch completes
2. Changes are all replicated around the cluster in a batch as part of the batch completion process. Reduces replication chatter for each update in the batch.
3. If synchronous replication or invalidation are used, a failure in replication/invalidation will cause the batch to roll back.
4. All the transaction related configurations apply for batching as well.

8.8. TRANSACTION RECOVERY

Recovery is a feature of XA transactions, which deal with the eventuality of a resource or possibly even the transaction manager failing, and recovering accordingly from such a situation.

8.8.1. When to use recovery

Consider a distributed transaction in which money is transferred from an account stored in an external database to an account stored in Red Hat Data Grid. When **TransactionManager.commit()** is invoked, both resources prepare successfully (1st phase). During the commit (2nd) phase, the database successfully applies the changes whilst Red Hat Data Grid fails before receiving the commit request from the transaction manager. At this point the system is in an inconsistent state: money is taken from the account in the external database but not visible yet in Red Hat Data Grid (since locks are only released during 2nd phase of a two-phase commit protocol). Recovery deals with this situation to make sure data in both the database and Red Hat Data Grid ends up in a consistent state.

8.8.2. How does it work

Recovery is coordinated by the transaction manager. The transaction manager works with Red Hat Data Grid to determine the list of in-doubt transactions that require manual intervention and informs the system administrator (via email, log alerts, etc). This process is transaction manager specific, but generally requires some configuration on the transaction manager.

Knowing the in-doubt transaction ids, the system administrator can now connect to the Red Hat Data Grid cluster and replay the commit of transactions or force the rollback. Red Hat Data Grid provides JMX tooling for this - this is explained extensively in the Transaction recovery and reconciliation section.

8.8.3. Configuring recovery

Recovery is *not* enabled by default in Red Hat Data Grid. If disabled, the **TransactionManager** won't be able to work with Red Hat Data Grid to determine the in-doubt transactions. The Transaction configuration section shows how to enable it.

NOTE: **recovery-cache** attribute is not mandatory and it is configured per-cache.

NOTE

For recovery to work, **mode** must be set to **FULL_XA**, since full-blown XA transactions are needed.

8.8.3.1. Enable JMX support

In order to be able to use JMX for managing recovery JMX support must be explicitly enabled. More about enabling JMX in the Management chapter.

8.8.4. Recovery cache

In order to track in-doubt transactions and be able to reply them, Red Hat Data Grid caches all transaction state for future use. This state is held only for in-doubt transaction, being removed for successfully completed transactions after when the commit/rollback phase completed.

This in-doubt transaction data is held within a local cache: this allows one to configure swapping this info to disk through cache loader in the case it gets too big. This cache can be specified through the **recovery-cache** configuration attribute. If not specified Red Hat Data Grid will configure a local cache for you.

It is possible (though not mandated) to share same recovery cache between all the Red Hat Data Grid caches that have recovery enabled. If the default recovery cache is overridden, then the specified recovery cache must use a TransactionManagerLookup that returns a different transaction manager than the one used by the cache itself.

8.8.5. Integration with the transaction manager

Even though this is transaction manager specific, generally a transaction manager would need a reference to a **XAResource** implementation in order to invoke **XAResource.recover()** on it. In order to obtain a reference to an Red Hat Data Grid **XAResource** following API can be used:

```
XAResource xar = cache.getAdvancedCache().getXAResource();
```

It is a common practice to run the recovery in a different process from the one running the transaction.

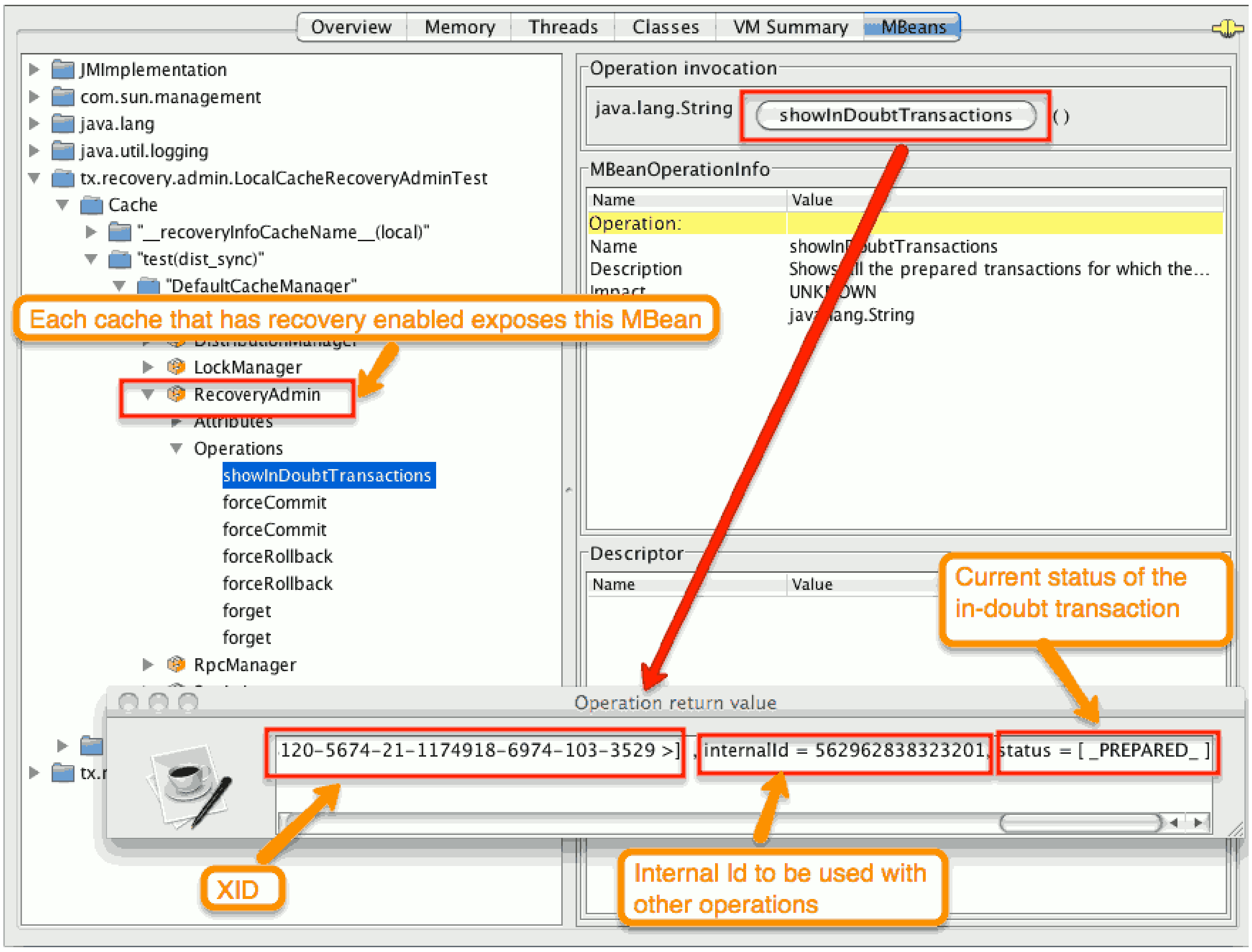
8.8.6. Reconciliation

The transaction manager informs the system administrator on in-doubt transaction in a proprietary way. At this stage it is assumed that the system administrator knows transaction's XID (a byte array).

A normal recovery flow is:

- **STEP 1**: The system administrator connects to an Red Hat Data Grid server through JMX, and lists the in doubt transactions. The image below demonstrates JConsole connecting to an Red Hat Data Grid node that has an in doubt transaction.

Figure 8.1. Show in-doubt transactions



Name	Value
Operation:	
Name	showInDoubtTransactions
Description	Shows all the prepared transactions for which the...
Impact	UNKNOWN
	java.lang.String

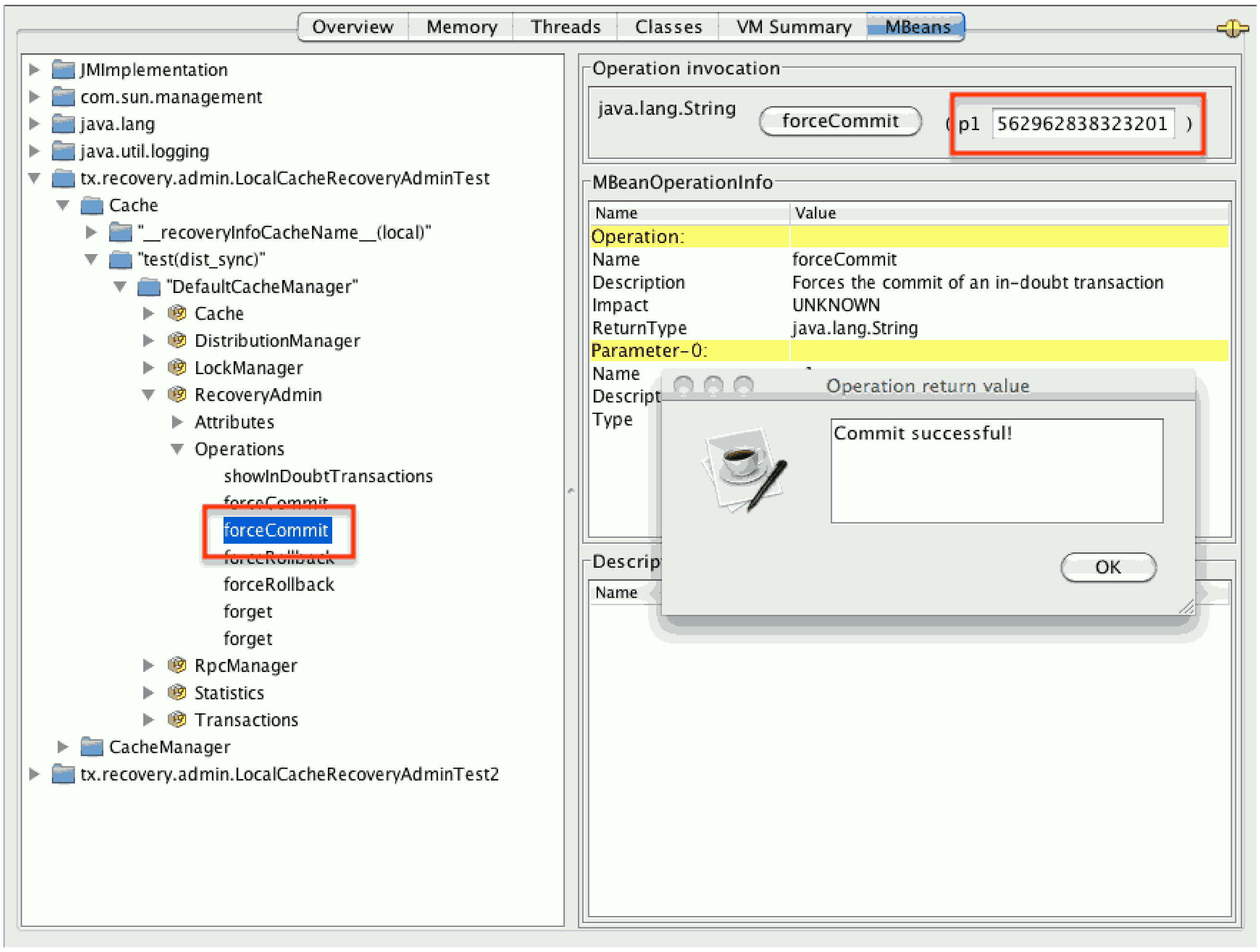
```
120-5674-21-1174918-6974-103-3529 >] , internalId = 562962838323201, status = [ _PREPARED_ ]
```

The status of each in-doubt transaction is displayed(in this example " *PREPARED* "). There might be multiple elements in the status field, e.g. "PREPARED" and "COMMITTED" in the case the transaction committed on certain nodes but not on all of them.

- **STEP 2**: The system administrator visually maps the XID received from the transaction manager to an Red Hat Data Grid internal id, represented as a number. This step is needed because the XID, a byte array, cannot conveniently be passed to the JMX tool (e.g. JConsole) and then re-assembled on Red Hat Data Grid's side.

- **STEP 3**: The system administrator forces the transaction's commit/rollback through the corresponding jmx operation, based on the internal id. The image below is obtained by forcing the commit of the transaction based on its internal id.

Figure 8.2. Force commit



Name	Value
Operation:	
Name	forceCommit
Description	Forces the commit of an in-doubt transaction
Impact	UNKNOWN
ReturnType	java.lang.String
Parameter-0:	
Name	
Descript	
Type	

```
Commit successful!
```

TIP

All JMX operations described above can be executed on any node, regardless of where the transaction originated.

8.8.6.1. Force commit/rollback based on XID

XID-based JMX operations for forcing in-doubt transactions' commit/rollback are available as well: these methods receive byte[] arrays describing the XID instead of the number associated with the transactions (as previously described at step 2). These can be useful e.g. if one wants to set up an automatic completion job for certain in-doubt transactions. This process is plugged into transaction manager’s recovery and has access to the transaction manager’s XID objects.

8.8.7. Want to know more?

The recovery design document describes in more detail the insides of transaction recovery implementation.

8.9. TOTAL ORDER BASED COMMIT PROTOCOL

The Total Order based protocol is a multi-master scheme (in this context, multi-master scheme means that all nodes can update all the data) as the (optimistic/pessimist) locking mode implemented in Red Hat Data Grid. This commit protocol relies on the concept of totally ordered delivery of messages which, informally, implies that each node which delivers a set of messages, delivers them in the same order.

This protocol comes with this advantages.

1. transactions can be committed in one phase, as they are delivered in the same order by the nodes that receive them.
2. it mitigates distributed deadlocks.

The weaknesses of this approach are the fact that its implementation relies on a single thread per node which delivers the transaction and its modification, and the slightly cost of total ordering the messages in **Transport**.

Thus, this protocol delivers best performance in scenarios of *high contention* , in which it can benefit from the single-phase commit and the deliver thread is not the bottleneck.

Currently, the Total Order based protocol is available only in *transactional* caches for *replicated* and *distributed* modes.

8.9.1. Overview

The Total Order based commit protocol only affects how transactions are committed by Red Hat Data Grid and the isolation level and write skew affects it behaviour.

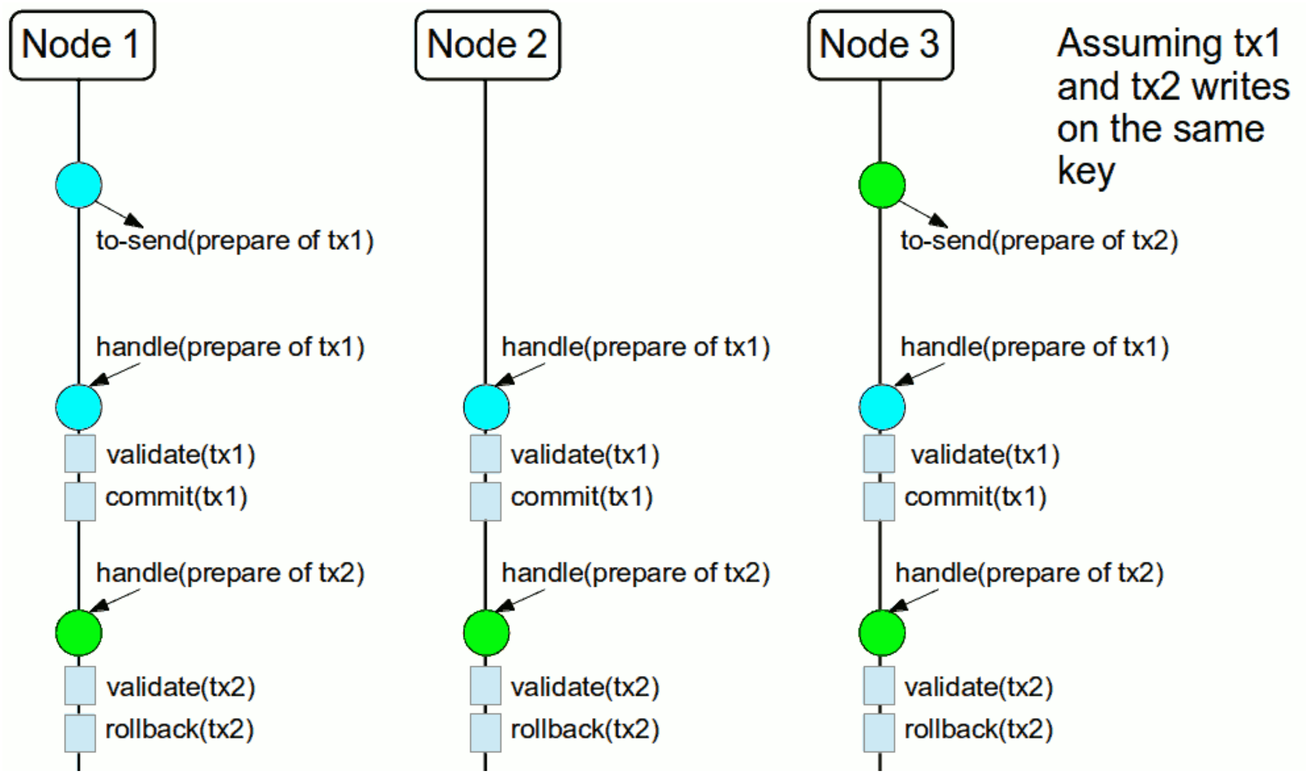
When write skew is disabled, the transaction can be committed/rolled back in single phase. The data consistency is guaranteed by the **Transport** that ensures that all owners of a key will deliver the same transactions set by the same order.

On other hand, when write skew is enabled, the protocol adapts and uses one phase commit when it is safe. In **XaResource** enlistment, we can use one phase if the **TransactionManager** request a commit in one phase (last resource commit optimization) and the Red Hat Data Grid cache is configured in replicated mode. This optimization is not safe in distributed mode because each node performs the write skew check validation in different keys subset. When in **Synchronization** enlistment, the **TransactionManager** does not provide any information if Red Hat Data Grid is the only resource enlisted (last resource commit optimization), so it is not possible to commit in a single phase.

8.9.1.1. Commit in one phase

When the transaction ends, Red Hat Data Grid sends the transaction (and its modification) in total order. This ensures all the transactions are deliver in the same order in all the involved Red Hat Data Grid nodes. As a result, when a transaction is delivered, it performs a deterministic write skew check over the same state (if enabled), leading to the same outcome (transaction commit or rollback).

Figure 8.3. 1-phase commit

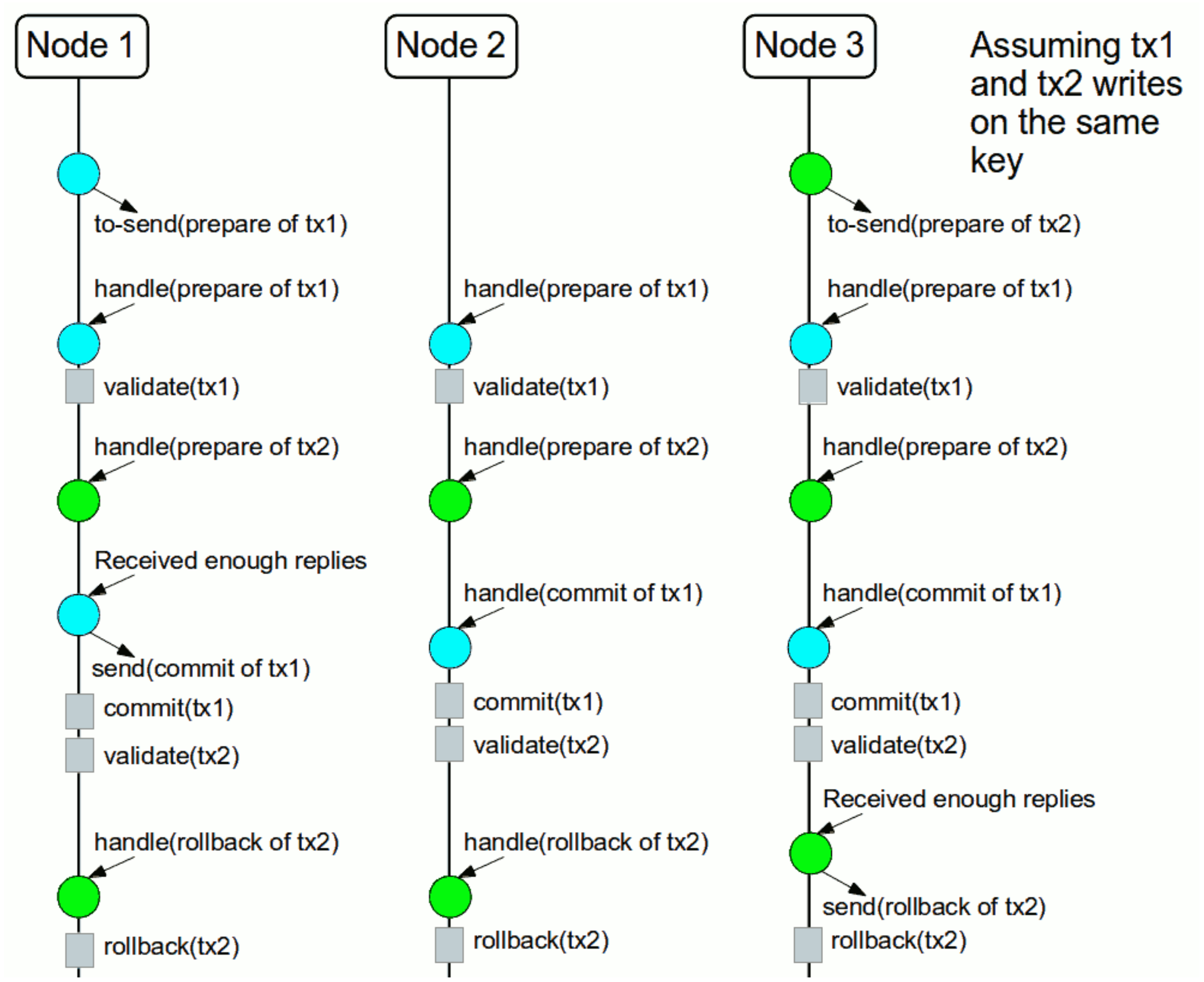


The figure above demonstrates a high level example with 3 nodes. **Node1** and **Node3** are running one transaction each and lets assume that both transaction writes on the same key. To make it more interesting, lets assume that both nodes tries to commit at the same time, represented by the first colored circle in the figure. The *blue* circle represents the transaction *tx1* and the *green* the transaction *tx2* . Both nodes do a remote invocation in total order (*to-send*) with the transaction's modifications. At this moment, all the nodes will agree in the same deliver order, for example, *tx1* followed by *tx2* . Then, each node delivers *tx1* , perform the validation and commits the modifications. The same steps are performed for *tx2* but, in this case, the validation will fail and the transaction is rollback in all the involved nodes.

8.9.1.2. Commit in two phases

In the first phase, it sends the modification in total order and the write skew check is performed. The result of the write skew check is sent back to the originator. As soon as it has the confirmation that all keys are successfully validated, it give a positive response to the **TransactionManager**. On other hand, if it receives a negative reply, it returns a negative response to the **TransactionManager**. Finally, the transaction is committed or aborted in the second phase depending of the **TransactionManager** request.

Figure 8.4. 2-phase commit



The figure above shows the scenario described in the first figure but now committing the transactions using two phases. When *tx1* is deliver, it performs the validation and it replies to the **TransactionManager**. Next, lets assume that *tx2* is deliver before the **TransactionManager** request the second phase for *tx1*. In this case, *tx2* will be enqueued and it will be validated only when *tx1* is completed. Eventually, the **TransactionManager** for *tx1* will request the second phase (the commit) and all the nodes are free to perform the validation of *tx2* .

8.9.1.3. Transaction Recovery

Transaction recovery is currently not available for Total Order based commit protocol.

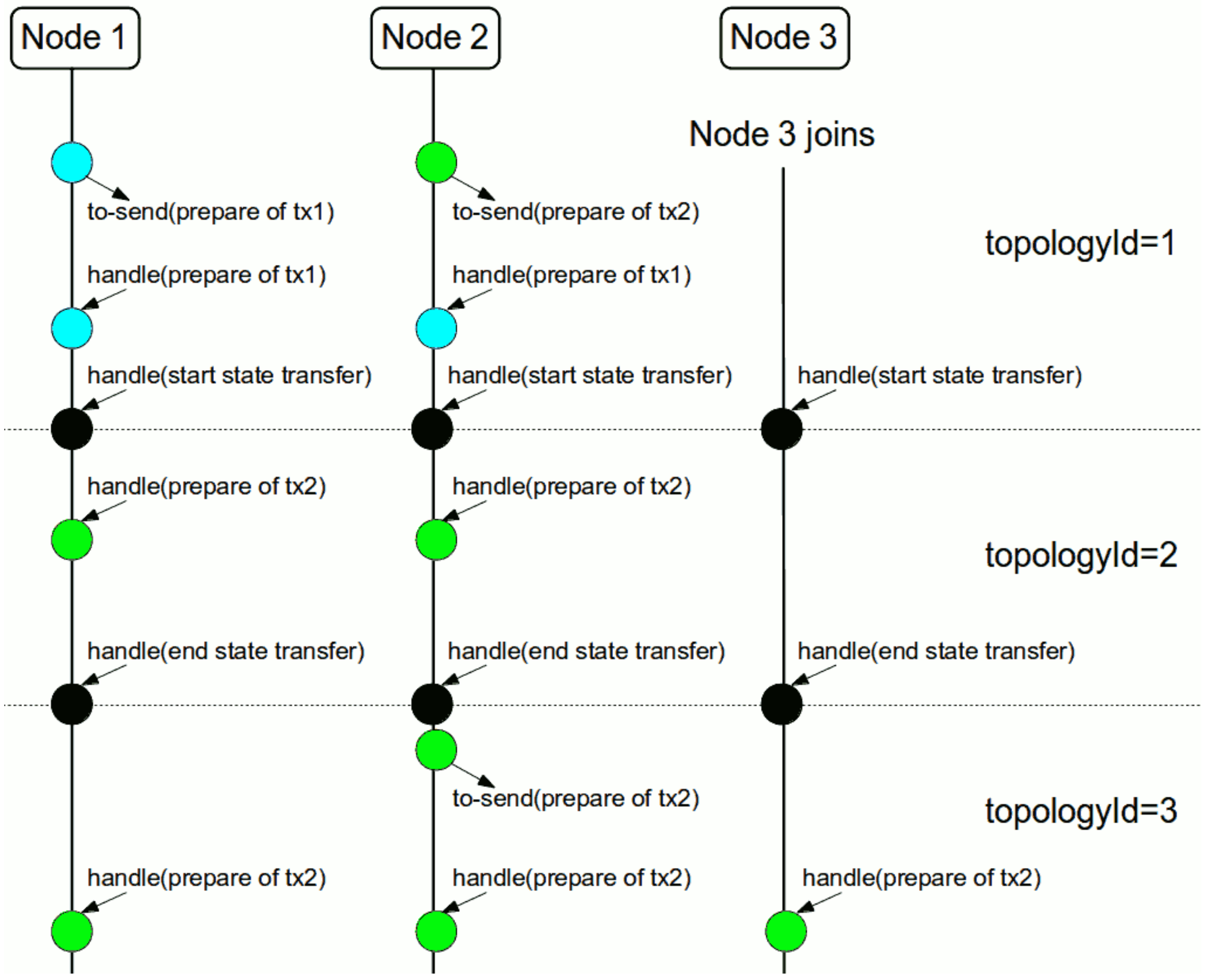
8.9.1.4. State Transfer

For simplicity reasons, the total order based commit protocol uses a blocking version of the current state transfer. The main differences are:

1. enqueue the transaction deliver while the state transfer is in progress;
2. the state transfer control messages (**CacheTopologyControlCommand**) are sent in total order.

This way, it provides a synchronization between the state transfer and the transactions deliver that is the same all the nodes. Although, the transactions caught in the middle of state transfer (i.e. sent before the state transfer start and deliver after it) needs to be re-sent to find a new total order involving the new joiners.

Figure 8.5. Node joining during transaction



The figure above describes a node joining. In the scenario, the *tx2* is sent in *topologyId=1* but when it is received, it is in *topologyId=2* . So, the transaction is re-sent involving the new nodes.

8.9.2. Configuration

To use total order in your cache, you need to add the **TOA** protocol in your **jgroups.xml** configuration file.

jgroups.xml

```
<tom.TOA />
```

NOTE

Check the JGroups Manual for more details.

NOTE

If you are interested in detail how JGroups guarantees total order, check the link::http://jgroups.org/manual/index.html#TOA[TOA manual].

Also, you need to set the **protocol=TOTAL_ORDER** in the **<transaction>** element, as shown in Transaction configuration.

8.9.3. When to use it?

Total order shows benefits when used in write intensive and high contented workloads. It avoids contention in the lock keys.

CHAPTER 9. LOCKING AND CONCURRENCY

Red Hat Data Grid makes use of multi-versioned concurrency control (MVCC) - a concurrency scheme popular with relational databases and other data stores. MVCC offers many advantages over coarse-grained Java synchronization and even JDK Locks for access to shared data, including:

- allowing concurrent readers and writers
- readers and writers do not block one another
- write skews can be detected and handled
- internal locks can be striped

9.1. LOCKING IMPLEMENTATION DETAILS

Red Hat Data Grid's MVCC implementation makes use of minimal locks and synchronizations, leaning heavily towards lock-free techniques such as compare-and-swap and lock-free data structures wherever possible, which helps optimize for multi-CPU and multi-core environments.

In particular, Red Hat Data Grid's MVCC implementation is heavily optimized for readers. Reader threads do not acquire explicit locks for entries, and instead directly read the entry in question.

Writers, on the other hand, need to acquire a write lock. This ensures only one concurrent writer per entry, causing concurrent writers to queue up to change an entry. To allow concurrent reads, writers make a copy of the entry they intend to modify, by wrapping the entry in an **MVCCEntry**. This copy isolates concurrent readers from seeing partially modified state. Once a write has completed, **MVCCEntry.commit()** will flush changes to the data container and subsequent readers will see the changes written.

9.1.1. How does it work in clustered caches?

In clustered caches, each key has a node responsible to lock the key. This node is called primary owner.

9.1.1.1. Non Transactional caches

1. The write operation is sent to the primary owner of the key.
2. The primary owner tries to lock the key.
   a. If it succeeds, it forwards the operation to the other owners;
   b. Otherwise, an exception is thrown.

NOTE

If the operation is conditional and it fails on the primary owner, it is not forwarded to the other owners.

NOTE

If the operation is executed locally in the primary owner, the first step is skipped.

9.1.2. Transactional caches

The transactional cache supports optimistic and pessimistic locking mode. Check section Transaction Locking for more information about it.

9.1.3. Isolation levels

Isolation level affects what transactions can read when running concurrently with other transaction. Check section Isolation Levels for more details about it.

9.1.4. The LockManager

The **LockManager** is a component that is responsible for locking an entry for writing. The **LockManager** makes use of a **LockContainer** to locate/hold/create locks. **LockContainers** come in two broad flavours, with support for lock striping and with support for one lock per entry.

9.1.5. Lock striping

Lock striping entails the use of a fixed-size, shared collection of locks for the entire cache, with locks being allocated to entries based on the entry's key's hash code. Similar to the way the JDK's **ConcurrentHashMap** allocates locks, this allows for a highly scalable, fixed-overhead locking mechanism in exchange for potentially unrelated entries being blocked by the same lock.

The alternative is to disable lock striping - which would mean a *new* lock is created per entry. This approach *may* give you greater concurrent throughput, but it will be at the cost of additional memory usage, garbage collection churn, etc.

DEFAULT LOCK STRIPING SETTINGS

lock striping is disabled by default, due to potential deadlocks that can happen if locks for different keys end up in the same lock stripe.

The size of the shared lock collection used by lock striping can be tuned using the **concurrencyLevel** attribute of the `<locking /> configuration element.

Configuration example:

```
<locking striping="false|true"/>
```

Or

```
new ConfigurationBuilder().locking().useLockStriping(false|true);
```

9.1.6. Concurrency levels

In addition to determining the size of the striped lock container, this concurrency level is also used to tune any JDK **ConcurrentHashMap** based collections where related, such as internal to **DataContainer**s. Please refer to the JDK **ConcurrentHashMap** Javadocs for a detailed discussion of concurrency levels, as this parameter is used in exactly the same way in Red Hat Data Grid.

Configuration example:

```
<locking concurrency-level="32"/>
```

Or

```
new ConfigurationBuilder().locking().concurrencyLevel(32);
```

9.1.7. Lock timeout

The lock timeout specifies the amount of time, in milliseconds, to wait for a contented lock.

Configuration example:

```
<locking acquire-timeout="10000"/>
```

Or

```
new ConfigurationBuilder().locking().lockAcquisitionTimeout(10000);
//alternatively
new ConfigurationBuilder().locking().lockAcquisitionTimeout(10, TimeUnit.SECONDS);
```

9.1.8. Consistency

The fact that a single owner is locked (as opposed to all owners being locked) does not break the following consistency guarantee: if key **K** is hashed to nodes **{A, B}** and transaction **TX1** acquires a lock for **K**, let's say on **A**. If another transaction, **TX2**, is started on **B** (or any other node) and **TX2** tries to lock **K** then it will fail with a timeout as the lock is already held by **TX1**. The reason for this is the that the lock for a key **K** is always, deterministically, acquired on the same node of the cluster, regardless of where the transaction originates.

9.2. DATA VERSIONING

Red Hat Data Grid supports two forms of data versioning: simple and external. The simple versioning is used in transactional caches for write skew check. See Write Skews.

The external versioning is used to encapsulate an external source of data versioning within Red Hat Data Grid, such as when using Red Hat Data Grid with Hibernate which in turn gets its data version information directly from a database.

In this scheme, a mechanism to pass in the version becomes necessary, and overloaded versions of **put()** and **putForExternalRead()** will be provided in **AdvancedCache** to take in an external data version. This is then stored on the **InvocationContext** and applied to the entry at commit time.

NOTE

Write skew checks cannot and will not be performed in the case of external data versioning.

CHAPTER 10. EXECUTING CODE IN THE GRID

The main benefit of a Cache is the ability to very quickly lookup a value by its key, even across machines. In fact this use alone is probably the reason many users use Red Hat Data Grid. However Red Hat Data Grid can provide many more benefits that aren't immediately apparent. Since Red Hat Data Grid is usually used in a cluster of machines we also have features available that can help utilize the entire cluster for performing the user's desired workload.

NOTE

This section covers only executing code in the grid using an embedded cache, if you are using a remote cache you should check out Executing code in the Remote Grid .

10.1. CLUSTER EXECUTOR

Since you have a group of machines, it makes sense to leverage their combined computing power for executing code on all of them them. The cache manager comes with a nice utility that allows you to execute arbitrary code in the cluster. Note this feature requires no Cache to be used. This Cluster Executor can be retrieved by calling executor() on the **EmbeddedCacheManager**. This executor is retrievable in both clustered and non clustered configurations.

NOTE

The ClusterExecutor is specifically designed for executing code where the code is not reliant upon the data in a cache and is used instead as a way to help users to execute code easily in the cluster.

This manager was built specifically using Java 8 and such has functional APIs in mind, thus all methods take a functional inteface as an argument. Also since these arguments will be sent to other nodes they need to be serializable. We even used a nice trick to ensure our lambdas are immediately Serializable. That is by having the arguments implement both Serializable and the real argument type (ie. Runnable or Function). The JRE will pick the most specific class when determining which method to invoke, so in that case your lambdas will always be serializable. It is also possible to use an Externalizer to possibly reduce message size further.

The manager by default will submit a given command to all nodes in the cluster including the node where it was submitted from. You can control on which nodes the task is executed on by using the **filterTargets** methods as is explained in the section.

10.1.1. Filtering execution nodes

It is possible to limit on which nodes the command will be ran. For example you may want to only run a computation on machines in the same rack. Or you may want to perform an operation once in the local site and again on a different site. A cluster executor can limit what nodes it sends requests to at the scope of same or different machine, rack or site level.

SameRack.java

```
EmbeddedCacheManager manager = ...;
manager.executor().filterTargets(ClusterExecutionPolicy.SAME_RACK).submit(...)
```

To use this topology base filtering you must enable topology aware consistent hashing through Server Hinting.

You can also filter using a predicate based on the **Address** of the node. This can also be optionally combined with topology based filtering in the previous code snippet.

We also allow the target node to be chosen by any means using a **Predicate** that will filter out which nodes can be considered for execution. Note this can also be combined with Topology filtering at the same time to allow even more fine control of where you code is executed within the cluster.

Predicate.java

```
EmbeddedCacheManager manager = ...;
// Just filter
manager.executor().filterTargets(a -> a.equals(..)).submit(...)
// Filter only those in the desired topology
manager.executor().filterTargets(ClusterExecutionPolicy.SAME_SITE, a -> a.equals(..)).submit(...)
```

10.1.2. Timeout

Cluster Executor allows for a timeout to be set per invocation. This defaults to the distributed sync timeout as configured on the Transport Configuration. This timeout works in both a clustered and non clustered cache manager. The executor may or may not interrupt the threads executing a task when the timeout expires. However when the timeout occurs any **Consumer** or **Future** will be completed passing back a **TimeoutException**. This value can be overridden by ivoking the timeout method and supplying the desired duration.

10.1.3. Single Node Submission

Cluster Executor can also run in single node submission mode instead of submitting the command to all nodes it will instead pick one of the nodes that would have normally received the command and instead submit it it to only one. Each submission will possibly use a different node to execute the task on. This can be very useful to use the ClusterExecutor as a **java.util.concurrent.Executor** which you may have noticed that ClusterExecutor implements.

SingleNode.java

```
EmbeddedCacheManager manager = ...;
manager.executor().singleNodeSubmission().submit(...)
```

10.1.3.1. Failover

When running in single node submission it may be desirable to also allow the Cluster Executor handle cases where an exception occurred during the processing of a given command by retrying the command again. When this occurs the Cluster Executor will choose a single node again to resubmit the command to up to the desired number of failover attempts. Note the chosen node could be any node that passes the topology or predicate check. Failover is enabled by invoking the overridden singleNodeSubmission method. The given command will be resubmitted again to a single node until either the command completes without exception or the total submission amount is equal to the provided failover count.

10.1.4. Example: PI Approximation

This example shows how you can use the ClusterExecutor to estimate the value of PI.

Pi approximation can greatly benefit from parallel distributed execution via Cluster Executor. Recall that area of the square is Sa = 4r2 and area of the circle is Ca=pi*r2. Substituting r2 from the second equation into the first one it turns out that pi = 4 * Ca/Sa. Now, image that we can shoot very large number of darts into a square; if we take ratio of darts that land inside a circle over a total number of darts shot we will approximate Ca/Sa value. Since we know that pi = 4 * Ca/Sa we can easily derive approximate value of pi. The more darts we shoot the better approximation we get. In the example below we shoot 1 billion darts but instead of "shooting" them serially we parallelize work of dart shooting across the entire Red Hat Data Grid cluster. Note this will work in a cluster of 1 was well, but will be slower.

```
public class PiAppx {

  public static void main (String [] arg){
    EmbeddedCacheManager cacheManager = ..
    boolean isCluster = ..

    int numPoints = 1_000_000_000;
    int numServers = isCluster ? cacheManager.getMembers().size() : 1;
    int numberPerWorker = numPoints / numServers;

    ClusterExecutor clusterExecutor = cacheManager.executor();
    long start = System.currentTimeMillis();
    // We receive results concurrently - need to handle that
    AtomicLong countCircle = new AtomicLong();
    CompletableFuture<Void> fut = clusterExecutor.submitConsumer(m -> {
      int insideCircleCount = 0;
      for (int i = 0; i < numberPerWorker; i++) {
        double x = Math.random();
        double y = Math.random();
        if (insideCircle(x, y))
          insideCircleCount++;
      }
      return insideCircleCount;
    }, (address, count, throwable) -> {
      if (throwable != null) {
        throwable.printStackTrace();
        System.out.println("Address: " + address + " encountered an error: " + throwable);
      } else {
        countCircle.getAndAdd(count);
      }
    });
    fut.whenComplete((v, t) -> {
      // This is invoked after all nodes have responded with a value or exception
      if (t != null) {
        t.printStackTrace();
        System.out.println("Exception encountered while waiting:" + t);
      } else {
        double appxPi = 4.0 * countCircle.get() / numPoints;

        System.out.println("Distributed PI appx is " + appxPi +
            " using " + numServers + " node(s), completed in " + (System.currentTimeMillis() - start) +
" ms");
      }
    });

    // May have to sleep here to keep alive if no user threads left
  }

  private static boolean insideCircle(double x, double y) {
        return (Math.pow(x - 0.5, 2) + Math.pow(y - 0.5, 2))
            <= Math.pow(0.5, 2);
    }
}
```

10.2. STREAMS

You may want to process a subset or all data in the cache to produce a result. This may bring thoughts of Map Reduce. Red Hat Data Grid allows the user to do something very similar but utilizes the standard JRE APIs to do so. Java 8 introduced the concept of a Stream which allows functional-style operations on collections rather than having to procedurally iterate over the data yourself. Stream operations can be implemented in a fashion very similar to MapReduce. Streams, just like MapReduce allow you to perform processing upon the entirety of your cache, possibly a very large data set, but in an efficient way.

NOTE

Streams are the preferred method when dealing with data that exists in the cache because streams automatically adjust to cluster topology changes.

Also since we can control how the entries are iterated upon we can more efficiently perform the operations in a cache that is distributed if you want it to perform all of the operations across the cluster concurrently.

A stream is retrieved from the entrySet, keySet or values collections returned from the Cache by invoking the stream or parallelStream methods.

10.2.1. Common stream operations

This section highlights various options that are present irrespective of what type of underlying cache you are using.

10.2.2. Key filtering

It is possible to filter the stream so that it only operates upon a given subset of keys. This can be done by invoking the filterKeys method on the **CacheStream**. This should always be used over a Predicate filter and will be faster if the predicate was holding all keys.

If you are familiar with the **AdvancedCache** interface you may be wondering why you even use getAll over this keyFilter. There are some small benefits (mostly smaller payloads) to using getAll if you need the entries as is and need them all in memory in the local node. However if you need to do processing on these elements a stream is recommended since you will get both distributed and threaded parallelism for free.

10.2.3. Segment based filtering

NOTE

This is an advanced feature and should only be used with deep knowledge of Red Hat Data Grid segment and hashing techniques. These segments based filtering can be useful if you need to segment data into separate invocations. This can be useful when integrating with other tools such as Apache Spark.

This option is only supported for replicated and distributed caches. This allows the user to operate upon a subset of data at a time as determined by the KeyPartitioner. The segments can be filtered by invoking filterKeySegments method on the **CacheStream**. This is applied after the key filter but before any intermediate operations are performed.

10.2.4. Local/Invalidation

A stream used with a local or invalidation cache can be used just the same way you would use a stream on a regular collection. Red Hat Data Grid handles all of the translations if necessary behind the scenes and works with all of the more interesting options (ie. storeAsBinary, compatibility mode, and a cache loader). Only data local to the node where the stream operation is performed will be used, for example invalidation only uses local entries.

10.2.5. Example

The code below takes a cache and returns a map with all the cache entries whose values contain the string "JBoss"

```
Map<Object, String> jbossValues = cache.entrySet().stream()
              .filter(e -> e.getValue().contains("JBoss"))
              .collect(Collectors.toMap(Map.Entry::getKey, Map.Entry::getValue));
```

10.3. DISTRIBUTION/REPLICATION/SCATTERED

This is where streams come into their stride. When a stream operation is performed it will send the various intermediate and terminal operations to each node that has pertinent data. This allows processing the intermediate values on the nodes owning the data, and only sending the final results back to the originating nodes, improving performance.

10.3.1. Rehash Aware

Internally the data is segmented and each node only performs the operations upon the data it owns as a primary owner. This allows for data to be processed evenly, assuming segments are granular enough to provide for equal amounts of data on each node.

When you are utilizing a distributed cache, the data can be reshuffled between nodes when a new node joins or leaves. Distributed Streams handle this reshuffling of data automatically so you don’t have to worry about monitoring when nodes leave or join the cluster. Reshuffled entries may be processed a second time, and we keep track of the processed entries at the key level or at the segment level (depending on the terminal operation) to limit the amount of duplicate processing.

It is possible but highly discouraged to disable rehash awareness on the stream. This should only be considered if your request can handle only seeing a subset of data if a rehash occurs. This can be done by invoking CacheStream.disableRehashAware() The performance gain for most operations when a rehash doesn’t occur is completely negligible. The only exceptions are for iterator and forEach, which will use less memory, since they do not have to keep track of processed keys.

WARNING

Please rethink disabling rehash awareness unless you really know what you are doing.

10.3.2. Serialization

Since the operations are sent across to other nodes they must be serializable by Red Hat Data Grid marshalling. This allows the operations to be sent to the other nodes.

The simplest way is to use a CacheStream instance and use a lambda just as you would normally. Red Hat Data Grid overrides all of the various Stream intermediate and terminal methods to take Serializable versions of the arguments (ie. SerializableFunction, SerializablePredicate…) You can find these methods at CacheStream. This relies on the spec to pick the most specific method as defined here.

In our previous example we used a **Collector** to collect all the results into a **Map**. Unfortunately the Collectors class doesn't produce Serializable instances. Thus if you need to use these, there are two ways to do so:

One option would be to use the CacheCollectors class which allows for a **Supplier<Collector>** to be provided. This instance could then use the Collectors to supply a **Collector** which is not serialized. You can read more details about how the collector peforms in a distributed fashion at distributed execution.

```
Map<Object, String> jbossValues = cache.entrySet().stream()
          .filter(e -> e.getValue().contains("Jboss"))
          .collect(CacheCollectors.serializableCollector(() -> Collectors.toMap(Map.Entry::getKey,
Map.Entry::getValue)));
```

Alternatively, you can avoid the use of CacheCollectors and instead use the overloaded **collect** methods that take **Supplier<Collector>**. These overloaded **collect** methods are only available via **CacheStream** interface.

```
Map<Object, String> jbossValues = cache.entrySet().stream()
          .filter(e -> e.getValue().contains("Jboss"))
          .collect(() -> Collectors.toMap(Map.Entry::getKey, Map.Entry::getValue));
```

If however you are not able to use the **Cache** and **CacheStream** interfaces you cannot utilize **Serializable** arguments and you must instead cast the lambdas to be **Serializable** manually by casting the lambda to multiple interfaces. It is not a pretty sight but it gets the job done.

```
Map<Object, String> jbossValues = map.entrySet().stream()
          .filter((Serializable & Predicate<Map.Entry<Object, String>>) e ->
e.getValue().contains("Jboss"))
          .collect(CacheCollectors.serializableCollector(() -> Collectors.toMap(Map.Entry::getKey,
Map.Entry::getValue)));
```

The recommended and most performant way is to use an AdvancedExternalizer as this provides the smallest payload. Unfortunately this means you cannot use lamdbas as advanced externalizers require defining the class before hand.

You can use an advanced externalizer as shown below:

```
Map<Object, String> jbossValues = cache.entrySet().stream()
          .filter(new ContainsFilter("Jboss"))
          .collect(() -> Collectors.toMap(Map.Entry::getKey, Map.Entry::getValue));

class ContainsFilter implements Predicate<Map.Entry<Object, String>> {
  private final String target;

  ContainsFilter(String target) {
    this.target = target;
  }

  @Override
  public boolean test(Map.Entry<Object, String> e) {
    return e.getValue().contains(target);
  }
}

class JbossFilterExternalizer implements AdvancedExternalizer<ContainsFilter> {

  @Override
  public Set<Class<? extends ContainsFilter>> getTypeClasses() {
    return Util.asSet(ContainsFilter.class);
  }

  @Override
  public Integer getId() {
    return CUSTOM_ID;
  }

  @Override
  public void writeObject(ObjectOutput output, ContainsFilter object) throws IOException {
    output.writeUTF(object.target);
  }

  @Override
  public ContainsFilter readObject(ObjectInput input) throws IOException,
ClassNotFoundException {
    return new ContainsFilter(input.readUTF());
  }
}
```

You could also use an advanced externalizer for the collector supplier to reduce the payload size even further.

```
Map<Object, String> jbossValues = cache.entrySet().stream()
          .filter(new ContainsFilter("Jboss"))
          .collect(ToMapCollectorSupplier.INSTANCE);

 class ToMapCollectorSupplier<K, U> implements Supplier<Collector<Map.Entry<K, U>, ?, Map<K,
U>>> {
  static final ToMapCollectorSupplier INSTANCE = new ToMapCollectorSupplier();

  private ToMapCollectorSupplier() { }
```

```
      @Override
      public Collector<Map.Entry<K, U>, ?, Map<K, U>> get() {
        return Collectors.toMap(Map.Entry::getKey, Map.Entry::getValue);
      }
    }

    class ToMapCollectorSupplierExternalizer implements
AdvancedExternalizer<ToMapCollectorSupplier> {

      @Override
      public Set<Class<? extends ToMapCollectorSupplier>> getTypeClasses() {
        return Util.asSet(ToMapCollectorSupplier.class);
      }

      @Override
      public Integer getId() {
        return CUSTOM_ID;
      }

      @Override
      public void writeObject(ObjectOutput output, ToMapCollectorSupplier object) throws IOException
{
      }

      @Override
      public ToMapCollectorSupplier readObject(ObjectInput input) throws IOException,
ClassNotFoundException {
        return ToMapCollectorSupplier.INSTANCE;
      }
    }
```

10.3.3. Parallel Computation

Distributed streams by default try to parallelize as much as possible. It is possible for the end user to control this and actually they always have to control one of the options. There are 2 ways these streams are parallelized.

Local to each node When a stream is created from the cache collection the end user can choose between invoking stream or parallelStream method. Depending on if the parallel stream was picked will enable multiple threading for each node locally. Note that some operations like a rehash aware iterator and forEach operations will always use a sequential stream locally. This could be enhanced at some point to allow for parallel streams locally.

Users should be careful when using local parallelism as it requires having a large number of entries or operations that are computationally expensive to be faster. Also it should be noted that if a user uses a parallel stream with **forEach** that the action should not block as this would be executed on the common pool, which is normally reserved for computation operations.

Remote requests When there are multiple nodes it may be desirable to control whether the remote requests are all processed at the same time concurrently or one at a time. By default all terminal operations except the iterator perform concurrent requests. The iterator, method to reduce overall memory pressure on the local node, only performs sequential requests which actually performs slightly better.

If a user wishes to change this default however they can do so by invoking the sequentialDistribution or parallelDistribution methods on the **CacheStream**.

10.3.4. Task timeout

It is possible to set a timeout value for the operation requests. This timeout is used only for remote requests timing out and it is on a per request basis. The former means the local execution will not timeout and the latter means if you have a failover scenario as described above the subsequent requests each have a new timeout. If no timeout is specified it uses the replication timeout as a default timeout. You can set the timeout in your task by doing the following:

```
CacheStream<Object, String> stream = cache.entrySet().stream();
stream.timeout(1, TimeUnit.MINUTES);
```

For more information about this, please check the java doc in timeout javadoc.

10.3.5. Injection

The Stream has a terminal operation called forEach which allows for running some sort of side effect operation on the data. In this case it may be desirable to get a reference to the **Cache** that is backing this Stream. If your **Consumer** implements the CacheAware interface the **injectCache** method be invoked before the accept method from the **Consumer** interface.

10.3.6. Distributed Stream execution

Distributed streams execution works in a fashion very similiar to map reduce. Except in this case we are sending zero to many intermediate operations (map, filter etc.) and a single terminal operation to the various nodes. The operation basically comes down to the following:

1. The desired segments are grouped by which node is the primary owner of the given segment
2. A request is generated to send to each remote node that contains the intermediate and terminal operations including which segments it should process
    a. The terminal operation will be performed locally if necessary
    b. Each remote node will receive this request and run the operations and subsequently send the response back
3. The local node will then gather the local response and remote responses together performing any kind of reduction required by the operations themselves.
4. Final reduced response is then returned to the user

In most cases all operations are fully distributed, as in the operations are all fully applied on each remote node and usually only the last operation or something related may be reapplied to reduce the results from multiple nodes. One important note is that intermediate values do not actually have to be serializable, it is the last value sent back that is the part desired (exceptions for various operations will be highlighted below).

Terminal operator distributed result reductions The following paragraphs describe how the distributed reductions work for the various terminal operators. Some of these are special in that an intermediate value may be required to be serializable instead of the final result.

allMatch noneMatch anyMatch

The allMatch operation is ran on each node and then all the results are logically anded together locally to get the appropriate value. The noneMatch and anyMatch operations use a logical or instead. These methods also have early termination support, stopping remote and local operations once the final result is known.

collect

The collect method is interesting in that it can do a few extra steps. The remote node performs everything as normal except it doesn't perform the final finisher upon the result and instead sends back the fully combined results. The local thread then combines the remote and local result into a value which is then finally finished. The key here to remember is that the final value doesn't have to be serializable but rather the values produced from the supplier and combiner methods.

count

The count method just adds the numbers together from each node.

findAny findFirst

The findAny operation returns just the first value they find, whether it was from a remote node or locally. Note this supports early termination in that once a value is found it will not process others. Note the findFirst method is special since it requires a sorted intermediate operation, which is detailed in the exceptions section.

max min

The max and min methods find the respective min or max value on each node then a final reduction is performed locally to ensure only the min or max across all nodes is returned.

reduce

The various reduce methods 1 , 2 , 3 will end up serializing the result as much as the accumulator can do. Then it will accumulate the local and remote results together locally, before combining if you have provided that. Note this means a value coming from the combiner doesn't have to be Serializable.

10.3.7. Key based rehash aware operators

The iterator, spliterator and forEach are unlike the other terminal operators in that the rehash awareness has to keep track of what keys per segment have been processed instead of just segments. This is to guarantee an exactly once (iterator & spliterator) or at least once behavior (forEach) even under cluster membership changes.

The **iterator** and **spliterator** operators when invoked on a remote node will return back batches of entries, where the next batch is only sent back after the last has been fully consumed. This batching is done to limit how many entries are in memory at a given time. The user node will hold onto which keys it has processed and when a given segment is completed it will release those keys from memory. This is why sequential processing is preferred for the iterator method, so only a subset of segment keys are held in memory at once, instead of from all nodes.

The **forEach()** method also returns batches, but it returns a batch of keys after it has finished processing at least a batch worth of keys. This way the originating node can know what keys have been processed already to reduce chances of processing the same entry again. Unfortunately this means it is possible to have an at least once behavior when a node goes down unexpectedly. In this case that node could have been processing a batch and not yet completed one and those entries that were processed but not in a completed batch will be ran again when the rehash failure operation occurs. Note that adding a node will not cause this issue as the rehash failover doesn't occur until all responses are received.

These operations batch sizes are both controlled by the same value which can be configured by invoking distributedBatchSize method on the **CacheStream**. This value will default to the **chunkSize** configured in state transfer. Unfortunately this value is a tradeoff with memory usage vs performance vs at least once and your mileage may vary.

Using **iterator** with replicated and distributed caches

When a node is the primary or backup owner of all requested segments for a distributed stream, Red Hat Data Grid performs the **iterator** or **spliterator** terminal operations locally, which optimizes performance as remote iterations are more resource intensive.

This optimization applies to both replicated and distributed caches. However, Red Hat Data Grid performs iterations remotely when using cache stores that are both **shared** and have **write-behind** enabled. In this case performing the iterations remotely ensures consistency.

10.3.8. Intermediate operation exceptions

There are some intermediate operations that have special exceptions, these are skip, peek, sorted 12. & distinct. All of these methods have some sort of artificial iterator implanted in the stream processing to guarantee correctness, they are documented as below. Note this means these operations may cause possibly severe performance degradation.

Skip

An artificial iterator is implanted up to the intermediate skip operation. Then results are brought locally so it can skip the appropriate amount of elements.

Sorted

WARNING: This operation requires having all entries in memory on the local node. An artificial iterator is implanted up to the intermediate sorted operation. All results are sorted locally. There are possible plans to have a distributed sort which returns batches of elements, but this is not yet implemented.

Distinct

WARNING: This operation requires having all or nearly all entries in memory on the local node. Distinct is performed on each remote node and then an artificial iterator returns those distinct values. Then finally all of those results have a distinct operation performed upon them.

The rest of the intermediate operations are fully distributed as one would expect.

10.3.9. Examples

Word Count

Word count is a classic, if overused, example of map/reduce paradigm. Assume we have a mapping of key → sentence stored on Red Hat Data Grid nodes. Key is a String, each sentence is also a String, and we have to count occurrence of all words in all sentences available. The implementation of such a distributed task could be defined as follows:

```
public class WordCountExample {

   /**
    * In this example replace c1 and c2 with
    * real Cache references
    *
    * @param args
    */
   public static void main(String[] args) {
      Cache<String, String> c1 = ...;
      Cache<String, String> c2 = ...;

      c1.put("1", "Hello world here I am");
      c2.put("2", "Infinispan rules the world");
```

```
        c1.put("3", "JUDCon is in Boston");
        c2.put("4", "JBoss World is in Boston as well");
        c1.put("12","JBoss Application Server");
        c2.put("15", "Hello world");
        c1.put("14", "Infinispan community");
        c2.put("15", "Hello world");

        c1.put("111", "Infinispan open source");
        c2.put("112", "Boston is close to Toronto");
        c1.put("113", "Toronto is a capital of Ontario");
        c2.put("114", "JUDCon is cool");
        c1.put("211", "JBoss World is awesome");
        c2.put("212", "JBoss rules");
        c1.put("213", "JBoss division of RedHat ");
        c2.put("214", "RedHat community");

        Map<String, Long> wordCountMap = c1.entrySet().parallelStream()
          .map(e -> e.getValue().split("\\s"))
          .flatMap(Arrays::stream)
          .collect(() -> Collectors.groupingBy(Function.identity(), Collectors.counting()));
    }
}
```

In this case it is pretty simple to do the word count from the previous example.

However what if we want to find the most frequent word in the example? If you take a second to think about this case you will realize you need to have all words counted and available locally first. Thus we actually have a few options.

We could use a finisher on the collector, which is invoked on the user thread after all the results have been collected. Some redundant lines have been removed from the previous example.

```
public class WordCountExample {
   public static void main(String[] args) {
      // Lines removed

      String mostFrequentWord = c1.entrySet().parallelStream()
         .map(e -> e.getValue().split("\\s"))
         .flatMap(Arrays::stream)
         .collect(() -> Collectors.collectingAndThen(
            Collectors.groupingBy(Function.identity(), Collectors.counting()),
               wordCountMap -> {
                  String mostFrequent = null;
                  long maxCount = 0;
                     for (Map.Entry<String, Long> e : wordCountMap.entrySet()) {
                        int count = e.getValue().intValue();
                        if (count > maxCount) {
                           maxCount = count;
                           mostFrequent = e.getKey();
                        }
                     }
                     return mostFrequent;
               }));

}
```

Unfortunately the last step is only going to be ran in a single thread, which if we have a lot of words could be quite slow. Maybe there is another way to parallelize this with Streams.

We mentioned before we are in the local node after processing, so we could actually use a stream on the map results. We can therefore use a parallel stream on the results.

```
public class WordFrequencyExample {
  public static void main(String[] args) {
    // Lines removed

    Map<String, Long> wordCount = c1.entrySet().parallelStream()
          .map(e -> e.getValue().split("\\s"))
          .flatMap(Arrays::stream)
          .collect(() -> Collectors.groupingBy(Function.identity(), Collectors.counting()));
    Optional<Map.Entry<String, Long>> mostFrequent =
wordCount.entrySet().parallelStream().reduce(
          (e1, e2) -> e1.getValue() > e2.getValue() ? e1 : e2);
```

This way you can still utilize all of the cores locally when calculating the most frequent element.

Remove specific entries

Distributed streams can also be used as a way to modify data where it lives. For example you may want to remove all entries in your cache that contain a specific word.

```
public class RemoveBadWords {
  public static void main(String[] args) {
    // Lines removed
    String word = ..

    c1.entrySet().parallelStream()
      .filter(e -> e.getValue().contains(word))
      .forEach((c, e) -> c.remove(e.getKey());
```

If we carefully note what is serialized and what is not, we notice that only the word along with the operations are serialized across to other nods as it is captured by the lambda. However the real saving piece is that the cache operation is performed on the primary owner thus reducing the amount of network traffic required to remove these values from the cache. The cache is not captured by the lambda as we provide a special BiConsumer method override that when invoked on each node passes the cache to the BiConsumer

One thing to keep in mind using the **forEach** command in this manner is that the underlying stream obtains no locks. The cache remove operation will still obtain locks naturally, but the value could have changed from what the stream saw. That means that the entry could have been changed after the stream read it but the remove actually removed it.

We have specifically added a new variant which is called **LockedStream**.

Plenty of other examples

The **Streams** API is a JRE tool and there are lots of examples for using it. Just remember that your operations need to be Serializable in some way.

10.4. DISTRIBUTED EXECUTION

NOTE

Distributed Executor has been deprecated as of Red Hat Data Grid 9.1. You should use either a Cluster Executor or Distributed Stream to perform the operations they were doing before.

Red Hat Data Grid provides distributed execution through a standard JDK ExecutorService interface. Tasks submitted for execution, instead of being executed in a local JVM, are executed on an entire cluster of Red Hat Data Grid nodes. Every DistributedExecutorService is bound to one particular cache. Tasks submitted will have access to key/value pairs from that particular cache if and only if the task submitted is an instance of DistributedCallable. Also note that there is nothing preventing users from submitting a familiar Runnable or Callable just like to any other ExecutorService. However, DistributedExecutorService, as it name implies, will likely migrate submitted Callable or Runnable to another JVM in Red Hat Data Grid cluster, execute it and return a result to task invoker. Due to a potential task migration to other nodes every Callable, Runnable and/or DistributedCallable submitted must be either Serializable or Externalizable. Also the value returned from a callable must be Serializable or Externalizable as well. If the value returned is not serializable a NotSerializableException will be thrown.

Red Hat Data Grid's distributed task executors use data from Red Hat Data Grid cache nodes as input for execution tasks. Most other distributed frameworks do not have that leverage and users have to specify input for distributed tasks from some well known location. Furthermore, users of Red Hat Data Grid distributed execution framework do not have to configure store for intermediate and final results thus removing another layer of complexity and maintenance.

Our distributed execution framework capitalizes on the fact input data in Red Hat Data Grid data grid is already load balanced (in case of DIST mode). Since input data is already balanced execution tasks will be automatically balanced as well; users do not have to explicitly assign work tasks to specific Red Hat Data Grid nodes. However, our framework accommodates users to specify arbitrary subset of cache keys as input for distributed execution tasks.

10.4.1. DistributedCallable API

In case users needs access to Red Hat Data Grid cache data for an execution of a task we recommend that you encapsulate task in DistributedCallable interface. DistributedCallable is a subtype of the existing Callable from java.util.concurrent package; DistributedCallable can be executed in a remote JVM and receive input from Red Hat Data Grid cache. Task's main algorithm could essentially remain unchanged, only the input source is changed. Existing Callable implementations most likely get their input in a form of some Java object/primitive while DistributedCallable gets its input from an Red Hat Data Grid cache. Therefore, users who have already implemented Callable interface to describe their task units would simply extend DistributedCallable and use keys from Red Hat Data Grid execution environment as input for the task. Implentation of DistributedCallable can in fact continue to support implementation of an already existing Callable while simultaneously be ready for distribited execution by extending DistributedCallable.

```
public interface DistributedCallable<K, V, T> extends Callable<T> {

   /**
    * Invoked by execution environment after DistributedCallable
    * has been migrated for execution to a specific node.
    *
    * @param cache
    *           cache whose keys are used as input data for this
    *           DistributedCallable task
    * @param inputKeys
    *          keys used as input for this DistributedCallable task
    */
   public void setEnvironment(Cache<K, V> cache, Set<K> inputKeys);

}
```

10.4.2. Callable and CDI

Users that do not want or can not implement DistributedCallable yet need a reference to input cache used in DistributedExecutorService have an option of the input cache being injected by CDI mechanism. Upon arrival of user's Callable to an Red Hat Data Grid executing node, Red Hat Data Grid CDI mechanism will provide appropriate cache reference and inject it to executing Callable. All one has to do is to declare a Cache field in Callable and annotate it with org.infinispan.cdi.Input annotation along with mandatory @Inject annotation.

```
public class CallableWithInjectedCache implements Callable<Integer>, Serializable {

   @Inject
   @Input
   private Cache<String, String> cache;


   @Override
   public Integer call() throws Exception {
     //use injected cache reference
     return 1;
   }
}
```

10.4.3. DistributedExecutorService, DistributedTaskBuilder and DistributedTask API

DistributedExecutorService is a simple extension of a familiar ExecutorService from java.util.concurrent package. However, advantages of DistributedExecutorService are not to be overlooked. Existing Callable tasks, instead of being executed in JDK's ExecutorService, are also eligible for execution on Red Hat Data Grid cluster. Red Hat Data Grid execution environment would migrate a task to execution node(s), run the task and return the result(s) to the calling node. Of course, not all Callable tasks would benefit from parallel distributed execution. Excellent candidates are long running and computationally intensive tasks that can run concurrently and/or tasks using input data that can be processed concurrently. For more details about good candidates for parallel execution and parallel algorithms in general refer to Introduction to Parallel Computing .

The second advantage of the DistributedExecutorService is that it allows a quick and simple implementation of tasks that take input from Red Hat Data Grid cache nodes, execute certain computation and return results to the caller. Users would specify which keys to use as input for specified DistributedCallable and submit that callable for execution on Red Hat Data Grid cluster. Red Hat Data Grid runtime would locate the appriate keys, migrate DistributedCallable to target execution node(s) and finally return a list of results for each executed Callable. Of course, users can omit specifying input keys in which case Red Hat Data Grid would execute DistributedCallable on all keys for a specified cache.

Lets see how we can use DistributedExecutorService If you already have Callable/Runnable tasks defined! Well, simply submit them to an instance of DefaultExecutorService for execution!

```
ExecutorService des = new DefaultExecutorService(cache);
Future<Boolean> future = des.submit(new SomeCallable());
Boolean r = future.get();
```

In case you need to specify more task parameters like task timeout, custom failover policy or execution policy use DistributedTaskBuilder and DistributedTask API.

```
DistributedExecutorService des = new DefaultExecutorService(cache);
DistributedTaskBuilder<Boolean> taskBuilder = des.createDistributedTaskBuilder(new
SomeCallable());
taskBuilder.timeout(10,TimeUnit.SECONDS);
...
...
DistributedTask<Boolean> distributedTask = taskBuilder.build();
Future<Boolean> future = des.submit(distributedTask);
Boolean r = future.get();
```

10.4.4. Distributed task failover

Distributed execution framework supports task failover. By default no failover policy is installed and task's Runnable/Callable/DistributedCallable will simply fail. Failover mechanism is invoked in the following cases:

a) Failover due to a node failure where task is executing

b) Failover due to a task failure (e.g. Callable task throws Exception).

Red Hat Data Grid provides random node failover policy which will attempt execution of a part of distributed task on another random node, if such node is available. However, users that have a need to implement a more sophisticated failover policy can implement DistributedTaskFailoverPolicy interface. For example, users might want to use consistent hashing (CH) mechanism for failover of uncompleted tasks. CH based failover might for example migrate failed task T to cluster node(s) having a backup of input data that was executed on a failed node F.

```
/**
 * DistributedTaskFailoverPolicy allows pluggable fail over target selection for a failed remotely
 * executed distributed task.
 *
 */
public interface DistributedTaskFailoverPolicy {

  /**
   * As parts of distributively executed task can fail due to the task itself throwing an exception
   * or it can be a system caused failure (e.g node failed or left cluster during task
   * execution etc).
   *
   * @param failoverContext
   *          the FailoverContext of the failed execution
   * @return result the Address of the node selected for fail over execution
   */
  Address failover(FailoverContext context);

  /**
   * Maximum number of fail over attempts permitted by this DistributedTaskFailoverPolicy
   *
```

```
     * @return max number of fail over attempts
     */
    int maxFailoverAttempts();
}
```

Therefore one could for example specify random failover execution policy simply by:

```
DistributedExecutorService des = new DefaultExecutorService(cache);
DistributedTaskBuilder<Boolean> taskBuilder = des.createDistributedTaskBuilder(new
SomeCallable());
taskBuilder.failoverPolicy(DefaultExecutorService.RANDOM_NODE_FAILOVER);
DistributedTask<Boolean> distributedTask = taskBuilder.build();
Future<Boolean> future = des.submit(distributedTask);
Boolean r = future.get();
```

10.4.5. Distributed task execution policy

DistributedTaskExecutionPolicy is an enum that allows tasks to specify its custom task execution policy across Red Hat Data Grid cluster. DistributedTaskExecutionPolicy effectively scopes execution of tasks to a subset of nodes. For example, someone might want to exclusively execute tasks on a local network site instead of a backup remote network centre as well. Others might, for example, use only a dedicated subset of a certain Red Hat Data Grid rack nodes for specific task execution. DistributedTaskExecutionPolicy is set per instance of DistributedTask.

```
DistributedExecutorService des = new DefaultExecutorService(cache);
DistributedTaskBuilder<Boolean> taskBuilder = des.createDistributedTaskBuilder(new
SomeCallable());
taskBuilder.executionPolicy(DistributedTaskExecutionPolicy.SAME_RACK);
DistributedTask<Boolean> distributedTask = taskBuilder.build();
Future<Boolean> future = des.submit(distributedTask);
Boolean r = future.get();
```

10.4.6. Examples

Pi approximation can greatly benefit from parallel distributed execution in DistributedExecutorService. Recall that area of the square is Sa = 4r2 and area of the circle is Ca=pi*r2. Substituting r2 from the second equation into the first one it turns out that pi = 4 * Ca/Sa. Now, image that we can shoot very large number of darts into a square; if we take ratio of darts that land inside a circle over a total number of darts shot we will approximate Ca/Sa value. Since we know that pi = 4 * Ca/Sa we can easily derive approximate value of pi. The more darts we shoot the better approximation we get. In the example below we shoot 10 million darts but instead of "shooting" them serially we parallelize work of dart shooting across entire Red Hat Data Grid cluster.

```
 public class PiAppx {

  public static void main (String [] arg){
    List<Cache> caches = ...;
    Cache cache = ...;

    int numPoints = 10000000;
    int numServers = caches.size();
    int numberPerWorker = numPoints / numServers;

    DistributedExecutorService des = new DefaultExecutorService(cache);
```

```
        long start = System.currentTimeMillis();
        CircleTest ct = new CircleTest(numberPerWorker);
        List<Future<Integer>> results = des.submitEverywhere(ct);
        int countCircle = 0;
        for (Future<Integer> f : results) {
           countCircle += f.get();
        }
        double appxPi = 4.0 * countCircle / numPoints;

        System.out.println("Distributed PI appx is " + appxPi +
        " completed in " + (System.currentTimeMillis() - start) + " ms");
     }

     private static class CircleTest implements Callable<Integer>, Serializable {

        /** The serialVersionUID */
        private static final long serialVersionUID = 3496135215525904755L;

        private final int loopCount;

        public CircleTest(int loopCount) {
           this.loopCount = loopCount;
        }

        @Override
        public Integer call() throws Exception {
           int insideCircleCount = 0;
           for (int i = 0; i < loopCount; i++) {
              double x = Math.random();
              double y = Math.random();
              if (insideCircle(x, y))
                 insideCircleCount++;
           }
           return insideCircleCount;
        }

        private boolean insideCircle(double x, double y) {
           return (Math.pow(x - 0.5, 2) + Math.pow(y - 0.5, 2))
           <= Math.pow(0.5, 2);
        }
     }
  }
```

CHAPTER 11. INDEXING AND QUERYING

11.1. OVERVIEW

Red Hat Data Grid supports indexing and searching of Java Pojo(s) or objects encoded via Protocol Buffers stored in the grid using powerful search APIs which complement its main Map-like API.

Querying is possible both in library and client/server mode (for Java, C#, Node.js and other clients), and Red Hat Data Grid can index data using Apache Lucene, offering an efficient full-text capable search engine in order to cover a wide range of data retrieval use cases.

Indexing configuration relies on a schema definition, and for that Red Hat Data Grid can use annotated Java classes when in library mode, and protobuf schemas for remote clients written in other languages. By standardizing on protobuf, Red Hat Data Grid allows full interoperability between Java and non-Java clients.

Apart from indexed queries, Red Hat Data Grid can run queries over non-indexed data (indexless queries) and over partially indexed data (hybrid queries).

In terms of Search APIs, Red Hat Data Grid has its own query language called *Ickle*, which is string-based and adds support for full-text querying. The Query DSL can be used for both embedded and remote java clients when full-text is not required; for Java embedded clients Red Hat Data Grid offers the Hibernate Search Query API which supports running Lucene queries in the grid, apart from advanced search capabilities like Faceted and Spatial search.

Finally, Red Hat Data Grid has support for Continuous Queries, which works in a reverse manner to the other APIs: instead of creating, executing a query and obtain results, it allows a client to register queries that will be evaluated continuously as data in the cluster changes, generating notifications whenever the changed data matches the queries.

11.2. EMBEDDED QUERYING

Embedded querying is available when Red Hat Data Grid is used as a library. No protobuf mapping is required, and both indexing and searching are done on top of Java objects. When in library mode, it is possible to run Lucene queries directly and use all the available Query APIs and it also allows flexible indexing configurations to keep latency to a minimal.

11.2.1. Quick example

We’re going to store *Book* instances in an Red Hat Data Grid cache called "books". *Book* instances will be indexed, so we enable indexing for the cache, letting Red Hat Data Grid configure the indexing automatically:

Red Hat Data Grid configuration:

infinispan.xml

```
<infinispan>
   <cache-container>
      <transport cluster="infinispan-cluster"/>
      <distributed-cache name="books">
         <indexing index="LOCAL" auto-config="true"/>
```

```
        </distributed-cache>
    </cache-container>
</infinispan>
```

Obtaining the cache:

```
import org.infinispan.Cache;
import org.infinispan.manager.DefaultCacheManager;
import org.infinispan.manager.EmbeddedCacheManager;

EmbeddedCacheManager manager = new DefaultCacheManager("infinispan.xml");
Cache<String, Book> cache = manager.getCache("books");
```

Each *Book* will be defined as in the following example; we have to choose which properties are indexed, and for each property we can optionally choose advanced indexing options using the annotations defined in the Hibernate Search project.

Book.java

```
import org.hibernate.search.annotations.*;
import java.util.Date;
import java.util.HashSet;
import java.util.Set;

//Values you want to index need to be annotated with @Indexed, then you pick which fields and how they are to be indexed:
@Indexed
public class Book {
  @Field String title;
  @Field String description;
  @Field @DateBridge(resolution=Resolution.YEAR) Date publicationYear;
  @IndexedEmbedded Set<Author> authors = new HashSet<Author>();
}
```

Author.java

```
public class Author {
  @Field String name;
  @Field String surname;
  // hashCode() and equals() omitted
}
```

Now assuming we stored several *Book* instances in our Red Hat Data Grid *Cache* , we can search them for any matching field as in the following example.

Using a Lucene Query:

```
// get the search manager from the cache:
SearchManager searchManager = org.infinispan.query.Search.getSearchManager(cache);

// create any standard Lucene query, via Lucene's QueryParser or any other means:
org.apache.lucene.search.Query fullTextQuery = //any Apache Lucene Query

// convert the Lucene query to a CacheQuery:
```

```
CacheQuery cacheQuery = searchManager.getQuery( fullTextQuery );

// get the results:
List<Object> found = cacheQuery.list();
```

A Lucene Query is often created by parsing a query in text format such as "title:infinispan AND authors.name:sanne", or by using the query builder provided by Hibernate Search.

```
// get the search manager from the cache:
SearchManager searchManager = org.infinispan.query.Search.getSearchManager( cache );

// you could make the queries via Lucene APIs, or use some helpers:
QueryBuilder queryBuilder = searchManager.buildQueryBuilderForClass(Book.class).get();

// the queryBuilder has a nice fluent API which guides you through all options.
// this has some knowledge about your object, for example which Analyzers
// need to be applied, but the output is a fairly standard Lucene Query.
org.apache.lucene.search.Query luceneQuery = queryBuilder.phrase()
                .onField("description")
                .andField("title")
                .sentence("a book on highly scalable query engines")
                .createQuery();

// the query API itself accepts any Lucene Query, and on top of that
// you can restrict the result to selected class types:
CacheQuery query = searchManager.getQuery(luceneQuery, Book.class);

// and there are your results!
List objectList = query.list();

for (Object book : objectList) {
    System.out.println(book);
}
```

Apart from *list()* you have the option for streaming results, or use pagination.

For searches that do not require Lucene or full-text capabilities and are mostly about aggregation and exact matches, we can use the Red Hat Data Grid Query DSL API:

```
import org.infinispan.query.dsl.QueryFactory;
import org.infinispan.query.dsl.Query;
import org.infinispan.query.Search;

// get the query factory:
QueryFactory queryFactory = Search.getQueryFactory(cache);

Query q = queryFactory.from(Book.class)
        .having("author.surname").eq("King")
        .build();

List<Book> list = q.list();
```

Finally, we can use an Ickle query directly, allowing for Lucene syntax in one or more predicates:

```
import org.infinispan.query.dsl.QueryFactory;
import org.infinispan.query.dsl.Query;

// get the query factory:
QueryFactory queryFactory = Search.getQueryFactory(cache);


Query q = queryFactory.create("from Book b where b.author.name = 'Stephen' and " +
           "b.description : (+'dark' -'tower')");

List<Book> list = q.list();
```

11.2.2. Indexing

Indexing in Red Hat Data Grid happens on a per-cache basis and by default a cache is not indexed. Enabling indexing is not mandatory but queries using an index will have a vastly superior performance. On the other hand, enabling indexing can impact negatively the write throughput of a cluster, so make sure to check the query performance guide for some strategies to minimize this impact depending on the cache type and use case.

11.2.2.1. Configuration

11.2.2.1.1. General format

To enable indexing via XML, you need to add the **<indexing>** element plus the **index** (index mode) to your cache configuration, and optionally pass additional properties.

```
<infinispan>
  <cache-container default-cache="default">
    <replicated-cache name="default">
      <indexing index="ALL">
        <property name="property.name">some value</property>
      </indexing>
    </replicated-cache>
  </cache-container>
</infinispan>
```

Programmatic:

```
import org.infinispan.configuration.cache.*;

ConfigurationBuilder cacheCfg = ...
cacheCfg.indexing().index(Index.ALL)
    .addProperty("property name", "propery value")
```

11.2.2.1.2. Index names

Each property inside the **index** element is prefixed with the index name, for the index named **org.infinispan.sample.Car** the **directory_provider** is **local-heap**:

```
  ...
  <indexing index="ALL">
    <property name="org.infinispan.sample.Car.directory_provider">local-heap</property>
    </indexing>
    ...
</infinispan>
```

```
cacheCfg.indexing()
  .index(Index.ALL)
    .addProperty("org.infinispan.sample.Car.directory_provider", "local-heap")
```

Red Hat Data Grid creates an index for each entity existent in a cache, and it allows to configure those indexes independently. For a class annotated with **@Indexed**, the index name is the fully qualified class name, unless overridden with the **name** argument in the annotation.

In the snippet below, the default storage for all entities is **infinispan**, but **Boat** instances will be stored on **local-heap** in an index named **boatIndex**. **Airplane** entities will also be stored in **local-heap**. Any other entity's index will be configured with the property prefixed by **default**.

```
package org.infinispan.sample;

@Indexed(name = "boatIndex")
public class Boat {

}

@Indexed
public class Airplane {

}
```

```
    ...
    <indexing index="ALL">
        <property name="default.directory_provider">infinispan</property>
        <property name="boatIndex.directory_provider">local-heap</property>
        <property name="org.infinispan.sample.Airplane.directory_provider">
            ram
        </property>
    </indexing>
    ...
</infinispan>
```

11.2.2.1.3. Specifying indexed Entities

Red Hat Data Grid can automatically recognize and manage indexes for different entity types in a cache. Future versions of Red Hat Data Grid will remove this capability so it's recommended to declare upfront which types are going to be indexed (list them by their fully qualified class name). This can be done via xml:

```
<infinispan>
  <cache-container default-cache="default">
    <replicated-cache name="default">
      <indexing index="ALL">
        <indexed-entities>
          <indexed-entity>com.acme.query.test.Car</indexed-entity>
          <indexed-entity>com.acme.query.test.Truck</indexed-entity>
        </indexed-entities>
```

```
            </indexing>
        </replicated-cache>
    </cache-container>
</infinispan>
```

or programmatically:

```
cacheCfg.indexing()
      .index(Index.ALL)
        .addIndexedEntity(Car.class)
        .addIndexedEntity(Truck.class)
```

In server mode, the class names listed under the 'indexed-entities' element must use the 'extended' class name format which is composed of a JBoss Modules module identifier, a slot name, and the fully qualified class name, these three components being separated by the ':' character, (eg. "com.acme.my-module-with-entity-classes:my-slot:com.acme.query.test.Car"). The entity classes must be located in the referenced module, which can be either a user supplied module deployed in the 'modules' folder of your server or a plain jar deployed in the 'deployments' folder. The module in question will become an automatic dependency of your Cache, so its eventual redeployment will cause the cache to be restarted.

NOTE

Only for server, if you fail to follow the requirement of using 'extended' class names and use a plain class name its resolution will fail due to missing class because the wrong ClassLoader is being used (the Red Hat Data Grid's internal class path is being used).

11.2.2.2. Index mode

An Red Hat Data Grid node typically receives data from two sources: local and remote. Local translates to clients manipulating data using the map API in the same JVM; remote data comes from other Red Hat Data Grid nodes during replication or rebalancing.

The index mode configuration defines, from a node in the cluster point of view, which data gets indexed.

Possible values:

- ALL: all data is indexed, local and remote.
- LOCAL: only local data is indexed.
- PRIMARY_OWNER: Only entries containing keys that the node is primary owner will be indexed, regardless of local or remote origin.
- NONE: no data is indexed. Equivalent to not configure indexing at all.

11.2.2.3. Index Managers

Index managers are central components in Red Hat Data Grid Querying responsible for the indexing configuration, distribution and internal lifecycle of several query components such as Lucene's *IndexReader* and *IndexWriter*. Each Index Manager is associated with a *Directory Provider*, which defines the physical storage of the index.

Regarding index distribution, Red Hat Data Grid can be configured with shared or non-shared indexes.

11.2.2.4. Shared indexes

A shared index is a single, distributed, cluster-wide index for a certain cache. The main advantage is that the index is visible from every node and can be queried as if the index were local, there is no need to broadcast queries to all members and aggregate the results. The downside is that Lucene does not allow more than a single process writing to the index at the same time, and the coordination of lock acquisitions needs to be done by a proper shared index capable index manager. In any case, having a single write lock cluster-wise can lead to some degree of contention under heavy writing.

Red Hat Data Grid supports shared indexes leveraging the Red Hat Data Grid Directory Provider, which stores indexes in a separate set of caches. Two index managers are available to use shared indexes: InfinispanIndexManager and AffinityIndexManager.

11.2.2.4.1. Effect of the index mode

Shared indexes should not use the **ALL** index mode since it'd lead to redundant indexing: since there is a single index cluster wide, the entry would get indexed when inserted via Cache API, and another time when Red Hat Data Grid replicates it to another node. The **ALL** mode is usually associates with non-shared indexes in order to create full index replicas on each node.

11.2.2.4.2. InfinispanIndexManager

This index manager uses the Red Hat Data Grid Directory Provider, and is suitable for creating shared indexes. Index mode should be set to **LOCAL** in this configuration.

Configuration:

```
<distributed-cache name="default" >
   <indexing index="LOCAL">
      <property name="default.indexmanager">
         org.infinispan.query.indexmanager.InfinispanIndexManager
      </property>
      <!-- optional: tailor each index cache -->
      <property name="default.locking_cachename">LuceneIndexesLocking_custom</property>
      <property name="default.data_cachename">LuceneIndexesData_custom</property>
      <property name="default.metadata_cachename">LuceneIndexesMetadata_custom</property>
   </indexing>
</distributed-cache>

<!-- Optional -->
<replicated-cache name="LuceneIndexesLocking_custom">
   <indexing index="NONE" />
   <-- extra configuration -->
</replicated-cache>

<!-- Optional -->
<replicated-cache name="LuceneIndexesMetadata_custom">
   <indexing index="NONE" />
   <-- extra configuration -->
</replicated-cache>

<!-- Optional -->
<distributed-cache name="LuceneIndexesData_custom">
   <-- extra configuration -->
   <indexing index="NONE" />
</distributed-cache>
```

Indexes are stored in a set of clustered caches, called by default *LuceneIndexesData*, *LuceneIndexesMetadata* and *LuceneIndexesLocking*.

The *LuceneIndexesLocking* cache is used to store Lucene locks, and it is a very small cache: it will contain one entry per entity (index).

The *LuceneIndexesMetadata* cache is used to store info about the logical files that are part of the index, such as names, chunks and sizes and it is also small in size.

The *LuceneIndexesData* cache is where most of the index is located: it is much bigger then the other two but should be smaller than the data in the cache itself, thanks to Lucene's efficient storing techniques.

It's not necessary to redefine the configuration of those 3 cases, Red Hat Data Grid will pick sensible defaults. Reasons re-define them would be performance tuning for a specific scenario, or for example to make them persistent by configuring a cache store.

In order to avoid index corruption when two or more nodes of the cluster try to write to the index at the same time, the *InfinispanIndexManager* internally elects a master in the cluster (which is the JGroups coordinator) and forwards all indexing works to this master.

11.2.2.4.3. AffinityIndexManager

The AffinityIndexManager is an **experimental** index manager used for shared indexes that also stores indexes using the Red Hat Data Grid Directory Provider. Unlike the InfinispanIndexManager, it does not have a single node (master) that handles all the indexing cluster wide, but rather splits the index using multiple shards, each shard being responsible for indexing data associated with one or more Red Hat Data Grid segments. For an in-depth description of the inner workings, please see the design doc.

The PRIMARY_OWNER index mode is required, together with a special kind of **KeyPartitioner**.

XML Configuration:

```
<distributed-cache name="default"
                   key-partitioner="org.infinispan.distribution.ch.impl.AffinityPartitioner">
    <indexing index="PRIMARY_OWNER">
        <property name="default.indexmanager">
            org.infinispan.query.affinity.AffinityIndexManager
        </property>
        <!-- optional: control the number of shards, the default is 4 -->
        <property name="default.sharding_strategy.nbr_of_shards">10</property>
    </indexing>
</distributed-cache>
```

Programmatic:

```
import org.infinispan.distribution.ch.impl.AffinityPartitioner;
import org.infinispan.query.affinity.AffinityIndexManager;

ConfigurationBuilder cacheCfg = ...
cacheCfg.clustering().hash().keyPartitioner(new AffinityPartitioner());
cacheCfg.indexing()
      .index(Index.PRIMARY_OWNER)
      .addProperty("default.indexmanager", AffinityIndexManager.class.getName())
      .addProperty("default.sharding_strategy.nbr_of_shards", "10")
```

The **AffinityIndexManager** by default will have as many shards as Red Hat Data Grid segments, but this value is configurable as seen in the example above.

The number of shards affects directly the query performance and writing throughput: generally speaking, a high number of shards offers better write throughput but has an adverse effect on query performance.

11.2.2.5. Non-shared indexes

Non-shared indexes are independent indexes at each node. This setup is particularly advantageous for replicated caches where each node has all the cluster data and thus can hold all the indexes as well, offering optimal query performance with zero network latency when querying. Another advantage is, since the index is local to each node, there is less contention during writes due to the fact that each node is subjected to its own index lock, not a cluster wide one.

Since each node might hold a partial index, it may be necessary to link#query_clustered_query_api[broadcast] queries in order to get correct search results, which can add latency. If the cache is REPL, though, the broadcast is not necessary: each node can hold a full local copy of the index and queries runs at optimal speed taking advantage of a local index.

Red Hat Data Grid has two index managers suitable for non-shared indexes: **directory-based** and **near-real-time**. Storage wise, non-shared indexes can be located in ram, filesystem, or Red Hat Data Grid local caches.

11.2.2.5.1. Effect of the index mode

The **directory-based** and **near-real-time** index managers can be associated with different index modes, resulting in different index distributions.

REPL caches combined with the **ALL** index mode will result in a full copy of the cluster-wide index on each node. This mode allows queries to become effectively local without network latency. This is the recommended mode to index any REPL cache, and that's the choice picked by the auto-config when the a REPL cache is detected. The **ALL** mode should not be used with DIST caches.

REPL or DIST caches combined with **LOCAL** index mode will cause each node to index only data inserted from the same JVM, causing an uneven distribution of the index. In order to obtain correct query results, it's necessary to use broadcast queries.

REPL or DIST caches combined with **PRIMARY_OWNER** will also need broadcast queries. Differently from the **LOCAL** mode, each node's index will contain indexed entries which key is primarily owned by the node according to the consistent hash, leading to a more evenly distributed indexes among the nodes.

11.2.2.5.2. directory-based index manager

This is the default Index Manager used when no index manager is configured. The **directory-based** index manager is used to manage indexes backed by a local lucene directory. It supports *ram*, *filesystem* and non-clustered *infinispan* storage.

Filesystem storage

This is the default storage, and used when index manager configuration is omitted. The index is stored in the filesystem using a MMapDirectory. It is the recommended storage for local indexes. Although indexes are persistent on disk, they get memory mapped by Lucene and thus offer decent query performance.

Configuration:

```
<replicated-cache name="myCache">
  <indexing index="ALL">
    <!-- Optional: define base folder for indexes -->
    <property name="default.indexBase">${java.io.tmpdir}/baseDir</property>
  </indexing>
</replicated-cache>
```

Red Hat Data Grid will create a different folder under **default.indexBase** for each entity (index) present in the cache.

Ram storage

Index is stored in memory using a Lucene RAMDirectory. Not recommended for large indexes or highly concurrent situations. Indexes stored in Ram are not persistent, so after a cluster shutdown a re-index is needed. Configuration:

```
<replicated-cache name="myCache">
  <indexing index="ALL">
    <property name="default.directory_provider">local-heap</property>
  </indexing>
</replicated-cache>
```

Red Hat Data Grid storage

Red Hat Data Grid storage makes use of the Red Hat Data Grid Lucene directory that saves the indexes to a set of caches; those caches can be configured like any other Red Hat Data Grid cache, for example by adding a cache store to have indexes persisted elsewhere apart from memory. In order to use Red Hat Data Grid storage with a non-shared index, it’s necessary to use LOCAL caches for the indexes:

```
<replicated-cache name="default">
   <indexing index="ALL">
      <property name="default.locking_cachename">LuceneIndexesLocking_custom</property>
      <property name="default.data_cachename">LuceneIndexesData_custom</property>
      <property name="default.metadata_cachename">LuceneIndexesMetadata_custom</property>
   </indexing>
</replicated-cache>

<local-cache name="LuceneIndexesLocking_custom">
   <indexing index="NONE" />
</local-cache>

<local-cache name="LuceneIndexesMetadata_custom">
   <indexing index="NONE" />
</local-cache>

<local-cache name="LuceneIndexesData_custom">
   <indexing index="NONE" />
</local-cache>
```

11.2.2.5.3. near-real-time index manager

Similar to the **directory-based** index manager but takes advantage of the Near-Real-Time features of Lucene. It has better write performance than the **directory-based** because it flushes the index to the underlying store less often. The drawback is that unflushed index changes can be lost in case of a non-clean shutdown. Can be used in conjunction with **local-heap**, **filesystem** and local infinispan storage. Configuration for each different storage type is the same as the directory-based index manager.

Example with ram:

```
<replicated-cache name="default">
   <indexing index="ALL">
      <property name="default.indexmanager">near-real-time</property>
      <property name="default.directory_provider">local-heap</property>
   </indexing>
</replicated-cache>
```

Example with filesystem:

```
<replicated-cache name="default">
   <indexing index="ALL">
      <property name="default.indexmanager">near-real-time</property>
   </indexing>
</replicated-cache>
```

11.2.2.6. External indexes

Apart from having shared and non-shared indexes managed by Red Hat Data Grid itself, it is possible to offload indexing to a third party search engine: currently Red Hat Data Grid supports Elasticsearch as a external index storage.

11.2.2.6.1. Elasticsearch IndexManager (experimental)

This index manager forwards all indexes to an external Elasticsearch server. This is an experimental integration and some features may not be available, for example **indexNullAs** for **@IndexedEmbedded** annotations is not currently supported .

Configuration:

```
<indexing index="LOCAL">
   <property name="default.indexmanager">elasticsearch</property>
   <property name="default.elasticsearch.host">link:http://elasticHost:9200</property>
   <!-- other elasticsearch configurations -->
</indexing>
```

The index mode should be set to **LOCAL**, since Red Hat Data Grid considers Elasticsearch as a single shared index. More information about Elasticsearch integration, including the full description of the configuration properties can be found at the Hibernate Search manual.

11.2.2.7. Automatic configuration

The attribute auto-config provides a simple way of configuring indexing based on the cache type. For replicated and local caches, the indexing is configured to be persisted on disk and not shared with any other processes. Also, it is configured so that minimum delay exists between the moment an object is indexed and the moment it is available for searches (near real time).

```
    <local-cache name="default">
      <indexing index="LOCAL" auto-config="true">
```

```
        </indexing>
    </local-cache>
```

NOTE

it is possible to redefine any property added via auto-config, and also add new properties, allowing for advanced tuning.

The auto config adds the following properties for replicated and local caches:

Property name	value	description
default.directory_provider	filesystem	Filesystem based index. More details at Hibernate Search documentation
default.exclusive_index_use	true	indexing operation in exclusive mode, allowing Hibernate Search to optimize writes
default.indexmanager	near-real-time	make use of Lucene near real time feature, meaning indexed objects are promptly available to searches
default.reader.strategy	shared	Reuse index reader across several queries, thus avoiding reopening it

For distributed caches, the auto-config configure indexes in Red Hat Data Grid itself, internally handled as a master-slave mechanism where indexing operations are sent to a single node which is responsible to write to the index.

The auto config properties for distributed caches are:

Property name	value	description
default.directory_provider	infinispan	Indexes stored in Red Hat Data Grid. More details at Hibernate Search documentation
default.exclusive_index_use	true	indexing operation in exclusive mode, allowing Hibernate Search to optimize writes
default.indexmanager	org.infinispan.query.indexmanager.InfinispanIndexManager	Delegates index writing to a single node in the Red Hat Data Grid cluster

Property name	value	description
default.reader.strategy	shared	Reuse index reader across several queries, avoiding reopening it

11.2.2.8. Re-indexing

Occasionally you might need to rebuild the Lucene index by reconstructing it from the data stored in the Cache. You need to rebuild the index if you change the definition of what is indexed on your types, or if you change for example some *Analyzer* parameter, as Analyzers affect how the index is written. Also, you might need to rebuild the index if you had it destroyed by some system administration mistake. To rebuild the index just get a reference to the MassIndexer and start it; beware it might take some time as it needs to reprocess all data in the grid!

```
// Blocking execution
SearchManager searchManager = Search.getSearchManager(cache);
searchManager.getMassIndexer().start();

// Non blocking execution
CompletableFuture<Void> future = searchManager.getMassIndexer().startAsyc();
```

TIP

This is also available as a **start** JMX operation on the MassIndexer MBean registered under the name **org.infinispan:type=Query,manager="{name-of-cache-manager}",cache="{name-of-cache}",component=MassIndexer**.

11.2.2.9. Mapping Entities

Red Hat Data Grid relies on the rich API of Hibernate Search in order to define fine grained configuration for indexing at entity level. This configuration includes which fields are annotated, which analyzers should be used, how to map nested objects and so on. Detailed documentation is available at the Hibernate Search manual.

11.2.2.9.1. @DocumentId

Unlike Hibernate Search, using *@DocumentId* to mark a field as identifier does not apply to Red Hat Data Grid values; in Red Hat Data Grid the identifier for all *@Indexed* objects is the key used to store the value. You can still customize how the key is indexed using a combination of *@Transformable* , custom types and custom *FieldBridge* implementations.

11.2.2.9.2. @Transformable keys

The key for each value needs to be indexed as well, and the key instance must be transformed in a *String*. Red Hat Data Grid includes some default transformation routines to encode common primitives, but to use a custom key you must provide an implementation of *org.infinispan.query.Transformer* .

Registering a Transformer via annotations

You can annotate your key type with *org.infinispan.query.Transformable* :

```
@Transformable(transformer = CustomTransformer.class)
```

```
public class CustomKey {
   ...
}

public class CustomTransformer implements Transformer {
   @Override
   public Object fromString(String s) {
      ...
      return new CustomKey(...);
   }

   @Override
   public String toString(Object customType) {
      CustomKey ck = (CustomKey) customType;
      return ...
   }
}
```

Registering a Transformer programmatically

Using this technique, you don't have to annotate your custom key type:

```
org.infinispan.query.SearchManager.registerKeyTransformer(Class<?>, Class<? extends
Transformer>)
```

11.2.2.9.3. Programmatic mapping

Instead of using annotations to map an entity to the index, it's also possible to configure it programmatically.

In the following example we map an object *Author* which is to be stored in the grid and made searchable on two properties but without annotating the class.

```
import org.apache.lucene.search.Query;
import org.hibernate.search.cfg.Environment;
import org.hibernate.search.cfg.SearchMapping;
import org.hibernate.search.query.dsl.QueryBuilder;
import org.infinispan.Cache;
import org.infinispan.configuration.cache.Configuration;
import org.infinispan.configuration.cache.ConfigurationBuilder;
import org.infinispan.configuration.cache.Index;
import org.infinispan.manager.DefaultCacheManager;
import org.infinispan.query.CacheQuery;
import org.infinispan.query.Search;
import org.infinispan.query.SearchManager;

import java.io.IOException;
import java.lang.annotation.ElementType;
import java.util.Properties;

SearchMapping mapping = new SearchMapping();
mapping.entity(Author.class).indexed()
       .property("name", ElementType.METHOD).field()
       .property("surname", ElementType.METHOD).field();
```

```
Properties properties = new Properties();
properties.put(Environment.MODEL_MAPPING, mapping);
properties.put("hibernate.search.[other options]", "[...]");

Configuration infinispanConfiguration = new ConfigurationBuilder()
        .indexing().index(Index.LOCAL)
        .withProperties(properties)
        .build();

DefaultCacheManager cacheManager = new DefaultCacheManager(infinispanConfiguration);

Cache<Long, Author> cache = cacheManager.getCache();
SearchManager sm = Search.getSearchManager(cache);

Author author = new Author(1, "Manik", "Surtani");
cache.put(author.getId(), author);

QueryBuilder qb = sm.buildQueryBuilderForClass(Author.class).get();
Query q = qb.keyword().onField("name").matching("Manik").createQuery();
CacheQuery cq = sm.getQuery(q, Author.class);
assert cq.getResultSize() == 1;
```

11.2.3. Querying APIs

You can query Red Hat Data Grid using:

- Lucene or Hibernate Search Queries. Red Hat Data Grid exposes the Hibernate Search DSL, which produces Lucene queries. You can run Lucene queries on single nodes or broadcast queries to multiple nodes in an Red Hat Data Grid cluster.
- Ickle queries, a custom string-based query language with full-text extensions.

11.2.3.1. Hibernate Search

Apart from supporting Hibernate Search annotations to configure indexing, it's also possible to query the cache using other Hibernate Search APIs

11.2.3.1.1. Running Lucene queries

To run a Lucene query directly, simply create and wrap it in a *CacheQuery*:

```
import org.infinispan.query.Search;
import org.infinispan.query.SearchManager;
import org.apache.lucene.Query;


SearchManager searchManager = Search.getSearchManager(cache);
Query query = searchManager.buildQueryBuilderForClass(Book.class).get()
            .keyword().wildcard().onField("description").matching("*test*").createQuery();
CacheQuery<Book> cacheQuery = searchManager.getQuery(query);
```

11.2.3.1.2. Using the Hibernate Search DSL

The Hibernate Search DSL can be used to create the Lucene Query, example:

```
import org.infinispan.query.Search;
import org.infinispan.query.SearchManager;
import org.apache.lucene.search.Query;

Cache<String, Book> cache = ...

SearchManager searchManager = Search.getSearchManager(cache);

Query luceneQuery = searchManager
                    .buildQueryBuilderForClass(Book.class).get()
                    .range().onField("year").from(2005).to(2010)
                    .createQuery();

List<Object> results = searchManager.getQuery(luceneQuery).list();
```

For a detailed description of the query capabilities of this DSL, see the relevant section of the Hibernate Search manual.

11.2.3.1.3. Faceted Search

Red Hat Data Grid support Faceted Searches by using the Hibernate Search **FacetManager**:

```
// Cache is indexed
Cache<Integer, Book> cache = ...

// Obtain the Search Manager
SearchManager searchManager = Search.getSearchManager(cache);

// Create the query builder
QueryBuilder queryBuilder = searchManager.buildQueryBuilderForClass(Book.class).get();

// Build any Lucene Query. Here it's using the DSL to do a Lucene term query on a book name
Query luceneQuery =
queryBuilder.keyword().wildcard().onField("name").matching("bitcoin").createQuery();

// Wrap into a cache Query
CacheQuery<Book> query = searchManager.getQuery(luceneQuery);

// Define the Facet characteristics
FacetingRequest request = queryBuilder.facet()
            .name("year_facet")
            .onField("year")
            .discrete()
            .orderedBy(FacetSortOrder.COUNT_ASC)
            .createFacetingRequest();

// Associated the FacetRequest with the query
FacetManager facetManager = query.getFacetManager().enableFaceting(request);

// Obtain the facets
List<Facet> facetList = facetManager.getFacets("year_facet");
```

A Faceted search like above will return the number books that match 'bitcoin' released on a yearly basis, for example:

```
AbstractFacet{facetingName='year_facet', fieldName='year', value='2008', count=1}
AbstractFacet{facetingName='year_facet', fieldName='year', value='2009', count=1}
AbstractFacet{facetingName='year_facet', fieldName='year', value='2010', count=1}
AbstractFacet{facetingName='year_facet', fieldName='year', value='2011', count=1}
AbstractFacet{facetingName='year_facet', fieldName='year', value='2012', count=1}
AbstractFacet{facetingName='year_facet', fieldName='year', value='2016', count=1}
AbstractFacet{facetingName='year_facet', fieldName='year', value='2015', count=2}
AbstractFacet{facetingName='year_facet', fieldName='year', value='2013', count=3}
```

For more info about Faceted Search, see Hibernate Search Faceting

11.2.3.1.4. Spatial Queries

Red Hat Data Grid also supports Spatial Queries, allowing to combining full-text with restrictions based on distances, geometries or geographic coordinates.

Example, we start by using the **@Spatial** annotation in our entity that will be searched, together with **@Latitude** and **@Longitude**:

```
@Indexed
@Spatial
public class Restaurant {

    @Latitude
    private Double latitude;

    @Longitude
    private Double longitude;

    @Field(store = Store.YES)
    String name;

    // Getters, Setters and other members omitted

  }
```

to run spatial queries, the Hibernate Search DSL can be used:

```
// Cache is configured as indexed
Cache<String, Restaurant> cache = ...

// Obtain the SearchManager
Searchmanager searchManager = Search.getSearchManager(cache);

// Build the Lucene Spatial Query
Query query = Search.getSearchManager(cache).buildQueryBuilderForClass(Restaurant.class).get()
        .spatial()
          .within( 2, Unit.KM )
            .ofLatitude( centerLatitude )
            .andLongitude( centerLongitude )
          .createQuery();

// Wrap in a cache Query
```

```
CacheQuery<Restaurant> cacheQuery = searchManager.getQuery(query);

List<Restaurant> nearBy = cacheQuery.list();
```

More info on Hibernate Search manual

11.2.3.1.5. IndexedQueryMode

It's possible to specify a query mode for indexed queries. IndexedQueryMode.BROADCAST allows to broadcast a query to each node of the cluster, retrieve the results and combine them before returning to the caller. It is suitable for use in conjunction with non-shared indexes, since each node's local index will have only a subset of the data indexed.

IndexedQueryMode.FETCH will execute the query in the caller. If all the indexes for the cluster wide data are available locally, performance will be optimal, otherwise this query mode may involve fetching indexes data from remote nodes.

The IndexedQueryMode is supported for Lucene Queries and Ickle String queries at the moment (no Red Hat Data Grid Query DSL).

Example:

```
CacheQuery<Person> broadcastQuery = Search.getSearchManager(cache).getQuery(new
MatchAllDocsQuery(), IndexedQueryMode.BROADCAST);

List<Person> result = broadcastQuery.list();
```

11.2.3.2. Red Hat Data Grid Query DSL

Red Hat Data Grid provides its own query DSL, independent of Lucene and Hibernate Search. Decoupling the query API from the underlying query and indexing mechanism makes it possible to introduce new alternative engines in the future, besides Lucene, and still being able to use the same uniform query API. The current implementation of indexing and searching is still based on Hibernate Search and Lucene so all indexing related aspects presented in this chapter still apply.

The new API simplifies the writing of queries by not exposing the user to the low level details of constructing Lucene query objects and also has the advantage of being available to remote Hot Rod clients. But before delving into further details, let's examine first a simple example of writing a query for the *Book* entity from the previous example.

Query example using Red Hat Data Grid's query DSL

```
import org.infinispan.query.dsl.*;

// get the DSL query factory from the cache, to be used for constructing the Query object:
QueryFactory qf = org.infinispan.query.Search.getQueryFactory(cache);

// create a query for all the books that have a title which contains "engine":
org.infinispan.query.dsl.Query query = qf.from(Book.class)
      .having("title").like("%engine%")
      .build();

// get the results:
List<Book> list = query.list();
```

The API is located in the *org.infinispan.query.dsl* package. A query is created with the help of the *QueryFactory* instance which is obtained from the per-cache *SearchManager*. Each *QueryFactory* instance is bound to the same *Cache* instance as the *SearchManager*, but it is otherwise a stateless and thread-safe object that can be used for creating multiple queries in parallel.

Query creation starts with the invocation of the **from(Class entityType)** method which returns a *QueryBuilder* object that is further responsible for creating queries targeted to the specified entity class from the given cache.

NOTE

A query will always target a single entity type and is evaluated over the contents of a single cache. Running a query over multiple caches or creating queries that target several entity types (joins) is not supported.

The *QueryBuilder* accumulates search criteria and configuration specified through the invocation of its DSL methods and is ultimately used to build a *Query* object by the invocation of the **QueryBuilder.build()** method that completes the construction. Being a stateful object, it cannot be used for constructing multiple queries at the same time (except for nested queries) but can be reused afterwards.

NOTE

This *QueryBuilder* is different from the one from Hibernate Search but has a somewhat similar purpose, hence the same name. We are considering renaming it in near future to prevent ambiguity.

Executing the query and fetching the results is as simple as invoking the **list()** method of the *Query* object. Once executed the *Query* object is not reusable. If you need to re-execute it in order to obtain fresh results then a new instance must be obtained by calling **QueryBuilder.build()**.

11.2.3.2.1. Filtering operators

Constructing a query is a hierarchical process of composing multiple criteria and is best explained following this hierarchy.

The simplest possible form of a query criteria is a restriction on the values of an entity attribute according to a filtering operator that accepts zero or more arguments. The entity attribute is specified by invoking the **having(String attributePath)** method of the query builder which returns an intermediate context object (*FilterConditionEndContext*) that exposes all the available operators. Each of the methods defined by *FilterConditionEndContext* is an operator that accepts an argument, except for **between** which has two arguments and **isNull** which has no arguments. The arguments are statically evaluated at the time the query is constructed, so if you’re looking for a feature similar to SQL’s correlated sub-queries, that is not currently available.

```
// a single query criterion
QueryBuilder qb = ...
qb.having("title").eq("Hibernate Search in Action");
```

Table 11.1. *FilterConditionEndContext* exposes the following filtering operators:

Filter	Arguments	Description
in	Collection values	Checks that the left operand is equal to one of the elements from the Collection of values given as argument.
in	Object... values	Checks that the left operand is equal to one of the (fixed) list of values given as argument.
contains	Object value	Checks that the left argument (which is expected to be an array or a Collection) contains the given element.
containsAll	Collection values	Checks that the left argument (which is expected to be an array or a Collection) contains all the elements of the given collection, in any order.
containsAll	Object... values	Checks that the left argument (which is expected to be an array or a Collection) contains all of the the given elements, in any order.
containsAny	Collection values	Checks that the left argument (which is expected to be an array or a Collection) contains any of the elements of the given collection.
containsAny	Object... values	Checks that the left argument (which is expected to be an array or a Collection) contains any of the the given elements.
isNull		Checks that the left argument is null.
like	String pattern	Checks that the left argument (which is expected to be a String) matches a wildcard pattern that follows the JPA rules.
eq	Object value	Checks that the left argument is equal to the given value.

Filter	Arguments	Description
equal	Object value	Alias for eq.
gt	Object value	Checks that the left argument is greater than the given value.
gte	Object value	Checks that the left argument is greater than or equal to the given value.
lt	Object value	Checks that the left argument is less than the given value.
lte	Object value	Checks that the left argument is less than or equal to the given value.
between	Object from, Object to	Checks that the left argument is between the given range limits.

It's important to note that query construction requires a multi-step chaining of method invocation that must be done in the proper sequence, must be properly completed exactly *once* and must not be done twice, or it will result in an error. The following examples are invalid, and depending on each case they lead to criteria being ignored (in benign cases) or an exception being thrown (in more serious ones).

```
// Incomplete construction. This query does not have any filter on "title" attribute yet,
// although the author may have intended to add one.
QueryBuilder qb1 = ...
qb1.having("title");
Query q1 = qb1.build(); // consequently, this query matches all Book instances regardless of title!

// Duplicated completion. This results in an exception at run-time.
// Maybe the author intended to connect two conditions with a boolean operator,
// but this does NOT actually happen here.
QueryBuilder qb2 = ...
qb2.having("title").like("%Data Grid%");
qb2.having("description").like("%clustering%");   // will throw java.lang.IllegalStateException:
Sentence already started. Cannot use 'having(..)' again.
Query q2 = qb2.build();
```

11.2.3.2.2. Filtering based on attributes of embedded entities

The **having** method also accepts dot separated attribute paths for referring to *embedded entity* attributes, so the following is a valid query:

```
// match all books that have an author named "Manik"
Query query = queryFactory.from(Book.class)
      .having("author.name").eq("Manik")
      .build();
```

Each part of the attribute path must refer to an existing indexed attribute in the corresponding entity or embedded entity class respectively. It’s possible to have multiple levels of embedding.

11.2.3.2.3. Boolean conditions

Combining multiple attribute conditions with logical conjunction (**and**) and disjunction (**or**) operators in order to create more complex conditions is demonstrated in the following example. The well known operator precedence rule for boolean operators applies here, so the order of DSL method invocations during construction is irrelevant. Here **and** operator still has higher priority than **or** even though **or** was invoked first.

```
// match all books that have "Data Grid" in their title
// or have an author named "Manik" and their description contains "clustering"
Query query = queryFactory.from(Book.class)
  .having("title").like("%Data Grid%")
  .or().having("author.name").eq("Manik")
  .and().having("description").like("%clustering%")
  .build();
```

Boolean negation is achieved with the **not** operator, which has highest precedence among logical operators and applies only to the next simple attribute condition.

```
// match all books that do not have "Data Grid" in their title and are authored by "Manik"
Query query = queryFactory.from(Book.class)
  .not().having("title").like("%Data Grid%")
  .and().having("author.name").eq("Manik")
  .build();
```

11.2.3.2.4. Nested conditions

Changing the precedence of logical operators is achieved with nested filter conditions. Logical operators can be used to connect two simple attribute conditions as presented before, but can also connect a simple attribute condition with the subsequent complex condition created with the same query factory.

```
// match all books that have an author named "Manik" and their title contains
// "Data Grid" or their description contains "clustering"
Query query = queryFactory.from(Book.class)
  .having("author.name").eq("Manik")
  .and(queryFactory.having("title").like("%Data Grid%")
        .or().having("description").like("%clustering%"))
  .build();
```

11.2.3.2.5. Projections

In some use cases returning the whole domain object is overkill if only a small subset of the attributes are actually used by the application, especially if the domain entity has embedded entities. The query language allows you to specify a subset of attributes (or attribute paths) to return - the projection. If projections are used then the **Query.list()** will not return the whole domain entity but will return a *List* of *Object[]*, each slot in the array corresponding to a projected attribute.

```
// match all books that have "Data Grid" in their title or description
// and return only their title and publication year
Query query = queryFactory.from(Book.class)
  .select("title", "publicationYear")
  .having("title").like("%Data Grid%")
  .or().having("description").like("%Data Grid%"))
  .build();
```

11.2.3.2.6. Sorting

Ordering the results based on one or more attributes or attribute paths is done with the **QueryBuilder.orderBy( )** method which accepts an attribute path and a sorting direction. If multiple sorting criteria are specified, then the order of invocation of **orderBy** method will dictate their precedence. But you have to think of the multiple sorting criteria as acting together on the tuple of specified attributes rather than in a sequence of individual sorting operations on each attribute.

```
// match all books that have "Data Grid" in their title or description
// and return them sorted by the publication year and title
Query query = queryFactory.from(Book.class)
  .orderBy("publicationYear", SortOrder.DESC)
  .orderBy("title", SortOrder.ASC)
  .having("title").like("%Data Grid%")
  .or().having("description").like("%Data Grid%"))
  .build();
```

11.2.3.2.7. Pagination

You can limit the number of returned results by setting the *maxResults* property of *QueryBuilder*. This can be used in conjunction with setting the *startOffset* in order to achieve pagination of the result set.

```
// match all books that have "clustering" in their title
// sorted by publication year and title
// and return 3'rd page of 10 results
Query query = queryFactory.from(Book.class)
  .orderBy("publicationYear", SortOrder.DESC)
  .orderBy("title", SortOrder.ASC)
  .startOffset(20)
  .maxResults(10)
  .having("title").like("%clustering%")
  .build();
```

NOTE

Even if the results being fetched are limited to *maxResults* you can still find the total number of matching results by calling **Query.getResultSize()**.

11.2.3.2.8. Grouping and Aggregation

Red Hat Data Grid has the ability to group query results according to a set of grouping fields and construct aggregations of the results from each group by applying an aggregation function to the set of values that fall into each group. Grouping and aggregation can only be applied to projection queries. The supported aggregations are: avg, sum, count, max, min. The set of grouping fields is specified with the *groupBy(field)* method, which can be invoked multiple times. The order used for defining grouping fields is not relevant. All fields selected in the projection must either be grouping fields or else they must be aggregated using one of the grouping functions described below. A projection field can be aggregated and used for grouping at the same time. A query that selects only grouping fields but no aggregation fields is legal.

Example: Grouping Books by author and counting them.

```
Query query = queryFactory.from(Book.class)
    .select(Expression.property("author"), Expression.count("title"))
    .having("title").like("%engine%")
    .groupBy("author")
    .build();
```

NOTE

A projection query in which all selected fields have an aggregation function applied and no fields are used for grouping is allowed. In this case the aggregations will be computed globally as if there was a single global group.

11.2.3.2.9. Aggregations

The following aggregation functions may be applied to a field: avg, sum, count, max, min

- avg() - Computes the average of a set of numbers. Accepted values are primitive numbers and instances of *java.lang.Number*. The result is represented as *java.lang.Double*. If there are no non-null values the result is *null* instead.
- count() - Counts the number of non-null rows and returns a *java.lang.Long*. If there are no non-null values the result is *0* instead.
- max() - Returns the greatest value found. Accepted values must be instances of *java.lang.Comparable*. If there are no non-null values the result is *null* instead.
- min() - Returns the smallest value found. Accepted values must be instances of *java.lang.Comparable*. If there are no non-null values the result is *null* instead.
- sum() - Computes the sum of a set of Numbers. If there are no non-null values the result is *null* instead. The following table indicates the return type based on the specified field.

Table 11.2. Table sum return type

Field Type	Return Type
Integral (other than BigInteger)	Long
Float or Double	Double
BigInteger	BigInteger
BigDecimal	BigDecimal

11.2.3.2.10. Evaluation of queries with grouping and aggregation

Aggregation queries can include filtering conditions, like usual queries. Filtering can be performed in two stages: before and after the grouping operation. All filter conditions defined before invoking the *groupBy* method will be applied before the grouping operation is performed, directly to the cache entries (not to the final projection). These filter conditions may reference any fields of the queried entity type, and are meant to restrict the data set that is going to be the input for the grouping stage. All filter conditions defined after invoking the *groupBy* method will be applied to the projection that results from the projection and grouping operation. These filter conditions can either reference any of the *groupBy* fields or aggregated fields. Referencing aggregated fields that are not specified in the select clause is allowed; however, referencing non-aggregated and non-grouping fields is forbidden. Filtering in this phase will reduce the amount of groups based on their properties. Sorting may also be specified similar to usual queries. The ordering operation is performed after the grouping operation and can reference any of the *groupBy* fields or aggregated fields.

11.2.3.2.11. Using Named Query Parameters

Instead of building a new Query object for every execution it is possible to include named parameters in the query which can be substituted with actual values before execution. This allows a query to be defined once and be efficiently executed many times. Parameters can only be used on the right-hand side of an operator and are defined when the query is created by supplying an object produced by the *org.infinispan.query.dsl.Expression.param(String paramName)* method to the operator instead of the usual constant value. Once the parameters have been defined they can be set by invoking either *Query.setParameter(parameterName, value)* or *Query.setParameters(parameterMap)* as shown in the examples below.

```
import org.infinispan.query.Search;
import org.infinispan.query.dsl.*;
[...]

QueryFactory queryFactory = Search.getQueryFactory(cache);
// Defining a query to search for various authors and publication years
Query query = queryFactory.from(Book.class)
    .select("title")
    .having("author").eq(Expression.param("authorName"))
    .and()
    .having("publicationYear").eq(Expression.param("publicationYear"))
    .build();

// Set actual parameter values
query.setParameter("authorName", "Doe");
query.setParameter("publicationYear", 2010);

// Execute the query
List<Book> found = query.list();
```

Alternatively, multiple parameters may be set at once by supplying a map of actual parameter values:

Setting multiple named parameters at once

```
import java.util.Map;
import java.util.HashMap;

[...]

Map<String, Object> parameterMap = new HashMap<>();
parameterMap.put("authorName", "Doe");
parameterMap.put("publicationYear", 2010);

query.setParameters(parameterMap);
```

NOTE

A significant portion of the query parsing, validation and execution planning effort is performed during the first execution of a query with parameters. This effort is not repeated during subsequent executions leading to better performance compared to a similar query using constant values instead of query parameters.

11.2.3.2.12. More Query DSL samples

Probably the best way to explore using the Query DSL API is to have a look at our tests suite. QueryDslConditionsTest is a fine example.

11.2.3.3. Ickle

Create relational and full-text queries in both Library and Remote Client-Server mode with the Ickle query language.

Ickle is string-based and has the following characteristics:

- Query Java classes and supports Protocol Buffers.
- Queries can target a single entity type.
- Queries can filter on properties of embedded objects, including collections.
- Supports projections, aggregations, sorting, named parameters.
- Supports indexed and non-indexed execution.
- Supports complex boolean expressions.
- Supports full-text queries.
- Does not support computations in expressions, such as **user.age > sqrt(user.shoeSize+3)**.
- Does not support joins.
- Does not support subqueries.
- Is supported across various {Red Hat Data Grid} APIs. Whenever a Query is produced by the QueryBuilder is accepted, including continuous queries or in event filters for listeners.

To use the API, first obtain a QueryFactory to the cache and then call the .create() method, passing in the string to use in the query. For instance:

```
QueryFactory qf = Search.getQueryFactory(remoteCache);
Query q = qf.create("from sample_bank_account.Transaction where amount > 20");
```

When using Ickle all fields used with full-text operators must be both **Indexed** and **Analysed**.

11.2.3.3.1. Ickle Query Language Parser Syntax

The parser syntax for the Ickle query language has some notable rules:

- Whitespace is not significant.
- Wildcards are not supported in field names.
- A field name or path must always be specified, as there is no default field.
- **&&** and **||** are accepted instead of **AND** or **OR** in both full-text and JPA predicates.
- **!** may be used instead of **NOT**.
- A missing boolean operator is interpreted as **OR**.
- String terms must be enclosed with either single or double quotes.
- Fuzziness and boosting are not accepted in arbitrary order; fuzziness always comes first.
- **!=** is accepted instead of **<>**.
- Boosting cannot be applied to **>**,**>=**,**<**,**⇐** operators. Ranges may be used to achieve the same result.

11.2.3.3.2. Fuzzy Queries

To execute a fuzzy query add ~ along with an integer, representing the distance from the term used, after the term. For instance

```
Query fuzzyQuery = qf.create("from sample_bank_account.Transaction where description :
'cofee'~2");
```

11.2.3.3.3. Range Queries

To execute a range query define the given boundaries within a pair of braces, as seen in the following example:

Query rangeQuery = qf.create("from sample_bank_account.Transaction where amount : [20 to 50]");

11.2.3.3.4. Phrase Queries

A group of words may be searched by surrounding them in quotation marks, as seen in the following example:

Query q = qf.create("from sample_bank_account.Transaction where description : 'bus fare'");

11.2.3.3.5. Proximity Queries

To execute a proximity query, finding two terms within a specific distance, add a ~ along with the distance after the phrase. For instance, the following example will find the words canceling and fee provided they are not more than 3 words apart:

```
Query proximityQuery = qf.create("from sample_bank_account.Transaction where description :
'canceling fee'~3 ");
```

11.2.3.3.6. Wildcard Queries

Both single-character and multi-character wildcard searches may be performed:

- A single-character wildcard search may be used with the ? character.
- A multi-character wildcard search may be used with the * character.

To search for text or test the following single-character wildcard search would be used:

```
Query wildcardQuery = qf.create("from sample_bank_account.Transaction where description : 'te?t'");
```

To search for test, tests, or tester the following multi-character wildcard search would be useD:

```
Query wildcardQuery = qf.create("from sample_bank_account.Transaction where description :
'test*'");
```

11.2.3.3.7. Regular Expression Queries

Regular expression queries may be performed by specifing a pattern between /. Ickle uses Lucene’s regular expression syntax, so to search for the words moat or boat the following could be used:

```
Query regExpQuery = qf.create("from sample_library.Book  where title : /[mb]oat/");
```

11.2.3.3.8. Boosting Queries

Terms may be boosted by adding a ^ after the term to increase their relevance in a given query, the higher the boost factor the more relevant the term will be. For instance to search for titles containing beer and wine with a higher relevance on beer, by a factor of 3, the following could be used:

```
Query boostedQuery = qf.create("from sample_library.Book where title : beer^3 OR wine");
```

11.2.3.4. Continuous Query

Continuous Queries allow an application to register a listener which will receive the entries that currently match a query filter, and will be continuously notified of any changes to the queried data set that result from further cache operations. This includes incoming matches, for values that have joined the set, updated matches, for matching values that were modified and continue to match, and outgoing matches, for values that have left the set. By using a Continuous Query the application receives a steady stream of events instead of having to repeatedly execute the same query to discover changes, resulting in a more efficient use of resources. For instance, all of the following use cases could utilize Continuous Queries:

- Return all persons with an age between 18 and 25 (assuming the Person entity has an *age* property and is updated by the user application).
- Return all transactions higher than $2000.
- Return all times where the lap speed of F1 racers were less than 1:45.00s (assuming the cache contains Lap entries and that laps are entered live during the race).

11.2.3.4.1. Continuous Query Execution

A continuous query uses a listener that is notified when:

- An entry starts matching the specified query, represented by a *Join* event.
- A matching entry is updated and continues to match the query, represented by an *Update* event.
- An entry stops matching the query, represented by a *Leave* event.

When a client registers a continuous query listener it immediately begins to receive the results currently matching the query, received as *Join* events as described above. In addition, it will receive subsequent notifications when other entries begin matching the query, as *Join* events, or stop matching the query, as *Leave* events, as a consequence of any cache operations that would normally generate creation, modification, removal, or expiration events. Updated cache entries will generate *Update* events if the entry matches the query filter before and after the operation. To summarize, the logic used to determine if the listener receives a *Join*, *Update* or *Leave* event is:

1. If the query on both the old and new values evaluate false, then the event is suppressed.
2. If the query on the old value evaluates false and on the new value evaluates true, then a *Join* event is sent.
3. If the query on both the old and new values evaluate true, then an *Update* event is sent.
4. If the query on the old value evaluates true and on the new value evaluates false, then a *Leave* event is sent.
5. If the query on the old value evaluates true and the entry is removed or expired, then a *Leave* event is sent.

NOTE

Continuous Queries can use the full power of the Query DSL except: grouping, aggregation, and sorting operations.

11.2.3.4.2. Running Continuous Queries

To create a continuous query you'll start by creating a Query object first. This is described in the Query DSL section. Then you'll need to obtain the ContinuousQuery (*org.infinispan.query.api.continuous.ContinuousQuery*) object of your cache and register the query and a continuous query listener (*org.infinispan.query.api.continuous.ContinuousQueryListener*) with it. A ContinuousQuery object associated to a cache can be obtained by calling the static method *org.infinispan.client.hotrod.Search.getContinuousQuery(RemoteCache<K, V> cache)* if running in remote mode or *org.infinispan.query.Search.getContinuousQuery(Cache<K, V> cache)* when running in embedded mode. Once the listener has been created it may be registered by using the addContinuousQueryListener method of ContinuousQuery:

```
continuousQuery.addContinuousQueryListener(query, listener);
```

The following example demonstrates a simple continuous query use case in embedded mode:

Registering a Continuous Query

```
import org.infinispan.query.api.continuous.ContinuousQuery;
import org.infinispan.query.api.continuous.ContinuousQueryListener;
import org.infinispan.query.Search;
import org.infinispan.query.dsl.QueryFactory;
import org.infinispan.query.dsl.Query;

import java.util.Map;
import java.util.concurrent.ConcurrentHashMap;

[...]

// We have a cache of Persons
Cache<Integer, Person> cache = ...

// We begin by creating a ContinuousQuery instance on the cache
ContinuousQuery<Integer, Person> continuousQuery = Search.getContinuousQuery(cache);

// Define our query. In this case we will be looking for any Person instances under 21 years of age.
QueryFactory queryFactory = Search.getQueryFactory(cache);
Query query = queryFactory.from(Person.class)
   .having("age").lt(21)
   .build();

final Map<Integer, Person> matches = new ConcurrentHashMap<Integer, Person>();

// Define the ContinuousQueryListener
ContinuousQueryListener<Integer, Person> listener = new ContinuousQueryListener<Integer,
Person>() {
   @Override
   public void resultJoining(Integer key, Person value) {
      matches.put(key, value);
   }

   @Override
   public void resultUpdated(Integer key, Person value) {
      // we do not process this event
   }

   @Override
   public void resultLeaving(Integer key) {
      matches.remove(key);
   }
};

// Add the listener and the query
continuousQuery.addContinuousQueryListener(query, listener);

[...]

// Remove the listener to stop receiving notifications
continuousQuery.removeContinuousQueryListener(listener);
```

As Person instances having an age less than 21 are added to the cache they will be received by the listener and will be placed into the *matches* map, and when these entries are removed from the cache or their age is modified to be greater or equal than 21 they will be removed from *matches*.

11.2.3.4.3. Removing Continuous Queries

To stop the query from further execution just remove the listener:

```
continuousQuery.removeContinuousQueryListener(listener);
```

11.2.3.4.4. Notes on performance of Continuous Queries

Continuous queries are designed to provide a constant stream of updates to the application, potentially resulting in a very large number of events being generated for particularly broad queries. A new temporary memory allocation is made for each event. This behavior may result in memory pressure, potentially leading to *OutOfMemoryErrors* (especially in remote mode) if queries are not carefully designed. To prevent such issues it is strongly recommended to ensure that each query captures the minimal information needed both in terms of number of matched entries and size of each match (projections can be used to capture the interesting properties), and that each *ContinuousQueryListener* is designed to quickly process all received events without blocking and to avoid performing actions that will lead to the generation of new matching events from the cache it listens to.

11.3. REMOTE QUERYING

Apart from supporting indexing and searching of Java entities to embedded clients, Red Hat Data Grid introduced support for remote, language neutral, querying.

This leap required two major changes:

- Since non-JVM clients cannot benefit from directly using Apache Lucene's Java API, Red Hat Data Grid defines its own new query language, based on an internal DSL that is easily implementable in all languages for which we currently have an implementation of the Hot Rod client.
- In order to enable indexing, the entities put in the cache by clients can no longer be opaque binary blobs understood solely by the client. Their structure has to be known to both server and client, so a common way of encoding structured data had to be adopted. Furthermore, allowing multi-language clients to access the data requires a language and platform-neutral encoding. Google's Protocol Buffers was elected as an encoding format for both over-the-wire and storage due to its efficiency, robustness, good multi-language support and support for schema evolution.

11.3.1. Storing Protobuf encoded entities

Remote clients that want to be able to index and query their stored entities must do so using the Protobuf encoding format. This is *key* for the search capability to work. But it's also possible to store Protobuf entities just for gaining the benefit of platform independence and not enable indexing if you do not need it.

Protobuf is all about structured data, so first thing you do to use it is define the structure of your data. This is accomplished by declaring protocol buffer message types in .proto files, like in the following example. Protobuf is a broad subject, we will not detail it here, so please consult the Protobuf Developer Guide for an in-depth explanation. It suffices to say for now that our example defines an entity (message type in protobuf speak) named *Book*, placed in a package named *book_sample*. Our entity declares several fields of primitive types and a repeatable field (an array basically) named *authors*. The *Author* message instances are embedded in the *Book* message instance.

library.proto

```
package book_sample;

message Book {
  required string title = 1;
  required string description = 2;
  required int32 publicationYear = 3; // no native Date type available in Protobuf

  repeated Author authors = 4;
}

message Author {
  required string name = 1;
  required string surname = 2;
}
```

There are a few important notes we need to make about Protobuf messages:

- nesting of messages is possible, but the resulting structure is strictly a tree, never a graph
- there is no concept of type inheritance
- collections are not supported but arrays can be easily emulated using repeated fields

Using Protobuf with the Java Hot Rod client is a two step process. First, the client must be configured to use a dedicated marshaller, *ProtoStreamMarshaller*. This marshaller uses the *ProtoStream* library to assist you in encoding your objects. The second step is instructing *ProtoStream* library on how to marshall your message types. The following example highlights this process.

```
import org.infinispan.client.hotrod.configuration.ConfigurationBuilder;
import org.infinispan.client.hotrod.marshall.ProtoStreamMarshaller;
import org.infinispan.protostream.SerializationContext;
...

ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder.addServer()
    .host("10.1.2.3").port(11234)
    .marshaller(new ProtoStreamMarshaller());

RemoteCacheManager remoteCacheManager = new RemoteCacheManager(clientBuilder.build());

SerializationContext serCtx =
ProtoStreamMarshaller.getSerializationContext(remoteCacheManager);

FileDescriptorSource fds = new FileDescriptorSource();
fds.addProtoFiles("/library.proto");
serCtx.registerProtoFiles(fds);
serCtx.registerMarshaller(new BookMarshaller());
serCtx.registerMarshaller(new AuthorMarshaller());

// Book and Author classes omitted for brevity
```

The interesting part in this sample is obtaining the *SerializationContext* associated to the *RemoteCacheManager* and then instructing ProtoStream about the protobuf types we want to marshall. The *SerializationContext* is provided by the library for this purpose. The **SerializationContext.registerProtoFiles** method receives the name of one or more classpath resources that is expected to be a protobuf definition containing our type declarations.

NOTE

A *RemoteCacheManager* has no *SerializationContext* associated with it unless it was configured to use a *ProtoStreamMarshaller*.

The next relevant part is the registration of per entity marshallers for our domain model types. They must be provided by the user for each type or marshalling will fail. Writing marshallers is a simple process. The *BookMarshaller* example should get you started. The most important thing you need to consider is they need to be stateless and threadsafe as a single instance of them is being used.

BookMarshaller.java

```
import org.infinispan.protostream.MessageMarshaller;
...

public class BookMarshaller implements MessageMarshaller<Book> {

   @Override
   public String getTypeName() {
      return "book_sample.Book";
   }

   @Override
   public Class<? extends Book> getJavaClass() {
      return Book.class;
   }

   @Override
   public void writeTo(ProtoStreamWriter writer, Book book) throws IOException {
      writer.writeString("title", book.getTitle());
      writer.writeString("description", book.getDescription());
      writer.writeInt("publicationYear", book.getPublicationYear());
      writer.writeCollection("authors", book.getAuthors(), Author.class);
   }

   @Override
   public Book readFrom(ProtoStreamReader reader) throws IOException {
      String title = reader.readString("title");
      String description = reader.readString("description");
      int publicationYear = reader.readInt("publicationYear");
      Set<Author> authors = reader.readCollection("authors", new HashSet<>(), Author.class);
      return new Book(title, description, publicationYear, authors);
   }
}
```

Once you've followed these steps to setup your client you can start reading and writing Java objects to the remote cache and the actual data stored in the cache will be protobuf encoded provided that marshallers were registered with the remote client for all involved types (*Book* and *Author* in our example). Keeping your objects stored in protobuf format has the benefit of being able to consume them with compatible clients written in different languages.

11.3.2. Indexing of Protobuf encoded entries

After configuring the client as described in the previous section you can start configuring indexing for your caches on the server side. Activating indexing and the various indexing specific configurations is identical to embedded mode and is detailed in the Querying Red Hat Data Grid chapter.

There is however an extra configuration step involved. While in embedded mode the indexing metadata is obtained via Java reflection by analyzing the presence of various Hibernate Search annotations on the entry's class, this is obviously not possible if the entry is protobuf encoded. The server needs to obtain the relevant metadata from the same descriptor (.proto file) as the client. The descriptors are stored in a dedicated cache on the server named *'___protobuf_metadata'*. Both keys and values in this cache are plain strings. Registering a new schema is therefore as simple as performing a *put* operation on this cache using the schema's name as key and the schema file itself as the value. Alternatively you can use the CLI (via the cache-container=*:register-proto-schemas() operation), the Management Console or the *ProtobufMetadataManager* MBean via JMX. Be aware that, when security is enabled, access to the schema cache via the remote protocols requires that the user belongs to the '___schema_manager' role.

NOTE

Once indexing is enabled for a cache all fields of Protobuf encoded entries will be fully indexed unless you use the *@Indexed* and *@Field* protobuf schema pseudo-annotations in order to control precisely what fields need to get indexed. The default behaviour can be very inefficient when dealing with types having many or very larger fields so we encourage you to always specify what fields should be indexed instead of relying on the default indexing behaviour. The indexing behaviour for protobuf message types that are not annotated can also be modified per each schema file by setting the protobuf schema option *'indexed_by_default'* to *false* (its default value is considered *true*) at the beginning of your schema file.

```
option indexed_by_default = false;  // This disables indexing of types that are not annotated for
indexing
```

11.3.3. A remote query example

You've managed to configure both client and server to talk protobuf and you've enabled indexing. Let's put some data in the cache and try to search for it then!

```
import org.infinispan.client.hotrod.*;
import org.infinispan.query.dsl.*;
...

RemoteCacheManager remoteCacheManager = ...;
RemoteCache<Integer, Book> remoteCache = remoteCacheManager.getCache();

Book book1 = new Book();
book1.setTitle("Hibernate in Action");
remoteCache.put(1, book1);

Book book2 = new Book();
book2.setTile("Hibernate Search in Action");
remoteCache.put(2, book2);

QueryFactory qf = Search.getQueryFactory(remoteCache);
Query query = qf.from(Book.class)
            .having("title").like("%Hibernate Search%")
            .build();

List<Book> list = query.list(); // Voila! We have our book back from the cache!
```

The key part of creating a query is obtaining the *QueryFactory* for the remote cache using the *org.infinispan.client.hotrod.Search.getQueryFactory()* method. Once you have this creating the query is similar to embedded mode which is covered in this section.

11.3.4. Analysis

Analysis is a process that converts input data into one or more terms that you can index and query.

11.3.4.1. Default Analyzers

Red Hat Data Grid provides a set of default analyzers as follows:

Definition	Description
standard	Splits text fields into tokens, treating whitespace and punctuation as delimiters.
simple	Tokenizes input streams by delimiting at non-letters and then converting all letters to lowercase characters. Whitespace and non-letters are discarded.
whitespace	Splits text streams on whitespace and returns sequences of non-whitespace characters as tokens.
keyword	Treats entire text fields as single tokens.
stemmer	Stems English words using the Snowball Porter filter.
ngram	Generates n-gram tokens that are 3 grams in size by default.
filename	Splits text fields into larger size tokens than the **standard** analyzer, treating whitespace as a delimiter and converts all letters to lowercase characters.

These analyzer definitions are based on Apache Lucene and are provided "as-is". For more information about tokenizers, filters, and CharFilters, see the appropriate Lucene documentation.

11.3.4.2. Using Analyzer Definitions

To use analyzer definitions, reference them by name in the *.proto* schema file.

1. Include the **Analyze.YES** attribute to indicate that the property is analyzed.
2. Specify the analyzer definition with the **@Analyzer** annotation.

The following example shows referenced analyzer definitions:

```
/* @Indexed */
message TestEntity {

   /* @Field(store = Store.YES, analyze = Analyze.YES, analyzer = @Analyzer(definition =
"keyword")) */
   optional string id = 1;

   /* @Field(store = Store.YES, analyze = Analyze.YES, analyzer = @Analyzer(definition = "simple"))
*/
   optional string name = 2;
}
```

11.3.4.3. Creating Custom Analyzer Definitions

If you require custom analyzer definitions, do the following:

1. Create an implementation of the **ProgrammaticSearchMappingProvider** interface packaged in a **JAR** file.
2. Provide a file named **org.infinispan.query.spi.ProgrammaticSearchMappingProvider** in the **META-INF/services/** directory of your **JAR**. This file should contain the fully qualified class name of your implementation.
3. Copy the **JAR** to the **standalone/deployments** directory of your Red Hat Data Grid installation.

IMPORTANT

Your deployment must be available to the Red Hat Data Grid server during startup. You cannot add the deployment if the server is already running.

The following is an example implementation of the **ProgrammaticSearchMappingProvider** interface:

```
import org.apache.lucene.analysis.core.LowerCaseFilterFactory;
import org.apache.lucene.analysis.core.StopFilterFactory;
import org.apache.lucene.analysis.standard.StandardFilterFactory;
import org.apache.lucene.analysis.standard.StandardTokenizerFactory;
import org.hibernate.search.cfg.SearchMapping;
import org.infinispan.Cache;
import org.infinispan.query.spi.ProgrammaticSearchMappingProvider;

public final class MyAnalyzerProvider implements ProgrammaticSearchMappingProvider {

   @Override
   public void defineMappings(Cache cache, SearchMapping searchMapping) {
      searchMapping
            .analyzerDef("standard-with-stop", StandardTokenizerFactory.class)
               .filter(StandardFilterFactory.class)
               .filter(LowerCaseFilterFactory.class)
               .filter(StopFilterFactory.class);
   }
}
```

4. Specify the **JAR** in the cache container configuration, for example:

```
<cache-container name="mycache" default-cache="default">
  <modules>
    <module name="deployment.analyzers.jar"/>
  </modules>
...
```

11.4. STATISTICS

Query *Statistics* can be obtained from the *SearchManager*, as demonstrated in the following code snippet.

```
SearchManager searchManager = Search.getSearchManager(cache);
org.hibernate.search.stat.Statistics statistics = searchManager.getStatistics();
```

TIP

This data is also available via JMX through the Hibernate Search StatisticsInfoMBean registered under the name **org.infinispan:type=Query,manager="{name-of-cache-manager}",cache="{name-of-cache}",component=Statistics**. Please note this MBean is always registered by Red Hat Data Grid but the statistics are collected only if statistics collection is enabled at cache level.

WARNING

Hibernate Search has its own configuration properties **hibernate.search.jmx_enabled** and **hibernate.search.generate_statistics** for JMX statistics as explained here. Using them with Red Hat Data Grid Query is forbidden as it will only lead to duplicated MBeans and unpredictable results.

11.5. PERFORMANCE TUNING

11.5.1. Batch writing in SYNC mode

By default, the Index Managers work in sync mode, meaning when data is written to Red Hat Data Grid, it will perform the indexing operations synchronously. This synchronicity guarantees indexes are always consistent with the data (and thus visible in searches), but can slowdown write operations since it will also perform a commit to the index. Committing is an extremely expensive operation in Lucene, and for that reason, multiple writes from different nodes can be automatically batched into a single commit to reduce the impact.

So, when doing data loads to Red Hat Data Grid with index enabled, try to use multiple threads to take advantage of this batching.

If using multiple threads does not result in the required performance, an alternative is to load data with indexing temporarily disabled and run a re-indexing operation afterwards. This can be done writing data with the **SKIP_INDEXING** flag:

```
cache.getAdvancedCache().withFlags(Flag.SKIP_INDEXING).put("key","value");
```

11.5.2. Writing using async mode

If it's acceptable a small delay between data writes and when that data is visible in queries, an index manager can be configured to work in **async mode**. The async mode offers much better writing performance, since in this mode commits happen at a configurable interval.

Configuration:

```
<distributed-cache name="default">
   <indexing index="LOCAL">
      <property name="default.indexmanager">
            org.infinispan.query.indexmanager.InfinispanIndexManager
      </property>
      <!-- Index data in async mode -->
      <property name="default.worker.execution">async</property>
      <!-- Optional: configure the commit interval, default is 1000ms -->
      <property name="default.index_flush_interval">500</property>
   </indexing>
</distributed-cache>
```

11.5.3. Index reader async strategy

Lucene internally works with snapshots of the index: once an *IndexReader* is opened, it will only see the index changes up to the point it was opened; further index changes will not be visible until the *IndexReader* is refreshed. The Index Managers used in Red Hat Data Grid by default will check the freshness of the index readers before every query and refresh them if necessary.

It is possible to tune this strategy to relax this freshness checking to a pre-configured interval by using the **reader.strategy** configuration set as **async**:

```
<distributed-cache name="default"
                   key-partitioner="org.infinispan.distribution.ch.impl.AffinityPartitioner">
   <indexing index="PRIMARY_OWNER">
      <property name="default.indexmanager">
            org.infinispan.query.affinity.AffinityIndexManager
      </property>
      <property name="default.reader.strategy">async</property>
      <!-- refresh reader every 1s, default is 5s -->
      <property name="default.reader.async_refresh_period_ms">1000</property>
   </indexing>
</distributed-cache>
```

The async reader strategy is particularly useful for Index Managers that rely on shards, such as the AffinityIndexManager.

11.5.4. Lucene Options

It is possible to apply tuning options in Lucene directly. For more details, see the Hibernate Search manual.

CHAPTER 12. CLUSTERED COUNTERS

Clustered counters are counters which are distributed and shared among all nodes in the Red Hat Data Grid cluster. Counters can have different consistency levels: strong and weak.

Although a strong/weak consistent counter has separate interfaces, both support updating its value, return the current value and they provide events when its value is updated. Details are provided below in this document to help you choose which one fits best your uses-case.

12.1. INSTALLATION AND CONFIGURATION

In order to start using the counters, you needs to add the dependency in your Maven **pom.xml** file:

pom.xml

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-clustered-counter</artifactId>
  <version>${version.infinispan}</version>
</dependency>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

The counters can be configured Red Hat Data Grid configuration file or on-demand via the **CounterManager** interface detailed later in this document. A counters configured in Red Hat Data Grid configuration file is created at boot time when the **EmbeddedCacheManager** is starting. Theses counters are started eagerly and they are available in all the cluster’s nodes.

configuration.xml

```
<?xml version="1.0" encoding="UTF-8"?>
<infinispan>
    <cache-container ...>
        <!-- if needed to persist counter, global state needs to be configured -->
        <global-state>
            ...
        </global-state>
        <!-- your caches configuration goes here -->
         <counters xmlns="urn:infinispan:config:counters:9.2" num-owners="3"
reliability="CONSISTENT">
             <strong-counter name="c1" initial-value="1" storage="PERSISTENT"/>
             <strong-counter name="c2" initial-value="2" storage="VOLATILE">
                 <lower-bound value="0"/>
             </strong-counter>
             <strong-counter name="c3" initial-value="3" storage="PERSISTENT">
                 <upper-bound value="5"/>
             </strong-counter>
             <strong-counter name="c4" initial-value="4" storage="VOLATILE">
                 <lower-bound value="0"/>
                 <upper-bound value="10"/>
             </strong-counter>
             <weak-counter name="c5" initial-value="5" storage="PERSISTENT" concurrency-level="1"/>
        </counters>
    </cache-container>
</infinispan>
```

or programmatically, in the **GlobalConfigurationBuilder**:

```
GlobalConfigurationBuilder globalConfigurationBuilder = ...;
CounterManagerConfigurationBuilder builder =
globalConfigurationBuilder.addModule(CounterManagerConfigurationBuilder.class);
builder.numOwner(3).reliability(Reliability.CONSISTENT);
builder.addStrongCounter().name("c1").initialValue(1).storage(Storage.PERSISTENT);
builder.addStrongCounter().name("c2").initialValue(2).lowerBound(0).storage(Storage.VOLATILE);
builder.addStrongCounter().name("c3").initialValue(3).upperBound(5).storage(Storage.PERSISTENT)
;
builder.addStrongCounter().name("c4").initialValue(4).lowerBound(0).upperBound(10).storage(Storag
e.VOLATILE);
builder.addWeakCounter().name("c5").initialValue(5).concurrencyLevel(1).storage(Storage.PERSIST
ENT);
```

On other hand, the counters can be configured on-demand, at any time after the **EmbeddedCacheManager** is initialized.

```
CounterManager manager = ...;
manager.defineCounter("c1",
CounterConfiguration.builder(CounterType.UNBOUNDED_STRONG).initialValue(1).storage(Storage.
PERSISTENT)build());
manager.defineCounter("c2",
CounterConfiguration.builder(CounterType.BOUNDED_STRONG).initialValue(2).lowerBound(0).stora
ge(Storage.VOLATILE).build());
manager.defineCounter("c3",
CounterConfiguration.builder(CounterType.BOUNDED_STRONG).initialValue(3).upperBound(5).stor
age(Storage.PERSISTENT).build());
manager.defineCounter("c4",
CounterConfiguration.builder(CounterType.BOUNDED_STRONG).initialValue(4).lowerBound(0).uppe
rBound(10).storage(Storage.VOLATILE).build());
manager.defineCounter("c2",
CounterConfiguration.builder(CounterType.WEAK).initialValue(5).concurrencyLevel(1).storage(Storag
e.PERSISTENT).build());
```

NOTE

CounterConfiguration is immutable and can be reused.

The method **defineCounter()** will return **true** if the counter is successful configured or **false** otherwise. However, if the configuration is invalid, the method will throw a **CounterConfigurationException**. To find out if a counter is already defined, use the method **isDefined()**.

```
CounterManager manager = ...
if (!manager.isDefined("someCounter")) {
    manager.define("someCounter", ...);
}
```

Per cluster attributes:

- **num-owners**: Sets the number of counter's copies to keep cluster-wide. A smaller number will make update operations faster but will support a lower number of server crashes. It **must be positive** and its default value is **2**.
- **reliability**: Sets the counter's update behavior in a network partition. Default value is **AVAILABLE** and valid values are:
  - **AVAILABLE**: all partitions are able to read and update the counter's value.
  - **CONSISTENT**: only the primary partition (majority of nodes) will be able to read and update the counter's value. The remaining partitions can only read its value.

Per counter attributes:

- **initial-value** [common]: Sets the counter's initial value. Default is **0** (zero).
- **storage** [common]: Sets the counter's behavior when the cluster is shutdown and restarted. Default value is **VOLATILE** and valid values are:
  - **VOLATILE**: the counter's value is only available in memory. The value will be lost when a cluster is shutdown.
  - **PERSISTENT**: the counter's value is stored in a private and local persistent store. The value is kept when the cluster is shutdown and restored after a restart.

NOTE

On-demand and **VOLATILE** counters will lose its value and configuration after a cluster shutdown. They must be defined again after the restart.

- **lower-bound** [strong]: Sets the strong consistent counter's lower bound. Default value is **Long.MIN_VALUE**.
- **upper-bound** [strong]: Sets the strong consistent counter's upper bound. Default value is **Long.MAX_VALUE**.

NOTE

If neither the **lower-bound** or **upper-bound** are configured, the strong counter is set as unbounded.

WARNING

The **initial-value** must be between **lower-bound** and **upper-bound** inclusive.

- **concurrency-level** [weak]: Sets the number of concurrent updates. Its value **must be positive** and the default value is **16**.

12.1.1. List counter names

To list all the counters defined, the method **CounterManager.getCounterNames()** returns a collection of all counter names created cluster-wide.

12.2. THE COUNTERMANAGER INTERFACE.

The **CounterManager** interface is the entry point to define, retrieve and remove a counter. It automatically listen to the creation of **EmbeddedCacheManager** and proceeds with the registration of an instance of it per **EmbeddedCacheManager**. It starts the caches needed to store the counter state and configures the default counters.

Retrieving the **CounterManager** is as simple as invoke the **EmbeddedCounterManagerFactory.asCounterManager(EmbeddedCacheManager)** as shown in the example below:

```
// create or obtain your EmbeddedCacheManager
EmbeddedCacheManager manager = ...;

// retrieve the CounterManager
CounterManager counterManager =
EmbeddedCounterManagerFactory.asCounterManager(manager);
```

For Hot Rod client, the **CounterManager** is registered in the RemoteCacheManager and it can be retrieved like:

```
// create or obtain your RemoteCacheManager
RemoteCacheManager manager = ...;

// retrieve the CounterManager
CounterManager counterManager = RemoteCounterManagerFactory.asCounterManager(manager);
```

NOTE

Hot Rod messages format can be found in Hot Rod Protocol 2.7

12.2.1. Remove a counter via CounterManager

WARNING

use with caution.

There is a difference between remove a counter via the **Strong/WeakCounter** interfaces and the **CounterManager**. The **CounterManager.remove(String)** removes the counter value from the cluster and removes all the listeners registered in the counter in the local counter instance. In addition, the counter instance is no longer reusable and it may return an invalid results.

On the other side, the **Strong/WeakCounter** removal only removes the counter value. The instance can still be reused and the listeners still works.

NOTE

The counter is re-created if it is accessed after a removal.

12.3. THE COUNTER

A counter can be strong (**StrongCounter**) or weakly consistent (**WeakCounter**) and both is identified by a name. They have a specific interface but they share some logic, namely, both of them are asynchronous (a **CompletableFuture** is returned by each operation), provide an update event and can be reset to its initial value.

If you don't want to use the async API, it is possible to return a synchronous counter via **sync()** method. The API is the same but without the **CompletableFuture** return value.

The following methods are common to both interfaces:

```
String getName();
CompletableFuture<Long> getValue();
CompletableFuture<Void> reset();
<T extends CounterListener> Handle<T> addListener(T listener);
CounterConfiguration getConfiguration();
CompletableFuture<Void> remove();
SyncStrongCounter sync(); //SyncWeakCounter for WeakCounter
```

- **getName()** returns the counter name (identifier).
- **getValue()** returns the current counter's value.
- **reset()** allows to reset the counter's value to its initial value.
- **addListener()** register a listener to receive update events. More details about it in the Notification and Events section.
- **getConfiguration()** returns the configuration used by the counter.
- **remove()** removes the counter value from the cluster. The instance can still be used and the listeners are kept.
- **sync()** creates a synchronous counter.

NOTE

The counter is re-created if it is accessed after a removal.

12.3.1. The StrongCounter interface: when the consistency or bounds matters.

The strong counter provides uses a single key stored in Red Hat Data Grid cache to provide the consistency needed. All the updates are performed under the key lock to updates its values. On other hand, the reads don't acquire any locks and reads the current value. Also, with this scheme, it allows to bound the counter value and provide atomic operations like compare-and-set/swap.

A **StrongCounter** can be retrieved from the **CounterManager** by using the **getStrongCounter()** method. As an example:

```
CounterManager counterManager = ...
StrongCounter aCounter = counterManager.getStrongCounter("my-counter);
```

WARNING

Since every operation will hit a single key, the **StrongCounter** has a higher contention rate.

The **StrongCounter** interface adds the following method:

```
default CompletableFuture<Long> incrementAndGet() {
   return addAndGet(1L);
}

default CompletableFuture<Long> decrementAndGet() {
   return addAndGet(-1L);
}

CompletableFuture<Long> addAndGet(long delta);

CompletableFuture<Boolean> compareAndSet(long expect, long update);

CompletableFuture<Long> compareAndSwap(long expect, long update);
```

- **incrementAndGet()** increments the counter by one and returns the new value.
- **decrementAndGet()** decrements the counter by one and returns the new value.
- **addAndGet()** adds a delta to the counter's value and returns the new value.
- **compareAndSet()** and **compareAndSwap()** atomically set the counter's value if the current value is the expected.

NOTE

A operation is considered completed when the **CompletableFuture** is completed.

NOTE

The difference between compare-and-set and compare-and-swap is that the former returns true if the operation succeeds while the later returns the previous value. The compare-and-swap is successful if the return value is the same as the expected.

12.3.1.1. Bounded StrongCounter

When bounded, all the update method above will throw a **CounterOutOfBoundsException** when they reached the lower or upper bound. The exception has the following methods to check which side bound has been reached:

```
public boolean isUpperBoundReached();
public boolean isLowerBoundReached();
```

12.3.1.2. Uses cases

The strong counter fits better in the following uses cases:

- When counter's value is needed after each update (example, cluster-wise ids generator or sequences)
- When a bounded counter is needed (example, rate limiter)

12.3.1.3. Usage Examples

```
StrongCounter counter = counterManager.getStrongCounter("unbounded_coutner");

// incrementing the counter
System.out.println("new value is " + counter.incrementAndGet().get());

// decrement the counter's value by 100 using the functional API
counter.addAndGet(-100).thenApply(v -> {
  System.out.println("new value is " + v);
  return null;
}).get

// alternative, you can do some work while the counter is updated
CompletableFuture<Long> f = counter.addAndGet(10);
// ... do some work ...
System.out.println("new value is " + f.get());

// and then, check the current value
System.out.println("current value is " + counter.getValue().get());

// finally, reset to initial value
counter.reset().get();
System.out.println("current value is " + counter.getValue().get());

// or set to a new value if zero
System.out.println("compare and set succeeded? " + counter.compareAndSet(0, 1));
```

And below, there is another example using a bounded counter:

```
StrongCounter counter = counterManager.getStrongCounter("bounded_counter");

// incrementing the counter
try {
   System.out.println("new value is " + counter.addAndGet(100).get());
} catch (ExecutionException e) {
   Throwable cause = e.getCause();
   if (cause instanceof CounterOutOfBoundsException) {
      if (((CounterOutOfBoundsException) cause).isUpperBoundReached()) {
         System.out.println("ops, upper bound reached.");
      } else if (((CounterOutOfBoundsException) cause).isLowerBoundReached()) {
         System.out.println("ops, lower bound reached.");
```

```
            }
        }
    }

    // now using the functional API
    counter.addAndGet(-100).handle((v, throwable) -> {
       if (throwable != null) {
          Throwable cause = throwable.getCause();
          if (cause instanceof CounterOutOfBoundsException) {
             if (((CounterOutOfBoundsException) cause).isUpperBoundReached()) {
                System.out.println("ops, upper bound reached.");
             } else if (((CounterOutOfBoundsException) cause).isLowerBoundReached()) {
                System.out.println("ops, lower bound reached.");
             }
          }
          return null;
       }
       System.out.println("new value is " + v);
       return null;
    }).get();
```

Compare-and-set vs Compare-and-swap examples:

```
StrongCounter counter = counterManager.getStrongCounter("my-counter");
long oldValue, newValue;
do {
   oldValue = counter.getValue().get();
   newValue = someLogic(oldValue);
} while (!counter.compareAndSet(oldValue, newValue).get());
```

With compare-and-swap, it saves one invocation counter invocation (**counter.getValue()**)

```
StrongCounter counter = counterManager.getStrongCounter("my-counter");
long oldValue = counter.getValue().get();
long currentValue, newValue;
do {
   currentValue = oldValue;
   newValue = someLogic(oldValue);
} while ((oldValue = counter.compareAndSwap(oldValue, newValue).get()) != currentValue);
```

12.3.2. The **WeakCounter** interface: when speed is needed

The **WeakCounter** stores the counter's value in multiple keys in Red Hat Data Grid cache. The number of keys created is configured by the **concurrency-level** attribute. Each key stores a partial state of the counter's value and it can be updated concurrently. It main advantage over the **StrongCounter** is the lower contention in the cache. On other hand, the read of its value is more expensive and bounds are not allowed.

WARNING

The reset operation should be handled with caution. It is **not** atomic and it produces intermediates values. These value may be seen by a read operation and by any listener registered.

A **WeakCounter** can be retrieved from the **CounterManager** by using the **getWeakCounter()** method. As an example:

```
CounterManager counterManager = ...
StrongCounter aCounter = counterManager.getWeakCounter("my-counter);
```

12.3.2.1. Weak Counter Interface

The **WeakCounter** adds the following methods:

```
default CompletableFuture<Void> increment() {
   return add(1L);
}

default CompletableFuture<Void> decrement() {
   return add(-1L);
}

CompletableFuture<Void> add(long delta);
```

They are similar to the `StrongCounter's methods but they don't return the new value.

12.3.2.2. Uses cases

The weak counter fits best in uses cases where the result of the update operation is not needed or the counter's value is not required too often. Collecting statistics is a good example of such an use case.

12.3.2.3. Examples

Below, there is an example of the weak counter usage.

```
WeakCounter counter = counterManager.getWeakCounter("my_counter");

// increment the counter and check its result
counter.increment().get();
System.out.println("current value is " + counter.getValue().get());

CompletableFuture<Void> f = counter.add(-100);
//do some work
f.get(); //wait until finished
System.out.println("current value is " + counter.getValue().get());

//using the functional API
```

```
counter.reset().whenComplete((aVoid, throwable) -> System.out.println("Reset done " + (throwable
== null ? "successfully" : "unsuccessfully"))).get();
System.out.println("current value is " + counter.getValue().get());
```

12.4. NOTIFICATIONS AND EVENTS

Both strong and weak counter supports a listener to receive its updates events. The listener must implement **CounterListener** and it can be registerer by the following method:

```
<T extends CounterListener> Handle<T> addListener(T listener);
```

The **CounterLister** has the following interface:

```
public interface CounterListener {
   void onUpdate(CounterEvent entry);
}
```

The **Handle** object returned has the main goal to remove the **CounterListener** when it is not longer needed. Also, it allows to have access to the **CounterListener** instance that is it handling. It has the following interface:

```
public interface Handle<T extends CounterListener> {
   T getCounterListener();
   void remove();
}
```

Finally, the **CounterEvent** has the previous and current value and state. It has the following interface:

```
public interface CounterEvent {
   long getOldValue();
   State getOldState();
   long getNewValue();
   State getNewState();
}
```

NOTE

The state is always **State.VALID** for unbounded strong counter and weak counter. **State.LOWER_BOUND_REACHED** and **State.UPPER_BOUND_REACHED** are only valid for bounded strong counters.

WARNING

The weak counter **reset()** operation will trigger multiple notification with intermediate values.

CHAPTER 13. CLUSTERED LOCK

A *clustered lock* is a lock which is distributed and shared among all nodes in the Red Hat Data Grid cluster and currently provides a way to execute code that will be synchronized between the nodes in a given cluster.

13.1. INSTALLATION

In order to start using the clustered locks, you needs to add the dependency in your Maven **pom.xml** file:

pom.xml

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-clustered-lock</artifactId>
  <version>${version.infinispan}</version>
</dependency>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

13.2. CLUSTEREDLOCK CONFIGURATION

Currently there is a single type of **ClusteredLock** supported : non reentrant, NODE ownership lock.

13.2.1. Ownership

- **NODE** When a **ClusteredLock** is defined, this lock can be used from all the nodes in the Red Hat Data Grid cluster. When the ownership is NODE type, this means that the owner of the lock is the Red Hat Data Grid node that acquired the lock at a given time. This means that each time we get a **ClusteredLock** instance with the **ClusteredCacheManager**, this instance will be the same instance for each Red Hat Data Grid node. This lock can be used to synchronize code between Red Hat Data Grid nodes. The advantage of this lock is that any thread in the node can release the lock at a given time.

- **INSTANCE** - not yet supported

When a **ClusteredLock** is defined, this lock can be used from all the nodes in the Red Hat Data Grid cluster. When the ownership is INSTANCE type, this means that the owner of the lock is the actual instance we acquired when **ClusteredLockManager.get("lockName")** is called.

This means that each time we get a **ClusteredLock** instance with the **ClusteredCacheManager**, this instance will be a new instance. This lock can be used to synchronize code between Red Hat Data Grid nodes and inside each Red Hat Data Grid node. The advantage of this lock is that only the instance that called 'lock' can release the lock.

13.2.2. Reentrancy

When a **ClusteredLock** is configured reentrant, the owner of the lock can reacquire the lock as many consecutive times as it wants while holding the lock.

Currently, only non reentrant locks are supported. This means that when two consecutive **lock** calls are sent for the same owner, the first call will acquire the lock if it's available, and the second call will block.

13.3. CLUSTEREDLOCKMANAGER INTERFACE

The **ClusteredLockManager** interface, **marked as experimental**, is the entry point to define, retrieve and remove a lock. It automatically listen to the creation of **EmbeddedCacheManager** and proceeds with the registration of an instance of it per **EmbeddedCacheManager**. It starts the internal caches needed to store the lock state.

Retrieving the **ClusteredLockManager** is as simple as invoking the **EmbeddedClusteredLockManagerFactory.from(EmbeddedCacheManager)** as shown in the example below:

```
// create or obtain your EmbeddedCacheManager
EmbeddedCacheManager manager = ...;

// retrieve the ClusteredLockManager
ClusteredLockManager clusteredLockManager =
EmbeddedClusteredLockManagerFactory.from(manager);
```

```
@Experimental
public interface ClusteredLockManager {

   boolean defineLock(String name);

   boolean defineLock(String name, ClusteredLockConfiguration configuration);

   ClusteredLock get(String name);

   ClusteredLockConfiguration getConfiguration(String name);

   boolean isDefined(String name);

   CompletableFuture<Boolean> remove(String name);

   CompletableFuture<Boolean> forceRelease(String name);
}
```

- **defineLock** : Defines a lock with the specified name and the default **ClusteredLockConfiguration**. It does not overwrite existing configurations.
- **defineLock(String name, ClusteredLockConfiguration configuration)** : Defines a lock with the specified name and **ClusteredLockConfiguration**. It does not overwrite existing configurations.
- **ClusteredLock get(String name)** : Get's a **ClusteredLock** by it's name. A call of **defineLock** must be done at least once in the cluster. See ownership level section to understand the implications of **get** method call.

Currently, the only ownership level supported is **NODE**.

- **ClusteredLockConfiguration getConfiguration(String name)** :

Returns the configuration of a **ClusteredLock**, if such exists.

- **boolean isDefined(String name)** : Checks if a lock is already defined.

- **CompletableFuture<Boolean> remove(String name)** : Removes a **ClusteredLock** if such exists.
- **CompletableFuture<Boolean> forceRelease(String name)** : Releases - or unlocks - a **ClusteredLock**, if such exists, no matter who is holding it at a given time. Calling this method may cause concurrency issues and has to be used in **exceptional situations**.

13.4. CLUSTEREDLOCK INTERFACE

ClusteredLock interface, **marked as experimental**, is the interface that implements the clustered locks.

```
@Experimental
public interface ClusteredLock {

   CompletableFuture<Void> lock();

   CompletableFuture<Boolean> tryLock();

   CompletableFuture<Boolean> tryLock(long time, TimeUnit unit);

   CompletableFuture<Void> unlock();

   CompletableFuture<Boolean> isLocked();

   CompletableFuture<Boolean> isLockedByMe();
}
```

- **lock** : Acquires the lock. If the lock is not available then call blocks until the lock is acquired. Currently, **there is no maximum time specified for a lock request to fail**, so this could cause thread starvation.
- **tryLock** Acquires the lock only if it is free at the time of invocation, and returns **true** in that case. This method does not block (or wait) for any lock acquisition.
- **tryLock(long time, TimeUnit unit)** If the lock is available this method returns immediately with **true**. If the lock is not available then the call waits until :
  - The lock is acquired
  - The specified waiting time elapses

If the time is less than or equal to zero, the method will not wait at all.

- **unlock**

Releases the lock. Only the holder of the lock may release the lock.

- **isLocked** Returns **true** when the lock is locked and **false** when the lock is released.
- **isLockedByMe** Returns **true** when the lock is owned by the caller and **false** when the lock is owned by someone else or it’s released.

13.4.1. Usage Examples

```
EmbeddedCache cm = ...;
```

```
ClusteredLockManager cclm = EmbeddedClusteredLockManagerFactory.from(cm);

lock.tryLock()
  .thenCompose(result -> {
     if (result) {
      try {
          // manipulate protected state
          } finally {
             return lock.unlock();
          }
     } else {
        // Do something else
     }
  });
}
```

13.5. CLUSTEREDLOCKMANAGER CONFIGURATION

You can configure **ClusteredLockManager** to use different strategies for locks, either declaratively or programmatically, with the following attributes:

num-owners

Defines the total number of nodes in each cluster that store the states of clustered locks. The default value is **-1**, which replicates the value to all nodes.

reliability

Controls how clustered locks behave when clusters split into partitions or multiple nodes leave a cluster. You can set the following values:

- **AVAILABLE**: Nodes in any partition can concurrently operate on locks.
- **CONSISTENT**: Only nodes that belong to the majority partition can operate on locks. This is the default value.

The following is an example declarative configuration for **ClusteredLockManager**:

```
<?xml version="1.0" encoding="UTF-8"?>
<infinispan
        xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
        xsi:schemaLocation="urn:infinispan:config:${infinispan.core.schema.version}
http://www.infinispan.org/schemas/infinispan-config-9.4.xsd"
        xmlns="urn:infinispan:config:9.4">
    ...
    <cache-container default-cache="default">
        <transport/>
        <local-cache name="default">
            <locking concurrency-level="100" acquire-timeout="1000"/>
        </local-cache>

        <clustered-locks xmlns="urn:infinispan:config:clustered-locks:9.4"
                         num-owners = "3"
                         reliability="AVAILABLE">
            <clustered-lock name="lock1" />
            <clustered-lock name="lock2" />
        </clustered-locks>
    </cache-container>
    ...
</infinispan>
```

CHAPTER 14. MULTIMAP CACHE

MutimapCache is a type of Red Hat Data Grid Cache that maps keys to values in which each key can contain multiple values.

14.1. INSTALLATION AND CONFIGURATION

pom.xml

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-multimap</artifactId>
  <version>${version.infinispan}</version>
</dependency>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

14.2. MULTIMAPCACHE API

MultimapCache API exposes several methods to interact with the Multimap Cache. All these methods are non-blocking in most of the cases. See [limitations]

```
public interface MultimapCache<K, V> {

  CompletableFuture<Void> put(K key, V value);

  CompletableFuture<Collection<V>> get(K key);

  CompletableFuture<Boolean> remove(K key);

  CompletableFuture<Boolean> remove(K key, V value);

  CompletableFuture<Void> remove(Predicate<? super V> p);

  CompletableFuture<Boolean> containsKey(K key);

  CompletableFuture<Boolean> containsValue(V value);

  CompletableFuture<Boolean> containsEntry(K key, V value);

  CompletableFuture<Long> size();

  boolean supportsDuplicates();

}
```

14.2.1. CompletableFuture<Void> put(K key, V value)

Puts a key-value pair in the multimap cache.

```
MultimapCache<String, String> multimapCache = ...;

multimapCache.put("girlNames", "marie")
```

```
            .thenCompose(r1 -> multimapCache.put("girlNames", "oihana"))
            .thenCompose(r3 -> multimapCache.get("girlNames"))
            .thenAccept(names -> {
                    if(names.contains("marie"))
                        System.out.println("Marie is a girl name");

                     if(names.contains("oihana"))
                        System.out.println("Oihana is a girl name");
                    });
```

The output of this code is :

```
Marie is a girl name
Oihana is a girl name
```

14.2.2. CompletableFuture<Collection<V>> get(K key)

Asynchronous that returns a view collection of the values associated with key in this multimap cache, if any. Any changes to the retrieved collection won't change the values in this multimap cache. When this method returns an empty collection, it means the key was not found.

14.2.3. CompletableFuture<Boolean> remove(K key)

Asynchronous that removes the entry associated with the key from the multimap cache, if such exists.

14.2.4. CompletableFuture<Boolean> remove(K key, V value)

Asynchronous that removes a key-value pair from the multimap cache, if such exists.

14.2.5. CompletableFuture<Void> remove(Predicate<? super V> p)

Asynchronous method. Removes every value that match the given predicate.

14.2.6. CompletableFuture<Boolean> containsKey(K key)

Asynchronous that returns true if this multimap contains the key.

14.2.7. CompletableFuture<Boolean> containsValue(V value)

Asynchronous that returns true if this multimap contains the value in at least one key.

14.2.8. CompletableFuture<Boolean> containsEntry(K key, V value)

Asynchronous that returns true if this multimap contains at least one key-value pair with the value.

14.2.9. CompletableFuture<Long> size()

Asynchronous that returns the number of key-value pairs in the multimap cache. It doesn't return the distinct number of keys.

14.2.10. boolean supportsDuplicates()

Asynchronous that returns true if the multimap cache supports duplicates. This means that the content of the multimap can be 'a' → ['1', '1', '2']. For now this method will always return false, as duplicates are not yet supported. The existence of a given value is determined by 'equals' and `hashcode' method’s contract.

14.3. CREATING A MULTIMAP CACHE

Currently the MultimapCache is configured as a regular cache. This can be done either by code or XML configuration. See how to configure a regular Cache in the section link to [configure a cache].

14.3.1. Embedded mode

```
// create or obtain your EmbeddedCacheManager
EmbeddedCacheManager cm = ... ;

// create or obtain a MultimapCacheManager passing the EmbeddedCacheManager
MultimapCacheManager multimapCacheManager =
EmbeddedMultimapCacheManagerFactory.from(cm);

// define the configuration for the multimap cache
multimapCacheManager.defineConfiguration(multimapCacheName, c.build());

// get the multimap cache
multimapCache = multimapCacheManager.get(multimapCacheName);
```

14.4. LIMITATIONS

In almost every case the Multimap Cache will behave as a regular Cache, but some limitations exist in the current version.

14.4.1. Support for duplicates

Duplicates are not supported yet. This means that the multimap won’t contain any duplicate key-value pair. Whenever put method is called, if the key-value pair already exist, this key-value par won’t be added. Methods used to check if a key-value pair is already present in the Multimap are the **equals** and **hashcode**.

14.4.2. Eviction

For now, the eviction works per key, and not per key-value pair. This means that whenever a key is evicted, all the values associated with the key will be evicted too. Eviction per key-value could be supported in the future.

14.4.3. Transactions

Implicit transactions are supported through the auto-commit and all the methods are non blocking. Explicit transactions work without blocking in most of the cases. Methods that will block are **size**, **containsEntry** and **remove(Predicate<? super V> p)**

CHAPTER 15. CDI SUPPORT

Red Hat Data Grid includes integration with Contexts and Dependency Injection (better known as CDI) via Red Hat Data Grid's **infinispan-cdi-embedded** or **infinispan-cdi-remote** module. CDI is part of Java EE specification and aims for managing beans' lifecycle inside the container. The integration allows to inject Cache interface and bridge Cache and CacheManager events. JCache annotations (JSR-107) are supported by **infinispan-jcache** and **infinispan-jcache-remote** artifacts. For more information have a look at Chapter 11 of the JCACHE specification.

15.1. MAVEN DEPENDENCIES

To include CDI support for Red Hat Data Grid in your project, use one of the following dependencies:

pom.xml for Embedded mode

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-cdi-embedded</artifactId>
  <version>${version.infinispan}</version>
</dependency>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

pom.xml for Remote mode

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-cdi-remote</artifactId>
  <version>${version.infinispan}</version>
</dependency>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

WHICH VERSION OF RED HAT DATA GRID SHOULD I USE?

We recommend using the latest final version Red Hat Data Grid.

15.2. EMBEDDED CACHE INTEGRATION

15.2.1. Inject an embedded cache

By default you can inject the default Red Hat Data Grid cache. Let's look at the following example:

Default cache injection

```
...
import javax.inject.Inject;

public class GreetingService {

    @Inject
    private Cache<String, String> cache;
    public String greet(String user) {
        String cachedValue = cache.get(user);
        if (cachedValue == null) {
            cachedValue = "Hello " + user;
            cache.put(user, cachedValue);
        }
        return cachedValue;
    }
}
```

If you want to use a specific cache rather than the default one, you just have to provide your own cache configuration and cache qualifier. See example below:

Qualifier example

```
...
import javax.inject.Qualifier;

@Qualifier
@Target({ElementType.FIELD, ElementType.PARAMETER, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
@Documented
public @interface GreetingCache {
}
```

Injecting Cache with qualifier

```
...
import org.infinispan.configuration.cache.Configuration;
import org.infinispan.configuration.cache.ConfigurationBuilder;
import org.infinispan.cdi.ConfigureCache;
import javax.enterprise.inject.Produces;

public class Config {

    @ConfigureCache("greeting-cache") // This is the cache name.
    @GreetingCache // This is the cache qualifier.
    @Produces
    public Configuration greetingCacheConfiguration() {
        return new ConfigurationBuilder()
                    .memory()
                        .size(1000)
                    .build();
    }

    // The same example without providing a custom configuration.
    // In this case the default cache configuration will be used.
    @ConfigureCache("greeting-cache")
    @GreetingCache
    @Produces
    public Configuration greetingCacheConfiguration;
}
```

To use this cache in the GreetingService add the **@GeetingCache** qualifier on your cache injection point.

15.2.2. Override the default embedded cache manager and configuration

You can override the default cache configuration used by the default **EmbeddedCacheManager**. For that, you just have to create a **Configuration** producer with default qualifiers as illustrated in the following snippet:

Overriding Configuration

```
public class Config {

    // By default CDI adds the @Default qualifier if no other qualifier is provided.
    @Produces
    public Configuration defaultEmbeddedCacheConfiguration() {
        return new ConfigurationBuilder()
                    .memory()
                        .size(100)
                    .build();
    }
}
```

It’s also possible to override the default **EmbeddedCacheManager**. The newly created manager must have default qualifiers and Application scope.

Overriding EmbeddedCacheManager

```
...
import javax.enterprise.context.ApplicationScoped;

public class Config {

    @Produces
    @ApplicationScoped
    public EmbeddedCacheManager defaultEmbeddedCacheManager() {
      return new DefaultCacheManager(new ConfigurationBuilder()
                                          .memory()
                                              .size(100)
                                          .build());
   }
}
```

15.2.3. Configure the transport for clustered use

To use Red Hat Data Grid in a clustered mode you have to configure the transport with the **GlobalConfiguration**. To achieve that override the default cache manager as explained in the previous section. Look at the following snippet:

Overriding default EmbeddedCacheManager

```
...
package org.infinispan.configuration.global.GlobalConfigurationBuilder;
```

```
@Produces
@ApplicationScoped
public EmbeddedCacheManager defaultClusteredCacheManager() {
    return new DefaultCacheManager(
        new GlobalConfigurationBuilder().transport().defaultTransport().build(),
        new ConfigurationBuilder().memory().size(7).build()
    );
}
```

15.3. REMOTE CACHE INTEGRATION

15.3.1. Inject a remote cache

With the CDI integration it's also possible to use a **RemoteCache** as illustrated in the following snippet:

Injecting RemoteCache

```
public class GreetingService {

    @Inject
    private RemoteCache<String, String> cache;

    public String greet(String user) {
        String cachedValue = cache.get(user);
        if (cachedValue == null) {
            cachedValue = "Hello " + user;
            cache.put(user, cachedValue);
        }
        return cachedValue;
    }
}
```

If you want to use another cache, for example the greeting-cache, add the **@Remote** qualifier on the cache injection point which contains the cache name.

Injecting RemoteCache with qualifier

```
public class GreetingService {

    @Inject
    @Remote("greeting-cache")
    private RemoteCache<String, String> cache;

    ...
}
```

Adding the **@Remote** cache qualifier on each injection point might be error prone. That's why the remote cache integration provides another way to achieve the same goal. For that you have to create your own qualifier annotated with **@Remote**:

RemoteCache qualifier

```
@Remote("greeting-cache")
```

```
@Qualifier
@Target({ElementType.FIELD, ElementType.PARAMETER, ElementType.METHOD})
@Retention(RetentionPolicy.RUNTIME)
@Documented
public @interface RemoteGreetingCache {
}
```

To use this cache in the GreetingService add the qualifier **@RemoteGreetingCache** qualifier on your cache injection.

15.3.2. Override the default remote cache manager

Like the embedded cache integration, the remote cache integration comes with a default remote cache manager producer. This default **RemoteCacheManager** can be overridden as illustrated in the following snippet:

Overriding default RemoteCacheManager

```
public class Config {

    @Produces
    @ApplicationScoped
    public RemoteCacheManager defaultRemoteCacheManager() {
        return new RemoteCacheManager(localhost, 1544);
    }
}
```

15.4. USE A CUSTOM REMOTE/EMBEDDED CACHE MANAGER FOR ONE OR MORE CACHE

It's possible to use a custom cache manager for one or more cache. You just need to annotate the cache manager producer with the cache qualifiers. Look at the following example:

```
public class Config {

   @GreetingCache
   @Produces
   @ApplicationScoped
   public EmbeddedCacheManager specificEmbeddedCacheManager() {
      return new DefaultCacheManager(new ConfigurationBuilder()
                                      .expiration()
                                          .lifespan(60000l)
                                      .build());
   }

   @RemoteGreetingCache
   @Produces
   @ApplicationScoped
   public RemoteCacheManager specificRemoteCacheManager() {
       return new RemoteCacheManager("localhost", 1544);
   }
}
```

With the above code the GreetingCache or the RemoteGreetingCache will be associated with the produced cache manager.

PRODUCER METHOD SCOPE

To work properly the producers must have the scope @ApplicationScoped . Otherwise each injection of cache will be associated to a new instance of cache manager.

15.5. USE JCACHE CACHING ANNOTATIONS

TIP

There is now a separate module for JSR 107 (JCACHE) integration, including API. See this chapter for details.

When CDI integration and JCache artifacts are present on the classpath, it is possible to use JCache annotations with CDI managed beans. These annotations provide a simple way to handle common use cases. The following caching annotations are defined in this specification:

- **@CacheResult** - caches the result of a method call
- **@CachePut** - caches a method parameter
- **@CacheRemoveEntry** - removes an entry from a cache
- **@CacheRemoveAll** - removes all entries from a cache

ANNOTATIONS TARGET TYPE

These annotations must only be used on methods.

To use these annotations, proper interceptors need to be declared in **beans.xml** file:

Interceptors for managed environments such as Application Servers

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://xmlns.jcp.org/xml/ns/javaee"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation="http://xmlns.jcp.org/xml/ns/javaee
http://xmlns.jcp.org/xml/ns/javaee/beans_1_1.xsd"
   version="1.2" bean-discovery-mode="annotated">

  <interceptors>
    <class>org.infinispan.jcache.annotation.InjectedCacheResultInterceptor</class>
    <class>org.infinispan.jcache.annotation.InjectedCachePutInterceptor</class>
    <class>org.infinispan.jcache.annotation.InjectedCacheRemoveEntryInterceptor</class>
    <class>org.infinispan.jcache.annotation.InjectedCacheRemoveAllInterceptor</class>
  </interceptors>
</beans>
```

Interceptors for unmanaged environments such as standalone applications

```
<?xml version="1.0" encoding="UTF-8"?>
<beans xmlns="http://xmlns.jcp.org/xml/ns/javaee"
   xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
   xsi:schemaLocation="http://xmlns.jcp.org/xml/ns/javaee
http://xmlns.jcp.org/xml/ns/javaee/beans_1_1.xsd"
   version="1.2" bean-discovery-mode="annotated">

  <interceptors>
    <class>org.infinispan.jcache.annotation.CacheResultInterceptor</class>
    <class>org.infinispan.jcache.annotation.CachePutInterceptor</class>
    <class>org.infinispan.jcache.annotation.CacheRemoveEntryInterceptor</class>
    <class>org.infinispan.jcache.annotation.CacheRemoveAllInterceptor</class>
  </interceptors>
</beans>
```

The following snippet of code illustrates the use of **@CacheResult** annotation. As you can see it simplifies the caching of the **Greetingservice#greet** method results.

Using JCache annotations

```
import javax.cache.interceptor.CacheResult;

public class GreetingService {

    @CacheResult
    public String greet(String user) {
        return "Hello" + user;
    }
}
```

The first version of the **GreetingService** and the above version have exactly the same behavior. The only difference is the cache used. By default it's the fully qualified name of the annotated method with its parameter types (e.g. **org.infinispan.example.GreetingService.greet(java.lang.String)**).

Using other cache than default is rather simple. All you need to do is to specify its name with the **cacheName** attribute of the cache annotation. For example:

Specifying cache name for JCache

```
@CacheResult(cacheName = "greeting-cache")
```

15.6. USE CACHE EVENTS AND CDI

It is possible to receive Cache and Cache Manager level events using CDI Events. You can achieve it using **@Observes** annotation as shown in the following snippet:

Event listeners based on CDI

```
import javax.enterprise.event.Observes;
import org.infinispan.notifications.cachemanagerlistener.event.CacheStartedEvent;
import org.infinispan.notifications.cachelistener.event.*;
```

```
public class GreetingService {

    // Cache level events
    private void entryRemovedFromCache(@Observes CacheEntryCreatedEvent event) {
        ...
    }

    // Cache Manager level events
    private void cacheStarted(@Observes CacheStartedEvent event) {
        ...
    }
}
```

TIP

Check Listeners and Notifications for more information about event types.

CHAPTER 16. JCACHE (JSR-107) PROVIDER

Red Hat Data Grid provides an implementation of JCache 1.0 API (JSR-107). JCache specifies a standard Java API for caching temporary Java objects in memory. Caching java objects can help get around bottlenecks arising from using data that is expensive to retrieve (i.e. DB or web service), or data that is hard to calculate. Caching these type of objects in memory can help speed up application performance by retrieving the data directly from memory instead of doing an expensive roundtrip or recalculation. This document specifies how to use JCache with Red Hat Data Grid's implementation of the specification, and explains key aspects of the API.

16.1. DEPENDENCIES

In order to start using Red Hat Data Grid JCache implementation, a single dependency needs to be added to the Maven pom.xml file:

pom.xml

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-jcache</artifactId>
  <version>${version.infinispan}</version>
  <scope>test</scope>
</dependency>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

16.2. CREATE A LOCAL CACHE

Creating a local cache, using default configuration options as defined by the JCache API specification, is as simple as doing the following:

```
import javax.cache.*;
import javax.cache.configuration.*;

// Retrieve the system wide cache manager
CacheManager cacheManager = Caching.getCachingProvider().getCacheManager();
// Define a named cache with default JCache configuration
Cache<String, String> cache = cacheManager.createCache("namedCache",
      new MutableConfiguration<String, String>());
```

WARNING

By default, the JCache API specifies that data should be stored as **storeByValue**, so that object state mutations outside of operations to the cache, won't have an impact in the objects stored in the cache. Red Hat Data Grid has so far implemented this using serialization/marshalling to make copies to store in the cache, and that way adhere to the spec. Hence, if using default JCache configuration with Red Hat Data Grid, data stored must be marshallable.

Alternatively, JCache can be configured to store data by reference (just like Red Hat Data Grid or JDK Collections work). To do that, simply call:

```
Cache<String, String> cache = cacheManager.createCache("namedCache",
    new MutableConfiguration<String, String>().setStoreByValue(false));
```

16.3. CREATE A REMOTE CACHE

Creating a remote cache (client-server mode), using default configuration options as defined by the JCache API specification, is as simple as doing the following:

```
import javax.cache.*;
import javax.cache.configuration.*;

// Retrieve the system wide cache manager via org.infinispan.jcache.remote.JCachingProvider
CacheManager cacheManager =
Caching.getCachingProvider("org.infinispan.jcache.remote.JCachingProvider").getCacheManager();
// Define a named cache with default JCache configuration
Cache<String, String> cache = cacheManager.createCache("remoteNamedCache",
    new MutableConfiguration<String, String>());
```

NOTE

In order to use the org.infinispan.jcache.remote.JCachingProvider, infinispan-jcache-remote-<version>.jar and all its transitive dependencies need to be on put your classpath.

16.4. STORE AND RETRIEVE DATA

Even though JCache API does not extend neither java.util.Map not java.util.concurrent.ConcurrentMap, it providers a key/value API to store and retrieve data:

```
import javax.cache.*;
import javax.cache.configuration.*;

CacheManager cacheManager = Caching.getCacheManager();
Cache<String, String> cache = cacheManager.createCache("namedCache",
    new MutableConfiguration<String, String>());
cache.put("hello", "world"); // Notice that javax.cache.Cache.put(K) returns void!
String value = cache.get("hello"); // Returns "world"
```

Contrary to standard java.util.Map, javax.cache.Cache comes with two basic put methods called put and getAndPut. The former returns **void** whereas the latter returns the previous value associated with the key. So, the equivalent of java.util.Map.put(K) in JCache is javax.cache.Cache.getAndPut(K).

TIP

Even though JCache API only covers standalone caching, it can be plugged with a persistence store, and has been designed with clustering or distribution in mind. The reason why javax.cache.Cache offers two put methods is because standard java.util.Map put call forces implementors to calculate the previous value. When a persistent store is in use, or the cache is distributed, returning the previous value could be an expensive operation, and often users call standard java.util.Map.put(K) without using the return value. Hence, JCache users need to think about whether the return value is relevant to them, in which case they need to call javax.cache.Cache.getAndPut(K) , otherwise they can call java.util.Map.put(K, V) which avoids returning the potentially expensive operation of returning the previous value.

16.5. COMPARING JAVA.UTIL.CONCURRENT.CONCURRENTMAP AND JAVAX.CACHE.CACHE APIS

Here's a brief comparison of the data manipulation APIs provided by java.util.concurrent.ConcurrentMap and javax.cache.Cache APIs.

Operation	java.util.concurrent.ConcurrentMap<K, V>	javax.cache.Cache<K, V>
store and no return	N/A	**void put(K key)**
store and return previous value	**V put(K key)**	**V getAndPut(K key)**
store if not present	**V putIfAbsent(K key, V value)**	**boolean putIfAbsent(K key, V value)**
retrieve	**V get(Object key)**	**V get(K key)**
delete if present	**V remove(Object key)**	**boolean remove(K key)**
delete and return previous value	**V remove(Object key)**	**V getAndRemove(K key)**
delete conditional	**boolean remove(Object key, Object value)**	**boolean remove(K key, V oldValue)**
replace if present	**V replace(K key, V value)**	**boolean replace(K key, V value)**
replace and return previous value	**V replace(K key, V value)**	**V getAndReplace(K key, V value)**
replace conditional	**boolean replace(K key, V oldValue, V newValue)**	**boolean replace(K key, V oldValue, V newValue)**

Comparing the two APIs, it's obvious to see that, where possible, JCache avoids returning the previous value to avoid operations doing expensive network or IO operations. This is an overriding principle in the design of JCache API. In fact, there's a set of operations that are present in java.util.concurrent.ConcurrentMap , but are not present in the javax.cache.Cache because they could be expensive to compute in a distributed cache. The only exception is iterating over the contents of the cache:

Operation	java.util.concurrent.ConcurrentMap<K, V>	javax.cache.Cache<K, V>
calculate size of cache	**int size()**	N/A
return all keys in the cache	**Set<K> keySet()**	N/A
return all values in the cache	**Collection<V> values()**	N/A
return all entries in the cache	**Set<Map.Entry<K, V>> entrySet()**	N/A
iterate over the cache	use **iterator()** method on keySet, values or entrySet	**Iterator<Cache.Entry<K, V>> iterator()**

16.6. CLUSTERING JCACHE INSTANCES

Red Hat Data Grid JCache implementation goes beyond the specification in order to provide the possibility to cluster caches using the standard API. Given a Red Hat Data Grid configuration file configured to replicate caches like this:

infinispan.xml

```
<infinispan>
  <cache-container default-cache="namedCache">
    <transport cluster="jcache-cluster" />
    <replicated-cache name="namedCache" />
  </cache-container>
</infinispan>
```

You can create a cluster of caches using this code:

```
import javax.cache.*;
import java.net.URI;

// For multiple cache managers to be constructed with the standard JCache API
// and live in the same JVM, either their names, or their classloaders, must
// be different.
// This example shows how to force their classloaders to be different.
// An alternative method would have been to duplicate the XML file and give
// it a different name, but this results in unnecessary file duplication.
ClassLoader tccl = Thread.currentThread().getContextClassLoader();
CacheManager cacheManager1 = Caching.getCachingProvider().getCacheManager(
    URI.create("infinispan-jcache-cluster.xml"), new TestClassLoader(tccl));
CacheManager cacheManager2 = Caching.getCachingProvider().getCacheManager(
    URI.create("infinispan-jcache-cluster.xml"), new TestClassLoader(tccl));

Cache<String, String> cache1 = cacheManager1.getCache("namedCache");
```

```
Cache<String, String> cache2 = cacheManager2.getCache("namedCache");

cache1.put("hello", "world");
String value = cache2.get("hello"); // Returns "world" if clustering is working

// --

public static class TestClassLoader extends ClassLoader {
  public TestClassLoader(ClassLoader parent) {
     super(parent);
  }
}
```

CHAPTER 17. MANAGEMENT TOOLING

Management of Red Hat Data Grid instances is all about exposing as much relevant statistical information that allows administrators to get a view of the state of each Red Hat Data Grid instance. Taking in account that a single installation could be made up of several tens or hundreds Red Hat Data Grid instances, providing clear and concise information in an efficient manner is imperative. The following sections dive into the range of management tooling that Red Hat Data Grid provides.

17.1. JMX

Over the years, JMX has become the de facto standard for management and administration of middleware and as a result, the Red Hat Data Grid team has decided to standardize on this technology for the exposure of management and statistical information.

17.1.1. Understanding The Exposed MBeans

By connecting to the VM(s) where Red Hat Data Grid is running with a standard JMX GUI such as JConsole or VisualVM you should find the following MBeans:

- For CacheManager level JMX statistics, without further configuration, you should see an MBean called *org.infinispan:type=CacheManager,name="DefaultCacheManager"* with properties specified by the CacheManager MBean .

- Using the cacheManagerName attribute in globalJmxStatistics XML element, or using the corresponding GlobalJmxStatisticsConfigurationBuilder.cacheManagerName(String cacheManagerName) call, you can name the cache manager in such way that the name is used as part of the JMX object name. So, if the name had been "Hibernate2LC", the JMX name for the cache manager would have been: *org.infinispan:type=CacheManager,name="Hibernate2LC"* . This offers a nice and clean way to manage environments where multiple cache managers are deployed, which follows JMX best practices .

- For Cache level JMX statistics, you should see several different MBeans depending on which configuration options have been enabled. For example, if you have configured a write behind cache store, you should see an MBean exposing properties belonging to the cache store component. All Cache level MBeans follow the same format though which is the following: **org.infinispan:type=Cache,name="${name-of-cache}(${cache-mode})",manager="${name-of-cache-manager}",component=${component-name}** where:

- ${name-of-cache} has been substituted by the actual cache name. If this cache represents the default cache, its name will be **___defaultCache**.

- ${cache-mode} has been substituted by the cache mode of the cache. The cache mode is represented by the lower case version of the possible enumeration values shown here.

- ${name-of-cache-manager} has been substituted by the name of the cache manager to which this cache belongs. The name is derived from the *cacheManagerName* attribute value in **globalJmxStatistics** element.

- ${component-name} has been substituted by one of the JMX component names in the JMX reference documentation .

For example, the cache store JMX component MBean for a default cache configured with synchronous distribution would have the following name:
**org.infinispan:type=Cache,name="___defaultcache(dist_sync)",manager="DefaultCacheManager
",component=CacheStore**

Please note that cache and cache manager names are quoted to protect against illegal characters being used in these user-defined names.

17.1.2. Enabling JMX Statistics

The MBeans mentioned in the previous section are always created and registered in the MBeanServer allowing you to manage your caches but some of their attributes do not expose meaningful values unless you take the extra step of enabling collection of statistics. Gathering and reporting statistics via JMX can be enabled at 2 different levels:

CacheManager level

The CacheManager is the entity that governs all the cache instances that have been created from it. Enabling CacheManager statistics collections differs depending on the configuration style:

- If configuring the CacheManager via XML, make sure you add the following XML under the **<cache-container />** element:

```
<cache-container statistics="true"/>
```

- If configuring the CacheManager programmatically, simply add the following code:

```
GlobalConfigurationBuilder globalConfigurationBuilder = ...
globalConfigurationBuilder.globalJmxStatistics().enable();
```

Cache level

At this level, you will receive management information generated by individual cache instances. Enabling Cache statistics collections differs depending on the configuration style:

- If configuring the Cache via XML, make sure you add the following XML under the one of the top level cache elements, such as **<local-cache />**:

```
<local-cache statistics="true"/>
```

- If configuring the Cache programmatically, simply add the following code:

```
ConfigurationBuilder configurationBuilder = ...
configurationBuilder.jmxStatistics().enable();
```

17.1.3. Monitoring cluster health

It is also possible to monitor Red Hat Data Grid cluster health using JMX. On CacheManager there’s an additional object called **CacheContainerHealth**. It contains the following attributes:

- cacheHealth - a list of caches and corresponding statuses (HEALTHY, UNHEALTHY or REBALANCING)
- clusterHealth - overall cluster health
- clusterName - cluster name
- freeMemoryKb - Free memory obtained from JVM runtime measured in KB
- numberOfCpus - The number of CPUs obtained from JVM runtime

- numberOfNodes - The number of nodes in the cluster
- totalMemoryKb - Total memory obtained from JVM runtime measured in KB

17.1.4. Multiple JMX Domains

There can be situations where several CacheManager instances are created in a single VM, or Cache names belonging to different CacheManagers under the same VM clash.

Using different JMX domains for multi cache manager environments should be last resort. Instead, it's possible to name a cache manager in such way that it can easily be identified and used by monitoring tools. For example:

- Via XML:

```
<cache-container statistics="true" name="Hibernate2LC"/>
```

- Programmatically:

```
GlobalConfigurationBuilder globalConfigurationBuilder = ...
globalConfigurationBuilder.globalJmxStatistics()
   .enable()
   .cacheManagerName("Hibernate2LC");
```

Using either of these options should result on the CacheManager MBean name being: **org.infinispan:type=CacheManager,name="Hibernate2LC"**

For the time being, you can still set your own jmxDomain if you need to and we also allow duplicate domains, or rather duplicate JMX names, but these should be limited to very special cases where different cache managers within the same JVM are named equally.

17.1.5. Registering MBeans In Non-Default MBean Servers

Let's discuss where Red Hat Data Grid registers all these MBeans. By default, Red Hat Data Grid registers them in the standard JVM MBeanServer platform . However, users might want to register these MBeans in a different MBeanServer instance. For example, an application server might work with a different MBeanServer instance to the default platform one. In such cases, users should implement the MBeanServerLookup interface provided by Red Hat Data Grid so that the getMBeanServer() method returns the MBeanServer under which Red Hat Data Grid should register the management MBeans. Once you have your implementation ready, simply configure Red Hat Data Grid with the fully qualified name of this class. For example:

- Via XML:

```
<cache-container statistics="true">
  <jmx mbean-server-lookup="com.acme.MyMBeanServerLookup" />
</cache-container>
```

- Programmatically:

```
GlobalConfigurationBuilder globalConfigurationBuilder = ...
globalConfigurationBuilder.globalJmxStatistics()
   .enable()
   .mBeanServerLookup(new com.acme.MyMBeanServerLookup());
```

17.1.6. Available MBeans

For a complete list of available MBeans, refer to the JMX reference documentation

17.2. COMMAND-LINE INTERFACE (CLI)

Red Hat Data Grid offers a simple Command-Line Interface (CLI) with which it is possible to interact with the data within the caches and with most of the internal components (e.g. transactions, cross-site backups, rolling upgrades).

The CLI is built out of two elements: a server-side module and the client command tool. The server-side module (**infinispan-cli-server-$VERSION.jar**) provides the actual interpreter for the commands and needs to be included alongside your application. Red Hat Data Grid Server includes CLI support out of the box.

Currently the server (and the client) use the JMX protocol to communicate, but in a future release we plan to support other communication protocols (in particular our own Hot Rod).

The CLI offers both an interactive and a batch mode. To invoke the client, run the *bin/cli.[sh|bat]* script.

The following is a list of command-line switches which affect how the CLI can be started:

```
-c, --connect=URL       connects to a running instance of Infinispan.
                        JMX over RMI jmx://[username[:password]]@host:port[/container[/cache]]
                        JMX over JBoss remoting
remoting://[username[:password]]@host:port[/container[/cache]]
-f, --file=FILE         reads input from the specified file instead of using
                        interactive mode. If FILE is '-', then commands will be read
                        from stdin
-h, --help              shows this help page
-v, --version           shows version information
```

- JMX over RMI is the traditional way in which JMX clients connect to MBeanServers. Please refer to the JDK Monitoring and Management documentation for details on how to configure the process to be monitored
- JMX over JBoss Remoting is the protocol of choice when your Red Hat Data Grid application is running inside EAP.

The connection to the application can also be initiated from within the CLI using the connect command.

```
[disconnected//]> connect jmx://localhost:12000
[jmx://localhost:12000/MyCacheManager/>
```

The CLI prompt will show the active connection information, including the currently selected CacheManager. Initially no cache is selected so, before performing any cache operations, one must be selected. For this the *cache* command is used. The CLI supports tab-completion for all commands and options and for most parameters where it makes sense to do so. Therefore typing *cache* and pressing TAB will show a list of active caches:

```
[jmx://localhost:12000/MyCacheManager/> cache
___defaultcache  namedCache
[jmx://localhost:12000/MyCacheManager/]> cache ___defaultcache
[jmx://localhost:12000/MyCacheManager/___defaultcache]>
```

Pressing TAB at an empty prompt will show the list of all available commands:

```
alias     cache      container  encoding   get     locate    remove    site      upgrade
abort     clearcache  create     end        help    put       replace   start     version
begin     commit     disconnect  evict      info    quit      rollback  stats
```

The CLI is based on Æsh and therefore offers many keyboard shortcuts to navigate and search the history of commands, to manipulate the cursor at the prompt, including both Emacs and VI modes of operation.

IMPORTANT

Red Hat Data Grid CLI sessions expire if they remain idle for more than six minutes. Running commands after the session expires results in the following message:

ISPN019015: Invalid session id '<session_id>'

You must restart the CLI to start a new session.

17.2.1. Commands

17.2.1.1. abort

The *abort* command is used to abort a running batch initiated by the *start* command

```
[jmx://localhost:12000/MyCacheManager/namedCache]> start
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> abort
[jmx://localhost:12000/MyCacheManager/namedCache]> get a
null
```

17.2.1.2. begin

The *begin* command starts a transaction. In order for this command to work, the cache(s) on which the subsequent operations are invoked must have transactions enabled.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> begin
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> put b b
[jmx://localhost:12000/MyCacheManager/namedCache]> commit
```

17.2.1.3. cache

The *cache* command selects the cache to use as default for all subsequent operations. If it is invoked without parameters it shows the currently selected cache.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> cache ___defaultcache
[jmx://localhost:12000/MyCacheManager/___defaultcache]> cache
___defaultcache
[jmx://localhost:12000/MyCacheManager/___defaultcache]>
```

17.2.1.4. clearcache

The *clearcache* command clears a cache from all content.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> clearcache
[jmx://localhost:12000/MyCacheManager/namedCache]> get a
null
```

17.2.1.5. commit

The *commit* command commits an ongoing transaction

```
[jmx://localhost:12000/MyCacheManager/namedCache]> begin
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> put b b
[jmx://localhost:12000/MyCacheManager/namedCache]> commit
```

17.2.1.6. container

The *container* command selects the default container (cache manager). Invoked without parameters it lists all available containers

```
[jmx://localhost:12000/MyCacheManager/namedCache]> container
MyCacheManager OtherCacheManager
[jmx://localhost:12000/MyCacheManager/namedCache]> container OtherCacheManager
[jmx://localhost:12000/OtherCacheManager/]>
```

17.2.1.7. create

The *create* command creates a new cache based on the configuration of an existing cache definition

```
[jmx://localhost:12000/MyCacheManager/namedCache]> create newCache like namedCache
[jmx://localhost:12000/MyCacheManager/namedCache]> cache newCache
[jmx://localhost:12000/MyCacheManager/newCache]>
```

17.2.1.8. deny

When authorization is enabled and the role mapper has been configured to be the ClusterRoleMapper, principal to role mappings are stored within the cluster registry (a replicated cache available to all nodes). The *deny* command can be used to deny roles previously assigned to a principal:

```
[remoting://localhost:9999]> deny supervisor to user1
```

17.2.1.9. disconnect

The *disconnect* command disconnects the currently active connection allowing the CLI to connect to another instance.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> disconnect
[disconnected//]
```

17.2.1.10. encoding

The *encoding* command is used to set a default codec to use when reading/writing entries from/to a cache. When invoked without arguments it shows the currently selected codec. This command is useful since currently remote protocols such as HotRod and Memcached wrap keys and values in specialized structures.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> encoding
none
[jmx://localhost:12000/MyCacheManager/namedCache]> encoding --list
memcached
hotrod
none
rest
[jmx://localhost:12000/MyCacheManager/namedCache]> encoding hotrod
```

17.2.1.11. end

The *end* command is used to successfully end a running batch initiated by the *start* command

```
[jmx://localhost:12000/MyCacheManager/namedCache]> start
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> end
[jmx://localhost:12000/MyCacheManager/namedCache]> get a
a
```

17.2.1.12. evict

The *evict* command is used to evict from the cache the entry associated with a specific key.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> evict a
```

17.2.1.13. get

The *get* command is used to show the value associated to a specified key. For primitive types and Strings, the *get* command will simply print the default representation. For other objects, a JSON representation of the object will be printed.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> get a
a
```

17.2.1.14. grant

When authorization is enabled and the role mapper has been configured to be the ClusterRoleMapper, principal to role mappings are stored within the cluster registry (a replicated cache available to all nodes). The *grant* command can be used to grant new roles to a principal:

```
[remoting://localhost:9999]> grant supervisor to user1
```

17.2.1.15. info

The *info* command is used to show the configuration of the currently selected cache or container.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> info
GlobalConfiguration{asyncListenerExecutor=ExecutorFactoryConfiguration{factory=org.infinispan.execu
ors.DefaultExecutorFactory@98add58},
asyncTransportExecutor=ExecutorFactoryConfiguration{factory=org.infinispan.executors.DefaultExecut
rFactory@7bc9c14c},
evictionScheduledExecutor=ScheduledExecutorFactoryConfiguration{factory=org.infinispan.executors.D
efaultScheduledExecutorFactory@7ab1a411},
replicationQueueScheduledExecutor=ScheduledExecutorFactoryConfiguration{factory=org.infinispan.ex
ecutors.DefaultScheduledExecutorFactory@248a9705},
globalJmxStatistics=GlobalJmxStatisticsConfiguration{allowDuplicateDomains=true, enabled=true,
jmxDomain='jboss.infinispan',
mBeanServerLookup=org.jboss.as.clustering.infinispan.MBeanServerProvider@6c0dc01,
cacheManagerName='local', properties={}}, transport=TransportConfiguration{clusterName='ISPN',
machineId='null', rackId='null', siteId='null', strictPeerToPeer=false, distributedSyncTimeout=240000,
transport=null, nodeName='null', properties={}},
serialization=SerializationConfiguration{advancedExternalizers=
{1100=org.infinispan.server.core.CacheValue$Externalizer@5fabc91d,
1101=org.infinispan.server.memcached.MemcachedValue$Externalizer@720bffd,
1104=org.infinispan.server.hotrod.ServerAddress$Externalizer@771c7eb2},
marshaller=org.infinispan.marshall.VersionAwareMarshaller@6fc21535, version=52,
classResolver=org.jboss.marshalling.ModularClassResolver@2efe83e5},
shutdown=ShutdownConfiguration{hookBehavior=DONT_REGISTER}, modules={},
site=SiteConfiguration{localSite='null'}}
```

17.2.1.16. locate

The *locate* command shows the physical location of a specified entry in a distributed cluster.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> locate a
[host/node1,host/node2]
```

17.2.1.17. put

The *put* command inserts an entry in the cache. If the cache previously contained a mapping for the key, the old value is replaced by the specified value. The user can control the type of data that the CLI will use to store the key and value. See the Data Types section.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> put b 100
[jmx://localhost:12000/MyCacheManager/namedCache]> put c 4139l
[jmx://localhost:12000/MyCacheManager/namedCache]> put d true
[jmx://localhost:12000/MyCacheManager/namedCache]> put e { "package.MyClass": {"i": 5, "x": null,
"b": true } }
```

The put command can optionally specify a lifespan and a maximum idle time.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a expires 10s
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a expires 10m maxidle 1m
```

17.2.1.18. replace

The *replace* command replaces an existing entry in the cache. If an old value is specified, then the replacement happens only if the value in the cache coincides.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> replace a b
[jmx://localhost:12000/MyCacheManager/namedCache]> get a
b
[jmx://localhost:12000/MyCacheManager/namedCache]> replace a b c
[jmx://localhost:12000/MyCacheManager/namedCache]> get a
c
[jmx://localhost:12000/MyCacheManager/namedCache]> replace a b d
[jmx://localhost:12000/MyCacheManager/namedCache]> get a
c
```

17.2.1.19. roles

When authorization is enabled and the role mapper has been configured to be the ClusterRoleMapper, principal to role mappings are stored within the cluster registry (a replicated cache available to all nodes). The *roles* command can be used to list the roles associated to a specific user, or to all users if one is not given:

```
[remoting://localhost:9999]> roles user1
[supervisor, reader]
```

17.2.1.20. rollback

The *rollback* command rolls back an ongoing transaction

```
[jmx://localhost:12000/MyCacheManager/namedCache]> begin
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> put b b
[jmx://localhost:12000/MyCacheManager/namedCache]> rollback
```

17.2.1.21. site

The *site* command performs operations related to the administration of cross-site replication. It can be used to obtain information related to the status of a site and to change the status (online/offline)

```
[jmx://localhost:12000/MyCacheManager/namedCache]> site --status NYC
online
[jmx://localhost:12000/MyCacheManager/namedCache]> site --offline NYC
ok
[jmx://localhost:12000/MyCacheManager/namedCache]> site --status NYC
offline
[jmx://localhost:12000/MyCacheManager/namedCache]> site --online NYC
```

17.2.1.22. start

The *start* command initiates a batch of operations.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> start
[jmx://localhost:12000/MyCacheManager/namedCache]> put a a
[jmx://localhost:12000/MyCacheManager/namedCache]> put b b
[jmx://localhost:12000/MyCacheManager/namedCache]> end
```

17.2.1.23. stats

The *stats* command displays statistics about a cache

```
[jmx://localhost:12000/MyCacheManager/namedCache]> stats
Statistics: {
  averageWriteTime: 143
  evictions: 10
  misses: 5
  hitRatio: 1.0
  readWriteRatio: 10.0
  removeMisses: 0
  timeSinceReset: 2123
  statisticsEnabled: true
  stores: 100
  elapsedTime: 93
  averageReadTime: 14
  removeHits: 0
  numberOfEntries: 100
  hits: 1000
}
LockManager: {
  concurrencyLevel: 1000
  numberOfLocksAvailable: 0
  numberOfLocksHeld: 0
}
```

17.2.2. upgrade

The *upgrade* command performs operations used during the rolling upgrade procedure. For a detailed description of this procedure please see Rolling Upgrades.

```
[jmx://localhost:12000/MyCacheManager/namedCache]> upgrade --synchronize=hotrod --all
[jmx://localhost:12000/MyCacheManager/namedCache]> upgrade --disconnectsource=hotrod --all
```

17.2.3. version

The *version* command displays version information about both the CLI client and the server

```
[jmx://localhost:12000/MyCacheManager/namedCache]> version
Client Version 5.2.1.Final
Server Version 5.2.1.Final
```

17.2.4. Data Types

The CLI understands the following types:

- string strings can either be quoted between single (') or double (") quotes, or left unquoted. In this case it must not contain spaces, punctuation and cannot begin with a number e.g. 'a string', key001
- int an integer is identified by a sequence of decimal digits, e.g. 256
- long a long is identified by a sequence of decimal digits suffixed by 'l', e.g. 1000l
- double
  - a double precision number is identified by a floating point number(with optional exponent part) and an optional 'd' suffix, e.g.3.14
- float
  - a single precision number is identified by a floating point number(with optional exponent part) and an 'f' suffix, e.g. 10.3f
- boolean a boolean is represented either by the keywords true and false
- UUID a UUID is represented by its canonical form XXXXXXXX-XXXX-XXXX-XXXX-XXXXXXXXXXXX
- JSON serialized Java classes can be represented using JSON notation, e.g. {"package.MyClass":{"i":5,"x":null,"b":true}}. Please note that the specified class must be available to the CacheManager's class loader.

17.2.5. Time Values

A time value is an integer number followed by time unit suffix: days (d), hours (h), minutes (m), seconds (s), milliseconds (ms).

17.2.6. Starting and Stopping Red Hat Data Grid Endpoints

Use the Command-Line Interface (CLI) to start and stop Red Hat Data Grid endpoint connectors.

Commands to start and stop endpoint connectors:

- Apply to individual endpoints. To stop or start all endpoint connectors, you must run the command on each endpoint connector.
- Take effect on single nodes only (not cluster-wide).

Procedure

1. Start the CLI and connect to Red Hat Data Grid.
2. List the endpoint connectors in the **datagrid-infinispan-endpoint** subsystem, as follows:

```
[standalone@localhost:9990 /] ls subsystem=datagrid-infinispan-endpoint
hotrod-connector     memcached-connector  rest-connector       router-connector
```

3. Navigate to the endpoint connector you want to start or stop, for example:

```
[standalone@localhost:9990 /] cd subsystem=datagrid-infinispan-endpoint
```

```
[standalone@localhost:9990 subsystem=datagrid-infinispan-endpoint] cd rest-connector=rest-connector
```

4. Use the **:stop-connector** and **:start-connector** commands as appropriate.

```
[standalone@localhost:9990 rest-connector=rest-connector] :stop-connector
{"outcome" => "success"}

[standalone@localhost:9990 rest-connector=rest-connector] :start-connector
{"outcome" => "success"}
```

17.3. HAWT.IO

Hawt.io, a slick, fast, HTML5-based open source management console, also has support for Red Hat Data Grid. Refer to Hawt.io’s documentation for information regarding this plugin.

17.4. WRITING PLUGINS FOR OTHER MANAGEMENT TOOLS

Any management tool that supports JMX already has basic support for Red Hat Data Grid. However, custom plugins could be written to adapt the JMX information for easier consumption.

CHAPTER 18. CUSTOM INTERCEPTORS

It is possible to add custom interceptors to Red Hat Data Grid, both declaratively and programatically. Custom interceptors are a way of extending Red Hat Data Grid by being able to influence or respond to any modifications to cache. Example of such modifications are: elements are added/removed/updated or transactions are committed. For a detailed list refer to CommandInterceptor API.

18.1. ADDING CUSTOM INTERCEPTORS DECLARATIVELY

Custom interceptors can be added on a per named cache basis. This is because each named cache have its own interceptor stack. Following xml snippet depicts the ways in which a custom interceptor can be added.

```
   <local-cache name="cacheWithCustomInterceptors">
      <!--
      Define custom interceptors.  All custom interceptors need to extend
org.jboss.cache.interceptors.base.CommandInterceptor
      -->
      <custom-interceptors>
         <interceptor position="FIRST" class="com.mycompany.CustomInterceptor1">
               <property name="attributeOne">value1</property>
               <property name="attributeTwo">value2</property>
         </interceptor>
         <interceptor position="LAST" class="com.mycompany.CustomInterceptor2"/>
         <interceptor index="3" class="com.mycompany.CustomInterceptor1"/>
         <interceptor before="org.infinispanpan.interceptors.CallInterceptor"
class="com.mycompany.CustomInterceptor2"/>
         <interceptor after="org.infinispanpan.interceptors.CallInterceptor"
class="com.mycompany.CustomInterceptor1"/>
      </custom-interceptors>
   </local-cache>
```

18.2. ADDING CUSTOM INTERCEPTORS PROGRAMATICALLY

In order to do that one needs to obtain a reference to the AdvancedCache . This can be done ass follows:

```
CacheManager cm = getCacheManager();//magic
Cache aCache = cm.getCache("aName");
AdvancedCache advCache = aCache.getAdvancedCache();
```

Then one of the *addInterceptor()* methods should be used to add the actual interceptor. For further documentation refer to AdvancedCache javadoc.

18.3. CUSTOM INTERCEPTOR DESIGN

When writing a custom interceptor, you need to abide by the following rules.

+ * Custom interceptors must extend BaseCustomInterceptor * Custom interceptors must declare a public, empty constructor to enable construction. * Custom interceptors will have setters for any property defined through property tags used in the XML configuration.

CHAPTER 19. RUNNING ON CLOUD SERVICES

In order to turn on Cloud support for Red Hat Data Grid library mode, one needs to add a new dependency to the classpath:

Cloud support in library mode

```
<dependency>
  <groupId>org.infinispan</groupId>
  <artifactId>infinispan-cloud</artifactId>
  <version>${version.infinispan}</version>
</dependency>
```

Replace **${version.infinispan}** with the appropriate version of Red Hat Data Grid.

The above dependency adds **infinispan-core** to the classpath as well as some default configurations.

19.1. GENERIC DISCOVERY PROTOCOLS

The main difference between running Red Hat Data Grid in a private environment and a cloud provider is that in the latter node discovery becomes a bit trickier because things like multicast don't work. To circumvent this you can use alternate JGroups PING protocols. Before delving into the cloud-specific, lets look at some generic discovery protocols.

19.1.1. TCPPing

The TCPPing approach contains a static list of the IP address of each member of the cluster in the JGroups configuration file. While this works it doesn't really help when cluster nodes are dynamically added to the cluster.

Sample TCPPing configuration

```
<config>
      <TCP bind_port="7800" />
      <TCPPING timeout="3000"
           initial_hosts="${jgroups.tcpping.initial_hosts:localhost[7800],localhost[7801]}"
           port_range="1"
           num_initial_members="3"/>
...
...
</config>
```

See JGroups TCPPING for more information about TCPPing.

19.1.2. GossipRouter

Another approach is to have a central server (Gossip, which each node will be configured to contact. This central server will tell each node in the cluster about each other node.

The address (ip:port) that the Gossip router is listening on can be injected into the JGroups configuration used by Red Hat Data Grid. To do this pass the gossip routers address as a system property to the JVM e.g. **-DGossipRouterAddress="10.10.2.4[12001]"** and reference this property in the JGroups configuration that Red Hat Data Grid is using e.g.

Sample TCPGOSSIP configuration

```
<config>
   <TCP bind_port="7800" />
   <TCPGOSSIP timeout="3000" initial_hosts="${GossipRouterAddress}" num_initial_members="3"
/>
...
...
</config>
```

More on Gossip Router @ http://www.jboss.org/community/wiki/JGroupsGossipRouter

19.2. AMAZON WEB SERVICES

When running on Amazon Web Service (AWS) platform and similar cloud based environment you can use the S3_PING protocol for discovery.

19.3. NATIVE_S3_PING

You can configure your JGroups instances to use a shared storage to exchange the details of the cluster nodes. NATIVE_S3_PING allows Amazon S3 to be used as the shared storage. Be sure that you have signed up for Amazon S3 as well as EC2 to use this method.

Sample NATIVE_S3_PING configuration

```
<config>
   <TCP bind_port="7800" />
   <org.jgroups.aws.s3.NATIVE_S3_PING
         region_name="replace this with your region (e.g. eu-west-1)"
         bucket_name="replace this with your bucket name"
         bucket_prefix="replace this with a prefix to use for entries in the bucket (optional)" />
</config>
```

19.3.1. JDBC_PING

A similar approach to S3_PING, but using a JDBC connection to a shared database. On EC2 that is quite easy using Amazon RDS. See the JDBC_PING Wiki page for details.

19.4. MICROSOFT AZURE

Red Hat Data Grid can be used on the Azure platform. Aside from using TCP_PING or GossipRouter, there is an Azure-specific discovery protocol:

19.4.1. AZURE_PING

AZURE_PING uses a shared Azure Blob Storage to store discovery information. Configuration is as follows:

```
<azure.AZURE_PING
 storage_account_name="replace this with your account name"
 storage_access_key="replace this with your access key"
 container="replace this with your container name"
/>
```

19.5. GOOGLE COMPUTE ENGINE

Red Hat Data Grid can be used on the Google Compute Engine (GCE) platform. Aside from using TCP_PING or GossipRouter, there is a GCE-specific discovery protocol:

19.5.1. GOOGLE_PING

GOOGLE_PING uses Google Cloud Storage (GCS) to store information about the cluster members.

```
<protocol type="GOOGLE_PING">
  <property name="location">The name of the bucket</property>
  <property name="access_key">The access key</property>
  <property name="secret_access_key">The secret access key</property>
</protocol>
```

19.6. KUBERNETES

Red Hat Data Grid in Kubernetes environments, such as OKD or OpenShift, can use Kube_PING or [DNS_PING] for cluster discovery.

19.6.1. Kube_PING

The JGroups Kube_PING protocol uses the following configuration:

Example KUBE_PING configuration

```
<config>
    <TCP bind_addr="${match-interface:eth.*}" />
    <kubernetes.KUBE_PING />
...
...
</config>
```

The most important thing is to bind JGroups to **eth0** interface, which is used by Docker containers for network communication.

KUBE_PING protocol is configured by environmental variables (which should be available inside a container). The most important thing is to set **KUBERNETES_NAMESPACE** to proper namespace. It might be either hardcoded or populated via Kubernetes' Downward API.

Since KUBE_PING uses Kubernetes API for obtaining available Pods, OpenShift requires adding additional privileges. Assuming that **oc project -q** returns current namespace and **default** is the service account name, one needs to run:

Adding additional OpenShift privileges

```
oc policy add-role-to-user view system:serviceaccount:$(oc project -q):default -n $(oc project -q)
```

After performing all above steps, the clustering should be enabled and all Pods should automatically form a cluster within a single namespace.

19.6.2. DNS_PING

The JGroups DNS_PING protocol uses the following configuration:

Example DNS_PING configuration

```
<stack name="dns-ping">
...
   <dns.DNS_PING
     dns_query="myservice.myproject.svc.cluster.local" />
...
</stack>
```

DNS_PING runs the specified query against the DNS server to get the list of cluster members.

For information about creating DNS entries for nodes in a cluster, see DNS for Services and Pods.

19.6.3. Using Kubernetes and OpenShift Rolling Updates

Since Pods in Kubernetes and OpenShift are immutable, the only way to alter the configuration is to roll out a new deployment. There are several different strategies to do that but we suggest using Rolling Updates.

An example Deployment Configuration (Kubernetes uses very similar concept called **Deployment**) looks like the following:

DeploymentConfiguration for Rolling Updates

```
- apiVersion: v1
  kind: DeploymentConfig
  metadata:
    name: infinispan-cluster
  spec:
    replicas: 3
    strategy:
      type: Rolling
      rollingParams:
        updatePeriodSeconds: 10
        intervalSeconds: 20
        timeoutSeconds: 600
        maxUnavailable: 1
        maxSurge: 1
    template:
      spec:
        containers:
        - args:
          - -Djboss.default.jgroups.stack=kubernetes
          image: jboss/infinispan-server:latest
          name: infinispan-server
          ports:
          - containerPort: 8181
            protocol: TCP
      - containerPort: 9990
        protocol: TCP
      - containerPort: 11211
        protocol: TCP
      - containerPort: 11222
        protocol: TCP
      - containerPort: 57600
        protocol: TCP
      - containerPort: 7600
        protocol: TCP
      - containerPort: 8080
        protocol: TCP
      env:
      - name: KUBERNETES_NAMESPACE
        valueFrom: {fieldRef: {apiVersion: v1, fieldPath: metadata.namespace}}
      terminationMessagePath: /dev/termination-log
      terminationGracePeriodSeconds: 90
      livenessProbe:
        exec:
          command:
          - /usr/local/bin/is_running.sh
        initialDelaySeconds: 10
        timeoutSeconds: 80
        periodSeconds: 60
        successThreshold: 1
        failureThreshold: 5
      readinessProbe:
         exec:
            command:
            - /usr/local/bin/is_healthy.sh
         initialDelaySeconds: 10
         timeoutSeconds: 40
         periodSeconds: 30
         successThreshold: 2
         failureThreshold: 5
```

It is also highly recommended to adjust the JGroups stack to discover new nodes (or leaves) more quickly. One should at least adjust the value of **FD_ALL** timeout and adjust it to the longest GC Pause.

Other hints for tuning configuration parameters are:

- OpenShift should replace running nodes one by one. This can be achieved by adjusting **rollingParams** (**maxUnavailable: 1** and **maxSurge: 1**).
- Depending on the cluster size, one needs to adjust **updatePeriodSeconds** and **intervalSeconds**. The bigger cluster size is, the bigger those values should be used.
- When using Initial State Transfer, the **initialDelaySeconds** value for both probes should be set to higher value.
- During Initial State Transfer nodes might not respond to probes. The best results are achieved with higher values of **failureThreshold** and **successThreshold** values.

19.6.4. Rolling upgrades with Kubernetes and OpenShift

Even though Rolling Upgrades and Rolling Update may sound similarly, they mean different things. The

Rolling Update is a process of replacing old Pods with new ones. In other words it is a process of rolling out new version of an application. A typical example is a configuration change. Since Pods are immutable, Kubernetes/OpenShift needs to replace them one by one in order to use the updated configuration bits. On the other hand the Rolling Upgrade is a process of migrating data from one Red Hat Data Grid cluster to another one. A typical example is migrating from one version to another.

For both Kubernetes and OpenShift, the Rolling Upgrade procedure is almost the same. It is based on a standard Rolling Upgrade procedure with small changes.

Key differences when upgrading using OpenShift/Kubernetes are:

- Depending on configuration, it is a good practice to use OpenShift Routes or Kubernetes Ingress API to expose services to the clients. During the upgrade the Route (or Ingress) used by the clients can be altered to point to the new cluster.

- Invoking CLI commands can be done by using Kubernetes (**kubectl exec**) or OpenShift clients (**oc exec**). Here is an example: **oc exec <POD_NAME> — '/opt/datagrid/bin/cli.sh' '-c' '--controller=$(hostname -i):9990' '/subsystem=datagrid-infinispan/cache-container=clustered/distributed-cache=default:disconnect-source(migrator-name=hotrod)'**

Key differences when upgrading using the library mode:

- Client application needs to expose JMX. It usually depends on application and environment type but the easiest way to do it is to add the following switches into the Java boostrap script **-Dcom.sun.management.jmxremote -Dcom.sun.management.jmxremote.port=<PORT>**.

- Connecting to the JMX can be done by forwarding ports. With OpenShift this might be achieved by using **oc port-forward** command whereas in Kubernetes by **kubectl port-forward**.

The last step in the Rolling Upgrade (removing a Remote Cache Store) needs to be performed differently. We need to use Kubernetes/OpenShift Rolling update command and replace Pods configuration with the one which does not contain Remote Cache Store.

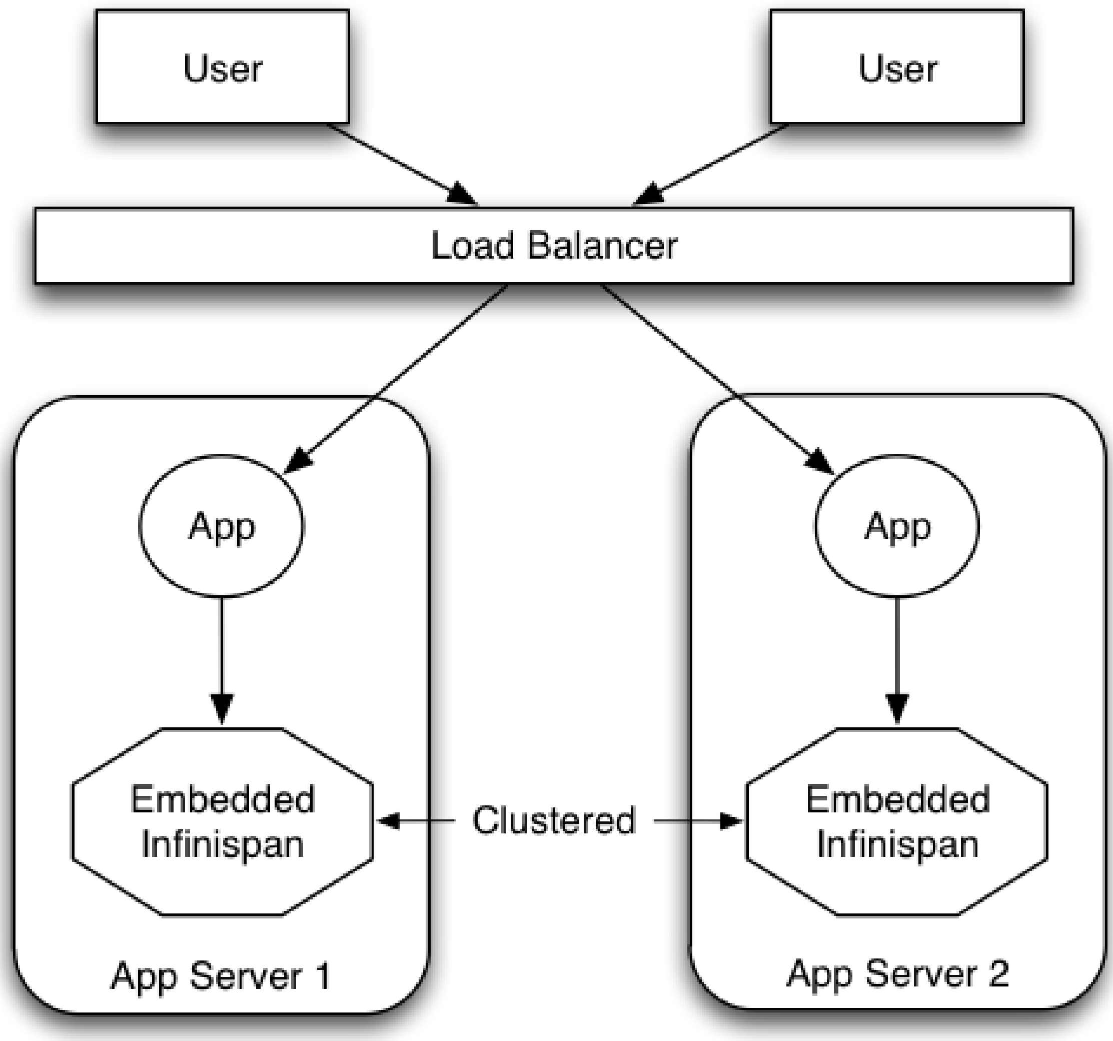
A detailed instruction might be found in ISPN-6673 ticket.

CHAPTER 20. CLIENT/SERVER

Red Hat Data Grid offers two alternative access methods: embedded mode and client-server mode.

- In Embedded mode the Red Hat Data Grid libraries co-exist with the user application in the same JVM as shown in the following diagram

Figure 20.1. Peer-to-peer access

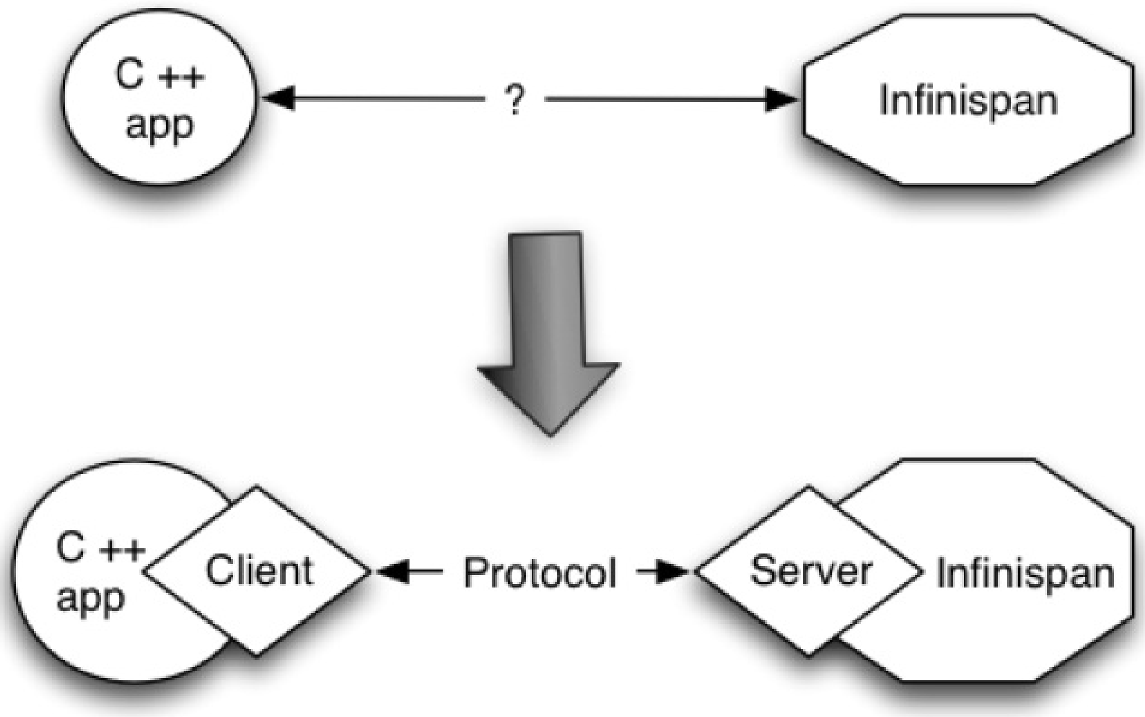


- Client-server mode is when applications access the data stored in a remote Red Hat Data Grid server using some kind of network protocol

20.1. WHY CLIENT/SERVER?

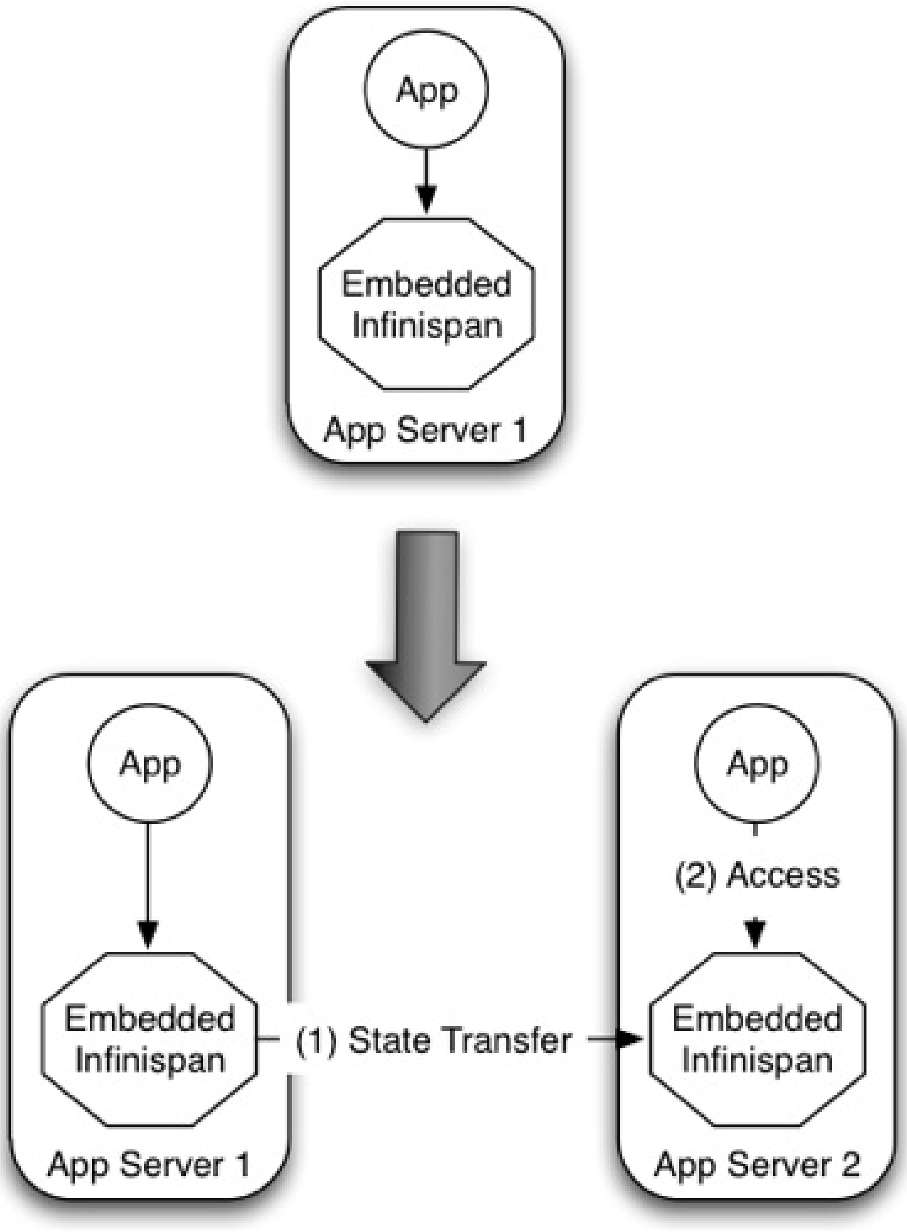
There are situations when accessing Red Hat Data Grid in a client-server mode might make more sense than embedding it within your application, for example, when trying to access Red Hat Data Grid from a non-JVM environment. Since Red Hat Data Grid is written in Java, if someone had a C\\ application that wanted to access it, it couldn't just do it in a p2p way. On the other hand, client-server would be perfectly suited here assuming that a language neutral protocol was used and the corresponding client and server implementations were available.

Figure 20.2. Non-JVM access



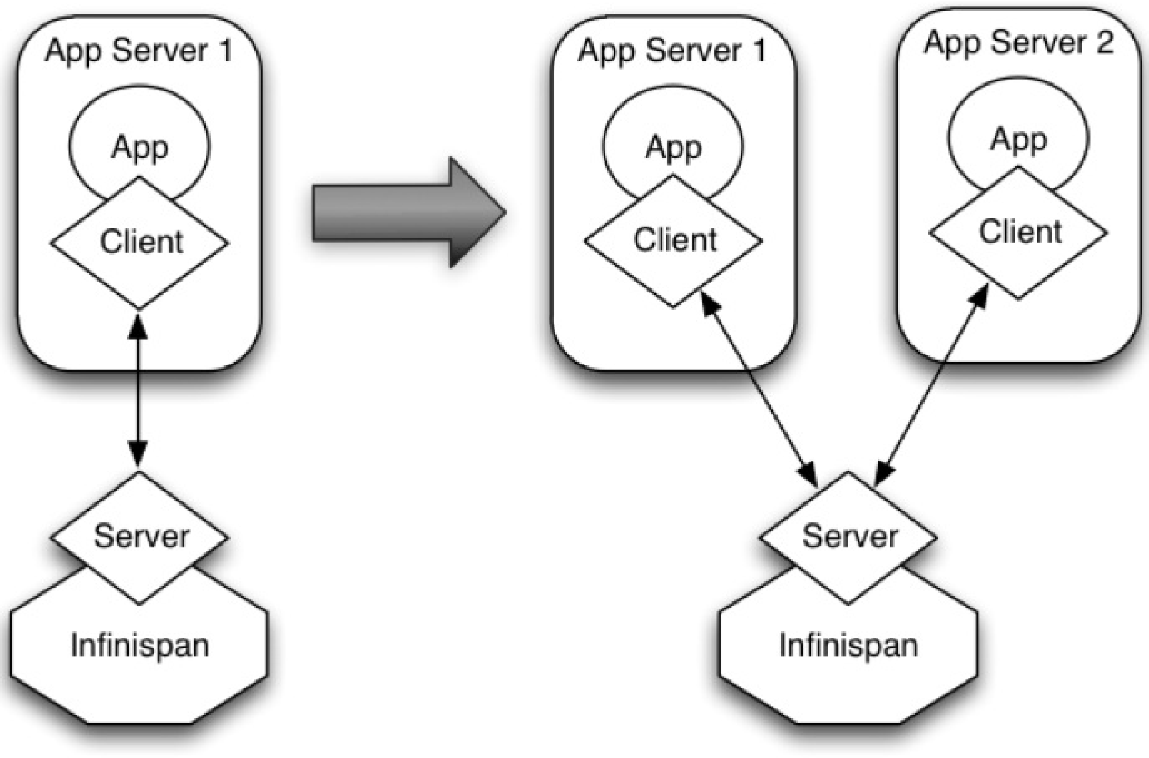
In other situations, Red Hat Data Grid users want to have an elastic application tier where you start/stop business processing servers very regularly. Now, if users deployed Red Hat Data Grid configured with distribution or state transfer, startup time could be greatly influenced by the shuffling around of data that happens in these situations. So in the following diagram, assuming Red Hat Data Grid was deployed in p2p mode, the app in the second server could not access Red Hat Data Grid until state transfer had completed.

Figure 20.3. Elasticity issue with P2P



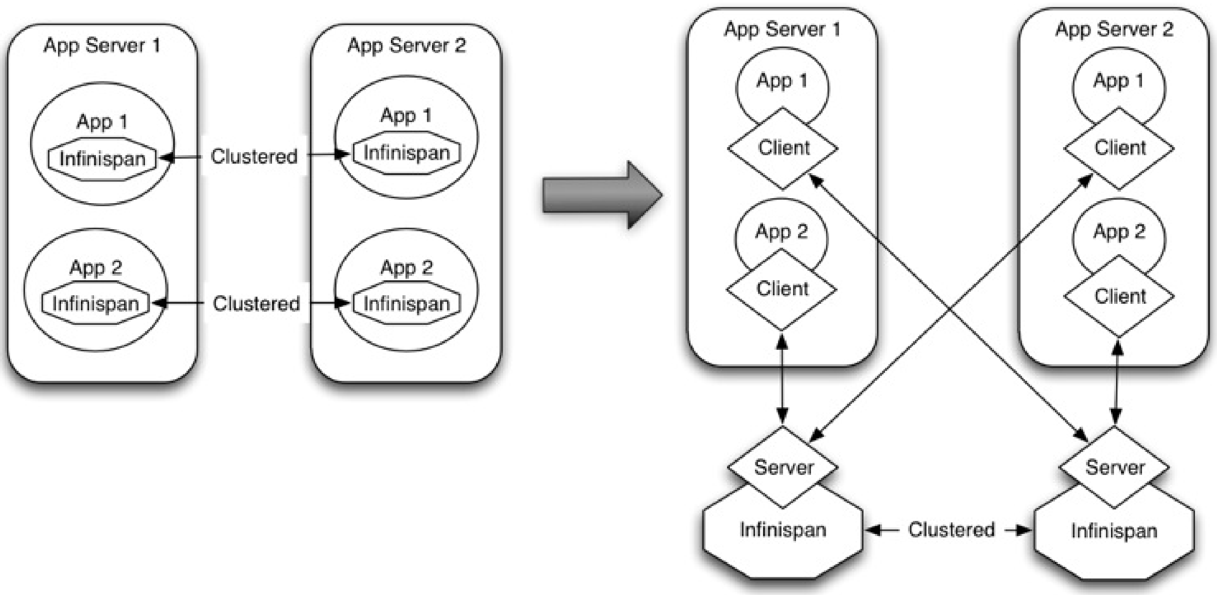
This effectively means that bringing up new application-tier servers is impacted by things like state transfer because applications cannot access Red Hat Data Grid until these processes have finished and if the state being shifted around is large, this could take some time. This is undesirable in an elastic environment where you want quick application-tier server turnaround and predictable startup times. Problems like this can be solved by accessing Red Hat Data Grid in a client-server mode because starting a new application-tier server is just a matter of starting a lightweight client that can connect to the backing data grid server. No need for rehashing or state transfer to occur and as a result server startup times can be more predictable which is very important for modern cloud-based deployments where elasticity in your application tier is important.

Figure 20.4. Achieving elasticity



Other times, it’s common to find multiple applications needing access to data storage. In this cases, you could in theory deploy an Red Hat Data Grid instance per each of those applications but this could be wasteful and difficult to maintain. Think about databases here, you don’t deploy a database alongside each of your applications, do you? So, alternatively you could deploy Red Hat Data Grid in client-server mode keeping a pool of Red Hat Data Grid data grid nodes acting as a shared storage tier for your applications.

Figure 20.5. Shared data storage



Deploying Red Hat Data Grid in this way also allows you to manage each tier independently, for example, you can upgrade you application or app server without bringing down your Red Hat Data Grid data grid nodes.

20.2. WHY USE EMBEDDED MODE?

Before talking about individual Red Hat Data Grid server modules, it's worth mentioning that in spite of all the benefits, client-server Red Hat Data Grid still has disadvantages over p2p. Firstly, p2p deployments are simpler than client-server ones because in p2p, all peers are equals to each other and hence this simplifies deployment. So, if this is the first time you're using Red Hat Data Grid, p2p is likely to be easier for you to get going compared to client-server.

Client-server Red Hat Data Grid requests are likely to take longer compared to p2p requests, due to the serialization and network cost in remote calls. So, this is an important factor to take in account when designing your application. For example, with replicated Red Hat Data Grid caches, it might be more performant to have lightweight HTTP clients connecting to a server side application that accesses Red Hat Data Grid in p2p mode, rather than having more heavyweight client side apps talking to Red Hat Data Grid in client-server mode, particularly if data size handled is rather large. With distributed caches, the difference might not be so big because even in p2p deployments, you're not guaranteed to have all data available locally.

Environments where application tier elasticity is not so important, or where server side applications access state-transfer-disabled, replicated Red Hat Data Grid cache instances are amongst scenarios where Red Hat Data Grid p2p deployments can be more suited than client-server ones.

20.3. SERVER MODULES

So, now that it's clear when it makes sense to deploy Red Hat Data Grid in client-server mode, what are available solutions? All Red Hat Data Grid server modules are based on the same pattern where the server backend creates an embedded Red Hat Data Grid instance and if you start multiple backends, they can form a cluster and share/distribute state if configured to do so. The server types below primarily differ in the type of listener endpoint used to handle incoming connections.

Here's a brief summary of the available server endpoints.

- **Hot Rod Server Module** - This module is an implementation of the Hot Rod binary protocol backed by Red Hat Data Grid which allows clients to do dynamic load balancing and failover and smart routing.
  - A variety of clients exist for this protocol.
  - If you're clients are running Java, this should be your defacto server module choice because it allows for dynamic load balancing and failover. This means that Hot Rod clients can dynamically detect changes in the topology of Hot Rod servers as long as these are clustered, so when new nodes join or leave, clients update their Hot Rod server topology view. On top of that, when Hot Rod servers are configured with distribution, clients can detect where a particular key resides and so they can route requests smartly.
  - Load balancing and failover is dynamically provided by Hot Rod client implementations using information provided by the server.
- **REST Server Module** - The REST server, which is distributed as a WAR file, can be deployed in any servlet container to allow Red Hat Data Grid to be accessed via a RESTful HTTP interface.
  - To connect to it, you can use any HTTP client out there and there're tons of different client implementations available out there for pretty much any language or system.

- This module is particularly recommended for those environments where HTTP port is the only access method allowed between clients and servers.
- Clients wanting to load balance or failover between different Red Hat Data Grid REST servers can do so using any standard HTTP load balancer such as mod_cluster . It's worth noting though these load balancers maintain a static view of the servers in the backend and if a new one was to be added, it would require manual update of the load balancer.

- **Memcached Server Module** - This module is an implementation of the Memcached text protocol backed by Red Hat Data Grid.
    - To connect to it, you can use any of the existing Memcached clients which are pretty diverse.
    - As opposed to Memcached servers, Red Hat Data Grid based Memcached servers can actually be clustered and hence they can replicate or distribute data using consistent hash algorithms around the cluster. So, this module is particularly of interest to those users that want to provide failover capabilities to the data stored in Memcached servers.
    - In terms of load balancing and failover, there're a few clients that can load balance or failover given a static list of server addresses (perl's Cache::Memcached for example) but any server addition or removal would require manual intervention.

20.4. WHICH PROTOCOL SHOULD I USE?

Choosing the right protocol depends on a number of factors.

	Hot Rod	HTTP / REST	Memcached
Topology-aware	Y	N	N
Hash-aware	Y	N	N
Encryption	Y	Y	N
Authentication	Y	Y	N
Conditional ops	Y	Y	Y
Bulk ops	Y	N	N
Transactions	N	N	N
Listeners	Y	N	N
Query	Y	Y	N
Execution	Y	N	N
Cross-site failover	Y	N	N

20.5. USING HOT ROD SERVER

The Red Hat Data Grid Server distribution contains a server module that implements Red Hat Data Grid's custom binary protocol called Hot Rod. The protocol was designed to enable faster client/server interactions compared to other existing text based protocols and to allow clients to make more intelligent decisions with regards to load balancing, failover and even data location operations. Please refer to Red Hat Data Grid Server's documentation for instructions on how to configure and run a HotRod server.

To connect to Red Hat Data Grid over this highly efficient Hot Rod protocol you can either use one of the clients described in this chapter, or use higher level tools such as Hibernate OGM.

20.6. HOT ROD PROTOCOL

The following articles provides detailed information about each version of the custom TCP client/server Hot Rod protocol.

- Hot Rod Protocol 1.0
- Hot Rod Protocol 1.1
- Hot Rod Protocol 1.2
- Hot Rod Protocol 1.3
- Hot Rod Protocol 2.0
- Hot Rod Protocol 2.1
- Hot Rod Protocol 2.2
- Hot Rod Protocol 2.3
- Hot Rod Protocol 2.4
- Hot Rod Protocol 2.5
- Hot Rod Protocol 2.6
- Hot Rod Protocol 2.7
- Hot Rod Protocol 2.8
- Hot Rod Protocol 2.9

20.6.1. Hot Rod Protocol 1.0

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 4.1.0.Final

IMPORTANT

All key and values are sent and stored as byte arrays. Hot Rod makes no assumptions about their types.

Some clarifications about the other types:

- vInt : Variable-length integers are defined defined as compressed, positive integers where the high-order bit of each byte indicates whether more bytes need to be read. The low-order seven bits are appended as increasingly more significant bits in the resulting integer value making it efficient to decode. Hence, values from zero to 127 are stored in a single byte, values from 128 to 16,383 are stored in two bytes, and so on:

Value	First byte	Second byte	Third byte
0	00000000		
1	00000001		
2	00000010		
...			
127	01111111		
128	10000000	00000001	
129	10000001	00000001	
130	10000010	00000001	
...			
16,383	11111111	01111111	
16,384	10000000	10000000	00000001
16,385	10000001	10000000	00000001
...			

- signed vInt: The vInt above is also able to encode negative values, but will always use the maximum size (5 bytes) no matter how small the endoded value is. In order to have a small payload for negative values too, signed vInts uses ZigZag encoding on top of the vInt encoding. More details here
- vLong : Refers to unsigned variable length long values similar to vInt but applied to longer values. They're between 1 and 9 bytes long.
- String : Strings are always represented using UTF-8 encoding.

20.6.1.1. Request Header

The header for a request is composed of:

Table 20.1. Request header

Field Name	Size	Value
Magic	1 byte	0xA0 = request
Message ID	vLong	ID of the message that will be copied back in the response. This allows for Hot Rod clients to implement the protocol in an asynchronous way.
Version	1 byte	Hot Rod server version. In this particular case, this is 10
Opcode	1 byte	Request operation code: 0x01 = put (since 1.0) 0x03 = get (since 1.0) 0x05 = putIfAbsent (since 1.0) 0x07 = replace (since 1.0) 0x09 = replaceIfUnmodified (since 1.0) 0x0B = remove (since 1.0) 0x0D = removeIfUnmodified (since 1.0) 0x0F = containsKey (since 1.0) 0x11 = getWithVersion (since 1.0) 0x13 = clear (since 1.0) 0x15 = stats (since 1.0) 0x17 = ping (since 1.0) 0x19 = bulkGet (since 1.2) 0x1B = getWithMetadata (since 1.2) 0x1D = bulkGetKeys (since 1.2) 0x1F = query (since 1.3) 0x21 = authMechList (since 2.0) 0x23 = auth (since 2.0) 0x25 = addClientListener (since 2.0) 0x27 = removeClientListener (since 2.0) 0x29 = size (since 2.0) 0x2B = exec (since 2.1) 0x2D = putAll (since 2.1) 0x2F = getAll (since 2.1) 0x31 = iterationStart (since 2.3) 0x33 = iterationNext (since 2.3) 0x35 = iterationEnd (since 2.3) 0x37 = getStream (since 2.6) 0x39 = putStream (since 2.6)
Cache Name Length	vInt	Length of cache name. If the passed length is 0 (followed by no cache name), the operation will interact with the default cache.
Cache Name	string	Name of cache on which to operate. This name must match the name of predefined cache in the Red Hat Data Grid configuration file.

Field Name	Size	Value
Flags	vInt	A variable length number representing flags passed to the system. Each flags is represented by a bit. Note that since this field is sent as variable length, the most significant bit in a byte is used to determine whether more bytes need to be read, hence this bit does not represent any flag. Using this model allows for flags to be combined in a short space. Here are the current values for each flag: 0x0001 = force return previous value
Client Intelligence	1 byte	This byte hints the server on the client capabilities: 0x01 = basic client, interested in neither cluster nor hash information 0x02 = topology-aware client, interested in cluster information 0x03 = hash-distribution-aware client, that is interested in both cluster and hash information
Topology Id	vInt	This field represents the last known view in the client. Basic clients will only send 0 in this field. When topology-aware or hash-distribution-aware clients will send 0 until they have received a reply from the server with the current view id. Afterwards, they should send that view id until they receive a new view id in a response.
Transaction Type	1 byte	This is a 1 byte field, containing one of the following well-known supported transaction types (For this version of the protocol, the only supported transaction type is 0): 0 = Non-transactional call, or client does not support transactions. The subsequent TX_ID field will be omitted. 1 = X/Open XA transaction ID (XID). This is a well-known, fixed-size format.
Transaction Id	byte array	The byte array uniquely identifying the transaction associated to this call. Its length is determined by the transaction type. If transaction type is 0, no transaction id will be present.

20.6.1.2. Response Header

The header for a response is composed of:

Table 20.2. Response header

Field Name	Size	Value
Magic	1 byte	0xA1 = response
Message ID	vLong	ID of the message, matching the request for which the response is sent.

Field Name	Size	Value
Opcode	1 byte	Response operation code: 0x02 = put (since 1.0) 0x04 = get (since 1.0) 0x06 = putIfAbsent (since 1.0) 0x08 = replace (since 1.0) 0x0A = replaceIfUnmodified (since 1.0) 0x0C = remove (since 1.0) 0x0E = removeIfUnmodified (since 1.0) 0x10 = containsKey (since 1.0) 0x12 = getWithVersion (since 1.0) 0x14 = clear (since 1.0) 0x16 = stats (since 1.0) 0x18 = ping (since 1.0) 0x1A = bulkGet (since 1.0) 0x1C = getWithMetadata (since 1.2) 0x1E = bulkGetKeys (since 1.2) 0x20 = query (since 1.3) 0x22 = authMechList (since 2.0) 0x24 = auth (since 2.0) 0x26 = addClientListener (since 2.0) 0x28 = removeClientListener (since 2.0) 0x2A = size (since 2.0) 0x2C = exec (since 2.1) 0x2E = putAll (since 2.1) 0x30 = getAll (since 2.1) 0x32 = iterationStart (since 2.3) 0x34 = iterationNext (since 2.3) 0x36 = iterationEnd (since 2.3) 0x38 = getStream (since 2.6) 0x3A = putStream (since 2.6) 0x50 = error (since 1.0)
Status	1 byte	Status of the response, possible values: 0x00 = No error 0x01 = Not put/removed/replaced 0x02 = Key does not exist 0x81 = Invalid magic or message id 0x82 = Unknown command 0x83 = Unknown version 0x84 = Request parsing error 0x85 = Server Error 0x86 = Command timed out
Topology Change Marker	string	This is a marker byte that indicates whether the response is prepended with topology change information. When no topology change follows, the content of this byte is 0. If a topology change follows, its contents are 1.

CAUTION

Exceptional error status responses, those that start with 0x8 ..., are followed by the length of the error message (as a vInt) and error message itself as String.

20.6.1.3. Topology Change Headers

The following section discusses how the response headers look for topology-aware or hash-distribution-aware clients when there's been a cluster or view formation change. Note that it's the server that makes the decision on whether it sends back the new topology based on the current topology id and the one the client sent. If they're different, it will send back the new topology.

20.6.1.4. Topology-Aware Client Topology Change Header

This is what topology-aware clients receive as response header when a topology change is sent back:

Field Name	Size	Value
Response header with topology change marker	variable	See previous section.
Topology Id	vInt	Topology ID
Num servers in topology	vInt	Number of Hot Rod servers running within the cluster. This could be a subset of the entire cluster if only a fraction of those nodes are running Hot Rod servers.
m1: Host/IP length	vInt	Length of hostname or IP address of individual cluster member that Hot Rod client can use to access it. Using variable length here allows for covering for hostnames, IPv4 and IPv6 addresses.
m1: Host/IP address	string	String containing hostname or IP address of individual cluster member that Hot Rod client can use to access it.
m1: Port	2 bytes (Unsigned Short)	Port that Hot Rod clients can use to communicate with this cluster member.
m2: Host/IP length	vInt	
m2: Host/IP address	string	
m2: Port	2 bytes (Unsigned Short)	
...etc		

20.6.1.5. Distribution-Aware Client Topology Change Header

This is what hash-distribution-aware clients receive as response header when a topology change is sent back:

Field Name	Size	Value
Response header with topology change marker	variable	See previous section.
Topology Id	vInt	Topology ID
Num Key Owners	2 bytes (Unsigned Short)	Globally configured number of copies for each Red Hat Data Grid distributed key
Hash Function Version	1 byte	Hash function version, pointing to a specific hash function in use. See Hot Rod hash functions for details.
Hash space size	vInt	Modulus used by Red Hat Data Grid for for all module arithmetic related to hash code generation. Clients will likely require this information in order to apply the correct hash calculation to the keys.
Num servers in topology	vInt	Number of Red Hat Data Grid Hot Rod servers running within the cluster. This could be a subset of the entire cluster if only a fraction of those nodes are running Hot Rod servers.
m1: Host/IP length	vInt	Length of hostname or IP address of individual cluster member that Hot Rod client can use to access it. Using variable length here allows for covering for hostnames, IPv4 and IPv6 addresses.
m1: Host/IP address	string	String containing hostname or IP address of individual cluster member that Hot Rod client can use to access it.
m1: Port	2 bytes (Unsigned Short)	Port that Hot Rod clients can use to communicat with this cluster member.
m1: Hashcode	4 bytes	32 bit integer representing the hashcode of a cluster member that a Hot Rod client can use indentify in which cluster member a key is located having applied the CSA to it.
m2: Host/IP length	vInt	
m2: Host/IP address	string	
m2: Port	2 bytes (Unsigned Short)	
m2: Hashcode	4 bytes	
...etc		

Field Name	Size	Value

It’s important to note that since hash headers rely on the consistent hash algorithm used by the server and this is a factor of the cache interacted with, hash-distribution-aware headers can only be returned to operations that target a particular cache. Currently ping command does not target any cache (this is to change as per ISPN-424) , hence calls to ping command with hash-topology-aware client settings will return a hash-distribution-aware header with "Num Key Owners", "Hash Function Version", "Hash space size" and each individual host’s hash code all set to 0. This type of header will also be returned as response to operations with hash-topology-aware client settings that are targeting caches that are not configured with distribution.

20.6.1.6. Operations

Get (0x03)/Remove (0x0B)/ContainsKey (0x0F)/GetWithVersion (0x11)

Common request format:

Field Name	Size	Value
Header	variable	Request header
Key Length	vInt	Length of key. Note that the size of a vint can be up to 5 bytes which in theory can produce bigger numbers than Integer.MAX_VALUE. However, Java cannot create a single array that’s bigger than Integer.MAX_VALUE, hence the protocol is limiting vint array lengths to Integer.MAX_VALUE.
Key	byte array	Byte array containing the key whose value is being requested.

Get response (0x04):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if key retrieved 0x02 = if key does not exist
Value Length	vInt	If success, length of value
Value	byte array	If success, the requested value

Remove response (0x0C):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if key removed 0x02 = if key does not exist
Previous value Length	vInt	If force return previous value flag was sent in the request and the key was removed, the length of the previous value will be returned. If the key does not exist, value length would be 0. If no flag was sent, no value length would be present.
Previous value	byte array	If force return previous value flag was sent in the request and the key was removed, previous value.

ContainsKey response (0x10):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if key exists 0x02 = if key does not exist

GetWithVersion response (0x12):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if key retrieved 0x02 = if key does not exist
Entry Version	8 bytes	Unique value of an existing entry’s modification. The protocol does not mandate that entry_version values are sequential. They just need to be unique per update at the key level.
Value Length	vInt	If success, length of value
Value	byte array	If success, the requested value

BulkGet

Request (0x19):

Field Name	Size	Value
Header	variable	Request header
Entry count	vInt	Maximum number of Red Hat Data Grid entries to be returned by the server (entry == key + associated value). Needed to support CacheLoader.load(int). If 0 then all entries are returned (needed for CacheLoader.loadAll()).

Response (0x20):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, data follows
More	1 byte	One byte representing whether more entries need to be read from the stream. So, when it's set to 1, it means that an entry follows, whereas when it's set to 0, it's the end of stream and no more entries are left to read. For more information on BulkGet look here
Key 1 Length	vInt	Length of key
Key 1	byte array	Retrieved key
Value 1 Length	vInt	Length of value
Value 1	byte array	Retrieved value
More	1 byte	
Key 2 Length	vInt	
Key 2	byte array	
Value 2 Length	vInt	
Value 2	byte array	
... etc		

Put (0x01)/PutIfAbsent (0x05)/Replace (0x07)

Common request format:

Field Name	Size	Value
Header	variable	Request header
Key Length	vInt	Length of key. Note that the size of a vint can be up to 5 bytes which in theory can produce bigger numbers than Integer.MAX_VALUE. However, Java cannot create a single array that's bigger than Integer.MAX_VALUE, hence the protocol is limiting vint array lengths to Integer.MAX_VALUE.
Key	byte array	Byte array containing the key whose value is being requested.
Lifespan	vInt	Number of seconds that a entry during which the entry is allowed to life. If number of seconds is bigger than 30 days, this number of seconds is treated as UNIX time and so, represents the number of seconds since 1/1/1970. If set to 0, lifespan is unlimited.
Max Idle	vInt	Number of seconds that a entry can be idle before it's evicted from the cache. If 0, no max idle time.
Value Length	vInt	Length of value
Value	byte-array	Value to be stored

Put response (0x02):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if stored
Previous value Length	vInt	If force return previous value flag was sent in the request and the key was put, the length of the previous value will be returned. If the key does not exist, value length would be 0. If no flag was sent, no value length would be present.
Previous value	byte array	If force return previous value flag was sent in the request and the key was put, previous value.

Replace response (0x08):

Field Name	Size	Value
Header	variable	Response header

Field Name	Size	Value
Response status	1 byte	0x00 = success, if stored 0x01 = if store did not happen because key does not exist
Previous value Length	vInt	If force return previous value flag was sent in the request, the length of the previous value will be returned. If the key does not exist, value length would be 0. If no flag was sent, no value length would be present.
Previous value	byte array	If force return previous value flag was sent in the request and the key was replaced, previous value.

PutIfAbsent response (0x06):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if stored 0x01 = if store did not happen because key was present
Previous value Length	vInt	If force return previous value flag was sent in the request, the length of the previous value will be returned. If the key does not exist, value length would be 0. If no flag was sent, no value length would be present.
Previous value	byte array	If force return previous value flag was sent in the request and the key was replaced, previous value.

ReplaceIfUnmodified

Request (0x09):

Field Name	Size	Value
Header	variable	Request header
Key Length	vInt	Length of key. Note that the size of a vint can be up to 5 bytes which in theory can produce bigger numbers than Integer.MAX_VALUE. However, Java cannot create a single array that's bigger than Integer.MAX_VALUE, hence the protocol is limiting vint array lengths to Integer.MAX_VALUE.
Key	byte array	Byte array containing the key whose value is being requested.
Lifespan	vInt	Number of seconds that a entry during which the entry is allowed to life. If number of seconds is bigger than 30 days, this number of seconds is treated as UNIX time and so, represents the number of seconds since 1/1/1970. If set to 0, lifespan is unlimited.

Field Name	Size	Value
Max Idle	vInt	Number of seconds that a entry can be idle before it's evicted from the cache. If 0, no max idle time.
Entry Version	8 bytes	Use the value returned by GetWithVersion operation.
Value Length	vInt	Length of value
Value	byte-array	Value to be stored

Response (0x0A):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if replaced 0x01 = if replace did not happen because key had been modified 0x02 = if not replaced because if key does not exist
Previous value Length	vInt	If force return previous value flag was sent in the request, the length of the previous value will be returned. If the key does not exist, value length would be 0. If no flag was sent, no value length would be present.
Previous value	byte array	If force return previous value flag was sent in the request and the key was replaced, previous value.

RemoveIfUnmodified

Request (0x0D):

Field Name	Size	Value
Header	variable	Request header
Key Length	vInt	Length of key. Note that the size of a vint can be up to 5 bytes which in theory can produce bigger numbers than Integer.MAX_VALUE. However, Java cannot create a single array that's bigger than Integer.MAX_VALUE, hence the protocol is limiting vint array lengths to Integer.MAX_VALUE.
Key	byte array	Byte array containing the key whose value is being requested.
Entry Version	8 bytes	Use the value returned by GetWithMetadata operation.

Response (0x0E):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if removed 0x01 = if remove did not happen because key had been modified 0x02 = if not removed because key does not exist
Previous value Length	vInt	If force return previous value flag was sent in the request, the length of the previous value will be returned. If the key does not exist, value length would be 0. If no flag was sent, no value length would be present.
Previous value	byte array	If force return previous value flag was sent in the request and the key was removed, previous value.

Clear

Request (0x13):

Field Name	Size	Value
Header	variable	Request header

Response (0x14):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if cleared

PutAll

Bulk operation to put all key value entries into the cache at the same time.

Request (0x2D):

Field Name	Size	Value
Header	variable	Request header
Lifespan	vInt	Number of seconds that provided entries are allowed to live. If number of seconds is bigger than 30 days, this number of seconds is treated as UNIX time and so, represents the number of seconds since 1/1/1970. If set to 0, lifespan is unlimited.

Field Name	Size	Value
Max Idle	vInt	Number of seconds that each entry can be idle before it's evicted from the cache. If 0, no max idle time.
Entry count	vInt	How many entries are being inserted
Key 1 Length	vInt	Length of key
Key 1	byte array	Retrieved key
Value 1 Length	vInt	Length of value
Value 1	byte array	Retrieved value
Key 2 Length	vInt	
Key 2	byte array	
Value 2 Length	vInt	
Value 2	byte array	
… continues until entry count is reached		

Response (0x2E):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if all put

GetAll

Bulk operation to get all entries that map to a given set of keys.

Request (0x2F):

Field Name	Size	Value
Header	variable	Request header
Key count	vInt	How many keys to find entries for

Field Name	Size	Value
Key 1 Length	vInt	Length of key
Key 1	byte array	Retrieved key
Key 2 Length	vInt	
Key 2	byte array	
... continues until key count is reached		

Response (0x30):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	
Entry count	vInt	How many entries are being returned
Key 1 Length	vInt	Length of key
Key 1	byte array	Retrieved key
Value 1 Length	vInt	Length of value
Value 1	byte array	Retrieved value
Key 2 Length	vInt	
Key 2	byte array	
Value 2 Length	vInt	
Value 2	byte array	
... continues until entry count is reached		0x00 = success, if the get returned sucessfully

Stats

Returns a summary of all available statistics. For each statistic returned, a name and a value is returned both in String UTF-8 format. The supported stats are the following:

Name	Explanation
timeSinceStart	Number of seconds since Hot Rod started.
currentNumberOfEntries	Number of entries currently in the Hot Rod server.
totalNumberOfEntries	Number of entries stored in Hot Rod server.
stores	Number of put operations.
retrievals	Number of get operations.
hits	Number of get hits.
misses	Number of get misses.
removeHits	Number of removal hits.
removeMisses	Number of removal misses.

Request (0x15):

Field Name	Size	Value
Header	variable	Request header

Response (0x16):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if stats retrieved
Number of stats	vInt	Number of individual stats returned.
Name 1 length	vInt	Length of named statistic.
Name 1	string	String containing statistic name.
Value 1 length	vInt	Length of value field.
Value 1	string	String containing statistic value.

Field Name	Size	Value
Name 2 length	vInt	
Name 2	string	
Value 2 length	vInt	
Value 2	String	
...etc		

Ping

Application level request to see if the server is available.

Request (0x17):

Field Name	Size	Value
Header	variable	Request header

Response (0x18):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if no errors

Error Handling

Error response (0x50)

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x8x = error response code
Error Message Length	vInt	Length of error message
Error Message	string	Error message. In the case of 0x84 , this error field contains the latest version supported by the Hot Rod server. Length is defined by total body length.

Multi-Get Operations

A multi-get operation is a form of get operation that instead of requesting a single key, requests a set of keys. The Hot Rod protocol does not include such operation but remote Hot Rod clients could easily implement this type of operations by either parallelizing/pipelining individual get requests. Another possibility would be for remote clients to use async or non-blocking get requests. For example, if a client wants N keys, it could send send N async get requests and then wait for all the replies. Finally, multi-get is not to be confused with bulk-get operations. In bulk-gets, either all or a number of keys are retrieved, but the client does not know which keys to retrieve, whereas in multi-get, the client defines which keys to retrieve.

20.6.1.7. Example - Put request

- Coded request

Byte	0	1	2	3	4	5	6	7
8	0xA0	0x09	0x41	0x01	0x07	0x4D ('M')	0x79 ('y')	0x43 ('C')
16	0x61 ('a')	0x63 ('c')	0x68 ('h')	0x65 ('e')	0x00	0x03	0x00	0x00
24	0x00	0x05	0x48 ('H')	0x65 ('e')	0x6C ('l')	0x6C ('l')	0x6F ('o')	0x00
32	0x00	0x05	0x57 ('W')	0x6F ('o')	0x72 ('r')	0x6C ('l')	0x64 ('d')	

- Field explanation

Field Name	Value	Field Name	Value
Magic (0)	0xA0	Message Id (1)	0x09
Version (2)	0x41	Opcode (3)	0x01
Cache name length (4)	0x07	Cache name(5-11)	'MyCache'
Flag (12)	0x00	Client Intelligence (13)	0x03
Topology Id (14)	0x00	Transaction Type (15)	0x00
Transaction Id (16)	0x00	Key field length (17)	0x05
Key (18 - 22)	'Hello'	Lifespan (23)	0x00
Max idle (24)	0x00	Value field length (25)	0x05

Field Name	Value	Field Name	Value
Value (26-30)	'World'		

- Coded response

Byte	0	1	2	3	4	5	6	7
8	0xA1	0x09	0x01	0x00	0x00			

- Field Explanation

Field Name	Value	Field Name	Value
Magic (0)	0xA1	Message Id (1)	0x09
Opcode (2)	0x01	Status (3)	0x00
Topology change marker (4)	0x00		

20.6.2. Hot Rod Protocol 1.1

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 5.1.0.FINAL

20.6.2.1. Request Header

The **version** field in the header is updated to **11**.

20.6.2.2. Distribution-Aware Client Topology Change Header

UPDATED FOR 1.1

This section has been modified to be more efficient when talking to distributed caches with virtual nodes enabled.

This is what hash-distribution-aware clients receive as response header when a topology change is sent back:

Field Name	Size	Value
Response header with topology change marker	variable	See previous section.

Field Name	Size	Value
Topology Id	vInt	Topology ID
Num Key Owners	2 bytes (Unsigned Short)	Globally configured number of copies for each Red Hat Data Grid distributed key
Hash Function Version	1 byte	Hash function version, pointing to a specific hash function in use. See Hot Rod hash functions for details.
Hash space size	vInt	Modulus used by Red Hat Data Grid for for all module arithmetic related to hash code generation. Clients will likely require this information in order to apply the correct hash calculation to the keys.
Num servers in topology	vInt	Number of Hot Rod servers running within the cluster. This could be a subset of the entire cluster if only a fraction of those nodes are running Hot Rod servers.
Num Virtual Nodes Owners	vInt	Field added in version 1.1 of the protocol that represents the number of configured virtual nodes. If no virtual nodes are configured or the cache is not configured with distribution, this field will contain 0.
m1: Host/IP length	vInt	Length of hostname or IP address of individual cluster member that Hot Rod client can use to access it. Using variable length here allows for covering for hostnames, IPv4 and IPv6 addresses.
m1: Host/IP address	string	String containing hostname or IP address of individual cluster member that Hot Rod client can use to access it.
m1: Port	2 bytes (Unsigned Short)	Port that Hot Rod clients can use to communicat with this cluster member.
m1: Hashcode	4 bytes	32 bit integer representing the hashcode of a cluster member that a Hot Rod client can use indentify in which cluster member a key is located having applied the CSA to it.
m2: Host/IP length	vInt	
m2: Host/IP address	string	
m2: Port	2 bytes (Unsigned Short)	
m2: Hashcode	4 bytes	

Field Name	Size	Value
...etc		

20.6.2.3. Server node hash code calculation

Adding support for virtual nodes has made version 1.0 of the Hot Rod protocol impractical due to bandwidth it would have taken to return hash codes for all virtual nodes in the clusters (this number could easily be in the millions). So, as of version 1.1 of the Hot Rod protocol, clients are given the base hash id or hash code of each server, and then they have to calculate the real hash position of each server both with and without virtual nodes configured. Here are the rules clients should follow when trying to calculate a node's hash code:

1\\. With *virtual nodes disabled* : Once clients have received the base hash code of the server, they need to normalize it in order to find the exact position of the hash wheel. The process of normalization involves passing the base hash code to the hash function, and then do a small calculation to avoid negative values. The resulting number is the node's position in the hash wheel:

```
public static int getNormalizedHash(int nodeBaseHashCode, Hash hashFct) {
  return hashFct.hash(nodeBaseHashCode) & Integer.MAX_VALUE; // make sure no negative
numbers are involved.
}
```

2\\. With *virtual nodes enabled* : In this case, each node represents N different virtual nodes, and to calculate each virtual node's hash code, we need to take the the range of numbers between 0 and N-1 and apply the following logic:

- For virtual node with 0 as id, use the technique used to retrieve a node's hash code, as shown in the previous section.
- For virtual nodes from 1 to N-1 ids, execute the following logic:

```
public static int virtualNodeHashCode(int nodeBaseHashCode, int id, Hash hashFct) {
  int virtualNodeBaseHashCode = id;
  virtualNodeBaseHashCode = 31 * virtualNodeBaseHashCode + nodeBaseHashCode;
  return getNormalizedHash(virtualNodeBaseHashCode, hashFct);
}
```

20.6.3. Hot Rod Protocol 1.2

INFINISPAN VERSIONS

This version of the protocol is implemented since Red Hat Data Grid 5.2.0.Final. Since Red Hat Data Grid 5.3.0, HotRod supports encryption via SSL. However, since this only affects the transport, the version number of the protocol has not been incremented.

20.6.3.1. Request Header

The **version** field in the header is updated to **12**.

Two new request operation codes have been added:

- 0x1B = getWithMetadata request
- 0x1D = bulkKeysGet request

Two new flags have been added too:

- 0x0002 = use cache-level configured default lifespan
- 0x0004 = use cache-level configured default max idle

20.6.3.2. Response Header

Two new response operation codes have been added:

- 0x1C = getWithMetadata response
- 0x1E = bulkKeysGet response

20.6.3.3. Operations

GetWithMetadata

Request (0x1B):

Field Name	Size	Value
Header	variable	Request header
Key Length	vInt	Length of key. Note that the size of a vint can be up to 5 bytes which in theory can produce bigger numbers than Integer.MAX_VALUE. However, Java cannot create a single array that's bigger than Integer.MAX_VALUE, hence the protocol is limiting vint array lengths to Integer.MAX_VALUE.
Key	byte array	Byte array containing the key whose value is being requested.

Response (0x1C):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if key retrieved 0x02 = if key does not exist
Flag	1 byte	A flag indicating whether the response contains expiration information. The value of the flag is obtained as a bitwise OR operation between INFINITE_LIFESPAN (0x01) and **INFINITE_MAXIDLE (0x02)**.

Field Name	Size	Value
Created	Long	(optional) a Long representing the timestamp when the entry was created on the server. This value is returned only if the flag's INFINITE_LIFESPAN bit is not set.
Lifespan	vInt	(optional) a vInt representing the lifespan of the entry in seconds. This value is returned only if the flag's INFINITE_LIFESPAN bit is not set.
LastUsed	Long	(optional) a Long representing the timestamp when the entry was last accessed on the server. This value is returned only if the flag's **INFINITE_MAXIDLE** bit is not set.
MaxIdle	vInt	(optional) a vInt representing the maxIdle of the entry in seconds. This value is returned only if the flag's **INFINITE_MAXIDLE** bit is not set.
Entry Version	8 bytes	Unique value of an existing entry's modification. The protocol does not mandate that entry_version values are sequential. They just need to be unique per update at the key level.
Value Length	vInt	If success, length of value
Value	byte array	If success, the requested value

BulkKeysGet

Request (0x1D):

Field Name	Size	Value
Header	variable	Request header
Scope	vInt	0 = Default Scope - This scope is used by RemoteCache.keySet() method. If the remote cache is a distributed cache, the server launch a stream operation to retrieve all keys from all of the nodes. (Remember, a topology-aware Hot Rod Client could be load balancing the request to any one node in the cluster). Otherwise, it'll get keys from the cache instance local to the server receiving the request (that is because the keys should be the same across all nodes in a replicated cache). 1 = Global Scope - This scope behaves the same to Default Scope. 2 = Local Scope - In case when remote cache is a distributed cache, the server will not launch a stream operation to retrieve keys from all nodes. Instead, it'll only get keys local from the cache instance local to the server receiving the request.

Response (0x1E):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, data follows
More	1 byte	One byte representing whether more keys need to be read from the stream. So, when it’s set to 1, it means that an entry follows, whereas when it’s set to 0, it’s the end of stream and no more entries are left to read. For more information on BulkGet look here
Key 1 Length	vInt	Length of key
Key 1	byte array	Retrieved key
More	1 byte	
Key 2 Length	vInt	
Key 2	byte array	
... etc		

20.6.4. Hot Rod Protocol 1.3

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 6.0.0.Final.

20.6.4.1. Request Header

The **version** field in the header is updated to **13**.

A new request operation code has been added:

- 0x1F = query request

20.6.4.2. Response Header

A new response operation code has been added:

- 0x20 = query response

20.6.4.3. Operations

Query

Request (0x1F):

Field Name	Size	Value
Header	variable	Request header
Query Length	vInt	The length of the protobuf encoded query object
Query	byte array	Byte array containing the protobuf encoded query object, having a length specified by previous field.

Response (0x20):

Field Name	Size	Value
Header	variable	Response header
Response payload Length	vInt	The length of the protobuf encoded response object
Response payload	byte array	Byte array containing the protobuf encoded response object, having a length specified by previous field.

As of Infinispan 6.0, the query and response objects are specified by the protobuf message types 'org.infinispan.client.hotrod.impl.query.QueryRequest' and 'org.infinispan.client.hotrod.impl.query.QueryResponse' defined in remote-query/remote-query-client/src/main/resources/org/infinispan/query/remote/client/query.proto. These definitions could change in future Infinispan versions, but as long as these evolutions will be kept backward compatible (according to the rules defined here) no new Hot Rod protocol version will be introduced to accommodate this.

20.6.5. Hot Rod Protocol 2.0

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 7.0.0.Final.

20.6.5.1. Request Header

The request header no longer contains **Transaction Type** and **Transaction ID** elements since they're not in use, and even if they were in use, there are several operations for which they would not make sense, such as **ping** or **stats** commands. Once transactions are implemented, the protocol version will be upped, with the necessary changes in the request header.

The **version** field in the header is updated to **20**.

Two new flags have been added:

- 0x0008 = operation skips loading from configured cache loader.
- 0x0010 = operation skips indexing. Only relevant when the query module is enabled for the cache

The following new request operation codes have been added:

- 0x21 = auth mech list request
- 0x23 = auth request
- 0x25 = add client remote event listener request
- 0x27 = remove client remote event listener request
- 0x29 = size request

20.6.5.2. Response Header

The following new response operation codes have been added:

- 0x22 = auth mech list response
- 0x24 = auth mech response
- 0x26 = add client remote event listener response
- 0x28 = remove client remote event listener response
- 0x2A = size response

Two new error codes have also been added to enable clients more intelligent decisions, particularly when it comes to fail-over logic:

- 0x87 = Node suspected. When a client receives this error as response, it means that the node that responded had an issue sending an operation to a third node, which was suspected. Generally, requests that return this error should be failed-over to other nodes.
- 0x88 = Illegal lifecycle state. When a client receives this error as response, it means that the server-side cache or cache manager are not available for requests because either stopped, they're stopping or similar situation. Generally, requests that return this error should be failed-over to other nodes.

Some adjustments have been made to the responses for the following commands in order to better handle response decoding without the need to keep track of the information sent. More precisely, the way previous values are parsed has changed so that the status of the command response provides clues on whether the previous value follows or not. More precisely:

- Put response returns **0x03** status code when put was successful and previous value follows.
- PutIfAbsent response returns **0x04** status code only when the putIfAbsent operation failed because the key was present and its value follows in the response. If the putIfAbsent worked, there would have not been a previous value, and hence it does not make sense returning anything extra.
- Replace response returns **0x03** status code only when replace happened and the previous or replaced value follows in the response. If the replace did not happen, it means that the cache entry was not present, and hence there's no previous value that can be returned.
- ReplaceIfUnmodified returns **0x03** status code only when replace happened and the previous or replaced value follows in the response.

- ReplaceIfUnmodified returns **0x04** status code only when replace did not happen as a result of the key being modified, and the modified value follows in the response.
- Remove returns **0x03** status code when the remove happened and the previous or removed value follows in the response. If the remove did not occur as a result of the key not being present, it does not make sense sending any previous value information.
- RemoveIfUnmodified returns **0x03** status code only when remove happened and the previous or replaced value follows in the response.
- RemoveIfUnmodified returns **0x04** status code only when remove did not happen as a result of the key being modified, and the modified value follows in the response.

20.6.5.3. Distribution-Aware Client Topology Change Header

In Infinispan 5.2, virtual nodes based consistent hashing was abandoned and instead segment based consistent hash was implemented. In order to satisfy the ability for Hot Rod clients to find data as reliably as possible, Red Hat Data Grid has been transforming the segment based consistent hash to fit Hot Rod 1.x protocol. Starting with version 2.0, a brand new distribution-aware topology change header has been implemented which suppors segment based consistent hashing suitably and provides 100% data location guarantees.

Field Name	Size	Value
Response header with topology change marker	variable	
Topology Id	vInt	Topology ID
Num servers in topology	vInt	Number of Red Hat Data Grid Hot Rod servers running within the cluster. This could be a subset of the entire cluster if only a fraction of those nodes are running Hot Rod servers.
m1: Host/IP length	vInt	Length of hostname or IP address of individual cluster member that Hot Rod client can use to access it. Using variable length here allows for covering for hostnames, IPv4 and IPv6 addresses.
m1: Host/IP address	string	String containing hostname or IP address of individual cluster member that Hot Rod client can use to access it.
m1: Port	2 bytes (Unsigned Short)	Port that Hot Rod clients can use to communicat with this cluster member.
m2: Host/IP length	vInt	
m2: Host/IP address	string	

Field Name	Size	Value
m2: Port	2 bytes (Unsigned Short)	
...	...	
Hash Function Version	1 byte	Hash function version, pointing to a specific hash function in use. See Hot Rod hash functions for details.
Num segments in topology	vInt	Total number of segments in the topology
Number of owners in segment	1 byte	This can be either 0, 1 or 2 owners.
First owner’s index	vInt	Given the list of all nodes, the position of this owner in this list. This is only present if number of owners for this segment is 1 or 2.
Second owner’s index	vInt	Given the list of all nodes, the position of this owner in this list. This is only present if number of owners for this segment is 2.

Given this information, Hot Rod clients should be able to recalculate all the hash segments and be able to find out which nodes are owners for each segment. Even though there could be more than 2 owners per segment, Hot Rod protocol limits the number of owners to send for efficiency reasons.

20.6.5.4. Operations

Auth Mech List

Request (0x21):

Field Name	Size	Value
Header	variable	Request header

Response (0x22):

Field Name	Size	Value
Header	variable	Response header
Mech count	vInt	The number of mechs
Mech 1	string	String containing the name of the SASL mech in its IANA-registered form (e.g. GSSAPI, CRAM-MD5, etc)

Field Name	Size	Value
Mech 2	string	
...etc		

The purpose of this operation is to obtain the list of valid SASL authentication mechs supported by the server. The client will then need to issue an Authenticate request with the preferred mech.

Authenticate

Request (0x23):

Field Name	Size	Value
Header	variable	Request header
Mech	string	String containing the name of the mech chosen by the client for authentication. Empty on the successive invocations
Response length	vInt	Length of the SASL client response
Response data	byte array	The SASL client response

Response (0x24):

Field Name	Size	Value
Header	variable	Response header
Completed	byte	0 if further processing is needed, 1 if authentication is complete
Challenge length	vInt	Length of the SASL server challenge
Challenge data	byte array	The SASL server challenge

The purpose of this operation is to authenticate a client against a server using SASL. The authentication process, depending on the chosen mech, might be a multi-step operation. Once complete the connection becomes authenticated

Add client listener for remote events

Request (0x25):

Field Name	Size	Value
Header	variable	Request header

Field Name	Size	Value
Listener ID	byte array	Listener identifier
Include state	byte	When this byte is set to **1**, cached state is sent back to remote clients when either adding a cache listener for the first time, or when the node where a remote listener is registered changes in a clustered environment. When enabled, state is sent back as cache entry created events to the clients. If set to **0**, no state is sent back to the client when adding a listener, nor it gets state when the node where the listener is registered changes.
Key/value filter factory name	string	Optional name of the key/value filter factory to be used with this listener. The factory is used to create key/value filter instances which allow events to be filtered directly in the Hot Rod server, avoiding sending events that the client is not interested in. If no factory is to be used, the length of the string is **0**.
Key/value filter factory parameter count	byte	The key/value filter factory, when creating a filter instance, can take an arbitrary number of parameters, enabling the factory to be used to create different filter instances dynamically. This count field indicates how many parameters will be passed to the factory. If no factory name was provided, this field is not present in the request.
Key/value filter factory parameter 1	byte array	First key/value filter factory parameter
Key/value filter factory parameter 2	byte array	Second key/value filter factory parameter
…		
Converter factory name	string	Optional name of the converter factory to be used with this listener. The factory is used to transform the contents of the events sent to clients. By default, when no converter is in use, events are well defined, according to the type of event generated. However, there might be situations where users want to add extra information to the event, or they want to reduce the size of the events. In these cases, a converter can be used to transform the event contents. The given converter factory name produces converter instances to do this job. If no factory is to be used, the length of the string is **0**.
Converter factory parameter count	byte	The converter factory, when creating a converter instance, can take an arbitrary number of parameters, enabling the factory to be used to create different converter instances dynamically. This count field indicates how many parameters will be passed to the factory. If no factory name was provided, this field is not present in the request.

Field Name	Size	Value
Converter factory parameter 1	byte array	First converter factory parameter
Converter factory parameter 2	byte array	Second converter factory parameter
...		

Response (0x26):

Field Name	Size	Value
Header	variable	Response header

Remove client listener for remote events

Request (0x27):

Field Name	Size	Value
Header	variable	Request header
Listener ID	byte array	Listener identifier

Response (0x28):

Field Name	Size	Value
Header	variable	Response header

Size

Request (0x29):

Field Name	Size	Value
Header	variable	Request header

Response (0x2A):

Field Name	Size	Value
Header	variable	Response header

Field Name	Size	Value
Size	vInt	Size of the remote cache, which is calculated globally in the clustered set ups, and if present, takes cache store contents into account as well.

Exec

Request (0x2B):

Field Name	Size	Value
Header	variable	Request header
Script	string	Name of the task to execute
Parameter Count	vInt	The number of parameters
Parameter 1 Name	string	The name of the first parameter
Parameter 1 Length	vInt	The length of the first parameter
Parameter 1 Value	byte array	The value of the first parameter

Response (0x2C):

Field Name	Size	Value
Header	variable	Response header
Response status	1 byte	0x00 = success, if execution completed successfully 0x85 = server error
Value Length	vInt	If success, length of return value
Value	byte array	If success, the result of the execution

20.6.5.5. Remote Events

Starting with Hot Rod 2.0, clients can register listeners for remote events happening in the server. Sending these events commences the moment a client adds a client listener for remote events.

Event Header:

Field Name	Size	Value
Magic	1 byte	0xA1 = response
Message ID	vLong	ID of event
Opcode	1 byte	Event type: 0x60 = cache entry created event 0x61 = cache entry modified event 0x62 = cache entry removed event 0x66 = counter event 0x50 = error
Status	1 byte	Status of the response, possible values: 0x00 = No error
Topology Change Marker	1 byte	Since events are not associated with a particular incoming topology ID to be able to decide whether a new topology is required to be sent or not, new topologies will never be sent with events. Hence, this marker will always have **0** value for events.

Table 20.3. Cache entry created event

Field Name	Size	Value
Header	variable	Event header with **0x60** operation code
Listener ID	byte array	Listener for which this event is directed
Custom marker	byte	Custom event marker. For created events, this is **0**.
Command retried	byte	Marker for events that are result of retried commands. If command is retried, it returns **1**, otherwise **0**.
Key	byte array	Created key
Version	long	Version of the created entry. This version information can be used to make conditional operations on this cache entry.

Table 20.4. Cache entry modified event

Field Name	Size	Value
Header	variable	Event header with **0x61** operation code
Listener ID	byte array	Listener for which this event is directed
Custom marker	byte	Custom event marker. For created events, this is **0**.

Field Name	Size	Value
Command retried	byte	Marker for events that are result of retried commands. If command is retried, it returns **1**, otherwise **0**.
Key	byte array	Modified key
Version	long	Version of the modified entry. This version information can be used to make conditional operations on this cache entry.

Table 20.5. Cache entry removed event

Field Name	Size	Value
Header	variable	Event header with **0x62** operation code
Listener ID	byte array	Listener for which this event is directed
Custom marker	byte	Custom event marker. For created events, this is **0**.
Command retried	byte	Marker for events that are result of retried commands. If command is retried, it returns **1**, otherwise **0**.
Key	byte array	Removed key

Table 20.6. Custom event

Field Name	Size	Value
Header	variable	Event header with event specific operation code
Listener ID	byte array	Listener for which this event is directed
Custom marker	byte	Custom event marker. For custom events, this is **1**.
Event data	byte array	Custom event data, formatted according to the converter implementation logic.

20.6.6. Hot Rod Protocol 2.1

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 7.1.0.Final.

20.6.6.1. Request Header

The **version** field in the header is updated to **21**.

20.6.6.2. Operations

Add client listener for remote events

An extra byte parameter is added at the end which indicates whether the client prefers client listener to work with raw binary data for filter/converter callbacks. If using raw data, its value is **1** otherwise **0**.

Request format:

Field Name	Size	Value
Header	variable	Request header
Listener ID	byte array	...
Include state	byte	...
Key/value filter factory parameter count	byte	...
...		
Converter factory name	string	...
Converter factory parameter count	byte	...
...		
Use raw data	byte	If filter/converter parameters should be raw binary, then **1**, otherwise **0**.

Custom event

Starting with Hot Rod 2.1, custom events can return raw data that the Hot Rod client should not try to unmarshall before passing it on to the user. The way this is transmitted to the Hot Rod client is by sending **2** as the custom event marker. So, the format of the custom event remains like this:

Field Name	Size	Value
Header	variable	Event header with event specific operation code
Listener ID	byte array	Listener for which this event is directed
Custom marker	byte	Custom event marker. For custom events whose event data needs to be unmarshalled before returning to user the value is **1**. For custom events that need to return the event data as-is to the user, the value is **2**.

Field Name	Size	Value
Event data	byte array	Custom event data. If the custom marker is **1**, the bytes represent the marshalled version of the instance returned by the converter. If custom marker is **2**, it represents the byte array, as returned by the converter.

20.6.7. Hot Rod Protocol 2.2

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 8.0

Added support for different time units.

20.6.7.1. Operations

Put/PutAll/PutIfAbsent/Replace/ReplaceIfUnmodified

Common request format:

Field Name	Size	Value
TimeUnits	Byte	Time units of lifespan (first 4 bits) and maxIdle (last 4 bits). Special units DEFAULT and INFINITE can be used for default server expiration and no expiration respectively. Possible values: 0x00 = SECONDS 0x01 = MILLISECONDS 0x02 = NANOSECONDS 0x03 = MICROSECONDS 0x04 = MINUTES 0x05 = HOURS 0x06 = DAYS 0x07 = DEFAULT 0x08 = INFINITE
Lifespan	vLong	Duration which the entry is allowed to life. Only sent when time unit is not DEFAULT or INFINITE
Max Idle	vLong	Duration that each entry can be idle before it’s evicted from the cache. Only sent when time unit is not DEFAULT or INFINITE

20.6.8. Hot Rod Protocol 2.3

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 8.0

20.6.8.1. Operations

Iteration Start

Request (0x31):

Field Name	Size	Value
Segments size	signed vInt	Size of the bitset encoding of the segments ids to iterate on. The size is the maximum segment id rounded to nearest multiple of 8. A value -1 indicates no segment filtering is to be done
Segments	byte array	(Optional) Contains the segments ids bitset encoded, where each bit with value 1 represents a segment in the set. Byte order is little-endian. Example: segments [1,3,12,13] would result in the following encoding: 00001010 00110000 size: 16 bits first byte: represents segments from 0 to 7, from which 1 and 3 are set second byte: represents segments from 8 to 15, from which 12 and 13 are set More details in the java.util.BitSet implementation. Segments will be sent if the previous field is not negative
FilterConverter size	signed vInt	The size of the String representing a KeyValueFilterConverter factory name deployed on the server, or -1 if no filter will be used
FilterConverter	UTF-8 byte array	(Optional) KeyValueFilterConverter factory name deployed on the server. Present if previous field is not negative
BatchSize	vInt	number of entries to transfers from the server at one go

Response (0x32):

Field Name	Size	Value
IterationId	String	The unique id of the iteration

Iteration Next

Request (0x33):

Field Name	Size	Value
IterationId	String	The unique id of the iteration

Response (0x34):

Field Name	Size	Value
Finished segments size	vInt	size of the bitset representing segments that were finished iterating
Finished segments	byte array	bitset encoding of the segments that were finished iterating
Entry count	vInt	How many entries are being returned
Key 1 Length	vInt	Length of key
Key 1	byte array	Retrieved key
Value 1 Length	vInt	Length of value
Value 1	byte array	Retrieved value
Key 2 Length	vInt	
Key 2	byte array	
Value 2 Length	vInt	
Value 2	byte array	
... continues until entry count is reached		

Iteration End

Request (0x35):

Field Name	Size	Value
IterationId	String	The unique id of the iteration

Response (0x36):

Header	variable	Response header
Response status	1 byte	0x00 = success, if execution completed successfully 0x05 = for non existent IterationId

20.6.9. Hot Rod Protocol 2.4

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 8.1

This Hot Rod protocol version adds three new status code that gives the client hints on whether the server has compatibility mode enabled or not:

- **0x06**: Success status and compatibility mode is enabled.
- **0x07**: Success status and return previous value, with compatibility mode is enabled.
- **0x08**: Not executed and return previous value, with compatibility mode is enabled.

The Iteration Start operation can optionally send parameters if a custom filter is provided and it’s parametrised:

20.6.9.1. Operations

Iteration Start

Request (0x31):

Field Name	Size	Value
Segments size	signed vInt	same as protocol version 2.3.
Segments	byte array	same as protocol version 2.3.
FilterConverter size	signed vInt	same as protocol version 2.3.
FilterConverter	UTF-8 byte array	same as protocol version 2.3.
Parameters size	byte	the number of params of the filter. Only present when FilterConverter is provided.
Parameters	byte[][]	an array of parameters, each parameter is a byte array. Only present if Parameters size is greater than 0.
BatchSize	vInt	same as protocol version 2.3.

The Iteration Next operation can optionally return projections in the value, meaning more than one value is contained in the same entry.

Iteration Next

Response (0x34):

Field Name	Size	Value
Finished segments size	vInt	same as protocol version 2.3.
Finished segments	byte array	same as protocol version 2.3.
Entry count	vInt	same as protocol version 2.3.
Number of value projections	vInt	Number of projections for the values. If 1, behaves like version protocol version 2.3.
Key1 Length	vInt	same as protocol version 2.3.
Key1	byte array	same as protocol version 2.3.
Value1 projection1 length	vInt	length of value1 first projection
Value1 projection1	byte array	retrieved value1 first projection
Value1 projection2 length	vInt	length of value2 second projection
Value1 projection2	byte array	retrieved value2 second projection
… continues until all projections for the value retrieved	Key2 Length	vInt
same as protocol version 2.3.	Key2	byte array
same as protocol version 2.3.	Value2 projection1 length	vInt
length of value 2 first projection	Value2 projection1	byte array
retrieved value 2 first projection	Value2 projection 2 length	vInt
length of value 2 second projection	Value2 projection 2	byte array

Field Name	Size	Value
retrieved value 2 second projection	… continues until entry count is reached	

1. Stats:

Statistics returned by previous Hot Rod protocol versions were local to the node where the Hot Rod operation had been called. Starting with 2.4, new statistics have been added which provide global counts for the statistics returned previously. If the Hot Rod is running in local mode, these statistics are not returned:

Name	Explanation
globalCurrentNumberOfEntries	Number of entries currently across the Hot Rod cluster.
globalStores	Total number of put operations across the Hot Rod cluster.
globalRetrievals	Total number of get operations across the Hot Rod cluster.
globalHits	Total number of get hits across the Hot Rod cluster.
globalMisses	Total number of get misses across the Hot Rod cluster.
globalRemoveHits	Total number of removal hits across the Hot Rod cluster.
globalRemoveMisses	Total number of removal misses across the Hot Rod cluster.

20.6.10. Hot Rod Protocol 2.5

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 8.2

This Hot Rod protocol version adds support for metadata retrieval along with entries in the iterator. It includes two changes:

- Iteration Start request includes an optional flag
- IterationNext operation may include metadata info for each entry if the flag above is set

Iteration Start

Request (0x31):

Field Name	Size	Value
Segments size	signed vInt	same as protocol version 2.4.
Segments	byte array	same as protocol version 2.4.
FilterConverter size	signed vInt	same as protocol version 2.4.
FilterConverter	UTF-8 byte array	same as protocol version 2.4.
Parameters size	byte	same as protocol version 2.4.
Parameters	byte[][]	same as protocol version 2.4.
BatchSize	vInt	same as protocol version 2.4.
Metadata	1 byte	1 if metadata is to be returned for each entry, 0 otherwise

Iteration Next

Response (0x34):

Field Name	Size	Value
Finished segments size	vInt	same as protocol version 2.4.
Finished segments	byte array	same as protocol version 2.4.
Entry count	vInt	same as protocol version 2.4.
Number of value projections	vInt	same as protocol version 2.4.
Metadata (entry 1)	1 byte	If set, entry has metadata associated
Expiration (entry 1)	1 byte	A flag indicating whether the response contains expiration information. The value of the flag is obtained as a bitwise OR operation between INFINITE_LIFESPAN (0x01) and **INFINITE_MAXIDLE (0x02)**. Only present if the metadata flag above is set

Field Name	Size	Value
Created (entry 1)	Long	(optional) a Long representing the timestamp when the entry was created on the server. This value is returned only if the flag's INFINITE_LIFESPAN bit is not set.
Lifespan (entry 1)	vInt	(optional) a vInt representing the lifespan of the entry in seconds. This value is returned only if the flag's INFINITE_LIFESPAN bit is not set.
LastUsed (entry 1)	Long	(optional) a Long representing the timestamp when the entry was last accessed on the server. This value is returned only if the flag's **INFINITE_MAXIDLE** bit is not set.
MaxIdle (entry 1)	vInt	(optional) a vInt representing the maxIdle of the entry in seconds. This value is returned only if the flag's **INFINITE_MAXIDLE** bit is not set.
Entry Version (entry 1)	8 bytes	Unique value of an existing entry's modification. Only present if Metadata flag is set
Key 1 Length	vInt	same as protocol version 2.4.
Key 1	byte array	same as protocol version 2.4.
Value 1 Length	vInt	same as protocol version 2.4.
Value 1	byte array	same as protocol version 2.4.
Metadata (entry 2)	1 byte	Same as for entry 1
Expiration (entry 2)	1 byte	Same as for entry 1
Created (entry 2)	Long	Same as for entry 1
Lifespan (entry 2)	vInt	Same as for entry 1
LastUsed (entry 2)	Long	Same as for entry 1
MaxIdle (entry 2)	vInt	Same as for entry 1
Entry Version (entry 2)	8 bytes	Same as for entry 1
Key 2 Length	vInt	
Key 2	byte array	

Field Name	Size	Value
Value 2 Length	vInt	
Value 2	byte array	
... continues until entry count is reached		

20.6.11. Hot Rod Protocol 2.6

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 9.0

This Hot Rod protocol version adds support for streaming get and put operations. It includes two new operations:

- GetStream for retrieving data as a stream, with an optional initial offset
- PutStream for writing data as a stream, optionally by specifying a version

GetStream

Request (0x37):

Field Name	Size	Value
Header	variable	Request header
Offset	vInt	The offset in bytes from which to start retrieving. Set to 0 to retrieve from the beginning
Key Length	vInt	Length of key. Note that the size of a vint can be up to 5 bytes which in theory can produce bigger numbers than Integer.MAX_VALUE. However, Java cannot create a single array that's bigger than Integer.MAX_VALUE, hence the protocol is limiting vint array lengths to Integer.MAX_VALUE.
Key	byte array	Byte array containing the key whose value is being requested.

GetStream

Response (0x38):

Field Name	Size	Value
Header	variable	Response header

Field Name	Size	Value
Response status	1 byte	0x00 = success, if key retrieved 0x02 = if key does not exist
Flag	1 byte	A flag indicating whether the response contains expiration information. The value of the flag is obtained as a bitwise OR operation between INFINITE_LIFESPAN (0x01) and **INFINITE_MAXIDLE (0x02)**.
Created	Long	(optional) a Long representing the timestamp when the entry was created on the server. This value is returned only if the flag's INFINITE_LIFESPAN bit is not set.
Lifespan	vInt	(optional) a vInt representing the lifespan of the entry in seconds. This value is returned only if the flag's INFINITE_LIFESPAN bit is not set.
LastUsed	Long	(optional) a Long representing the timestamp when the entry was last accessed on the server. This value is returned only if the flag's **INFINITE_MAXIDLE** bit is not set.
MaxIdle	vInt	(optional) a vInt representing the maxIdle of the entry in seconds. This value is returned only if the flag's **INFINITE_MAXIDLE** bit is not set.
Entry Version	8 bytes	Unique value of an existing entry's modification. The protocol does not mandate that entry_version values are sequential. They just need to be unique per update at the key level.
Value Length	vInt	If success, length of value
Value	byte array	If success, the requested value

PutStream

Request (0x39)

Field Name	Size	Value
Header	variable	Request header
Entry Version	8 bytes	Possible values 0 = Unconditional put -1 = Put If Absent Other values = pass a version obtained by **GetWithMetadata** operation to perform a conditional replace.

Field Name	Size	Value
Key Length	vInt	Length of key. Note that the size of a vint can be up to 5 bytes which in theory can produce bigger numbers than Integer.MAX_VALUE. However, Java cannot create a single array that's bigger than Integer.MAX_VALUE, hence the protocol is limiting vint array lengths to Integer.MAX_VALUE.
Key	byte array	Byte array containing the key whose value is being requested.
Value Chunk 1 Length	vInt	The size of the first chunk of data. If this value is 0 it means the client has completed transferring the value and the operation should be performed.
Value Chunk 1	byte array	Array of bytes forming the fist chunk of data.
…continues until the value is complete		

Response (0x3A):

Field Name	Size	Value
Header	variable	Response header

On top of these additions, this Hot Rod protocol version improves remote listener registration by adding a byte that indicates at a global level, which type of events the client is interested in. For example, a client can indicate that only created events, or only expiration and removal events…etc. More fine grained event interests, e.g. per key, can be defined using the key/value filter parameter.

So, the new add listener request looks like this:

Add client listener for remote events

Request (0x25):

Field Name	Size	Value
Header	variable	Request header
Listener ID	byte array	Listener identifier

Field Name	Size	Value
Include state	byte	When this byte is set to **1**, cached state is sent back to remote clients when either adding a cache listener for the first time, or when the node where a remote listener is registered changes in a clustered environment. When enabled, state is sent back as cache entry created events to the clients. If set to **0**, no state is sent back to the client when adding a listener, nor it gets state when the node where the listener is registered changes.
Key/value filter factory name	string	Optional name of the key/value filter factory to be used with this listener. The factory is used to create key/value filter instances which allow events to be filtered directly in the Hot Rod server, avoiding sending events that the client is not interested in. If no factory is to be used, the length of the string is **0**.
Key/value filter factory parameter count	byte	The key/value filter factory, when creating a filter instance, can take an arbitrary number of parameters, enabling the factory to be used to create different filter instances dynamically. This count field indicates how many parameters will be passed to the factory. If no factory name was provided, this field is not present in the request.
Key/value filter factory parameter 1	byte array	First key/value filter factory parameter
Key/value filter factory parameter 2	byte array	Second key/value filter factory parameter
…		
Converter factory name	string	Optional name of the converter factory to be used with this listener. The factory is used to transform the contents of the events sent to clients. By default, when no converter is in use, events are well defined, according to the type of event generated. However, there might be situations where users want to add extra information to the event, or they want to reduce the size of the events. In these cases, a converter can be used to transform the event contents. The given converter factory name produces converter instances to do this job. If no factory is to be used, the length of the string is **0**.
Converter factory parameter count	byte	The converter factory, when creating a converter instance, can take an arbitrary number of parameters, enabling the factory to be used to create different converter instances dynamically. This count field indicates how many parameters will be passed to the factory. If no factory name was provided, this field is not present in the request.
Converter factory parameter 1	byte array	First converter factory parameter

Field Name	Size	Value
Converter factory parameter 2	byte array	Second converter factory parameter
...		
Listener even type interests	vInt	A variable length number representing listener event type interests. Each event type is represented by a bit. Each flags is represented by a bit. Note that since this field is sent as variable length, the most significant bit in a byte is used to determine whether more bytes need to be read, hence this bit does not represent any flag. Using this model allows for flags to be combined in a short space. Here are the current values for each flag: 0x01 = cache entry created events 0x02 = cache entry modified events 0x04 = cache entry removed events 0x08 = cache entry expired events

20.6.12. Hot Rod Protocol 2.7

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 9.2

This Hot Rod protocol version adds support for transaction operations. It includes 3 new operations:

- Prepare, with the transaction write set (i.e. modified keys), it tries to prepare and validate the transaction in the server.
- Commit, commits a prepared transaction.
- Rollback, rollbacks a prepared transaction.

Prepare Request

Request (0x3B):

Field Name	Size	Value
Header	variable	Request header
Xid	XID	The transaction ID (XID)
OnePhaseCommit	byte	When it is set to **1**, the server will use one-phase-commit if available (XA only)
Number of keys	vInt	The number of keys
For each key (keys must be distinct)		

Field Name	Size	Value
Key Length	vInt	Length of key. Note that the size of a vInt can be up to 5 bytes which in theory can produce bigger numbers than **Integer.MAX_VALUE**. However, Java cannot create a single array that's bigger than **Integer.MAX_VALUE**, hence the protocol is limiting vInt array lengths to **Integer.MAX_VALUE**.
Key	byte array	Byte array containing the key
Control Byte	Byte	A bit set with the following meaning: 0x01 = **NOT_READ** 0x02 = **NON_EXISTING** 0x04 = **REMOVE_OPERATION** Note that **NOT_READ** and **NON_EXISTING** can't be set at the same time.
Version Read	long	The version read. Only sent when **NOT_READ** and **NON_EXISTING** aren't present.
TimeUnits	Byte	Time units of lifespan (first 4 bits) and maxIdle (last 4 bits). Special units **DEFAULT** and **INFINITE** can be used for default server expiration and no expiration respectively. Possible values: 0x00 = **SECONDS** 0x01 = **MILLISECONDS** 0x02 = **NANOSECONDS** 0x03 = **MICROSECONDS** 0x04 = **MINUTES** 0x05 = **HOURS** 0x06 = **DAYS** 0x07 = **DEFAULT** 0x08 = **INFINITE** Only sent when **REMOVE_OPERATION** isn't set.
Lifespan	vLong	Duration which the entry is allowed to life. Only sent when time unit is not **DEFAULT** or **INFINITE** and **REMOVE_OPERATION** isn't set.
Max Idle	vLong	Duration that each entry can be idle before it's evicted from the cache. Only sent when time unit is not **DEFAULT** or **INFINITE** and **REMOVE_OPERATION** isn't set.
Value Length	vInt	Length of value. Only sent if **REMOVE_OPERATION** isn't set.
Value	byte-array	Value to be stored. Only sent if **REMOVE_OPERATION** isn't set.

Commit and Rollback Request

Request. Commit (0x3D) and Rollback (0x3F):

Field Name	Size	Value
Header	variable	Request header
Xid	XID	The transaction ID (XID)

Response from prepare, commit and rollback request.

Response. Prepare (0x3C), Commit (0x3E) and Rollback (0x40)

Field Name	Size	Value
Header	variable	Response header
XA return code	vInt	The XA code representing the prepare response. Can be **XA_OK(0)**, **XA_RDONLY(3)** or any of the error codes (see **XaException**). This field isn't present if the response state is different from **Successful**.

XID Format

The XID in the requests has the following format:

Field Name	Size	Value
Format ID	signed vInt	The XID format.
Length of Global Transaction id	byte	The length of global transaction id byte array. It max value is **64**.
Global Transaction Id	byte array	The global transaction id.
Length of Branch Qualifier	byte	The length of branch qualifier byte array. It max value is **64**.
Branch Qualifier	byte array	The branch qualifier.

Counter Configuration encoding format

The **CounterConfiguration** class encoding format is the following:

NOTE

In counter related operation, the **Cache Name** field in Request Header can be empty.

NOTE

Summary of **Status** value in the Response Header:
* **0x00**: Operation successful.
* **0x01**: Operation failed.
* **0x02**: The counter isn't defined.
* **0x04**: The counter reached a boundary. Only possible for **STRONG** counters.

Field Name	Size	Value
Flags	byte	The **CounterType** and **Storage** encoded. Only the less significant bits are used as following: 1st bit: **1** for **WEAK** counter and **0** for **STRONG** counter. 2nd bit: **1** for **BOUNDED** counter and **0** for **UNBOUNDED** counter 3rd bit: **1** for **PERSISTENT** storage and **0** for **VOLATILE** storage.
Concurrency Level	vInt	(Optional) the counter's concurrency-level. Only present if the counter is **WEAK**.
Lower bound	long	(Optional) the lower bound of a bounded counter. Only present if the counter is **BOUNDED**.
Upper bound	long	(Optional) the upper bound of a bounded counter. Only present if the counter is **BOUNDED**.
Initial value	long	The counter's initial value.

Counter create operation

Creates a counter if it doesn't exist.

Table 20.7. Request (0x4B)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter's name
Counter Configuration	variable	The counter's configuration. See CounterConfiguration encode.

Table 20.8. Response (0x4C)

Field Name	Size	Value
Header	variable	Response header

Response Header **Status** possible values:

- **0x00**: Operation successful.
- **0x01**: Operation failed. Counter is already defined.
- See the Reponse Header for error codes.

Counter get configuration operation

Returns the counter's configuration.

Table 20.9. Request (0x4D)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter's name.

Table 20.10. Response (0x4E)

Field Name	Size	Value
Header	variable	Response header
Counter Configuration	variable	(Optional) The counter's configuration. Only present if **Status==0x00**. See CounterConfiguration encode.

Response Header **Status** possible values:

- **0x00**: Operation successful.
- **0x02**: Counter doesn't exist.
- See the Reponse Header for error codes.

Counter is defined operation

Checks if the counter is defined.

Table 20.11. Request (0x4F)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter's name

Table 20.12. Response (0x51)

Field Name	Size	Value
Header	variable	Response header

Response Header **Status** possible values:

- **0x00**: Counter is defined.
- **0x01**: Counter isn't defined.
- See the Reponse Header for error codes.

Counter add-and-get operation

Adds a value to the counter and returns the new value.

Table 20.13. Request (0x52)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter's name
Value	long	The value to add

Table 20.14. Response (0x53)

Field Name	Size	Value
Header	variable	Response header
Value	long	(Optional) the counter's new value. Only present if **Status==0x00**.

NOTE

Since the **WeakCounter** doesn't have access to the new value, the **value** is zero.

Response Header **Status** possible values:

- **0x00**: Operation successful.
- **0x02**: The counter isn't defined.
- **0x04**: The counter reached its boundary. Only possible for **STRONG** counters.
- See the Reponse Header for error codes.

Counter reset operation

Resets the counter’s value.

Table 20.15. Request (0x54)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter’s name

Table 20.16. Response (0x55)

Field Name	Size	Value
Header	variable	Response header

Response Header **Status** possible values:

- **0x00**: Operation successful.
- **0x02**: Counter isn’t defined.
- See the Reponse Header for error codes.

Counter get operation

Returns the counter’s value.

Table 20.17. Request (0x56)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter’s name

Table 20.18. Response (0x57)

Field Name	Size	Value
Header	variable	Response header
Value	long	(Optional) the counter’s value. Only present if **Status==0x00**.

Response Header **Status** possible values:

- **0x00**: Operation successful.
- **0x02**: Counter isn’t defined.

- See the Reponse Header for error codes.

Counter compare-and-swap operation

Compares and only updates the counter value if the current value is the expected.

Table 20.19. Request (0x58)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter's name
Expect	long	The counter's expected value.
Update	long	The counter's value to set.

Table 20.20. Response (0x59)

Field Name	Size	Value
Header	variable	Response header
Value	long	(Optional) the counter's value. Only present if **Status==0x00**.

Response Header **Status** possible values:

- **0x00**: Operation successful.
- **0x02**: The counter isn't defined.
- **0x04**: The counter reached its boundary. Only possible for **STRONG** counters.
- See the Reponse Header for error codes.

Counter add and remove listener

Adds/Removes a listener for a counter

Table 20.21. Request ADD (0x5A) / REMOVE (0x5C)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter's name
Listener-id	byte array	The listener's id

Table 20.22. Response: ADD (0x5B) / REMOVE (0x5D)

Field Name	Size	Value
Header	variable	Response header

Response Header **Status** possible values:

- **0x00**: Operation successful and the connection used in the request will be used to send event (add) or the connection can be removed (remove).
- **0x01**: Operation successful and the current connection is still in use.
- **0x02**: The counter isn't defined.
- See the Reponse Header for error codes.

Table 20.23. Counter Event (0x66)

Field Name	Size	Value
Header	variable	Event header with operation code **0x66**
Name	string	The counter's name
Listener-id	byte array	The listener's id
Encoded Counter State	byte	Encoded old and new counter state. Bit set: **------00**: Valid old state **------01**: Lower bound reached old state **------10**: Upper bound reached old state **----00--**: Valid new state **----01--**: Lower bound reached new state **----10--**: Upper bound reached new state
Old value	long	Counter's old value
New value	long	Counter's new value

NOTE

All counters under a **CounterManager** implementation can use the same **listener-id**.

NOTE

A connection is dedicated to a single **listener-id** and can receive events from different counters.

Counter remove operation

Removes the counter from the cluster.

NOTE

The counter is re-created if it is accessed again.

Table 20.24. Request (0x5E)

Field Name	Size	Value
Header	variable	Request header
Name	string	The counter's name

Table 20.25. Response (0x5F)

Field Name	Size	Value
Header	variable	Response header

Response Header **Status** possible values:

- **0x00**: Operation successful.
- **0x02**: The counter isn't defined.
- See the Reponse Header for error codes.

20.6.13. Hot Rod Protocol 2.8

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 9.3

Events

The protocol allows clients to send requests on the same connection that was previously used for Add Client Listener operation, and in protocol < 2.8 is reserved for sending events to the client. This includes registering additional listeners, therefore receiving events for multiple listeners.

The binary format of requests/responses/events does not change but the previously meaningless **messageId** in events must be set to:

- **messageId** of the Add Client Listener operation for the include-current-state events
- **0** for the events sent after the Add Client Listener operation has been finished (response sent).

The same holds for counter events: client can send further requests after Counter Add Listener. Previously meaningless **messageId** in counter event is always set to **0**.

These modifications of the protocol do not require any changes on the client side (as the client simply won't send additional operations if it does not support that; the changes are more permissive to the clients) but the server has to handle load on the connection correctly.

MediaType

This Hot Rod protocol version also adds support for specifying the MediaType of Keys and Values, allowing data to be read (and written) in different formats. This information is part of the Header.

The data formats are described using a *MediaType* object, that is represented as follows:

Field Name	Size	Value
type	1 byte	0x00 = No MediaType supplied 0x01 = Pre-defined MediaType supplied 0x02 = Custom MediaType supplied
id	vInt	(Optional) For a pre-defined MediaType (type=0x01), the Id of the MediaType. The currently supported Ids can be found at MediaTypeIds
customString	string	(Optional) If a custom MediaType is supplied (type=0x02), the custom MediaType of the key, including type and subtype. E.g.: *text/plain*, *application/json*, etc.
paramSize	vInt	The size of the parameters for the MediaType
paramKey1	string	(Optional) The first parameter's key
paramValue1	string	(Optional) The first parameter's value
...	...	...
paramKeyN	string	(Optional) The nth parameter's key
paramValueN	string	(Optional) The nth parameter's value

20.6.13.1. Request Header

The request header has the following extra fields:

Field Name	Type	Value
Key Format	MediaType	The MediaType to be used for keys during the operation. It applies to both the keys sent and received.
Value Format	MediaType	Analogous to Key Format, but applied for the values.

20.6.14. Hot Rod Protocol 2.9

INFINISPAN VERSIONS

This version of the protocol is implemented since Infinispan 9.4

Compatibility Mode removal

The compatibility mode hint from the *Response status* fields from the operations is not sent anymore. Consequently, the following statuses are removed:

- **0x06**: Success status with compatibility mode.
- **0x07**: Success status with return previous value and compatibility mode.
- **0x08**: Not executed with return previous value and compatibility mode.

To figure out what is the server's storage, the configured MediaType of keys and values are returned on the ping operation:

Ping Response (0x18):

Field Name	Size	Value
Header	variable	same as before
Response status	1 byte	same as before
Key Type	MediaType	Media Type of the key stored in the server
Value Type	MediaType	Media Type of the value stored in the server

New query format

This version supports query requests and responses in JSON format. The format of the operations **0x1F** (Query Request) and **0x20** (Query Response) are not changed.

To send JSON payloads, the "Value Format" field in the header should be *application/json*.

Query Request (0x1F):

Field Name	Size	Value
Header	variable	Request header
Query Length	vInt	The length of the UTF-8 encoded query object.

Field Name	Size	Value

Query	byte array	Byte array containing the JSON (UTF-8) encoded query object, having a length specified by the previous field. Example of payload:
		`{`
		` "query":"From Entity where field1:'value1'",`
		` "offset": 12,`
		` "max-results": 1000,`
		` "query-mode": "FETCH"`
		`}`
		Where:
		`query: the Ickle query String.`
		`offset: the index of the first result to return.`
		`max_results: the maximum number of results to return.`
		`query_mode: the indexed query mode. Either FETCH or BROADCAST. FECTH is the default.`

Query Response (0x20):

Field Name	Size	Value
Header	variable	Response header
Response payload Length	vInt	The length of the UTF-8 encoded response object

Field Name	Size	Value

Response payload	byte array	Byte array containing the JSON encoded response object, having a length specified by previous field. Example payload:
		```
		{
		  "total_results":801,
		  "hits":[
		    {
		      "hit":{
		        "field1":565,
		        "field2":"value2"
		      }
		    },
		    {
		      "hit":{
		        "field1":34,
		        "field2":"value22"
		      }
		    }
		  ]
		}
		```
		 Where:
		```
		total_results: the total number of results of the query.
		hits: an ARRAY of OBJECT representing the results.
		hit: each OBJECT above contain another OBJECT in the "hit"
		field, containing the result of the query, in JSON format.
		```

Also, this version introduces 3 new operations for Hot Rod transactions:

- Prepare Request V2: It adds new parameters to the request. The response stays the same.
- Forget Transaction Request: Removes transaction information in the server.
- Fetch In-Doubt Transactions Request: Fetches all in-doubt transactions's Xid.

Prepare Request V2

Request (0x7D):

Field Name	Size	Value
Header	variable	Request header
Xid	XID	The transaction ID (XID)
OnePhaseCommit	byte	When it is set to **1**, the server will use one-phase-commit if available (XA only)

Field Name	Size	Value
Recoverable	byte	Set to **1** to allow recovery in this transactions
Timeout	long	The idle timeout in milliseconds. If the transaction isn't recoverable (**Recoverable=0**), the server rollbacks the transaction if it has been idle for this amount of time.
Number of keys	vInt	The number of keys
	For each key (keys must be distinct)	
Key Length	vInt	Length of key. Note that the size of a vInt can be up to 5 bytes which in theory can produce bigger numbers than **Integer.MAX_VALUE**. However, Java cannot create a single array that's bigger than **Integer.MAX_VALUE**, hence the protocol is limiting vInt array lengths to **Integer.MAX_VALUE**.
Key	byte array	Byte array containing the key
Control Byte	Byte	A bit set with the following meaning: 0x01 = **NOT_READ** 0x02 = **NON_EXISTING** 0x04 = **REMOVE_OPERATION** Note that **NOT_READ** and **NON_EXISTING** can't be set at the same time.
Version Read	long	The version read. Only sent when **NOT_READ** and **NON_EXISTING** aren't present.
TimeUnits	Byte	Time units of lifespan (first 4 bits) and maxIdle (last 4 bits). Special units **DEFAULT** and **INFINITE** can be used for default server expiration and no expiration respectively. Possible values: 0x00 = **SECONDS** 0x01 = **MILLISECONDS** 0x02 = **NANOSECONDS** 0x03 = **MICROSECONDS** 0x04 = **MINUTES** 0x05 = **HOURS** 0x06 = **DAYS** 0x07 = **DEFAULT** 0x08 = **INFINITE** Only sent when **REMOVE_OPERATION** isn't set.
Lifespan	vLong	Duration which the entry is allowed to life. Only sent when time unit is not **DEFAULT** or **INFINITE** and **REMOVE_OPERATION** isn't set.
Max Idle	vLong	Duration that each entry can be idle before it's evicted from the cache. Only sent when time unit is not **DEFAULT** or **INFINITE** and **REMOVE_OPERATION** isn't set.

Field Name	Size	Value
Value Length	vInt	Length of value. Only sent if **REMOVE_OPERATION** isn't set.
Value	byte-array	Value to be stored. Only sent if **REMOVE_OPERATION** isn't set.

Response (0x7E)

Field Name	Size	Value
Header	variable	Response header
XA return code	vInt	The XA code representing the prepare response. Can be **XA_OK(0)**, **XA_RDONLY(3)** or any of the error codes (see **XaException**). This field isn't present if the response state is different from **Successful**.

Forget Transaction

Request (0x79)

Field Name	Size	Value
Header	variable	Request header
Xid	XID	The transaction ID (XID)

Response (0x7A)

Field Name	Size	Value
Header	variable	Response header

Fetch in-doubt transactions

Request (0x7B)

Field Name	Size	Value
Header	variable	Request header

Response (0x7C)

Field Name	Size	Value
Header	variable	Response header
Number of Xid	vInt	The number of Xid in response
For each entry:		
Xid	XID	The transaction ID (XID)

20.6.15. Hot Rod Hash Functions

Red Hat Data Grid makes use of a consistent hash function to place nodes on a hash wheel, and to place keys of entries on the same wheel to determine where entries live.

In Infinispan 4.2 and earlier, the hash space was hardcoded to 10240, but since 5.0, the hash space is Integer.MAX_INT . Please note that since Hot Rod clients should not assume a particular hash space by default, every time a hash-topology change is detected, this value is sent back to the client via the Hot Rod protocol.

When interacting with Red Hat Data Grid via the Hot Rod protocol, it is mandated that keys (and values) are byte arrays, to ensure platform neutral behavior. As such, smart-clients which are aware of hash distribution on the backend would need to be able to calculate the hash codes of such byte array keys, again in a platform-neutral manner. To this end, the hash functions used by Red Hat Data Grid are versioned and documented, so that it can be re-implemented by non-Java clients if needed.

The version of the hash function in use is provided in the Hot Rod protocol, as the hash function version parameter.

1. Version 1 (single byte, 0x01) The initial version of the hash function in use is based on Austin Appleby's MurmurHash 2.0 algorithm , a fast, non-cryptographic hash that exhibits excellent distribution, collision resistance and avalanche behavior. The specific version of the algorithm used is the slightly slower, endian-neutral version that allows consistent behavior across both big- and little-endian CPU architectures. Red Hat Data Grid's version also hard-codes the hash seed as -1. For details of the algorithm, please visit Austin Appleby's MurmurHash 2.0 page . Other implementations are detailed on Wikipedia . This hash function was the default one used by the Hot Rod server until Infinispan 4.2.1. Since Infinispan 5.0, the server never uses hash version 1. Since Infinispan 9.0, the client ignores hash version 1.

2. Version 2 (single byte, 0x02) Since Infinispan 5.0, a new hash function is used by default which is based on Austin Appleby's MurmurHash 3.0 algorithm . Detailed information about the hash function can be found in this wiki. Compared to 2.0, it provides better performance and spread. Since Infinispan 7.0, the server only uses version 2 for HotRod 1.x clients.

3. Version 3 (single byte, 0x03) Since Infinispan 7.0, a new hash function is used by default. The function is still based on wiki, but is also aware of the hash segments used in the server's ConsistentHash.

20.6.16. Hot Rod Admin Tasks

Admin operations are handled by the Exec operation with a set of well known tasks. Admin tasks are named according to the following rules:

@@context@name

All parameters are UTF-8 encoded strings. Parameters are specific to each task, with the exception of the **flags** parameter which is common to all commands. The **flags** parameter contains zero or more space-separated values which may affect the behaviour of the command. The following table lists all currently available flags.

Admin tasks return the result of the operation represented as a JSON string.

Table 20.26. FLAGS

Flag	Description
permanent	Requests that the command’s effect be made permanent into the server’s configuration. If the server cannot comply with the request, the entire operation will fail with an error

20.6.16.1. Admin tasks

Table 20.27. @@cache@create

Parameter	Description	Required
name	The name of the cache to create.	Yes
template	The name of the cache configuration template to use for the new cache.	No
configuration	the XML declaration of a cache configuration to use.	No
flags	See the flags table above.	No

Table 20.28. @@cache@remove

Parameter	Description	Required
name	The name of the cache to remove.	Yes
flags	See the flags table above.	No

@@cache@names

Returns the cache names as a JSON array of strings, e.g. ["cache1", "cache2"]

Table 20.29. @@cache@reindex

Parameter	Description	Required
name	The name of the cache to reindex.	Yes

Parameter	Description	Required
flags	See the flags table above.	No, all flags will be ignored

20.7. JAVA HOT ROD CLIENT

Hot Rod is a binary, language neutral protocol. This article explains how a Java client can interact with a server via the Hot Rod protocol. A reference implementation of the protocol written in Java can be found in all Red Hat Data Grid distributions, and this article focuses on the capabilities of this java client.

TIP

Looking for more clients? Visit this website for clients written in a variety of different languages.

20.7.1. Configuration

The Java Hot Rod client can be configured both programmatically and externally, through a configuration file.

The code snippet below illustrates the creation of a client instance using the available Java fluent API:

```
org.infinispan.client.hotrod.configuration.ConfigurationBuilder cb
      = new org.infinispan.client.hotrod.configuration.ConfigurationBuilder();
cb.tcpNoDelay(true)
  .statistics()
      .enable()
      .jmxDomain("org.infinispan")
  .addServer()
      .host("127.0.0.1")
      .port(11222);
RemoteCacheManager rmc = new RemoteCacheManager(cb.build());
```

For a complete reference to the available configuration option please refer to the ConfigurationBuilder's javadoc.

It is also possible to configure the Java Hot Rod client using a properties file, e.g.:

```
# Hot Rod client configuration
infinispan.client.hotrod.server_list = 127.0.0.1:11222
infinispan.client.hotrod.marshaller = org.infinispan.commons.marshall.jboss.GenericJBossMarshaller
infinispan.client.hotrod.async_executor_factory =
org.infinispan.client.hotrod.impl.async.DefaultAsyncExecutorFactory
infinispan.client.hotrod.default_executor_factory.pool_size = 1
infinispan.client.hotrod.hash_function_impl.2 =
org.infinispan.client.hotrod.impl.consistenthash.ConsistentHashV2
infinispan.client.hotrod.tcp_no_delay = true
infinispan.client.hotrod.tcp_keep_alive = false
infinispan.client.hotrod.request_balancing_strategy =
org.infinispan.client.hotrod.impl.transport.tcp.RoundRobinBalancingStrategy
infinispan.client.hotrod.key_size_estimate = 64
infinispan.client.hotrod.value_size_estimate = 512
infinispan.client.hotrod.force_return_values = false

## Connection pooling configuration
maxActive=-1
maxIdle = -1
whenExhaustedAction = 1
minEvictableIdleTimeMillis=300000
minIdle = 1
```

The properties file is then passed to one of constructors of RemoteCacheManager. You can use property substitution to replace values at runtime with Java system properties:

```
infinispan.client.hotrod.server_list = ${server_list}
```

In the above example the value of the *infinispan.client.hotrod.server_list* property will be expanded to the value of the *server_list* Java system property, which means that the value should be taken from a system property named **jboss.bind.address.management** and if it is not defined use 127.0.0.1.

TIP

To use **hotrod-client.properties** somewhere other than your classpath, do:

```
ConfigurationBuilder b = new ConfigurationBuilder();
Properties p = new Properties();
try(Reader r = new FileReader("/path/to/hotrod-client.properties")) {
   p.load(r);
   b.withProperties(p);
}
RemoteCacheManager rcm = new RemoteCacheManager(b.build());
```

For a complete reference of the available configuration options for the properties file please refer to remote client configuration javadoc.

20.7.2. Authentication

If the server has set up authentication, you need to configure your client accordingly. Depending on the mechs enabled on the server, the client must provide the required information.

20.7.2.1. DIGEST-MD5

DIGEST-MD5 is the recommended approach for simple username/password authentication scenarios. If you are using the default realm on the server (*"ApplicationRealm"*), all you need to do is provide your credentials as follows:

Hot Rod client configuration with DIGEST-MD5 authentication

```
ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .security()
        .ssl()
```

```
            .username("myuser")
            .password("qwer1234!");
remoteCacheManager = new RemoteCacheManager(clientBuilder.build());
RemoteCache<String, String> cache = remoteCacheManager.getCache("secured");
```

20.7.2.2. PLAIN

The PLAIN mechanism is not really recommended unless the connection is also encrypted, as anyone can sniff the clear-text password being sent along the wire.

Hot Rod client configuration with DIGEST-MD5 authentication

```
ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .security()
        .authentication()
            .saslMechanism("PLAIN")
            .username("myuser")
            .password("qwer1234!");
remoteCacheManager = new RemoteCacheManager(clientBuilder.build());
RemoteCache<String, String> cache = remoteCacheManager.getCache("secured");
```

20.7.2.3. EXTERNAL

The EXTERNAL mechanism is special in that it doesn’t explicitly provide credentials but uses the client certificate as identity. In order for this to work, in addition to the *TrustStore* (to validate the server certificate) you need to provide a *KeyStore* (to supply the client certificate).

Hot Rod client configuration with EXTERNAL authentication (client cert)

```
ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .security()
        .ssl()
            // TrustStore is a KeyStore which contains part of the server certificate chain (e.g. the CA Root
public cert)
            .trustStoreFileName("/path/to/truststore")
            .trustStorePassword("truststorepassword".toCharArray())
            // KeyStore containing this client's own certificate
            .keyStoreFileName("/path/to/keystore")
            .keyStorePassword("keystorepassword".toCharArray())
        .authentication()
            .saslMechanism("EXTERNAL");
remoteCacheManager = new RemoteCacheManager(clientBuilder.build());
RemoteCache<String, String> cache = remoteCacheManager.getCache("secured");
```

For more details, read the Encryption section below.

20.7.2.4. GSSAPI (Kerberos)

GSSAPI/Kerberos requires a much more complex setup, but it is used heavily in enterprises with centralized authentication servers. To successfully authenticate with Kerberos, you need to create a *LoginContext*. This will obtain a Ticket Granting Ticket (TGT) which will be used as a token to authenticate with the service.

You will need to define a login module in a login configuration file:

gss.conf

```
GssExample {
    com.sun.security.auth.module.Krb5LoginModule required client=TRUE;
};
```

If you are using the IBM JDK, the above becomes:

gss-ibm.conf

```
GssExample {
    com.ibm.security.auth.module.Krb5LoginModule required client=TRUE;
};
```

You will also need to set the following system properties:

java.security.auth.login.config=gss.conf

java.security.krb5.conf=/etc/krb5.conf

The krb5.conf file is dependent on your environment and needs to point to your KDC. Ensure that you can authenticate via Kerberos using *kinit*.

Next up, configure your client as follows:

Hot Rod client GSSAPI configuration

```
LoginContext lc = new LoginContext("GssExample", new BasicCallbackHandler("krb_user",
"krb_password".toCharArray()));
lc.login();
Subject clientSubject = lc.getSubject();

ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .security()
        .authentication()
            .enable()
            .serverName("infinispan-server")
            .saslMechanism("GSSAPI")
            .clientSubject(clientSubject)
            .callbackHandler(new BasicCallbackHandler());
remoteCacheManager = new RemoteCacheManager(clientBuilder.build());
RemoteCache<String, String> cache = remoteCacheManager.getCache("secured");
```

For brevity we used the same callback handler both for obtaining the client subject and for handling authentication in the SASL GSSAPI mech, however different callbacks will actually be invoked: NameCallback and PasswordCallback are needed to construct the client subject, while the AuthorizeCallback will be called during the SASL authentication.

20.7.2.5. Custom CallbackHandlers

In all of the above examples, the Hot Rod client is setting up a default *CallbackHandler* for you that supplies the provided credentials to the SASL mechanism. For advanced scenarios it may be necessary to provide your own custom *CallbackHandler*:

Hot Rod client configuration with authentication via callback

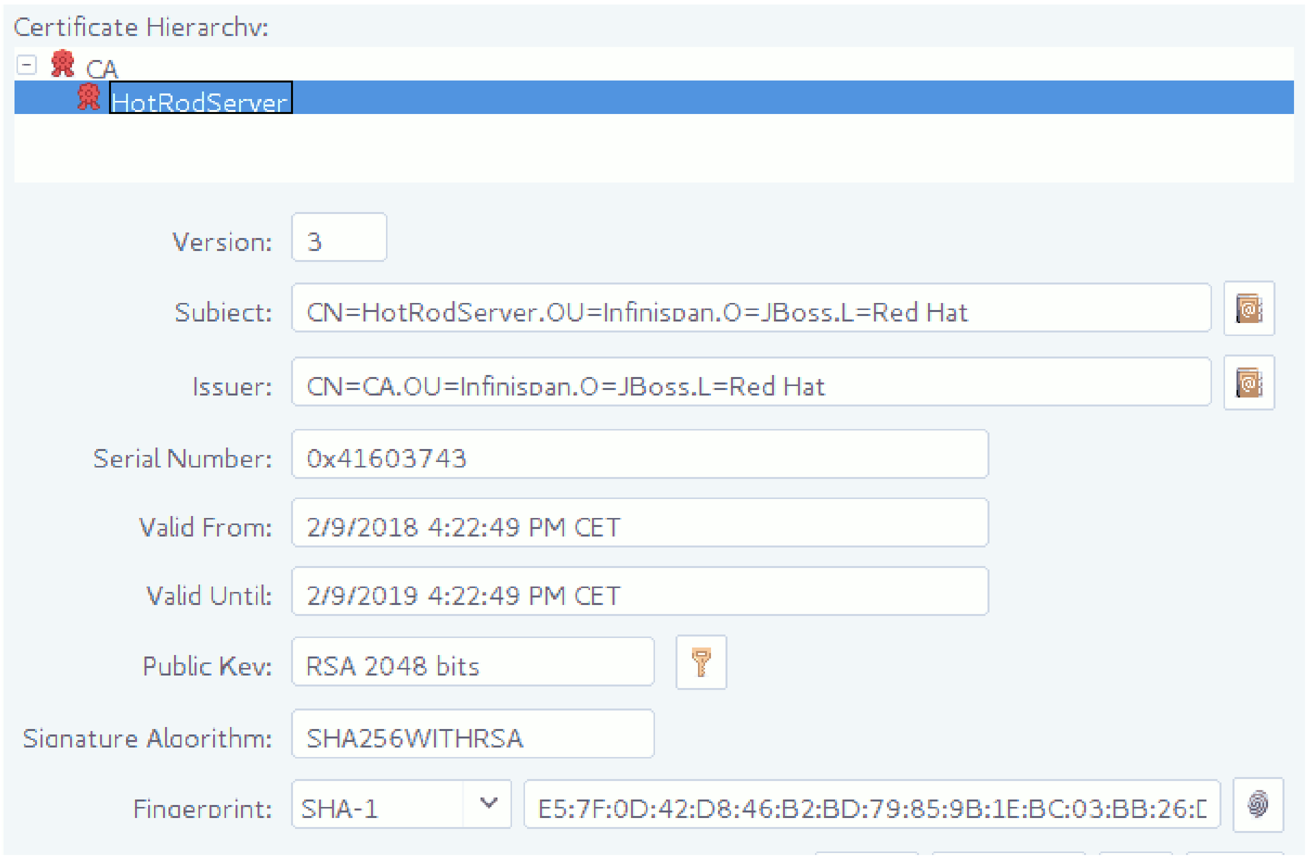
```
public class MyCallbackHandler implements CallbackHandler {
   final private String username;
   final private char[] password;
   final private String realm;

   public MyCallbackHandler(String username, String realm, char[] password) {
      this.username = username;
      this.password = password;
      this.realm = realm;
   }

   @Override
   public void handle(Callback[] callbacks) throws IOException, UnsupportedCallbackException {
      for (Callback callback : callbacks) {
         if (callback instanceof NameCallback) {
            NameCallback nameCallback = (NameCallback) callback;
            nameCallback.setName(username);
         } else if (callback instanceof PasswordCallback) {
            PasswordCallback passwordCallback = (PasswordCallback) callback;
            passwordCallback.setPassword(password);
         } else if (callback instanceof AuthorizeCallback) {
            AuthorizeCallback authorizeCallback = (AuthorizeCallback) callback;
            authorizeCallback.setAuthorized(authorizeCallback.getAuthenticationID().equals(
                  authorizeCallback.getAuthorizationID()));
         } else if (callback instanceof RealmCallback) {
            RealmCallback realmCallback = (RealmCallback) callback;
            realmCallback.setText(realm);
         } else {
            throw new UnsupportedCallbackException(callback);
         }
      }
   }
}

ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .security()
        .authentication()
            .enable()
            .serverName("myhotrodserver")
            .saslMechanism("DIGEST-MD5")
            .callbackHandler(new MyCallbackHandler("myuser", "ApplicationRealm",
"qwer1234!".toCharArray()));
remoteCacheManager = new RemoteCacheManager(clientBuilder.build());
RemoteCache<String, String> cache = remoteCacheManager.getCache("secured");
```

The actual type of callbacks that your CallbackHandler will need to be able to handle are mech-specific, so the above is just a simple example.

20.7.3. Encryption

Encryption uses TLS/SSL, so it requires setting up an appropriate server certificate chain. Generally, a certificate chain looks like the following:

Figure 20.6. Certificate chain



Certificate Hierarchy:

- CA
  - HotRodServer

Version:	3
Subject:	CN=HotRodServer.OU=Infinispan.O=JBoss.L=Red Hat
Issuer:	CN=CA.OU=Infinispan.O=JBoss.L=Red Hat
Serial Number:	0x41603743
Valid From:	2/9/2018 4:22:49 PM CET
Valid Until:	2/9/2019 4:22:49 PM CET
Public Key:	RSA 2048 bits
Signature Algorithm:	SHA256WITHRSA
Fingerprint:	SHA-1 E5:7F:0D:42:D8:46:B2:BD:79:85:9B:1E:BC:03:BB:26:C

In the above example there is one certificate authority *"CA"* which has issued a certificate for *"HotRodServer"*. In order for a client to trust the server, it needs at least a portion of the above chain (usually, just the public certificate for *"CA"*). This certificate needs to placed in a keystore and used as a *TrustStore* on the client and used as shown below:

Hot Rod client configuration with TLS (server cert)

```
ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .security()
        .ssl()
            // TrustStore is a KeyStore which contains part of the server certificate chain (e.g. the CA Root
public cert)
            .trustStoreFileName("/path/to/truststore")
            .trustStorePassword("truststorepassword".toCharArray());
RemoteCache<String, String> cache = remoteCacheManager.getCache("secured");
```

20.7.3.1. SNI

The server may have been configured with TLS/SNI support (Server Name Indication). This means that the server is presenting multiple identities (probably bound to separate cache containers). The client can specify which identity to connect to by specifying its name:

Hot Rod client configuration with SNI (server cert)

```
ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .security()
        .ssl()
            .sniHostName("myservername")
            // TrustStore is a KeyStore which contains part of the server certificate chain (e.g. the CA Root
public cert)
            .trustStoreFileName("/path/to/truststore")
            .trustStorePassword("truststorepassword".toCharArray());
RemoteCache<String, String> cache = remoteCacheManager.getCache("secured");
```

20.7.3.2. Client certificates

With the above configurations the client trusts the server. For increased security, a server administrator may have set up the server to require the client to offer a valid certificate for mutual trust. This kind of configuration requires the client to present its own certificate, usually issued by the same certificate authority as the server. This certificate must be stored in a keystore and used as follows:

Hot Rod client configuration with TLS (server and client cert)

```
ConfigurationBuilder clientBuilder = new ConfigurationBuilder();
clientBuilder
    .addServer()
        .host("127.0.0.1")
        .port(11222)
    .security()
        .ssl()
            // TrustStore is a KeyStore which contains part of the server certificate chain (e.g. the CA Root
public cert)
            .trustStoreFileName("/path/to/truststore")
            .trustStorePassword("truststorepassword".toCharArray())
            // KeyStore containing this client's own certificate
            .keyStoreFileName("/path/to/keystore")
            .keyStorePassword("keystorepassword".toCharArray())
RemoteCache<String, String> cache = remoteCacheManager.getCache("secured");
```

Please read the KeyTool documentation for more details on KeyStores. Additionally, the KeyStore Explorer is a great GUI tool for easily managing KeyStores.

20.7.4. Basic API

Below is a sample code snippet on how the client API can be used to store or retrieve information from a Hot Rod server using the Java Hot Rod client. It assumes that a Hot Rod server has been started bound to the default location (localhost:11222)

```
//API entry point, by default it connects to localhost:11222
CacheContainer cacheContainer = new RemoteCacheManager();

//obtain a handle to the remote default cache
Cache<String, String> cache = cacheContainer.getCache();

//now add something to the cache and make sure it is there
cache.put("car", "ferrari");
assert cache.get("car").equals("ferrari");

//remove the data
cache.remove("car");
assert !cache.containsKey("car") : "Value must have been removed!";
```

The client API maps the local API: RemoteCacheManager corresponds to DefaultCacheManager (both implement CacheContainer). This common API facilitates an easy migration from local calls to remote calls through Hot Rod: all one needs to do is switch between DefaultCacheManager and RemoteCacheManager - which is further simplified by the common CacheContainer interface that both inherit.

20.7.5. RemoteCache(.keySet|.entrySet|.values)

The collection methods **keySet**, **entrySet** and **values** are backed by the remote cache. That is that every method is called back into the **RemoteCache**. This is useful as it allows for the various keys, entries or values to be retrieved lazily, and not requiring them all be stored in the client memory at once if the user does not want. These collections adhere to the **Map** specification being that **add** and **addAll** are not supported but all other methods are supported.

One thing to note is the **Iterator.remove** and **Set.remove** or **Collection.remove** methods require more than 1 round trip to the server to operate. You can check out the RemoteCache Javadoc to see more details about these and the other methods.

Iterator Usage

The iterator method of these collections uses **retrieveEntries** internally, which is described below. If you notice **retrieveEntries** takes an argument for the batch size. There is no way to provide this to the iterator. As such the batch size can be configured via system property **infinispan.client.hotrod.batch_size** or through the ConfigurationBuilder when configuring the **RemoteCacheManager**.

Also the **retrieveEntries** iterator returned is **Closeable** as such the iterators from **keySet**, **entrySet** and **values** return an **AutoCloseable** variant. Therefore you should always close these `Iterator`s when you are done with them.

```
try (CloseableIterator<Entry<K, V>> iterator = remoteCache.entrySet().iterator) {
 ...
}
```

What if I want a deep copy and not a backing collection?

Previous version of **RemoteCache** allowed for the retrieval of a deep copy of the **keySet**. This is still possible with the new backing map, you just have to copy the contents yourself. Also you can do this with **entrySet** and **values**, which we didn't support before.

```
Set<K> keysCopy = remoteCache.keySet().stream().collect(Collectors.toSet());
```

Please use extreme cautiong with this as a large number of keys can and will cause OutOfMemoryError in the client.

```
Set keys = remoteCache.keySet();
```

20.7.6. Remote Iterator

Alternatively, if memory is a concern (different batch size) or you wish to do server side filtering or conversion), use the remote iterator api to retrieve entries from the server. With this method you can limit the entries that are retrieved or even returned a converted value if you dont' need all properties of your entry.

```
// Retrieve all entries in batches of 1000
int batchSize = 1000;
try (CloseableIterator<Entry<Object, Object>> iterator = remoteCache.retrieveEntries(null,
batchSize)) {
    while(iterator.hasNext()) {
      // Do something
    }
}

// Filter by segment
Set<Integer> segments = ...
try (CloseableIterator<Entry<Object, Object>> iterator = remoteCache.retrieveEntries(null, segments,
batchSize)) {
    while(iterator.hasNext()) {
      // Do something
    }
}

// Filter by custom filter
try (CloseableIterator<Entry<Object, Object>> iterator =
remoteCache.retrieveEntries("myFilterConverterFactory", segments, batchSize)) {
    while(iterator.hasNext()) {
      // Do something
    }
}
```

In order to use custom filters, it's necessary to deploy them first in the server. Follow the steps:

- Create a factory for the filter extending KeyValueFilterConverterFactory, annotated with @NamedFactory containing the name of the factory, example:

```
import java.io.Serializable;

import org.infinispan.filter.AbstractKeyValueFilterConverter;
import org.infinispan.filter.KeyValueFilterConverter;
import org.infinispan.filter.KeyValueFilterConverterFactory;
import org.infinispan.filter.NamedFactory;
import org.infinispan.metadata.Metadata;

@NamedFactory(name = "myFilterConverterFactory")
public class MyKeyValueFilterConverterFactory implements KeyValueFilterConverterFactory {

   @Override
   public KeyValueFilterConverter<String, SampleEntity1, SampleEntity2> getFilterConverter() {
      return new MyKeyValueFilterConverter();
   }
   // Filter implementation. Should be serializable or externalizable for DIST caches
   static class MyKeyValueFilterConverter extends AbstractKeyValueFilterConverter<String,
SampleEntity1, SampleEntity2> implements Serializable {
      @Override
      public SampleEntity2 filterAndConvert(String key, SampleEntity1 entity, Metadata metadata) {
         // returning null will case the entry to be filtered out
         // return SampleEntity2 will convert from the cache type SampleEntity1
      }

      @Override
      public MediaType format() {
         // returns the MediaType that data should be presented to this converter.
         // When ommitted, the server will use "application/x-java-object".
         // Returning null will cause the filter/converter to be done in the storage format.
      }
   }
}
```

- Create a jar with a **META-INF/services/org.infinispan.filter.KeyValueFilterConverterFactory** file and within it, write the fully qualified class name of the filter factory class implementation.
- Optional: If the filter uses custom key/value classes, these must be included in the JAR so that the filter can correctly unmarshall key and/or value instances.
- Deploy the JAR file in the Red Hat Data Grid Server.

20.7.7. Versioned API

A RemoteCacheManager provides instances of RemoteCache interface that represents a handle to the named or default cache on the remote cluster. API wise, it extends the Cache interface to which it also adds some new methods, including the so called versioned API. Please find below some examples of this API link:#server_hotrod_failover[but to understand the motivation behind it, make sure you read this section.

The code snippet bellow depicts the usage of these versioned methods:

```
// To use the versioned API, remote classes are specifically needed
RemoteCacheManager remoteCacheManager = new RemoteCacheManager();
RemoteCache<String, String> cache = remoteCacheManager.getCache();

remoteCache.put("car", "ferrari");
RemoteCache.VersionedValue valueBinary = remoteCache.getVersioned("car");

// removal only takes place only if the version has not been changed
// in between. (a new version is associated with 'car' key on each change)
assert remoteCache.remove("car", valueBinary.getVersion());
assert !cache.containsKey("car");
```

In a similar way, for replace:

```
remoteCache.put("car", "ferrari");
RemoteCache.VersionedValue valueBinary = remoteCache.getVersioned("car");
assert remoteCache.replace("car", "lamborghini", valueBinary.getVersion());
```

For more details on versioned operations refer to RemoteCache 's javadoc.

20.7.8. Async API

This is "borrowed" from the Red Hat Data Grid core and it is largely discussed here.

20.7.9. Streaming API

When sending / receiving large objects, it might make sense to stream them between the client and the server. The Streaming API implements methods similar to the Hot Rod Basic API and Hot Rod Versioned API described above but, instead of taking the value as a parameter, they return instances of InputStream and OutputStream. The following example shows how one would write a potentially large object:

```
RemoteStreamingCache<String> streamingCache = remoteCache.streaming();
OutputStream os = streamingCache.put("a_large_object");
os.write(...);
os.close();
```

Reading such an object through streaming:

```
RemoteStreamingCache<String> streamingCache = remoteCache.streaming();
InputStream is = streamingCache.get("a_large_object");
for(int b = is.read(); b >= 0; b = is.read()) {
   ...
}
is.close();
```

NOTE

The streaming API does **not** apply marshalling/unmarshalling to the values. For this reason you cannot access the same entries using both the streaming and non-streaming API at the same time, unless you provide your own marshaller to detect this situation.

The InputStream returned by the **RemoteStreamingCache.get(K key)** method implements the **VersionedMetadata** interface, so you can retrieve version and expiration information:

```
RemoteStreamingCache<String> streamingCache = remoteCache.streaming();
InputStream is = streamingCache.get("a_large_object");
int version = ((VersionedMetadata) is).getVersion();
for(int b = is.read(); b >= 0; b = is.read()) {
   ...
}
is.close();
```

NOTE

Conditional write methods (**putIfAbsent**, **replace**) only perform the actual condition check once the value has been completely sent to the server (i.e. when the **close()** method has been invoked on the **OutputStream**.

20.7.10. Creating Event Listeners

Java Hot Rod clients can register listeners to receive cache-entry level events. Cache entry created, modified and removed events are supported.

Creating a client listener is very similar to embedded listeners, except that different annotations and event classes are used. Here's an example of a client listener that prints out each event received:

```
import org.infinispan.client.hotrod.annotation.*;
import org.infinispan.client.hotrod.event.*;

@ClientListener
public class EventPrintListener {

   @ClientCacheEntryCreated
   public void handleCreatedEvent(ClientCacheEntryCreatedEvent e) {
      System.out.println(e);
   }

   @ClientCacheEntryModified
   public void handleModifiedEvent(ClientCacheEntryModifiedEvent e) {
      System.out.println(e);
   }

   @ClientCacheEntryRemoved
   public void handleRemovedEvent(ClientCacheEntryRemovedEvent e) {
      System.out.println(e);
   }

}
```

ClientCacheEntryCreatedEvent and **ClientCacheEntryModifiedEvent** instances provide information on the affected key, and the version of the entry. This version can be used to invoke conditional operations on the server, such as **replaceWithVersion** or **removeWithVersion**.

ClientCacheEntryRemovedEvent events are only sent when the remove operation succeeds. In other words, if a remove operation is invoked but no entry is found or no entry should be removed, no event is generated. Users interested in removed events, even when no entry was removed, can develop event customization logic to generate such events. More information can be found in the customizing client events section.

All **ClientCacheEntryCreatedEvent**, **ClientCacheEntryModifiedEvent** and **ClientCacheEntryRemovedEvent** event instances also provide a **boolean isCommandRetried()** method that will return true if the write command that caused this had to be retried again due to a topology change. This could be a sign that this event has been duplicated or another event was dropped and replaced (eg: ClientCacheEntryModifiedEvent replaced ClientCacheEntryCreatedEvent).

Once the client listener implementation has been created, it needs to be registered with the server. To do so, execute:

```
RemoteCache<?, ?> cache = ...
cache.addClientListener(new EventPrintListener());
```

20.7.11. Removing Event Listeners

When an client event listener is not needed any more, it can be removed:

```
EventPrintListener listener = ...
cache.removeClientListener(listener);
```

20.7.12. Filtering Events

In order to avoid inundating clients with events, users can provide filtering functionality to limit the number of events fired by the server for a particular client listener. To enable filtering, a cache event filter factory needs to be created that produces filter instances:

```
import org.infinispan.notifications.cachelistener.filter.CacheEventFilterFactory;
import org.infinispan.filter.NamedFactory;

@NamedFactory(name = "static-filter")
class StaticCacheEventFilterFactory implements CacheEventFilterFactory {
  @Override
  public CacheEventFilterFactory<Integer, String> getFilter(Object[] params) {
    return new StaticCacheEventFilter();
  }
}

// Serializable, Externalizable or marshallable with Infinispan Externalizers
// needed when running in a cluster
class StaticCacheEventFilter implements CacheEventFilter<Integer, String>, Serializable {
  @Override
  public boolean accept(Integer key, String oldValue, Metadata oldMetadata,
        String newValue, Metadata newMetadata, EventType eventType) {
    if (key.equals(1)) // static key
      return true;

    return false;
  }
}
```

The cache event filter factory instance defined above creates filter instances which statically filter out all entries except the one whose key is **1**.

To be able to register a listener with this cache event filter factory, the factory has to be given a unique name, and the Hot Rod server needs to be plugged with the name and the cache event filter factory instance. Plugging the Red Hat Data Grid Server with a custom filter involves the following steps:

1. Create a JAR file with the filter implementation within it.

2. Optional: If the cache uses custom key/value classes, these must be included in the JAR so that the callbacks can be executed with the correctly unmarshalled key and/or value instances. If the client listener has **useRawData** enabled, this is not necessary since the callback key/value instances will be provided in binary format.

3. Create a **META-INF/services/org.infinispan.notifications.cachelistener.filter.CacheEventFilterFactory** file within the JAR file and within it, write the fully qualified class name of the filter class implementation.

4. Deploy the JAR file in the Red Hat Data Grid Server.

On top of that, the client listener needs to be linked with this cache event filter factory by adding the factory's name to the @ClientListener annotation:

```
@ClientListener(filterFactoryName = "static-filter")
public class EventPrintListener { ... }
```

And, register the listener with the server:

```
RemoteCache<?, ?> cache = ...
cache.addClientListener(new EventPrintListener());
```

Dynamic filter instances that filter based on parameters provided when the listener is registered are also possible. Filters use the parameters received by the filter factories to enable this option. For example:

```
import org.infinispan.notifications.cachelistener.filter.CacheEventFilterFactory;
import org.infinispan.notifications.cachelistener.filter.CacheEventFilter;

class DynamicCacheEventFilterFactory implements CacheEventFilterFactory {
  @Override
  public CacheEventFilter<Integer, String> getFilter(Object[] params) {
    return new DynamicCacheEventFilter(params);
  }
}

// Serializable, Externalizable or marshallable with Infinispan Externalizers
// needed when running in a cluster
class DynamicCacheEventFilter implements CacheEventFilter<Integer, String>, Serializable {
  final Object[] params;

  DynamicCacheEventFilter(Object[] params) {
    this.params = params;
  }

  @Override
  public boolean accept(Integer key, String oldValue, Metadata oldMetadata,
      String newValue, Metadata newMetadata, EventType eventType) {
    if (key.equals(params[0])) // dynamic key
      return true;

    return false;
  }
}
```

The dynamic parameters required to do the filtering are provided when the listener is registered:

```
RemoteCache<?, ?> cache = ...
cache.addClientListener(new EventPrintListener(), new Object[]{1}, null);
```

WARNING

Filter instances have to marshallable when they are deployed in a cluster so that the filtering can happen right where the event is generated, even if the even is generated in a different node to where the listener is registered. To make them marshallable, either make them extend **Serializable**, **Externalizable**, or provide a custom **Externalizer** for them.

20.7.13. Skipping Notifications

Include the **SKIP_LISTENER_NOTIFICATION** flag when calling remote API methods to perform operations without getting event notifications from the server. For example, to prevent listener notifications when creating or modifying values, set the flag as follows:

```
remoteCache.withFlags(Flag.SKIP_LISTENER_NOTIFICATION).put(1, "one");
```

IMPORTANT

The **SKIP_LISTENER_NOTIFICATION** flag is available from Red Hat Data Grid version 7.3.2. You must upgrade both the Red Hat Data Grid and Hot Rod client to this version or later before you can set the flag.

20.7.14. Customizing Events

The events generated by default contain just enough information to make the event relevant but they avoid cramming too much information in order to reduce the cost of sending them. Optionally, the information shipped in the events can be customised in order to contain more information, such as values, or to contain even less information. This customization is done with **CacheEventConverter** instances generated by a **CacheEventConverterFactory**:

```
import org.infinispan.notifications.cachelistener.filter.CacheEventConverterFactory;
import org.infinispan.notifications.cachelistener.filter.CacheEventConverter;
import org.infinispan.filter.NamedFactory;

@NamedFactory(name = "static-converter")
class StaticConverterFactory implements CacheEventConverterFactory {
  final CacheEventConverter<Integer, String, CustomEvent> staticConverter = new
StaticCacheEventConverter();
  public CacheEventConverter<Integer, String, CustomEvent> getConverter(final Object[] params) {
    return staticConverter;
  }
}

// Serializable, Externalizable or marshallable with Infinispan Externalizers
// needed when running in a cluster
class StaticCacheEventConverter implements CacheEventConverter<Integer, String, CustomEvent>,
Serializable {
  public CustomEvent convert(Integer key, String oldValue, Metadata oldMetadata, String newValue,
Metadata newMetadata, EventType eventType) {
    return new CustomEvent(key, newValue);
  }
}

// Needs to be Serializable, Externalizable or marshallable with Infinispan Externalizers
// regardless of cluster or local caches
static class CustomEvent implements Serializable {
  final Integer key;
  final String value;
  CustomEvent(Integer key, String value) {
    this.key = key;
    this.value = value;
  }
}
```

In the example above, the converter generates a new custom event which includes the value as well as the key in the event. This will result in bigger event payloads compared with default events, but if combined with filtering, it can reduce its network bandwidth cost.

WARNING

The target type of the converter must be either **Serializable** or **Externalizable**. In this particular case of converters, providing an Externalizer will not work by default since the default Hot Rod client marshaller does not support them.

Handling custom events requires a slightly different client listener implementation to the one demonstrated previously. To be more precise, it needs to handle **ClientCacheEntryCustomEvent** instances:

```
import org.infinispan.client.hotrod.annotation.*;
import org.infinispan.client.hotrod.event.*;

@ClientListener
public class CustomEventPrintListener {

  @ClientCacheEntryCreated
  @ClientCacheEntryModified
  @ClientCacheEntryRemoved
  public void handleCustomEvent(ClientCacheEntryCustomEvent<CustomEvent> e) {
    System.out.println(e);
  }

}
```

The **ClientCacheEntryCustomEvent** received in the callback exposes the custom event via **getEventData** method, and the **getType** method provides information on whether the event generated was as a result of cache entry creation, modification or removal.

Similar to filtering, to be able to register a listener with this converter factory, the factory has to be given a unique name, and the Hot Rod server needs to be plugged with the name and the cache event converter factory instance. Plugging the Red Hat Data Grid Server with an event converter involves the following steps:

1. Create a JAR file with the converter implementation within it.
2. Optional: If the cache uses custom key/value classes, these must be included in the JAR so that the callbacks can be executed with the correctly unmarshalled key and/or value instances. If the client listener has **useRawData** enabled, this is not necessary since the callback key/value instances will be provided in binary format.
3. Create a **META-INF/services/org.infinispan.notifications.cachelistener.filter.CacheEventConverterFactory** file within the JAR file and within it, write the fully qualified class name of the converter class implementation.
4. Deploy the JAR file in the Red Hat Data Grid Server.

On top of that, the client listener needs to be linked with this converter factory by adding the factory's name to the @ClientListener annotation:

```
@ClientListener(converterFactoryName = "static-converter")
public class CustomEventPrintListener { ... }
```

And, register the listener with the server:

```
RemoteCache<?, ?> cache = ...
cache.addClientListener(new CustomEventPrintListener());
```

Dynamic converter instances that convert based on parameters provided when the listener is registered are also possible. Converters use the parameters received by the converter factories to enable this option. For example:

```
import org.infinispan.notifications.cachelistener.filter.CacheEventConverterFactory;
import org.infinispan.notifications.cachelistener.filter.CacheEventConverter;

@NamedFactory(name = "dynamic-converter")
class DynamicCacheEventConverterFactory implements CacheEventConverterFactory {
  public CacheEventConverter<Integer, String, CustomEvent> getConverter(final Object[] params) {
    return new DynamicCacheEventConverter(params);
  }
}

// Serializable, Externalizable or marshallable with Infinispan Externalizers needed when running in a
cluster
class DynamicCacheEventConverter implements CacheEventConverter<Integer, String,
CustomEvent>, Serializable {
  final Object[] params;

  DynamicCacheEventConverter(Object[] params) {
    this.params = params;
    }

    public CustomEvent convert(Integer key, String oldValue, Metadata oldMetadata,
        String newValue, Metadata newMetadata, EventType eventType) {
      // If the key matches a key given via parameter, only send the key information
      if (params[0].equals(key))
        return new CustomEvent(key, null);

      return new CustomEvent(key, newValue);
    }
  }
```

The dynamic parameters required to do the conversion are provided when the listener is registered:

```
RemoteCache<?, ?> cache = ...
cache.addClientListener(new EventPrintListener(), null, new Object[]{1});
```

WARNING

Converter instances have to marshallable when they are deployed in a cluster, so that the conversion can happen right where the event is generated, even if the even is generated in a different node to where the listener is registered. To make them marshallable, either make them extend **Serializable**, **Externalizable**, or provide a custom **Externalizer** for them.

20.7.15. Filter and Custom Events

If you want to do both event filtering and customization, it's easier to implement **org.infinispan.notifications.cachelistener.filter.CacheEventFilterConverter** which allows both filter and customization to happen in a single step. For convenience, it's recommended to extend **org.infinispan.notifications.cachelistener.filter.AbstractCacheEventFilterConverter** instead of implementing **org.infinispan.notifications.cachelistener.filter.CacheEventFilterConverter** directly. For example:

```
import org.infinispan.notifications.cachelistener.filter.CacheEventConverterFactory;
import org.infinispan.notifications.cachelistener.filter.CacheEventConverter;

@NamedFactory(name = "dynamic-filter-converter")
class DynamicCacheEventFilterConverterFactory implements CacheEventFilterConverterFactory {
  public CacheEventFilterConverter<Integer, String, CustomEvent> getFilterConverter(final Object[]
params) {
    return new DynamicCacheEventFilterConverter(params);
  }
}

// Serializable, Externalizable or marshallable with Infinispan Externalizers needed when running in a
cluster
//
class DynamicCacheEventFilterConverter extends AbstractCacheEventFilterConverter<Integer,
String, CustomEvent>, Serializable {
    final Object[] params;

    DynamicCacheEventFilterConverter(Object[] params) {
      this.params = params;
    }

    public CustomEvent filterAndConvert(Integer key, String oldValue, Metadata oldMetadata,
        String newValue, Metadata newMetadata, EventType eventType) {
      // If the key matches a key given via parameter, only send the key information
      if (params[0].equals(key))
        return new CustomEvent(key, null);

      return new CustomEvent(key, newValue);
    }
}
```

Similar to filters and converters, to be able to register a listener with this combined filter/converter factory, the factory has to be given a unique name via the **@NamedFactory** annotation, and the Hot Rod server needs to be plugged with the name and the cache event converter factory instance. Plugging the Red Hat Data Grid Server with an event converter involves the following steps:

1. Create a JAR file with the converter implementation within it.
2. Optional: If the cache uses custom key/value classes, these must be included in the JAR so that the callbacks can be executed with the correctly unmarshalled key and/or value instances. If the client listener has **useRawData** enabled, this is not necessary since the callback key/value instances will be provided in binary format.
3. Create a **META-INF/services/org.infinispan.notifications.cachelistener.filter.CacheEventFilterConverterFactory** file within the JAR file and within it, write the fully qualified class name of the converter class implementation.
4. Deploy the JAR file in the Red Hat Data Grid Server.

From a client perspective, to be able to use the combined filter and converter class, the client listener must define the same filter factory and converter factory names, e.g.:

```
@ClientListener(filterFactoryName = "dynamic-filter-converter", converterFactoryName = "dynamic-filter-converter")
public class CustomEventPrintListener { ... }
```

The dynamic parameters required in the example above are provided when the listener is registered via either filter or converter parameters. If filter parameters are non-empty, those are used, otherwise, the converter parameters:

```
RemoteCache<?, ?> cache = ...
cache.addClientListener(new CustomEventPrintListener(), new Object[]{1}, null);
```

20.7.16. Event Marshalling

Hot Rod servers can store data in different formats, but in spite of that, Java Hot Rod client users can still develop **CacheEventConverter** or **CacheEventFilter** instances that work on typed objects. By default, filters and converter will use data as POJO (application/x-java-object) but it is possible to override the desired format by overriding the method **format()** from the filter/converter. If the format returns **null**, the filter/converter will receive data as it's stored.

As indicated in the Marshalling Data section, Hot Rod Java clients can be configured to use a different **org.infinispan.commons.marshall.Marshaller** instance. If doing this and deploying **CacheEventConverter** or **CacheEventFilter** instances, to be able to present filters/converter with Java Objects rather than marshalled content, the server needs to be able to convert between objects and the binary format produced by the marshaller.

To deploy a Marshaller instance server-side, follow a similar method to the one used to deploy **CacheEventConverter** or **CacheEventFilter** instances:

1. Create a JAR file with the converter implementation within it.
2. Create a **META-INF/services/org.infinispan.commons.marshall.Marshaller** file within the JAR file and within it, write the fully qualified class name of the marshaller class implementation.
3. Deploy the JAR file in the Red Hat Data Grid Server.

Note that the Marshaller could be deployed in either a separate jar, or in the same jar as the **CacheEventConverter** and/or **CacheEventFilter** instances.

20.7.16.1. Deploying Protostream Marshallers

If a cache stores protobuf content, as it happens when using protostream marshaller in the Hot Rod client, it's not necessary to deploy a custom marshaller since the format is already support by the server: there are transcoders from protobuf format to most common formats like JSON and POJO.

When using filters/converters with those caches, and it's desirable to use filter/converters with Java Objects rather binary prototobuf data, it's necessary to deploy the extra protostream marshallers so that the server can unmarshall the data before filtering/converting. To do so, follow these steps:

1. Create a JAR file that includes an implementation of the following interface:

   ```
   org.infinispan.query.remote.client.ProtostreamSerializationContextInitializer
   ```

   Your implementation should add extra marshallers and optional Protobuf (**.proto**) files to the **Serialization** context for the Cache Manager.

2. Create the following file inside your JAR file:

   ```
   META-
   INF/services/org.infinispan.query.remote.client.ProtostreamSerializationContextInitializer
   ```

   This file should contain the fully qualified class name of your **ProtostreamSerializationContextInitializer** implementation.

3. Create a **META-INF/MANIFEST.MF** file inside your JAR file that contains the following:

   ```
   Dependencies: org.infinispan.protostream, org.infinispan.remote-query.client
   ```

4. Update your JBoss deployment structure file, **jboss-deployment-structure.xml**, to include the following content so that Red Hat Data Grid Server can access your custom classes:

   ```
   <jboss-deployment-structure xmlns="urn:jboss:deployment-structure:1.2">
   ```

```
    <deployment>
     <dependencies>
       <module name="org.infinispan.protostream" />
       <module name="org.infinispan.remote-query.client" services="import"/>
     </dependencies>
  </deployment>
</jboss-deployment-structure>
```

5. Deploy the JAR file to Red Hat Data Grid Server by adding it to the **standalone/deployments** folder.

6. Configure the deployment in the appropriate Cache Manager as follows:

```
<cache-container name="local" default-cache="default">
  <modules>
    <module name="deployment.my-file.jar"/>
  </modules>
  ...
</cache-container>
```

IMPORTANT

JAR files that deploy custom classes to Red Hat Data Grid Server must be available at startup. You cannot deploy JARs to running server instances.

20.7.17. Listener State Handling

Client listener annotation has an optional **includeCurrentState** attribute that specifies whether state will be sent to the client when the listener is added or when there's a failover of the listener.

By default, **includeCurrentState** is false, but if set to true and a client listener is added in a cache already containing data, the server iterates over the cache contents and sends an event for each entry to the client as a **ClientCacheEntryCreated** (or custom event if configured). This allows clients to build some local data structures based on the existing content. Once the content has been iterated over, events are received as normal, as cache updates are received. If the cache is clustered, the entire cluster wide contents are iterated over.

includeCurrentState also controls whether state is received when the node where the client event listener is registered fails and it's moved to a different node. The next section discusses this topic in depth.

20.7.18. Listener Failure Handling

When a Hot Rod client registers a client listener, it does so in a single node in a cluster. If that node fails, the Java Hot Rod client detects that transparently and fails over all listeners registered in the node that failed to another node.

During this fail over the client might miss some events. To avoid missing these events, the client listener annotation contains an optional parameter called **includeCurrentState** which if set to true, when the failover happens, the cache contents can iterated over and **ClientCacheEntryCreated** events (or custom events if configured) are generated. By default, **includeCurrentState** is set to false.

Java Hot Rod clients can be made aware of such fail over event by adding a callback to handle it:

```
@ClientCacheFailover
public void handleFailover(ClientCacheFailoverEvent e) {
  ...
}
```

This is very useful in use cases where the client has cached some data, and as a result of the fail over, taking in account that some events could be missed, it could decide to clear any locally cached data when the fail over event is received, with the knowledge that after the fail over event, it will receive events for the contents of the entire cache.

20.7.19. Near Caching

The Java Hot Rod client can be optionally configured with a near cache, which means that the Hot Rod client can keep a local cache that stores recently used data. Enabling near caching can significantly improve the performance of read operations **get** and **getVersioned** since data can potentially be located locally within the Hot Rod client instead of having to go remote.

To enable near caching, the user must set the near cache mode to **INVALIDATED**. By doing that near cache is populated upon retrievals from the server via calls to **get** or **getVersioned** operations. When near cached entries are updated or removed server-side, the cached near cache entries are invalidated. If a key is requested after it's been invalidated, it'll have to be re-fetched from the server.

WARNING

You should not use **maxIdle** expiration with near caches, as near-cache reads will not propagate the last access change to the server and to the other clients.

When near cache is enabled, its size must be configured by defining the maximum number of entries to keep in the near cache. When the maximum is reached, near cached entries are evicted. If providing 0 or a negative value, it is assumed that the near cache is unbounded.

WARNING

Users should be careful when configuring near cache to be unbounded since it shifts the responsibility to keep the near cache's size within the boundaries of the client JVM to the user.

The Hot Rod client's near cache mode is configured using the **NearCacheMode** enumeration and calling:

```
import org.infinispan.client.hotrod.configuration.ConfigurationBuilder;
import org.infinispan.client.hotrod.configuration.NearCacheMode;
...

// Unbounded invalidated near cache
```

```
ConfigurationBuilder unbounded = new ConfigurationBuilder();
unbounded.nearCache().mode(NearCacheMode.INVALIDATED).maxEntries(-1);

// Bounded invalidated near cache
ConfigurationBuilder bounded = new ConfigurationBuilder();
bounded.nearCache().mode(NearCacheMode.INVALIDATED).maxEntries(100);
```

Since the configuration is shared by all caches obtained from a single **RemoteCacheManager**, you may not want to enable near-caching for all of them. You can use the **cacheNamePattern** configuration attribute to define a regular expression which matches the names of the caches for which you want near-caching. Caches whose name don't match the regular expression, will not have near-caching enabled.

```
// Bounded invalidated near cache with pattern matching
ConfigurationBuilder bounded = new ConfigurationBuilder();
bounded.nearCache()
  .mode(NearCacheMode.INVALIDATED)
  .maxEntries(100)
  .cacheNamePattern("near.*"); // enable near-cache only for caches whose name starts with 'near'
```

NOTE

Near caches work the same way for local caches as they do for clustered caches, but in a clustered cache scenario, if the server node sending the near cache notifications to the Hot Rod client goes down, the Hot Rod client transparently fails over to another node in the cluster, clearing the near cache along the way.

20.7.20. Unsupported methods

Some of the Cache methods are not being supported by the RemoteCache . Calling one of these methods results in an UnsupportedOperationException being thrown. Most of these methods do not make sense on the remote cache (e.g. listener management operations), or correspond to methods that are not supported by local cache as well (e.g. containsValue). Another set of unsupported operations are some of the atomic operations inherited from ConcurrentMap :

```
boolean remove(Object key, Object value);
boolean replace(Object key, Object value);
boolean replace(Object key, Object oldValue, Object value);
```

RemoteCache offers alternative versioned methods for these atomic operations, that are also network friendly, by not sending the whole value object over the network, but a version identifier. See the section on versioned API.

Each one of these unsupported operation is documented in the RemoteCache javadoc.

20.7.21. Return values

There is a set of methods that alter a cached entry and return the previous existing value, e.g.:

```
V remove(Object key);
V put(K key, V value);
```

By default on RemoteCache, these operations return null even if such a previous value exists. This approach reduces the amount of data sent over the network. However, if these return values are needed they can be enforced on a per invocation basis using flags:

```
cache.put("aKey", "initialValue");
assert null == cache.put("aKey", "aValue");
assert "aValue".equals(cache.withFlags(Flag.FORCE_RETURN_VALUE).put("aKey",
  "newValue"));
```

This default behavior can can be changed through force-return-value=true configuration parameter (see configuration section bellow).

20.7.22. Hot Rod Transactions

You can configure and use Hot Rod clients in JTA Transactions.

To participate in a transaction, the Hot Rod client requires the TransactionManager with which it interacts and whether it participates in the transaction through the Synchronization or XAResource interface.

IMPORTANT

Transactions are optimistic in that clients acquire write locks on entries during the prepare phase. To avoid data inconsistency, be sure to read about Detecting Conflicts with Transactions.

20.7.22.1. Configuring the Server

Caches in the server must also be transactional for clients to participate in JTA Transactions.

The following server configuration is required, otherwise transactions rollback only:

- Isolation level must be **REPEATABLE_READ**.
- Locking mode must be **PESSIMISTIC**. In a future release, **OPTIMISTIC** locking mode will be supported.
- Transaction mode should be **NON_XA** or **NON_DURABLE_XA**. Hot Rod transactions cannot use **FULL_XA** because it degrades performance.

Hot Rod transactions have their own recovery mechanism.

20.7.22.2. Configuring Hot Rod Clients

When you create the RemoteCacheManager, you can set the default TransactionManager and TransactionMode that the RemoteCache uses.

The RemoteCacheManager lets you create only one configuration for transactional caches, as in the following example:

```
org.infinispan.client.hotrod.configuration.ConfigurationBuilder cb = new
org.infinispan.client.hotrod.configuration.ConfigurationBuilder();
//other client configuration parameters
cb.transaction().transactionManagerLookup(GenericTransactionManagerLookup.getInstance());
cb.transaction().transactionMode(TransactionMode.NON_XA);
cb.transaction().timeout(1, TimeUnit.MINUTES)
RemoteCacheManager rmc = new RemoteCacheManager(cb.build());
```

The preceding configuration applies to all instances of a remote cache. If you need to apply different configurations to remote cache instances, you can override the RemoteCache configuration. See Overriding RemoteCacheManager Configuration.

See ConfigurationBuilder Javadoc for documentation on configuration parameters.

You can also configure the Java Hot Rod client with a properties file, as in the following example:

```
infinispan.client.hotrod.transaction.transaction_manager_lookup =
org.infinispan.client.hotrod.transaction.lookup.GenericTransactionManagerLookup
infinispan.client.hotrod.transaction.transaction_mode = NON_XA
infinispan.client.hotrod.transaction.timeout = 60000
```

20.7.22.2.1. TransactionManagerLookup Interface

TransactionManagerLookup provides an entry point to fetch a TransactionManager.

Available implementations of **TransactionManagerLookup**:

GenericTransactionManagerLookup

A lookup class that locates TransactionManagers running in Java EE application servers. Defaults to the RemoteTransactionManager if it cannot find a TransactionManager.

TIP

In most cases, GenericTransactionManagerLookup is suitable. However, you can implement the **TransactionManagerLookup** interface if you need to integrate a custom TransactionManager.

RemoteTransactionManagerLookup

A basic, and volatile, TransactionManager if no other implementation is available. Note that this implementation has significant limitations when handling concurrent transactions and recovery.

20.7.22.2.2. Transaction Modes

TransactionMode controls how a RemoteCache interacts with the TransactionManager.

IMPORTANT

Configure transaction modes on both the Red Hat Data Grid server and your client application. If clients attempt to perform transactional operations on non-transactional caches, runtime exceptions can occur.

Transaction modes are the same in both the Red Hat Data Grid configuration and client settings. Use the following modes with your client, see the Red Hat Data Grid configuration schema for the server:

NONE

The RemoteCache does not interact with the TransactionManager. This is the default mode and is non-transactional.

NON_XA

The RemoteCache interacts with the TransactionManager via Synchronization.

NON_DURABLE_XA

The RemoteCache interacts with the TransactionManager via XAResource. Recovery capabilities are disabled.

FULL_XA

The RemoteCache interacts with the TransactionManager via XAResource. Recovery capabilities are enabled. Invoke the **XaResource.recover()** method to retrieve transactions to recover.

20.7.22.3. Overriding Configuration for Cache Instances

Because RemoteCacheManager does not support different configurations for each cache instance. However, RemoteCacheManager includes the **getCache(String)** method that returns the RemoteCache instances and lets you override some configuration parameters, as follows:

getCache(String cacheName, TransactionMode transactionMode)

Returns a RemoteCache and overrides the configured TransactionMode.

getCache(String cacheName, boolean forceReturnValue, TransactionMode transactionMode)

Same as previous, but can also force return values for write operations.

getCache(String cacheName, TransactionManager transactionManager)

Returns a RemoteCache and overrides the configured TransactionManager.

getCache(String cacheName, boolean forceReturnValue, TransactionManager transactionManager)

Same as previous, but can also force return values for write operations.

getCache(String cacheName, TransactionMode transactionMode, TransactionManager transactionManager)

Returns a RemoteCache and overrides the configured TransactionManager and TransactionMode. Uses the configured values, if **transactionManager** or **transactionMode** is null.

getCache(String cacheName, boolean forceReturnValue, TransactionMode transactionMode, TransactionManager transactionManager)

Same as previous, but can also force return values for write operations.

NOTE

The **getCache(String)** method returns RemoteCache instances regardless of whether they are transaction or not. RemoteCache includes a **getTransactionManager()** method that returns the TransactionManager that the cache uses. If the RemoteCache is not transactional, the method returns **null**.

20.7.22.4. Detecting Conflicts with Transactions

Transactions use the initial values of keys to detect conflicts. For example, "k" has a value of "v" when a transaction begins. During the prepare phase, the transaction fetches "k" from the server to read the value. If the value has changed, the transaction rolls back to avoid a conflict.

NOTE

Transactions use versions to detect changes instead of checking value equality.

The **forceReturnValue** parameter controls write operations to the RemoteCache and helps avoid conflicts. It has the following values:

- If **true**, the TransactionManager fetches the most recent value from the server before performing write operations. However, the **forceReturnValue** parameter applies only to write operations that access the key for the first time.
- If **false**, the TransactionManager does not fetch the most recent value from the server before performing write operations. Because this setting

NOTE

This parameter does not affect *conditional* write operations such as **replace** or **putIfAbsent** because they require the most recent value.

The following transactions provide an example where the **forceReturnValue** parameter can prevent conflicting write operations:

Transaction 1 (TX1)

```
RemoteCache<String, String> cache = ...
TransactionManager tm = ...

tm.begin();
cache.put("k", "v1");
tm.commit();
```

Transaction 2 (TX2)

```
RemoteCache<String, String> cache = ...
TransactionManager tm = ...

tm.begin();
cache.put("k", "v2");
tm.commit();
```

In this example, TX1 and TX2 are executed in parallel. The initial value of "k" is "v".

- If **forceReturnValue = true**, the **cache.put()** operation fetches the value for "k" from the server in both TX1 and TX2. The transaction that acquires the lock for "k" first then commits. The other transaction rolls back during the commit phase because the transaction can detect that "k" has a value other than "v".
- If **forceReturnValue = false**, the **cache.put()** operation does not fetch the value for "k" from the server and returns null. Both TX1 and TX2 can successfully commit, which results in a conflict. This occurs because neither transaction can detect that the initial value of "k" changed.

The following transactions include **cache.get()** operations to read the value for "k" before doing the **cache.put()** operations:

Transaction 1 (TX1)

```
RemoteCache<String, String> cache = ...
TransactionManager tm = ...
```

```
tm.begin();
cache.get("k");
cache.put("k", "v1");
tm.commit();
```

Transaction 2 (TX2)

```
RemoteCache<String, String> cache = ...
TransactionManager tm = ...

tm.begin();
cache.get("k");
cache.put("k", "v2");
tm.commit();
```

In the preceding examples, TX1 and TX2 both read the key so the **forceReturnValue** parameter does not take effect. One transaction commits, the other rolls back. However, the **cache.get()** operation requires an additional server request. If you do not need the return value for the **cache.put()** operation that server request is inefficient.

20.7.22.5. Using the Configured Transaction Manager and Transaction Mode

The following example shows how to use the **TransactionManager** and **TransactionMode** that you configure in the **RemoteCacheManager**:

```
//Configure the transaction manager and transaction mode.
org.infinispan.client.hotrod.configuration.ConfigurationBuilder cb = new
org.infinispan.client.hotrod.configuration.ConfigurationBuilder();
cb.transaction().transactionManagerLookup(RemoteTransactionManagerLookup.getInstance());
cb.transaction().transactionMode(TransactionMode.NON_XA);

RemoteCacheManager rcm = new RemoteCacheManager(cb.build());

//The my-cache instance uses the RemoteCacheManager configuration.
RemoteCache<String, String> cache = rcm.getCache("my-cache");

//Return the transaction manager that the cache uses.
TransactionManager tm = cache.getTransactionManager();

//Perform a simple transaction.
tm.begin();
cache.put("k1", "v1");
System.out.println("K1 value is " + cache.get("k1"));
tm.commit();
```

20.7.22.6. Overriding the Transaction Manager

The following example shows how to override **TransactionManager** with the **getCache** method:

```
//Configure the transaction manager and transaction mode.
org.infinispan.client.hotrod.configuration.ConfigurationBuilder cb = new
org.infinispan.client.hotrod.configuration.ConfigurationBuilder();
cb.transaction().transactionManagerLookup(RemoteTransactionManagerLookup.getInstance());
cb.transaction().transactionMode(TransactionMode.NON_XA);

RemoteCacheManager rcm = new RemoteCacheManager(cb.build());

//Define a custom TransactionManager.
TransactionManager myCustomTM = ...

//Override the TransactionManager for the my-cache instance. Use the default configuration if null is
returned.
RemoteCache<String, String> cache = rcm.getCache("my-cache", null, myCustomTM);

//Perform a simple transaction.
myCustomTM.begin();
cache.put("k1", "v1");
System.out.println("K1 value is " + cache.get("k1"));
myCustomTM.commit();
```

20.7.22.7. Overriding the Transaction Mode

The following example shows how to override **TransactionMode** with the **getCache** method:

```
//Configure the transaction manager and transaction mode.
org.infinispan.client.hotrod.configuration.ConfigurationBuilder cb = new
org.infinispan.client.hotrod.configuration.ConfigurationBuilder();
cb.transaction().transactionManagerLookup(RemoteTransactionManagerLookup.getInstance());
cb.transaction().transactionMode(TransactionMode.NON_XA);

RemoteCacheManager rcm = new RemoteCacheManager(cb.build());

//Override the transaction mode for the my-cache instance.
RemoteCache<String, String> cache = rcm.getCache("my-cache",
TransactionMode.NON_DURABLE_XA, null);

//Return the transaction manager that the cache uses.
TransactionManager tm = cache.getTransactionManager();

//Perform a simple transaction.
tm.begin();
cache.put("k1", "v1");
System.out.println("K1 value is " + cache.get("k1"));
tm.commit();
```

20.7.23. Client Intelligence

Client intelligence refers to mechanisms the **HotRod** protocol provides for clients to locate and send requests to Red Hat Data Grid servers.

Basic intelligence

Clients do not store any information about Red Hat Data Grid clusters or key hash values.

Topology-aware

Clients receive and store information about Red Hat Data Grid clusters. Clients maintain an internal mapping of the cluster topology that changes whenever servers join or leave clusters.

To receive a cluster topology, clients need the address (**IP:HOST**) of at least one Hot Rod server at startup. After the client connects to the server, Red Hat Data Grid transmits the topology to the client. When servers join or leave the cluster, Red Hat Data Grid transmits an updated topology to the client.

Distribution-aware

Clients are topology-aware and store consistent hash values for keys.

For example, take a **put(k,v)** operation. The client calculates the hash value for the key so it can locate the exact server on which the data resides. Clients can then connect directly to the owner to dispatch the operation.

The benefit of distribution-aware intelligence is that Red Hat Data Grid servers do not need to look up values based on key hashes, which uses less resources on the server side. Another benefit is that servers respond to client requests more quickly because it skips additional network roundtrips.

20.7.23.1. Request Balancing

Clients that use topology-aware intelligence use request balancing for all requests. The default balancing strategy is round-robin, so topology-aware clients always send requests to servers in round-robin order.

For example, **s1**, **s2**, **s3** are servers in a Red Hat Data Grid cluster. Clients perform request balancing as follows:

```
CacheContainer cacheContainer = new RemoteCacheManager();
Cache<String, String> cache = cacheContainer.getCache();

//client sends put request to s1
cache.put("key1", "aValue");
//client sends put request to s2
cache.put("key2", "aValue");
//client sends get request to s3
String value = cache.get("key1");
//client dispatches to s1 again
cache.remove("key2");
//and so on...
```

Clients that use distribution-aware intelligence use request balancing only for failed requests. When requests fail, distribution-aware clients retry the request on the next available server.

Custom balancing policies

You can implement FailoverRequestBalancingStrategy and specify your class in your **hotrod-client.properties** configuration.

20.7.24. Persistent connections

In order to avoid creating a TCP connection on each request (which is a costly operation), the client keeps a pool of persistent connections to all the available servers and it reuses these connections whenever it is possible. The validity of the connections is checked using an async thread that iterates over the connections in the pool and sends a HotRod ping command to the server. By using this connection validation process the client is being proactive: there's a hight chance for broken connections to be found while being idle in the pool and no on actual request from the application.

The number of connections per server, total number of connections, how long should a connection be kept idle in the pool before being closed - all these (and more) can be configured. Please refer to the javadoc of RemoteCacheManager for a list of all possible configuration elements.

20.7.25. Marshalling data

The Hot Rod client allows one to plug in a custom marshaller for transforming user objects into byte arrays and the other way around. This transformation is needed because of Hot Rod's binary nature - it doesn't know about objects.

The marshaller can be plugged through the "marshaller" configuration element (see Configuration section): the value should be the fully qualified name of a class implementing the Marshaller interface. This is a optional parameter, if not specified it defaults to the GenericJBossMarshaller - a highly optimized implementation based on the JBoss Marshalling library.

Since version 6.0, there's a new marshaller available to Java Hot Rod clients based on Protostream which generates portable payloads. You can find more information about it here.

WARNING: If developing your own custom marshaller, take care of potential injection attacks.

To avoid such attacks, make the marshaller verify that any class names read, before instantiating it, is amongst the expected/allowed class names.

The client configuration can be enhanced with a list of regular expressions for classes that are allowed to be read.

WARNING: These checks are opt-in, so if not configured, any class can be read.

In the example below, only classes with fully qualified names containing **Person** or **Employee** would be allowed:

```
import org.infinispan.client.hotrod.configuration.ConfigurationBuilder;

...
ConfigurationBuilder configBuilder = ...
configBuilder.addJavaSerialWhiteList(".*Person.*", ".*Employee.*");
```

20.7.26. Reading data in different data formats

By default, every Hot Rod client operation will use the configured marshaller when reading and writing from the server for both keys and values. See Marshalling Data. Using the DataFormat API, it's possible to decorate remote caches so that all operations can happen with a custom data format.

20.7.26.1. Using different marshallers for Key and Values

Marshallers for Keys and Values can be overridden at run time. For example, to bypass all serialization in the Hot Rod client and read the byte[] as they are stored in the server:

```
// Existing Remote cache instance
RemoteCache<String, Pojo> remoteCache = ...

// IdentityMarshaller is a no-op marshaller
DataFormat rawKeyAndValues =
DataFormat.builder().keyMarshaller(IdentityMarshaller.INSTANCE).valueMarshaller(IdentityMarshaller.I
NSTANCE).build();

// Will create a new instance of RemoteCache with the supplied DataFormat
RemoteCache<byte[], byte[]> rawResultsCache = remoteCache.withDataFormat(rawKeyAndValues);
```

20.7.26.2. Reading data in different formats

Apart from defining custom key and value marshallers, it's also possible to request/send data in different formats specified by a **org.infinispan.commons.dataconversion.MediaType**:

```
// Existing remote cache using ProtostreamMarshaller
RemoteCache<String, Pojo> protobufCache = ...

// Request values returned as JSON, using the UTF8StringMarshaller that converts between UTF-8 to
String:
DataFormat jsonString =
DataFormat.builder().valueType(MediaType.APPLICATION_JSON).valueMarshaller(new
UTF8StringMarshaller().build();

RemoteCache<String, String> jsonStrCache = remoteCache.withDataFormat(jsonString);

// Alternativelly, it's possible to request JSON values but marshalled/unmarshalled with a custom
value marshaller that returns `org.codehaus.jackson.JsonNode` objects:
DataFormat jsonNode =
DataFormat.builder().valueType(MediaType.APPLICATION_JSON).valueMarshaller(new
CustomJacksonMarshaller().build();

RemoteCache<String, JsonNode> jsonNodeCache = remoteCache.withDataFormat(jsonNode);
```

IMPORTANT

The data conversions happen in the server, and if it doesn't support converting from the storage format to the request format and vice versa, an error will be returned. For more details on server data format configuration and supported conversions, see here.

WARNING

Using different marshallers and formats for the key, with **.keyMarshaller()** and **.keyType()** may interfere with the client intelligence routing mechanism, causing it contact the server that is not the owner of the key during Hot Rod operations. This will not result in errors but can result in extra hops inside the cluster to execute the operation. If performance is critical, make sure to use the keys in the format stored by the server.

20.7.27. Statistics

Various server usage statistics can be obtained through the RemoteCache .stats() method. This returns a ServerStatistics object - please refer to javadoc for details on the available statistics.

20.7.28. Multi-Get Operations

The Java Hot Rod client does not provide multi-get functionality out of the box but clients can build it themselves with the given APIs.

20.7.29. Failover capabilities

Hot Rod clients' capabilities to keep up with topology changes helps with request balancing and more importantly, with the ability to failover operations if one or several of the servers fail.

Some of the conditional operations mentioned above, including **putIfAbsent**, **replace** with and without version, and conditional **remove** have strict method return guarantees, as well as those operations where returning the previous value is forced.

In spite of failures, these methods return values need to be guaranteed, and in order to do so, it's necessary that these methods are not applied partially in the cluster in the event of failure. For example, imagine a **replace()** operation called in a server for key=k1 with **Flag.FORCE_RETURN_VALUE**, whose current value is **A** and the replace wants to set it to **B**. If the replace fails, it could happen that some servers contain **B** and others contain **A**, and during the failover, the original **replace()** could end up returning **B**, if the replace failovers to a node where **B** is set, or could end up returning **A**.

To avoid this kind of situations, whenever Java Hot Rod client users want to use conditional operations, or operations whose previous value is required, it's important that the cache is configured to be transactional in order to avoid incorrect conditional operations or return values.

20.7.30. Site Cluster Failover

On top of the in-cluster failover, Hot Rod clients are also able to failover to different clusters, which could be represented as an independent site.

The way site cluster failover works is that if all the main cluster nodes are not available, the client checks to see if any other clusters have been defined in which cases it tries to failover to the alternative cluster. If the failover succeeds, the client will remain connected to the alternative cluster until this becomes unavailable, in which case it'll try any other clusters defined, and ultimately, it'll try the original server settings.

To configure a cluster in the Hot Rod client, one host/port pair details must be provided for each of the clusters configured. For example:

```
org.infinispan.client.hotrod.configuration.ConfigurationBuilder cb
      = new org.infinispan.client.hotrod.configuration.ConfigurationBuilder();
cb.addCluster().addClusterNode("remote-cluster-host", 11222);
RemoteCacheManager rmc = new RemoteCacheManager(cb.build());
```

NOTE

Remember that regardless of the cluster definitions, the initial server(s) configuration must be provided unless the initial servers can be resolved using the default server host and port details.

20.7.31. Manual Site Cluster Switch

As well as supporting automatic site cluster failover, Java Hot Rod clients can also switch between site clusters manually by calling RemoteCacheManager's **switchToCluster(clusterName)** and **switchToDefaultCluster()**.

Using **switchToCluster(clusterName)**, users can force a client to switch to one of the clusters pre-defined in the Hot Rod client configuration. To switch to the initial servers defined in the client configuration, call **switchToDefaultCluster()**.

20.7.32. Monitoring the Hot Rod client

The Hot Rod client can be monitored and managed via JMX similarly to what is described in the Management chapter. By enabling statistics, an MBean will be registered for the **RemoteCacheManager** as well as for each **RemoteCache** obtained through it. Through these MBeans it is possible to obtain statistics about remote and near-cache hits/misses and connection pool usage.

20.7.33. Concurrent Updates

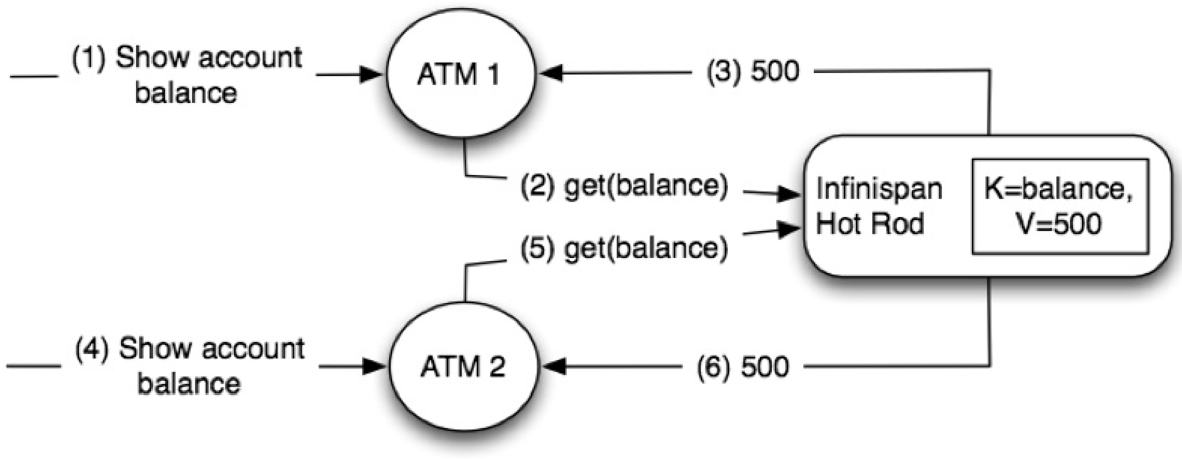
Data structures, such as Red Hat Data Grid Cache , that are accessed and modified concurrently can suffer from data consistency issues unless there're mechanisms to guarantee data correctness. Red Hat Data Grid Cache, since it implements ConcurrentMap , provides operations such as conditional replace , putIfAbsent , and conditional remove to its clients in order to guarantee data correctness. It even allows clients to operate against cache instances within JTA transactions, hence providing the necessary data consistency guarantees.

However, when it comes to Hot Rod protocol backed servers, clients do not yet have the ability to start remote transactions but they can call instead versioned operations to mimic the conditional methods provided by the embedded Red Hat Data Grid cache instance API. Let's look at a real example to understand how it works.

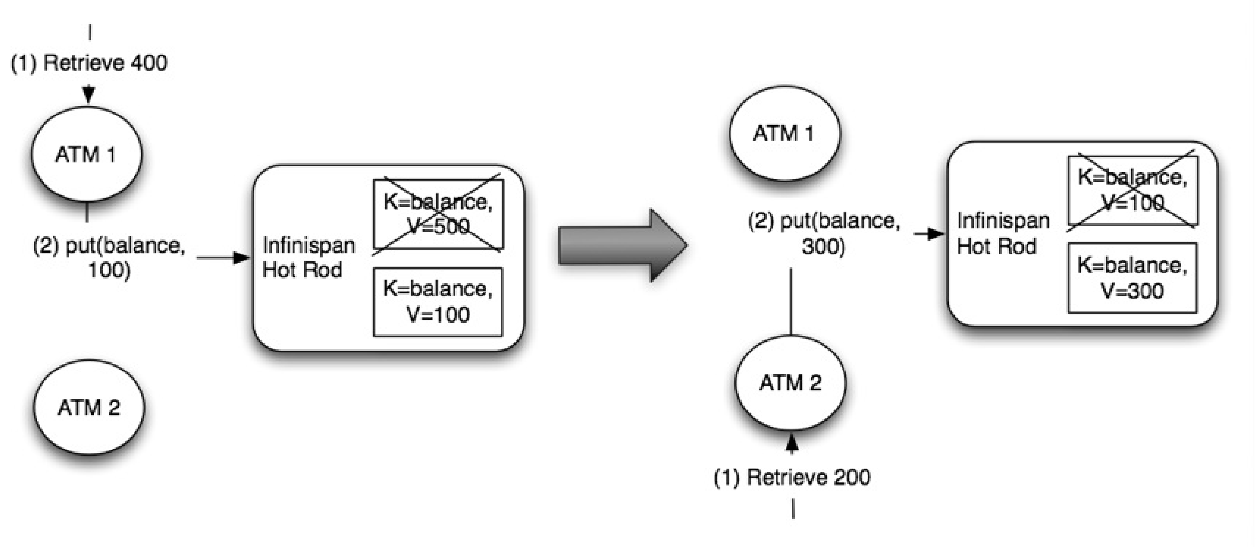
20.7.33.1. Data Consistency Problem

Imagine you have two ATMs that connect using Hot Rod to a bank where an account's balance is stored. Two closely followed operations to retrieve the latest balance could return 500 CHF (swiss francs) as shown below:

Figure 20.7. Concurrent readers



Next a customer connects to the first ATM and requests 400 CHF to be retrieved. Based on the last value read, the ATM could calculate what the new balance is, which is 100 CHF, and request a put with this new value. Let's imagine now that around the same time another customer connects to the ATM and requests 200 CHF to be retrieved. Let's assume that the ATM thinks it has the latest balance and based on its calculations it sets the new balance to 300 CHF:

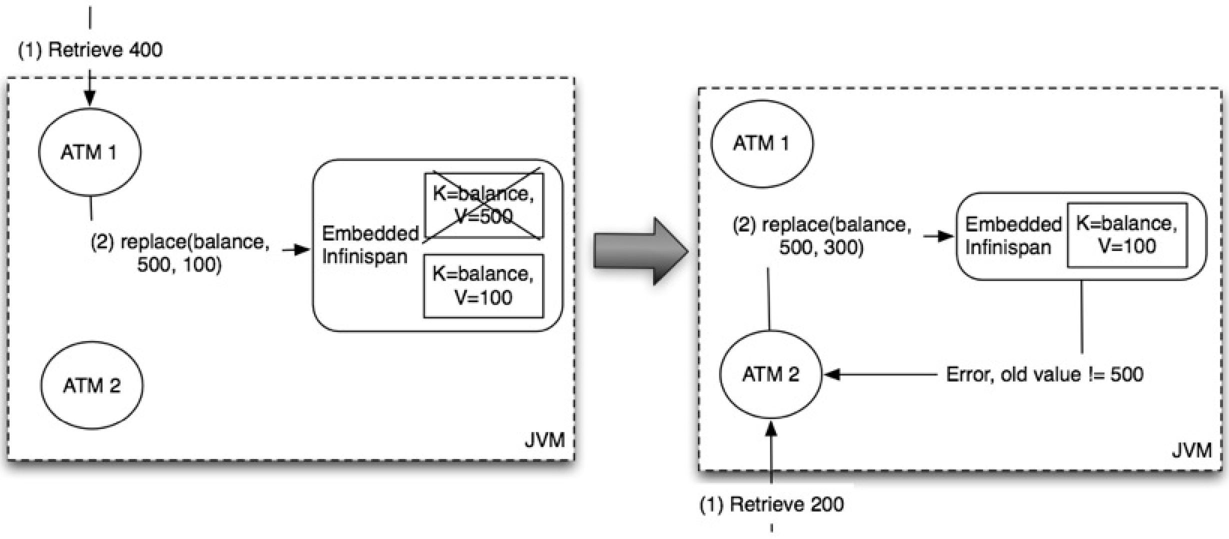


Obviously, this would be wrong. Two concurrent updates have resulted in an incorrect account balance. The second update should not have been allowed since the balance the second ATM had was incorrect. Even if the ATM would have retrieved the balance before calculating the new balance, someone could have updated between the new balance being retrieved and the update. Before finding out how to solve this issue in a client-server scenario with Hot Rod, let's look at how this is solved when Red Hat Data Grid clients run in peer-to-peer mode where clients and Red Hat Data Grid live within the same JVM.

20.7.33.2. Embedded-mode Solution

If the ATM and the Red Hat Data Grid instance storing the bank account lived in the same JVM, the ATM could use the conditional replace API referred at the beginning of this article. So, it could send the previous known value to verify whether it has changed since it was last read. By doing so, the first operation could double check that the balance is still 500 CHF when it was to update to 100 CHF. Now, when the second operation comes, the current balance would not be 500 CHF any more and hence the conditional replace call would fail, hence avoiding data consistency issues:

Figure 20.8. P2P solution

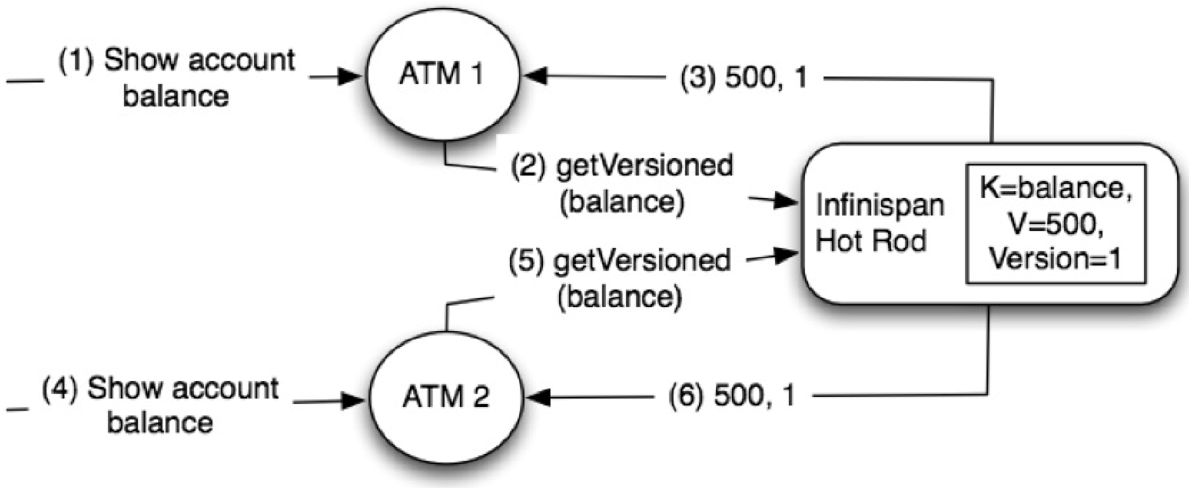


20.7.33.3. Client-Server Solution

In theory, Hot Rod could use the same p2p solution but sending the previous value would be not practical. In this example, the previous value is just an integer but the value could be a lot bigger and hence forcing clients to send it to the server would be rather wasteful. Instead, Hot Rod offers versioned operations to deal with this situation.

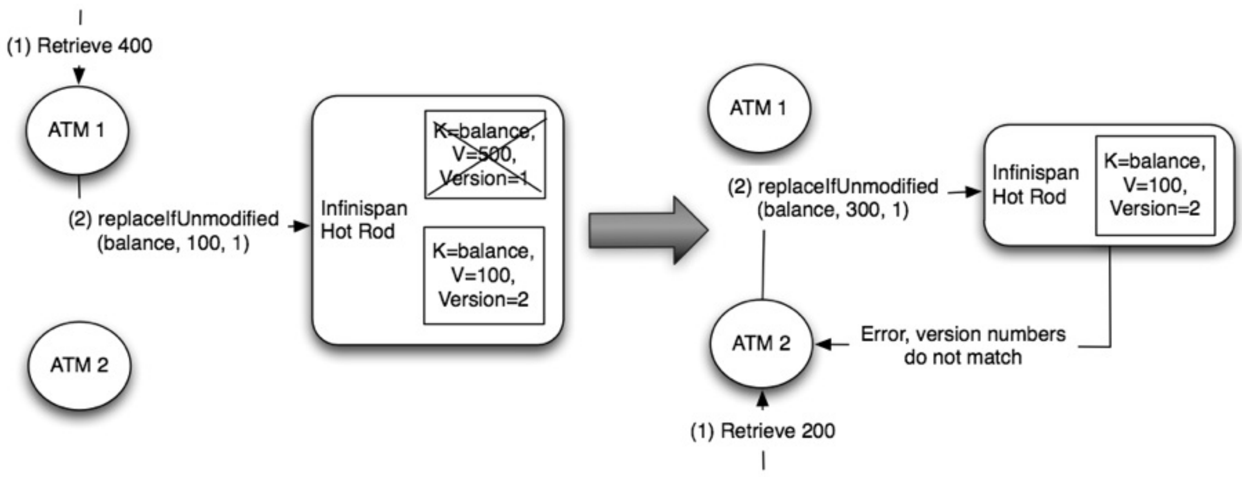
Basically, together with each key/value pair, Hot Rod stores a version number which uniquely identifies each modification. So, using an operation called getVersioned or getWithVersion , clients can retrieve not only the value associated with a key, but also the current version. So, if we look at the previous example once again, the ATMs could call getVersioned and get the balance's version:

Figure 20.9. Get versioned



When the ATMs wanted to modify the balance, instead of just calling put, they could call replaceIfUnmodified operation passing the latest version number of which the clients are aware of. The operation will only succeed if the version passed matches the version in the server. So, the first modification by the ATM would be allowed since the client passes 1 as version and the server side version for the balance is also 1. On the other hand, the second ATM would not be able to make the modification because after the first ATMs modification the version would have been incremented to 2, and now the passed version (1) and the server side version (2) would not match:

Figure 20.10. Replace if versions match


(1) Retrieve 400
ATM 1
(2) replaceIfUnmodified (balance, 100, 1)
Infinispan Hot Rod
K=balance, V=500, Version=1
K=balance, V=100, Version=2
ATM 2
ATM 1
(2) replaceIfUnmodified (balance, 300, 1)
Infinispan Hot Rod
K=balance, V=100, Version=2
ATM 2
Error, version numbers do not match
(1) Retrieve 200

20.7.34. Javadocs

It is highly recommended to read the following Javadocs (this is pretty much all the public API of the client):

- RemoteCacheManager
- RemoteCache

20.8. REST SERVER

The Red Hat Data Grid Server distribution contains a module that implements RESTful HTTP access to the Red Hat Data Grid data grid, built on Netty.

20.8.1. Running the REST server

The REST server endpoint is part of the Red Hat Data Grid Server and by default listens on port 8080. To run the server locally, download the zip distribution and execute in the extracted directory:

```
bin/standalone.sh -b 0.0.0.0
```

or alternatively, run via docker:

```
docker run -it -p 8080:8080 -e "APP_USER=user" -e "APP_PASS=changeme" jboss/infinispan-
server
```

20.8.1.1. Security

The REST server is protected by authentication, so before usage it is necessary to create an application login. When running via docker, this is achieved by the APP_USER and APP_PASS command line arguments, but when running locally, this can be done with:

```
bin/add-user.sh -u user -p changeme -a
```

20.8.2. Supported protocols

The REST Server supports HTTP/1.1 as well as HTTP/2 protocols. It is possible to switch to HTTP/2 by either performing a HTTP/1.1 Upgrade procedure or by negotiating communication protocol using TLS/ALPN extension.

Note: TLS/ALPN with JDK8 requires additional steps from the client perspective. Please refer to your client documentation but it is very likely that you will need Jetty ALPN Agent or OpenSSL bindings.

20.8.3. REST API

HTTP PUT and POST methods are used to place data in the cache, with URLs to address the cache name and key(s) - the data being the body of the request (the data can be anything you like). Other headers are used to control the cache settings and behaviour.

20.8.3.1. Data formats

20.8.3.1.1. Configuration

Each cache exposed via REST stores data in a configurable data format defined by a MediaType. More details in the configuration here.

An example of storage configuration is as follows:

```
<cache>
  <encoding>
    <key media-type="application/x-java-object; type=java.lang.Integer"/>
    <value media-type="application/xml; charset=UTF-8"/>
  </encoding>
</cache>
```

When no MediaType is configured, Red Hat Data Grid assumes "application/octet-stream" for both keys and values, with the following exceptions:

- If the cache is indexed, it assumes "application/x-protostream"
- If the cache is configured with compatibility mode, it assumes "application/x-java-object"

20.8.3.1.2. Supported formats

Data can be written and read in different formats than the storage format; Red Hat Data Grid can convert between those formats when required.

The following "standard" formats can be converted interchangeably:

- *application/x-java-object*
- *application/octet-stream*
- *application/x-www-form-urlencoded*
- *text/plain*

The following formats can be converted to/from the formats above:

- *application/xml*
- *application/json*
- *application/x-jboss-marshalling*
- *application/x-protostream*
- *application/x-java-serialized*

Finally, the following conversion is also supported:

- Between *application/x-protostream* and *application/json*

All the REST API calls can provide headers describing the content written or the required format of the content when reading. Red Hat Data Grid supports the standard HTTP/1.1 headers "Content-Type" and "Accept" that are applied for values, plus the "Key-Content-Type" with similar effect for keys.

20.8.3.1.3. Accept header

The REST server is compliant with the RFC-2616 Accept header, and will negotiate the correct MediaType based on the conversions supported. Example, sending the following header when reading data:

```
Accept: text/plain;q=0.7, application/json;q=0.8, */*;q=0.6
```

will cause Red Hat Data Grid to try first to return content in JSON format (higher priority 0.8). If it's not possible to convert the storage format to JSON, next format tried will be *text/plain* (second highest priority 0.7), and finally it falls back to **/**, that will pick a format suitable for displaying automatically based on the cache configuration.

20.8.3.1.4. Key-Content-Type header

Most REST API calls have the Key included in the URL. Red Hat Data Grid will assume the Key is a *java.lang.String* when handling those calls, but it's possible to use a specific header *Key-Content-Type* for keys in different formats.

Examples:

- Specifying a byte[] Key as a Base64 string:

API call:

```
`PUT /my-cache/AQIDBDM=`
```

Headers:

Key-Content-Type: application/octet-stream

- Specifying a byte[] Key as a hexadecimal string:

API call:

GET /my-cache/0x01CA03042F

Headers:

```
Key-Content-Type: application/octet-stream; encoding=hex
```

- Specifying a double Key:

API call:

POST /my-cache/3.141456

Headers:

```
Key-Content-Type: application/x-java-object;type=java.lang.Double
```

The *type* parameter for *application/x-java-object* is restricted to:

- Primitive wrapper types
- java.lang.String

- Bytes, making *application/x-java-object;type=Bytes* equivalent to *application/octet-stream;encoding=hex*

20.8.3.2. Putting data in

20.8.3.2.1. PUT /{cacheName}/{cacheKey}

A PUT request of the above URL form will place the payload (body) in the given cache, with the given key (the named cache must exist on the server). For example **http://someserver/hr/payRoll-3** (in which case **hr** is the cache name, and **payRoll-3** is the key). Any existing data will be replaced, and Time-To-Live and Last-Modified values etc will updated (if applicable).

20.8.3.2.2. POST /{cacheName}/{cacheKey}

Exactly the same as PUT, only if a value in a cache/key already exists, it will return a Http CONFLICT status (and the content will not be updated).

Headers

- Key-Content-Type: OPTIONAL The content type for the Key present in the URL.
- Content-Type : OPTIONAL The MediaType of the Value being sent.
- performAsync : OPTIONAL true/false (if true, this will return immediately, and then replicate data to the cluster on its own. Can help with bulk data inserts/large clusters.)
- timeToLiveSeconds : OPTIONAL number (the number of seconds before this entry will automatically be deleted). If no parameter is sent, Red Hat Data Grid assumes configuration default value. Passing any negative value will create an entry which will live forever.
- maxIdleTimeSeconds : OPTIONAL number (the number of seconds after last usage of this entry when it will automatically be deleted). If no parameter is sent, Red Hat Data Grid configuration default value. Passing any negative value will create an entry which will live forever.

Passing 0 as parameter for timeToLiveSeconds and/or maxIdleTimeSeconds

- If both **timeToLiveSeconds** and **maxIdleTimeSeconds** are 0, the cache will use the default **lifespan** and **maxIdle** values configured in XML/programmatically
- If *only* **maxIdleTimeSeconds** is 0, it uses the **timeToLiveSeconds** value passed as parameter (or -1 if not present), and default **maxIdle** configured in XML/programmatically
- If *only* **timeToLiveSeconds** is 0, it uses default **lifespan** configured in XML/programmatically, and **maxIdle** is set to whatever came as parameter (or -1 if not present)

JSON/Protostream conversion

When caches are indexed, or specifically configured to store *application/x-protostream*, it's possible to send and receive JSON documents that are automatically converted to/from protostream. In order for the conversion to work, a protobuf schema must be registered.

The registration can be done via REST, by doing a POST/PUT in the ___*protobuf_metadata* cache. Example using cURL:

```
curl -u user:password -X POST --data-binary @./schema.proto
http://127.0.0.1:8080/rest/___protobuf_metadata/schema.proto
```

When writing a JSON document, a special field ***_type*** must be present in the document to identity the protobuf *Message* corresponding to the document.

For example, consider the following schema:

```
message Person  {
  required string name = 1;
  required int32 age = 2;
}
```

A conformant JSON document would be:

```
{
   "_type": "Person",
   "name": "user1",
   "age": 32
}
```

20.8.3.3. Getting data back out

HTTP GET and HEAD are used to retrieve data from entries.

20.8.3.3.1. GET /{cacheName}/{cacheKey}

This will return the data found in the given cacheName, under the given key - as the body of the response. A Content-Type header will be present in the response according to the Media Type negotiation. Browsers can use the cache directly of course (eg as a CDN). An ETag will be returned unique for each entry, as will the Last-Modified and Expires headers field indicating the state of the data at the given URL. ETags allow browsers (and other clients) to ask for data only in the case where it has changed (to save on bandwidth) - this is standard HTTP and is honoured by Red Hat Data Grid.

Headers

- Key-Content-Type: OPTIONAL The content type for the Key present in the URL. When omitted, *application/x-java-object; type=java.lang.String* is assumed
- Accept: OPTIONAL The required format to return the content

It is possible to obtain additional information by appending the "extended" parameter on the query string, as follows:

GET /cacheName/cacheKey?extended

This will return the following custom headers:

- Cluster-Primary-Owner: the node name of the primary owner for this key
- Cluster-Node-Name: the JGroups node name of the server that has handled the request
- Cluster-Physical-Address: the physical JGroups address of the server that has handled the request.

20.8.3.3.2. **HEAD /{cacheName}/{cacheKey}**

The same as GET, only no content is returned (only the header fields). You will receive the same content that you stored. E.g., if you stored a String, this is what you get back. If you stored some XML or JSON, this is what you will receive. If you stored a binary (base 64 encoded) blob, perhaps a serialized; Java; object - you will need to; deserialize this yourself.

Similarly to the GET method, the HEAD method also supports returning extended information via headers. See above.

Headers

- Key-Content-Type: OPTIONAL The content type for the Key present in the URL. When omitted, *application/x-java-object; type=java.lang.String* is assumed

20.8.3.4. Listing keys

20.8.3.4.1. **GET /{cacheName}**

This will return a list of keys present in the given cacheName as the body of the response. The format of the response can be controlled via the Accept header as follows:

- *application/xml* - the list of keys will be returned in XML format.
- *application/json* - the list of keys will be return in JSON format.
- *text/plain* - the list of keys will be returned in plain text format, one key per line

If the cache identified by cacheName is distributed, only the keys owned by the node handling the request will be returned. To return all keys, append the "global" parameter to the query, as follows:

GET /cacheName?global

20.8.3.5. Removing data

Data can be removed at the cache key/element level, or via a whole cache name using the HTTP delete method.

20.8.3.5.1. **DELETE /{cacheName}/{cacheKey}**

Removes the given key name from the cache.

Headers

- Key-Content-Type: OPTIONAL The content type for the Key present in the URL. When omitted, *application/x-java-object; type=java.lang.String* is assumed

20.8.3.5.2. **DELETE /{cacheName}**

Removes ALL the entries in the given cache name (i.e., everything from that path down). If the operation is successful, it returns 200 code.

MAKE IT QUICKER!

Set the header performAsync to true to return immediately and let the removal happen in the background.

20.8.3.6. Querying

The REST server supports Ickle Queries in JSON format. It's important that the cache is configured with *application/x-protostream* for both Keys and Values. If the cache is indexed, no configuration is needed.

20.8.3.6.1. GET /{cacheName}?action=search&query={ickle query}

Will execute an Ickle query in the given cache name.

Request parameters

- *query*: REQUIRED the query string
- *max_results*: OPTIONAL the number of results to return, default is *10*
- *offset*: OPTIONAL the index of the first result to return, default is *0*
- *query_mode*: OPTIONAL the execution mode of the query once it's received by server. Valid values are *FETCH* and *BROADCAST*. Default is *FETCH*.

Query Result

Results are JSON documents containing one or more hits. Example:

```
{
  "total_results" : 150,
  "hits" : [ {
    "hit" : {
      "name" : "user1",
      "age" : 35
    }
  }, {
    "hit" : {
       "name" : "user2",
       "age" : 42
    }
  }, {
    "hit" : {
       "name" : "user3",
       "age" : 12
    }
  } ]
}
```

- *total_results*: NUMBER, the total number of results from the query.
- *hits*: ARRAY, list of matches from the query
- *hit*: OBJECT, each result from the query. Can contain all fields or just a subset of fields in case a *Select* clause is used.

20.8.3.6.2. POST /{cacheName}?action=search

Similar to que query using GET, but the body of the request is used instead to specify the query parameters.

Example:

```
{
 "query":"from Entity where name:\"user1\"",
 "max_results":20,
 "offset":10
}
```

20.8.4. CORS

The REST server supports CORS including preflight and rules based on the request origin.

Example:

```
<rest-connector name="rest1" socket-binding="rest" cache-container="default">
   <cors-rules>
      <cors-rule name="restrict host1" allow-credentials="false">
         <allowed-origins>http://host1,https://host1</allowed-origins>
         <allowed-methods>GET</allowed-methods>
      </cors-rule>
      <cors-rule name="allow ALL" allow-credentials="true" max-age-seconds="2000">
         <allowed-origins>*</allowed-origins>
         <allowed-methods>GET,OPTIONS,POST,PUT,DELETE</allowed-methods>
         <allowed-headers>Key-Content-Type</allowed-headers>
      </cors-rule>
   </cors-rules>
</rest-connector>
```

The rules are evaluated sequentially based on the "Origin" header set by the browser; in the example above if the origin is either "http://host1" or "https://host1" the rule "restrict host1" will apply, otherwise the next rule will be tested. Since the rule "allow ALL" permits all origins, any script coming from a different origin will be able to perform the methods specified and use the headers supplied.

The <cors-rule> element can be configured as follows:

Config	Description	Mandatory
name	The name of the rule	yes
allow-credentials	Enable CORS requests to use credentials	no
allowed-origins	A comma separated list used to set the CORS 'Access-Control-Allow-Origin' header to indicate the response can be shared with the origins	yes

Config	Description	Mandatory
allowed-methods	A comma separated list used to set the CORS 'Access-Control-Allow-Methods' header in the preflight response to specify the methods allowed for the configured origin(s)	yes
max-age-seconds	The amount of time CORS preflight request headers can be cached	no
expose-headers	A comma separated list used to set the CORS 'Access-Control-Expose-Headers' in the preflight response to specify which headers can be exposed to the configured origin(s)	no

20.8.5. Client side code

Part of the point of a RESTful service is that you don't need to have tightly coupled client libraries/bindings. All you need is a HTTP client library. For Java, Apache HTTP Commons Client works just fine (and is used in the integration tests), or you can use java.net API.

20.8.5.1. Ruby example

```ruby
# Shows how to interact with the REST api from ruby.
# No special libraries, just standard net/http
#
# Author: Michael Neale
#
require 'net/http'

uri = URI.parse('http://localhost:8080/rest/default/MyKey')
http = Net::HTTP.new(uri.host, uri.port)

#Create new entry

post = Net::HTTP::Post.new(uri.path, {"Content-Type" => "text/plain"})
post.basic_auth('user','pass')
post.body = "DATA HERE"

resp = http.request(post)

puts "POST response code : " + resp.code

#get it back

get = Net::HTTP::Get.new(uri.path)
```

```
get.basic_auth('user','pass')
resp = http.request(get)

puts "GET response code: " + resp.code
puts "GET Body: " + resp.body

#use PUT to overwrite

put = Net::HTTP::Put.new(uri.path, {"Content-Type" => "text/plain"})
put.basic_auth('user','pass')
put.body = "ANOTHER DATA HERE"

resp = http.request(put)

puts "PUT response code : " + resp.code

#and remove...
delete = Net::HTTP::Delete.new(uri.path)
delete.basic_auth('user','pass')

resp = http.request(delete)

puts "DELETE response code : " + resp.code

#Create binary data like this... just the same...

uri = URI.parse('http://localhost:8080/rest/default/MyLogo')
put = Net::HTTP::Put.new(uri.path, {"Content-Type" => "application/octet-stream"})
put.basic_auth('user','pass')
put.body = File.read('./logo.png')

resp = http.request(put)

puts "PUT response code : " + resp.code

#and if you want to do json...
require 'rubygems'
require 'json'

#now for fun, lets do some JSON !
uri = URI.parse('http://localhost:8080/rest/jsonCache/user')
put = Net::HTTP::Put.new(uri.path, {"Content-Type" => "application/json"})
put.basic_auth('user','pass')

data = {:name => "michael", :age => 42 }
put.body = data.to_json

resp = http.request(put)

puts "PUT response code : " + resp.code

get = Net::HTTP::Get.new(uri.path)
get.basic_auth('user','pass')
resp = http.request(get)

puts "GET Body: " + resp.body
```

20.8.5.2. Python 3 example

```
import urllib.request

# Setup basic auth
base_uri = 'http://localhost:8080/rest/default'
auth_handler = urllib.request.HTTPBasicAuthHandler()
auth_handler.add_password(user='user', passwd='pass', realm='ApplicationRealm', uri=base_uri)
opener = urllib.request.build_opener(auth_handler)
urllib.request.install_opener(opener)

# putting data in
data = "SOME DATA HERE \!"

req = urllib.request.Request(url=base_uri + '/Key', data=data.encode("UTF-8"), method='PUT',
                             headers={"Content-Type": "text/plain"})
with urllib.request.urlopen(req) as f:
    pass

print(f.status)
print(f.reason)

# getting data out
resp = urllib.request.urlopen(base_uri + '/Key')
print(resp.read().decode('utf-8'))
```

20.8.5.3. Java example

```
package org.infinispan;

import java.io.BufferedReader;
import java.io.IOException;
import java.io.InputStreamReader;
import java.io.OutputStreamWriter;
import java.net.HttpURLConnection;
import java.net.URL;
import java.util.Base64;

/**
 * Rest example accessing a cache.
 *
 * @author Samuel Tauil (samuel@redhat.com)
 */
public class RestExample {

    /**
     * Method that puts a String value in cache.
     *
     * @param urlServerAddress URL containing the cache and the key to insert
     * @param value            Text to insert
     * @param user             Used for basic auth
     * @param password         Used for basic auth
     */
    public void putMethod(String urlServerAddress, String value, String user, String password) throws
IOException {
        System.out.println("----------------------------------------");
        System.out.println("Executing PUT");
        System.out.println("----------------------------------------");
        URL address = new URL(urlServerAddress);
        System.out.println("executing request " + urlServerAddress);
        HttpURLConnection connection = (HttpURLConnection) address.openConnection();
        System.out.println("Executing put method of value: " + value);
        connection.setRequestMethod("PUT");
        connection.setRequestProperty("Content-Type", "text/plain");
        addAuthorization(connection, user, password);
        connection.setDoOutput(true);

        OutputStreamWriter outputStreamWriter = new
OutputStreamWriter(connection.getOutputStream());
        outputStreamWriter.write(value);

        connection.connect();
        outputStreamWriter.flush();
        System.out.println("----------------------------------------");
        System.out.println(connection.getResponseCode() + " " + connection.getResponseMessage());
        System.out.println("----------------------------------------");
        connection.disconnect();
    }

    /**
     * Method that gets a value by a key in url as param value.
     *
     * @param urlServerAddress URL containing the cache and the key to read
     * @param user             Used for basic auth
     * @param password         Used for basic auth
     * @return String value
     */
    public String getMethod(String urlServerAddress, String user, String password) throws
IOException {
        String line;
        StringBuilder stringBuilder = new StringBuilder();

        System.out.println("----------------------------------------");
        System.out.println("Executing GET");
        System.out.println("----------------------------------------");

        URL address = new URL(urlServerAddress);
        System.out.println("executing request " + urlServerAddress);

        HttpURLConnection connection = (HttpURLConnection) address.openConnection();
        connection.setRequestMethod("GET");
        connection.setRequestProperty("Content-Type", "text/plain");
        addAuthorization(connection, user, password);
        connection.setDoOutput(true);

        BufferedReader bufferedReader = new BufferedReader(new
InputStreamReader(connection.getInputStream()));

        connection.connect();

        while ((line = bufferedReader.readLine()) != null) {
            stringBuilder.append(line).append('\n');
        }

        System.out.println("Executing get method of value: " + stringBuilder.toString());

        System.out.println("----------------------------------------");
        System.out.println(connection.getResponseCode() + " " + connection.getResponseMessage());
        System.out.println("----------------------------------------");

        connection.disconnect();

        return stringBuilder.toString();
    }

    private void addAuthorization(HttpURLConnection connection, String user, String pass) {
        String credentials = user + ":" + pass;
        String basic = Base64.getEncoder().encodeToString(credentials.getBytes());
        connection.setRequestProperty("Authorization", "Basic " + basic);
    }

    /**
     * Main method example.
     */
    public static void main(String[] args) throws IOException {
        RestExample restExample = new RestExample();
        String user = "user";
        String pass = "pass";
        restExample.putMethod("http://localhost:8080/rest/default/1", "Infinispan REST Test", user,
pass);
        restExample.getMethod("http://localhost:8080/rest/default/1", user, pass);
    }
}
```

20.9. MEMCACHED SERVER

The Red Hat Data Grid Server distribution contains a server module that implements the Memcached text protocol. This allows Memcached clients to talk to one or several Red Hat Data Grid backed Memcached servers. These servers could either be working standalone just like Memcached does where each server acts independently and does not communicate with the rest, or they could be clustered where servers replicate or distribute their contents to other Red Hat Data Grid backed Memcached servers, thus providing clients with failover capabilities. Please refer to Red Hat Data Grid Server's memcached server guide for instructions on how to configure and run a Memcached server.

20.9.1. Client Encoding

The memcached text protocol assumes data values read and written by clients are raw bytes. The support for type negotiation will come with the memcached binary protocol implementation, as part of ISPN-8726.

Although it's not possible for a memcached client to negotiate the data type to obtain data from the server or send data in different formats, the server can optionally be configured to handle values encoded with a certain Media Type. By setting the **client-encoding** attribute in the **memcached-connector** element, the server will return content in this configured format, and clients also send data in this format.

The **client-encoding** is useful when a single cache is accessed from multiple remote endpoints (Rest, HotRod, Memcached) and it allows to tailor the responses/requests to memcached text clients. For more infomarmation on interoperability between endpoints, consult Endpoint Interop guide.

20.9.2. Command Clarifications

20.9.2.1. Flush All

Even in a clustered environment, flush_all command leads to the clearing of the Red Hat Data Grid Memcached server where the call lands. There's no attempt to propagate this flush to other nodes in the cluster. This is done so that flush_all with delay use case can be reproduced with the Red Hat Data Grid Memcached server. The aim of passing a delay to flush_all is so that different Memcached servers in a full can be flushed at different times, and hence avoid overloading the database with requests as a result of all Memcached servers being empty. For more info, check the Memcached text protocol section on flush_all .

20.9.3. Unsupported Features

This section explains those parts of the memcached text protocol that for one reason or the other, are not currently supported by the Red Hat Data Grid based memcached implementation.

20.9.3.1. Individual Stats

Due to difference in nature between the original memcached implementation which is C/C\\ based and the Red Hat Data Grid implementation which is Java based, there're some general purpose stats that are not supported. For these unsupported stats, Red Hat Data Grid memcached server always returns 0.

Unsupported statistics

- pid
- pointer_size
- rusage_user
- rusage_system
- bytes
- curr_connections
- total_connections
- connection_structures
- auth_cmds
- auth_errors
- limit_maxbytes
- threads
- conn_yields

- reclaimed

20.9.3.2. Statistic Settings

The settings statistics section of the text protocol has not been implemented due to its volatility.

20.9.3.3. Settings with Arguments Parameter

Since the arguments that can be send to the Memcached server are not documented, Red Hat Data Grid Memcached server does not support passing any arguments to stats command. If any parameters are passed, the Red Hat Data Grid Memcached server will respond with a CLIENT_ERROR .

20.9.3.4. Delete Hold Time Parameter

Memcached does no longer honor the optional hold time parameter to delete command and so the Red Hat Data Grid based memcached server does not implement such feature either.

20.9.3.5. Verbosity Command

Verbosity command is not supported since Red Hat Data Grid logging cannot be simplified to defining the logging level alone.

20.9.4. Talking To Red Hat Data Grid Memcached Servers From Non-Java Clients

This section shows how to talk to Red Hat Data Grid memcached server via non-java client, such as a python script.

20.9.4.1. Multi Clustered Server Tutorial

The example showcases the distribution capabilities of Red Hat Data Grid memcached severs that are not available in the original memcached implementation.

- Start two clustered nodes: This configuration is the same one used for the GUI demo:

  ```
  $ ./bin/standalone.sh -c clustered.xml -Djboss.node.name=nodeA
  $ ./bin/standalone.sh -c clustered.xml -Djboss.node.name=nodeB -
  Djboss.socket.binding.port-offset=100
  ```

Alternatively use

```
$ ./bin/domain.sh
```

Which automatically starts two nodes.

- Execute test_memcached_write.py script which basically executes several write operations against the Red Hat Data Grid memcached server bound to port 11211. If the script is executed successfully, you should see an output similar to this:

  ```
  Connecting to 127.0.0.1:11211
  Testing set ['Simple_Key': Simple value] ... OK
  Testing set ['Expiring_Key' : 999 : 3] ... OK
  Testing increment 3 times ['Incr_Key' : starting at 1 ]
  Initialise at 1 ... OK
  ```

```
Increment by one ... OK
Increment again ... OK
Increment yet again ... OK
Testing decrement 1 time ['Decr_Key' : starting at 4 ]
Initialise at 4 ... OK
Decrement by one ... OK
Testing decrement 2 times in one call ['Multi_Decr_Key' : 3 ]
Initialise at 3 ... OK
Decrement by 2 ... OK
```

- Execute test_memcached_read.py script which connects to server bound to 127.0.0.1:11311 and verifies that it can read the data that was written by the writer script to the first server. If the script is executed successfully, you should see an output similar to this:

```
Connecting to 127.0.0.1:11311
Testing get ['Simple_Key'] should return Simple value ... OK
Testing get ['Expiring_Key'] should return nothing... OK
Testing get ['Incr_Key'] should return 4 ... OK
Testing get ['Decr_Key'] should return 3 ... OK
Testing get ['Multi_Decr_Key'] should return 1 ... OK
```

20.10. EXECUTING CODE IN THE REMOTE GRID

In an earlier section we described executing code in the grid. Unfortunately these methods are designed to be used in an embedded scenario with direct access to the grid. This section will detail how you can perform similar functions but while using a remote client connected to the grid.

20.11. SCRIPTING

Scripting is a feature of Red Hat Data Grid Server which allows invoking server-side scripts from remote clients. Scripting leverages the JDK's javax.script ScriptEngines, therefore allowing the use of any JVM languages which offer one. By default, the JDK comes with Nashorn, a ScriptEngine capable of running JavaScript.

20.11.1. Installing scripts

Scripts are stored in a special script cache, named '___script_cache'. Adding a script is therefore as simple as put+ting it into the cache itself. If the name of the script contains a filename extension, e.g. +myscript.js, then that extension determines the engine that will be used to execute it. Alternatively the script engine can be selected using script metadata (see below). Be aware that, when security is enabled, access to the script cache via the remote protocols requires that the user belongs to the '___script_manager' role.

20.11.2. Script metadata

Script metadata is additional information about the script that the user can provide to the server to affect how a script is executed. It is contained in a specially-formatted comment on the first lines of the script.

Properties are specified as key=value pairs, separated by commas. You can use several different comment styles: The //, **;;**, **#** depending on the scripting language you use. You can split metadata over multiple lines if necessary, and you can use single (') or double (") quotes to delimit your values.

The following are examples of valid metadata comments:

```
// name=test, language=javascript
// mode=local, parameters=[a,b,c]
```

20.11.2.1. Metadata properties

The following metadata property keys are available

- mode: defines the mode of execution of a script. Can be one of the following values:
    - local: the script will be executed only by the node handling the request. The script itself however can invoke clustered operations
    - distributed: runs the script using the Distributed Executor Service
- language: defines the script engine that will be used to execute the script, e.g. Javascript
- extension: an alternative method of specifying the script engine that will be used to execute the script, e.g. js
- role: a specific role which is required to execute the script
- parameters: an array of valid parameter names for this script. Invocations which specify parameter names not included in this list will cause an exception.
- datatype: optional property providing information, in the form of Media Types (also known as MIME) about the type of the data stored in the caches, as well as parameter and return values. Currently it only accepts a single value which is **text/plain; charset=utf-8**, indicating that data is String UTF-8 format. This metadata parameter is designed for remote clients that only support a particular type of data, making it easy for them to retrieve, store and work with parameters.

Since the execution mode is a characteristic of the script, nothing special needs to be done on the client to invoke scripts in different modes.

20.11.3. Script bindings

The script engine within Red Hat Data Grid exposes several internal objects as bindings in the scope of the script execution. These are:

- cache: the cache against which the script is being executed
- marshaller: the marshaller to use for marshalling/unmarshalling data to the cache
- cacheManager: the cacheManager for the cache
- scriptingManager: the instance of the script manager which is being used to run the script. This can be used to run other scripts from a script.

20.11.4. Script parameters

Aside from the standard bindings described above, when a script is executed it can be passed a set of named parameters which also appear as bindings. Parameters are passed as name,value pairs where name is a string and value can be any value that is understood by the marshaller in use.

The following is an example of a JavaScript script which takes two parameters, multiplicand and multiplier and multiplies them. Because the last operation is an expression evaluation, its result is returned to the invoker.

```
// mode=local,language=javascript
multiplicand * multiplier
```

To store the script in the script cache, use the following Hot Rod code:

```
RemoteCache<String, String> scriptCache = cacheManager.getCache("___script_cache");
scriptCache.put("multiplication.js",
  "// mode=local,language=javascript\n" +
  "multiplicand * multiplier\n");
```

20.11.5. Running Scripts using the Hot Rod Java client

The following example shows how to invoke the above script by passing two named parameters.

```
RemoteCache<String, Integer> cache = cacheManager.getCache();
// Create the parameters for script execution
Map<String, Object> params = new HashMap<>();
params.put("multiplicand", 10);
params.put("multiplier", 20);
// Run the script on the server, passing in the parameters
Object result = cache.execute("multiplication.js", params);
```

20.11.6. Distributed execution

The following is a script which runs on all nodes. Each node will return its address, and the results from all nodes will be collected in a List and returned to the client.

```
// mode:distributed,language=javascript
cacheManager.getAddress().toString();
```

20.12. SERVER TASKS

Server tasks are server-side scripts defined in Java language. To develop a server task, you should define a class that extends **org.infinispan.tasks.ServerTask** interface, defined in **infinispan-tasks-api** module.

A typical server task implementation would implement these methods:

- **setTaskContext** allows server tasks implementors to access execution context information. This includes task parameters, cache reference on which the task is executed…etc. Normally, implementors would store this information locally and use it when the task is actually executed.
- **getName** should return a unique name for the task. The client will use this name to to invoke the task.
- **getExecutionMode** is used to decide whether to invoke the task in 1 node in a cluster of N nodes or invoke it in N nodes. For example, server tasks that invoke stream processing are only required to be executed in 1 node in the cluster. This is because stream processing itself makes sure processing is distributed to all nodes in cluster.
- **call** is the method that’s invoked when the user invokes the server task.

Here’s an example of a hello greet task that takes as parameter the name of the person to greet.

```
package example;

import org.infinispan.tasks.ServerTask;
import org.infinispan.tasks.TaskContext;

public class HelloTask implements ServerTask<String> {

   private TaskContext ctx;

   @Override
   public void setTaskContext(TaskContext ctx) {
      this.ctx = ctx;
   }

   @Override
   public String call() throws Exception {
      String name = (String) ctx.getParameters().get().get("name");
      return "Hello " + name;
   }

   @Override
   public String getName() {
      return "hello-task";
   }

}
```

Once the task has been implemented, it needs to be wrapped inside a jar. The jar is then deployed to the Red Hat Data Grid Server and from them on it can be invoked. The Red Hat Data Grid Server uses service loader pattern to load the task, so implementations need to adhere to these requirements. For example, server task implementations must have a zero-argument constructor.

Moreover, the jar must contain a **META-INF/services/org.infinispan.tasks.ServerTask** file containing the fully qualified name(s) of the server tasks included in the jar. For example:

```
example.HelloTask
```

With jar packaged, the next step is to push the jar to the Red Hat Data Grid Server. The server is powered by WildFly Application Server, so if using Maven Wildfly's Maven plugin can be used for this:

```
<plugin>
   <groupId>org.wildfly.plugins</groupId>
   <artifactId>wildfly-maven-plugin</artifactId>
   <version>1.2.0.Final</version>
</plugin>
```

Then call the following from command line:

```
$ mvn package wildfly:deploy
```

Alternative ways of deployment jar files to Wildfly Application Server are explained here.

Executing the task can be done using the following code:

```
// Create a configuration for a locally-running server
ConfigurationBuilder builder = new ConfigurationBuilder();
builder.addServer().host("127.0.0.1").port(11222);

// Connect to the server
RemoteCacheManager cacheManager = new RemoteCacheManager(builder.build());

// Obtain the remote cache
RemoteCache<String, String> cache = cacheManager.getCache();

// Create task parameters
Map<String, String> parameters = new HashMap<>();
parameters.put("name", "developer");

// Execute task
String greet = cache.execute("hello-task", parameters);
System.out.println(greet);
```

CHAPTER 21. COMPATIBILITY MODE

WARNING

Compatibility mode is deprecated and will be removed from Red Hat Data Grid. To achieve interoperability between remote endpoints, you should use protocol interoperability capabilities. See Protocol Interoperability.

Compatibility mode configures Red Hat Data Grid caches so that you can access Red Hat Data Grid in multiple ways. Achieving such compatibility requires extra work from Red Hat Data Grid in order to make sure that contents are converted back and forth between the different formats of each endpoint and this is the reason why compatibility mode is disabled by default.

21.1. ENABLE COMPATIBILITY MODE

For compatibility mode to work as expected, all endpoints need to be configured with the same cache manager, and need to talk to the same cache. If you're using the brand new Red Hat Data Grid Server distribution , this is all done for you. If you're in the mood to experiment with this in a standalone unit test, this class shows you how you can start multiple endpoints from a single class.

So, to get started using Red Hat Data Grid's compatibility mode, it needs to be enabled, either via XML:

infinispan.xml

```xml
<local-cache>
  <compatibility/>
</local-cache>
```

Or programmatically:

```java
ConfigurationBuilder builder = ...
builder.compatibility().enable();
```

The key thing to remember about Red Hat Data Grid's compatibility mode is that where possible, it tries to store data unmarshalling or deserializing it. It does so because the most common use case is for it to store Java objects and having Java objects stored in deserialized form means that they're very easy to use from an embedded cache. With this in mind, it makes some assumptions. For example, if something is stored via Hot Rod, it's most likely coming from the reference Hot Rod client, which is written in Java, and which uses a marshaller that keeps binary payloads very compact. So, when the Hot Rod operation reaches the compatibility layer, it will try to unmarshall it, by default using the same default marshaller used by the Java Hot Rod client, hence providing good out-of-the-box support for the majority of cases.

21.1.1. Optional: Configuring Compatibility Marshaller

It could happen though the client might be using a Hot Rod client written for another language other than Java, say Ruby or Python . In this case, some kind of custom marshaller needs to be configured that either translates that serialized payload into a Java object to be stored in the cache, or keeps it in serialized form. Both options are valid, but of course it will have an impact on what kind of objects are retrieved from Red Hat Data Grid if using the embedded cache. The marshaller is expected to implement this interface. Configuring the compatibility marshaller is optional and can be done via XML:

infinispan.xml

```
<local-cache>
  <compatibility marshaller="com.acme.CustomMarshaller"/>
</local-cache>
```

Or programmatically:

```
ConfigurationBuilder builder = ...
builder.compatibility().enable().marshaller(new com.acme.CustomMarshaller());
```

One concrete example of this marshaller logic can be found in the SpyMemcachedCompatibleMarshaller . Spy Memcached uses their own transcoders in order to marshall objects, so the compatibility marshaller created is in charge of marshalling/unmarshalling data stored via Spy Memcached client. If you want to retrieve data stored via Spy Memcached via say Hot Rod, you can configure the Java Hot Rod client to use this same marshaller, and this is precisely what the test where the Spy Memcached marshaller is located is demonstrating.

21.2. CODE EXAMPLES

The best code examples available showing compatibility in action can be found in the Red Hat Data Grid Compatibility Mode testsuite, but more will be developed in the near future.

CHAPTER 22. PROTOCOL INTEROPERABILITY

Clients exchange data with Red Hat Data Grid through endpoints such as REST or Hot Rod.

Each endpoint uses a different protocol so that clients can read and write data in a suitable format. Because Red Hat Data Grid can interoperate with multiple clients at the same time, it must convert data between client formats and the storage formats.

To configure Red Hat Data Grid endpoint interoperability, you should define the MediaType that sets the format for data stored in the cache.

22.1. CONSIDERATIONS WITH MEDIA TYPES AND ENDPOINT INTEROPERABILITY

Configuring Red Hat Data Grid to store data with a specific media type affects client interoperability.

Although REST clients do support sending and receiving encoded binary data, they are better at handling text formats such as JSON, XML, or plain text.

Memcached text clients can handle String-based keys and byte[] values but cannot negotiate data types with the server. These clients do not offer much flexibility when handling data formats because of the protocol definition.

Java Hot Rod clients are suitable for handling Java objects that represent entities that reside in the cache. Java Hot Rod clients use marshalling operations to serialize and deserialize those objects into byte arrays.

Similarly, non-Java Hot Rod clients, such as the C++, C#, and Javascript clients, are suitable for handling objects in the respective languages. However, non-Java Hot Rod clients can interoperate with Java Hot Rod clients using platform independent data formats.

22.2. REST, HOT ROD, AND MEMCACHED INTEROPERABILITY WITH TEXT-BASED STORAGE

You can configure key and values with a text-based storage format.

For example, specify **text/plain; charset=UTF-8**, or any other character set, to set plain text as the media type. You can also specify a media type for other text-based formats such as JSON (**application/json**) or XML (**application/xml**) with an optional character set.

The following example configures the cache to store entries with the **text/plain; charset=UTF-8** media type:

```
<cache>
  <encoding>
    <key media-type="text/plain; charset=UTF-8"/>
    <value media-type="text/plain; charset=UTF-8"/>
  </encoding>
</cache>
```

To handle the exchange of data in a text-based format, you must configure Hot Rod clients with the **org.infinispan.commons.marshall.StringMarshaller** marshaller.

REST clients must also send the correct headers when writing and reading from the cache, as follows:

- Write: **Content-Type: text/plain; charset=UTF-8**
- Read: **Accept: text/plain; charset=UTF-8**

Memcached clients do not require any configuration to handle text-based formats.

This configuration is compatible with...	
REST clients	Yes
Java Hot Rod clients	Yes
Memcached clients	Yes
Non-Java Hot Rod clients	No
Querying and Indexing	No
Custom Java objects	No

22.3. REST, HOT ROD, AND MEMCACHED INTEROPERABILITY WITH CUSTOM JAVA OBJECTS

If you store entries in the cache as marshalled, custom Java objects, you should configure the cache with the MediaType of the marshalled storage.

Java Hot Rod clients use the JBoss marshalling storage format as the default to store entries in the cache as custom Java objects.

The following example configures the cache to store entries with the **application/x-jboss-marshalling** media type:

```
<distributed-cache name="my-cache">
  <encoding>
    <key media-type="application/x-jboss-marshalling"/>
    <value media-type="application/x-jboss-marshalling"/>
  </encoding>
</distributed-cache>
```

If you use the Protostream marshaller, configure the MediaType as **application/x-protostream**. For UTF8Marshaller, configure the MediaType as **text/plain**.

TIP

If only Hot Rod clients interact with the cache, you do not need to configure the MediaType.

Because REST clients are most suitable for handling text formats, you should use primitives such as **java.lang.String** for keys. Otherwise, REST clients must handle keys as **bytes[]** using a supported binary encoding.

REST clients can read values for cache entries in XML or JSON format. However, the classes must be available in the server.

To read and write data from Memcached clients, you must use **java.lang.String** for keys. Values are stored and returned as marshalled objects.

Some Java Memcached clients allow data transformers that marshall and unmarshall objects. You can also configure the Memcached server module to encode responses in different formats, such as 'JSON' which is language neutral. This allows non-Java clients to interact with the data even if the storage format for the cache is Java-specific. See Client Encoding details for the Red Hat Data Grid Memcached server module.

NOTE

Storing Java objects in the cache requires you to deploy entity classes to Data Grid. See Deploying Entity Classes.

This configuration is compatible with...	
REST clients	Yes
Java Hot Rod clients	Yes
Memcached clients	Yes
Non-Java Hot Rod clients	No
Querying and Indexing	No
Custom Java objects	Yes

22.4. JAVA AND NON-JAVA CLIENT INTEROPERABILITY WITH PROTOBUF

Storing data in the cache as Protobuf encoded entries provides a platform independent configuration that enables Java and Non-Java clients to access and query the cache from any endpoint.

If indexing is configured for the cache, Red Hat Data Grid automatically stores keys and values with the **application/x-protostream** media type.

If indexing is not configured for the cache, you can configure it to store entries with the **application/x-protostream** media type as follows:

```
<distributed-cache name="my-cache">
  <encoding>
    <key media-type="application/x-protostream"/>
    <value media-type="application/x-protostream"/>
  </encoding>
</distributed-cache>
```

Red Hat Data Grid converts between **application/x-protostream** and **application/json**, which allows REST clients to read and write JSON formatted data. However REST clients must send the correct headers, as follows:

Read Header

```
Read: Accept: application/json
```

Write Header

```
Write: Content-Type: application/json
```

IMPORTANT

The **application/x-protostream** media type uses Protobuf encoding, which requires you to register a Protocol Buffers schema definition that describes the entities and marshallers that the clients use. See Storing Protobuf Entities.

This configuration is compatible with...	
REST clients	Yes
Java Hot Rod clients	Yes
Non-Java Hot Rod clients	Yes
Querying and Indexing	Yes
Custom Java objects	Yes

22.5. CUSTOM CODE INTEROPERABILITY

You can deploy custom code with Red Hat Data Grid. For example, you can deploy scripts, tasks, listeners, converters, and merge policies. Because your custom code can access data directly in the cache, it must interoperate with clients that access data in the cache through different endpoints.

For example, you might create a remote task to handle custom objects stored in the cache while other clients store data in binary format.

To handle interoperability with custom code you can either convert data on demand or store data as Plain Old Java Objects (POJOs).

22.5.1. Converting Data On Demand

If the cache is configured to store data in a binary format such as **application/x-protostream** or **application/x-jboss-marshalling**, you can configure your deployed code to perform cache operations using Java objects as the media type. See Overriding the MediaType Programmatically.

This approach allows remote clients to use a binary format for storing cache entries, which is optimal. However, you must make entity classes available to the server so that it can convert between binary format and Java objects.

Additionally, if the cache uses Protobuf (**application/x-protostream**) as the binary format, you must deploy protostream marshallers so that Data Grid can unmarshall data from your custom code. See Deploying Protostream Marshallers.

22.5.2. Storing Data as POJOs

Storing unmarshalled Java objects in the server is not recommended. Doing so requires Red Hat Data Grid to serialize data when remote clients read from the cache and then deserialize data when remote clients write to the cache.

The following example configures the cache to store entries with the **application/x-java-object** media type:

```
<distributed-cache name="my-cache">
  <encoding>
    <key media-type="application/x-java-object"/>
    <value media-type="application/x-java-object"/>
  </encoding>
</distributed-cache>
```

Hot Rod clients must use a supported marshaller when data is stored as POJOs in the cache, either the JBoss marshaller or the default Java serialization mechanism. You must also deploy the classes must be deployed in the server.

REST clients must use a storage format that Red Hat Data Grid can convert to and from Java objects, currently JSON or XML.

NOTE

Storing Java objects in the cache requires you to deploy entity classes to Red Hat Data Grid. See Deploying Entity Classes.

Memcached clients must send and receive a serialized version of the stored POJO, which is a JBoss marshalled payload by default. However if you configure the Client Encoding in the appropriate Memcached connector, you change the storage format so that Memcached clients use a platform neutral format such as **JSON**.

This configuration is compatible with...	
REST clients	Yes
Java Hot Rod clients	Yes
Non-Java Hot Rod clients	No
Querying and Indexing	Yes. However, querying and indexing works with POJOs only if the entities are annotated.

This configuration is compatible with...	
Custom Java objects	Yes

22.6. DEPLOYING ENTITY CLASSES

If you plan to store entries in the cache as custom Java objects or POJOs, you must deploy entity classes to Red Hat Data Grid. Clients always exchange objects as **bytes[]**. The entity classes represent those custom objects so that Red Hat Data Grid can serialize and deserialize them.

To make entity classes available to the server, do the following:

- Create a **JAR** file that contains the entities and dependencies.
- Stop Red Hat Data Grid if it is running.
  Red Hat Data Grid loads entity classes during boot. You cannot make entity classes available to Red Hat Data Grid if the server is running.
- Copy the **JAR** file to the ***$RHDG_HOME/standalone/deployments/*** directory.
- Specify the **JAR** file as a module in the cache manager configuration, as in the following example:

```
<cache-container name="local" default-cache="default">
  <modules>
    <module name="deployment.my-entities.jar"/>
  </modules>
  ...
</cache-container>
```

CHAPTER 23. SECURITY

Security within Red Hat Data Grid is implemented at several layers:

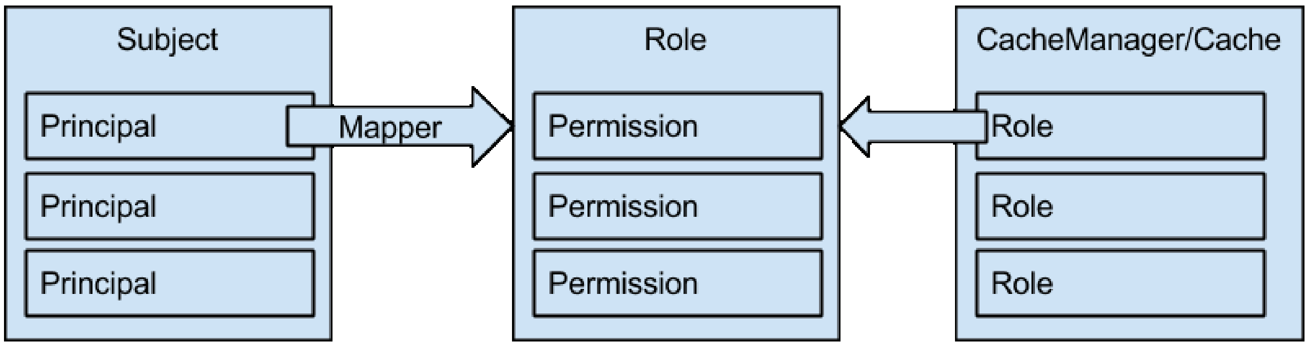
- within the core library, to provide coarse-grained access control to CacheManagers, Caches and data
- over remote protocols, to obtain credentials from remote clients and to secure the transport using encryption
- between nodes in a cluster, so that only authorized nodes can join and to secure the transport using encryption

In order to maximize compatibility and integration, Red Hat Data Grid uses widespread security standards where possible and appropriate, such as X.509 certificates, SSL/TLS encryption and Kerberos/GSSAPI. Also, to avoid pulling in any external dependencies and to increase the ease of integration with third party libraries and containers, the implementation makes use of any facilities provided by the standard Java security libraries (JAAS, JSSE, JCA, JCE, SASL, etc). For this reason, the Red Hat Data Grid core library only provides interfaces and a set of basic implementations.

23.1. EMBEDDED SECURITY

Applications interact with Red Hat Data Grid using its API within the same JVM. The two main components which are exposed by the Red Hat Data Grid API are CacheManagers and Caches. If an application wants to interact with a secured CacheManager and Cache, it should provide an identity which Red Hat Data Grid's security layer will validate against a set of required roles and permissions. If the identity provided by the user application has sufficient permissions, then access will be granted, otherwise an exception indicating a security violation will be thrown. The identity is represented by the javax.security.auth.Subject class which is a wrapper around multiple Principals, e.g. a user and all the groups it belongs to. Since the Principal name is dependent on the owning system (e.g. a Distinguished Name in LDAP), Red Hat Data Grid needs to be able to map Principal names to roles. Roles, in turn, represent one or more permissions. The following diagram shows the relationship between the various elements:

Figure 23.1. Roles/Permissions mapping



23.1.1. Embedded Permissions

Access to a cache manager or a cache is controlled by using a list of required permissions. Permissions are concerned with the type of action that is performed on one of the above entities and not with the type of data being manipulated. Some of these permissions can be narrowed to specifically named entities, where applicable (e.g. a named cache). Depending on the type of entity, there are different types of permission available:

23.1.1.1. Cache Manager permissions

- CONFIGURATION (defineConfiguration): whether a new cache configuration can be defined
- LISTEN (addListener): whether listeners can be registered against a cache manager
- LIFECYCLE (stop): whether the cache manager can be stopped
- ALL: a convenience permission which includes all of the above

23.1.1.2. Cache permissions

- READ (get, contains): whether entries can be retrieved from the cache
- WRITE (put, putIfAbsent, replace, remove, evict): whether data can be written/replaced/removed/evicted from the cache
- EXEC (distexec, streams): whether code execution can be run against the cache
- LISTEN (addListener): whether listeners can be registered against a cache
- BULK_READ (keySet, values, entrySet, query): whether bulk retrieve operations can be executed
- BULK_WRITE (clear, putAll): whether bulk write operations can be executed
- LIFECYCLE (start, stop): whether a cache can be started / stopped
- ADMIN (getVersion, addInterceptor*, removeInterceptor, getInterceptorChain, getEvictionManager, getComponentRegistry, getDistributionManager, getAuthorizationManager, evict, getRpcManager, getCacheConfiguration, getCacheManager, getInvocationContextContainer, setAvailability, getDataContainer, getStats, getXAResource): whether access to the underlying components/internal structures is allowed
- ALL: a convenience permission which includes all of the above
- ALL_READ: combines READ and BULK_READ
- ALL_WRITE: combines WRITE and BULK_WRITE

Some permissions might need to be combined with others in order to be useful. For example, suppose you want to allow only "supervisors" to be able to run stream operations, while "standard" users can only perform puts and gets, you would define the following mappings:

```
<role name="standard" permission="READ WRITE" />
<role name="supervisors" permission="READ WRITE EXEC"/>
```

23.1.2. Embedded API

When a DefaultCacheManager has been constructed with security enabled using either the programmatic or declarative configuration, it returns a SecureCache which will check the security context before invoking any operations on the underlying caches. A SecureCache also makes sure that applications cannot retrieve lower-level insecure objects (such as DataContainer). In Java, executing code with a specific identity usually means wrapping the code to be executed within a PrivilegedAction:

```
import org.infinispan.security.Security;

Security.doAs(subject, new PrivilegedExceptionAction<Void>() {
```

```
public Void run() throws Exception {
   cache.put("key", "value");
}
});
```

If you are using Java 8, the above call can be simplified to:

```
Security.doAs(mySubject, PrivilegedAction<String>() -> cache.put("key", "value"));
```

Notice the use of Security.doAs() in place of the typical Subject.doAs(). While in Red Hat Data Grid you can use either, unless you really need to modify the AccessControlContext for reasons specific to your application's security model, using Security.doAs() provides much better performance. If you need the current Subject, use the following:

```
Security.getSubject();
```

which will automatically retrieve the Subject either from the Red Hat Data Grid's context or from the AccessControlContext.

Red Hat Data Grid also fully supports running under a full-blown SecurityManager. The Red Hat Data Grid distribution contains an example security.policy file which you should customize with the appropriate paths before supplying it to your JVM.

23.1.3. Embedded Configuration

There are two levels of configuration: global and per-cache. The global configuration defines the set of roles/permissions mappings while each cache can decide whether to enable authorization checks and the required roles.

Programmatic

```
  GlobalConfigurationBuilder global = new GlobalConfigurationBuilder();
  global
    .security()
      .authorization().enable()
        .principalRoleMapper(new IdentityRoleMapper())
        .role("admin")
          .permission(AuthorizationPermission.ALL)
        .role("supervisor")
          .permission(AuthorizationPermission.EXEC)
          .permission(AuthorizationPermission.READ)
          .permission(AuthorizationPermission.WRITE)
        .role("reader")
          .permission(AuthorizationPermission.READ);
  ConfigurationBuilder config = new ConfigurationBuilder();
  config
    .security()
      .authorization()
        .enable()
        .role("admin")
        .role("supervisor")
        .role("reader");
```

Declarative

```
<infinispan>
  <cache-container default-cache="secured" name="secured">
    <security>
      <authorization>
        <identity-role-mapper />
        <role name="admin" permissions="ALL" />
        <role name="reader" permissions="READ" />
        <role name="writer" permissions="WRITE" />
        <role name="supervisor" permissions="READ WRITE EXEC"/>
      </authorization>
    </security>
    <local-cache name="secured">
      <security>
        <authorization roles="admin reader writer supervisor" />
      </security>
    </local-cache>
  </cache-container>

</infinispan>
```

23.1.3.1. Role Mappers

In order to convert the Principals in a Subject into a set of roles to be used when authorizing, a suitable PrincipalRoleMapper must be specified in the global configuration. Red Hat Data Grid comes with 3 mappers and also allows you to provide a custom one:

- IdentityRoleMapper (Java: org.infinispan.security.impl.IdentityRoleMapper, XML: <identity-role-mapper />): this mapper just uses the Principal name as the role name
- CommonNameRoleMapper (Java: org.infinispan.security.impl.CommonRoleMapper, XML: <common-name-role-mapper />): if the Principal name is a Distinguished Name (DN), this mapper extracts the Common Name (CN) and uses it as a role name. For example the DN cn=managers,ou=people,dc=example,dc=com will be mapped to the role managers
- ClusterRoleMapper (Java: org.infinispan.security.impl.ClusterRoleMapper XML: <cluster-role-mapper />): a mapper which uses the ClusterRegistry to store principal to role mappings. This allows the use of the CLI's GRANT and DENY commands to add/remove roles to a principal.
- Custom role mappers (XML: <custom-role-mapper class="a.b.c" />): just supply the fully-qualified class name of an implementation of org.infinispan.security.PrincipalRoleMapper

23.2. CLUSTER SECURITY

JGroups can be configured so that nodes need to authenticate each other when joining / merging. The authentication uses SASL and is setup by adding the SASL protocol to your JGroups XML configuration above the GMS protocol, as follows:

```
<SASL mech="DIGEST-MD5"
    client_name="node_user"
    client_password="node_password"

server_callback_handler_class="org.example.infinispan.security.JGroupsSaslServerCallbackHandler"

client_callback_handler_class="org.example.infinispan.security.JGroupsSaslClientCallbackHandler"
    sasl_props="com.sun.security.sasl.digest.realm=test_realm" />
```

In the above example, the SASL mech will be DIGEST-MD5. Each node will need to declare the user and password it will use when joining the cluster. The behaviour of a node differs depending on whether it is the coordinator or any other node. The coordinator acts as the SASL server, whereas joining/merging nodes act as SASL clients. Therefore two different CallbackHandlers are required, the server_callback_handler_class will be used by the coordinator, and the client_callback_handler_class will be used by the other nodes. The SASL protocol in JGroups is only concerned with the authentication process. If you wish to implement node authorization, you can do so within the server callback handler, by throwing an Exception. The following example shows how this can be done:

```
public class AuthorizingServerCallbackHandler implements CallbackHandler {

    @Override
    public void handle(Callback[] callbacks) throws IOException, UnsupportedCallbackException {
        for (Callback callback : callbacks) {
            ...
            if (callback instanceof AuthorizeCallback) {
                AuthorizeCallback acb = (AuthorizeCallback) callback;
                UserProfile user = UserManager.loadUser(acb.getAuthenticationID());
                if (!user.hasRole("myclusterrole")) {
                    throw new SecurityException("Unauthorized node " +user);
                }
            }
            ...
        }
    }
}
```

CHAPTER 24. GRID FILE SYSTEM

Red Hat Data Grid's GridFileSystem is an experimental API that exposes an Red Hat Data Grid-backed data grid as a file system.

> **WARNING**
>
> This is an *experimental* API. Use at your own risk.

Specifically, the API works as an extension to the JDK's File , InputStream and OutputStream classes: specifically, GridFile, GridInputStream and GridOutputStream. A helper class, GridFilesystem, is also included.

Essentially, the GridFilesystem is backed by 2 Red Hat Data Grid caches - one for metadata (typically replicated) and one for the actual data (typically distributed). The former is replicated so that each node has metadata information locally and would not need to make RPC calls to list files, etc. The latter is distributed since this is where the bulk of storage space is used up, and a scalable mechanism is needed here. Files themselves are chunked and each chunk is stored as a cache entry, as a byte array.

Here is a quick code snippet demonstrating usage:

```
Cache<String,byte[]> data = cacheManager.getCache("distributed");
Cache<String,GridFile.Metadata> metadata = cacheManager.getCache("replicated");
GridFilesystem fs = new GridFilesystem(data, metadata);

// Create directories
File file=fs.getFile("/tmp/testfile/stuff");
fs.mkdirs(); // creates directories /tmp/testfile/stuff

// List all files and directories under "/usr/local"
file=fs.getFile("/usr/local");
File[] files=file.listFiles();

// Create a new file
file=fs.getFile("/tmp/testfile/stuff/README.txt");
file.createNewFile();
```

Copying stuff to the grid file system:

```
InputStream in=new FileInputStream("/tmp/my-movies/dvd-image.iso");
OutputStream out=fs.getOutput("/grid-movies/dvd-image.iso");
byte[] buffer=new byte[20000];
int len;
while((len=in.read(buffer, 0, buffer.length)) != -1) out.write(buffer, 0, len);
in.close();
out.close();
```

Reading stuff from the grid:

```
InputStream in=in.getInput("/grid-movies/dvd-image.iso");
OutputStream out=new FileOutputStream("/tmp/my-movies/dvd-image.iso");
byte[] buffer=new byte[200000];
int len;
while((len=in.read(buffer, 0, buffer.length)) != -1) out.write(buffer, 0, len);
in.close();
out.close();
```

24.1. WEBDAV DEMO

Red Hat Data Grid ships with a demo WebDAV application that makes use of the grid file system APIs. This demo app is packaged as a WAR file which can be deployed in a servlet container, such as JBoss AS or Tomcat, and exposes the grid as a file system over WebDAV. This could then be mounted as a remote drive on your operating system.

CHAPTER 25. CROSS SITE REPLICATION

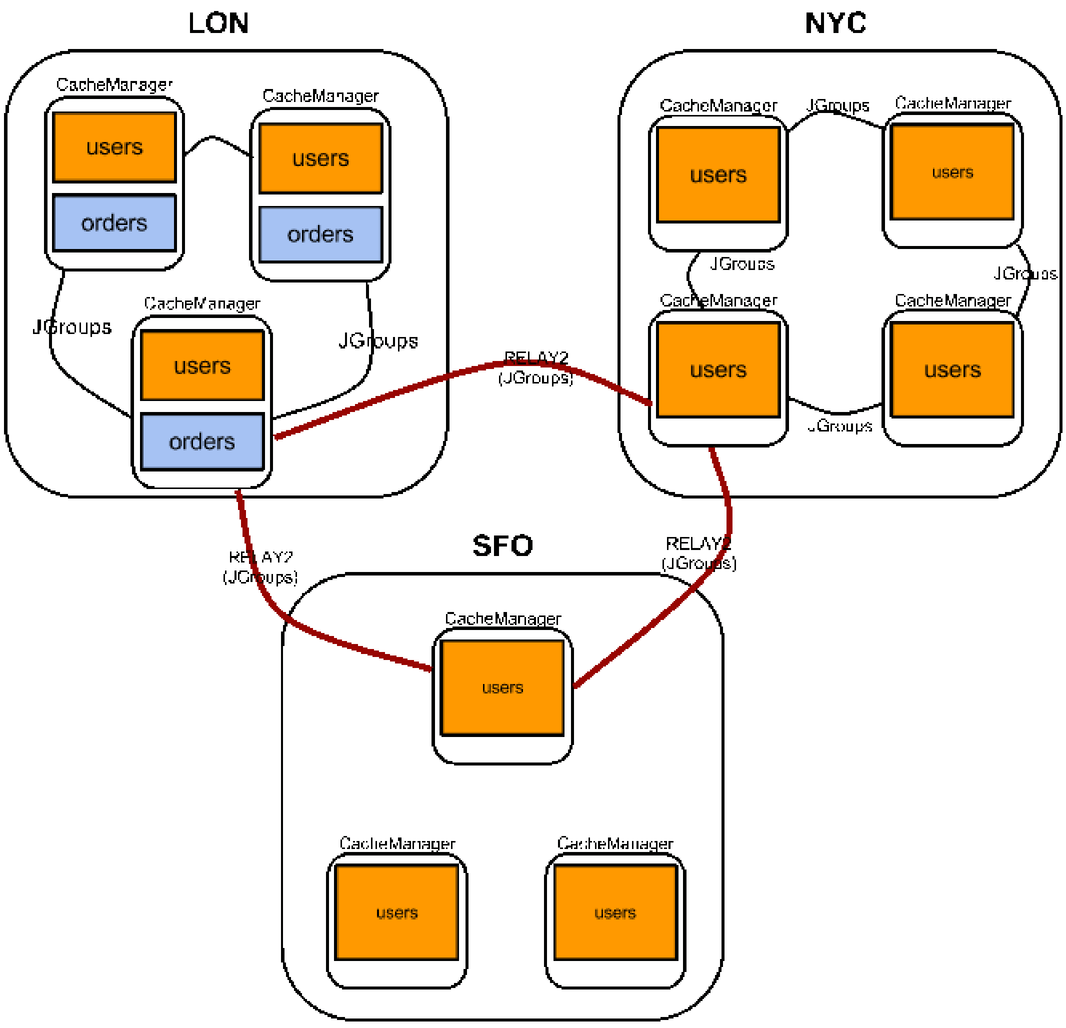
Cross site (x-site) replication allows backing up the data from one cluster to other clusters, potentially situated in different geographical location. The cross-site replication is built on top of JGroups' RELAY2 protocol . This document describes the technical design of cross site replication in more detail.

NOTE

Cross site replication needs the backup cache running in the site master node(s) (i.e. node which receives the backup and applies it). The backup cache starts automatically when it receives the first backup request.

25.1. SAMPLE DEPLOYMENT

The diagram below depicts a possible setup of replicated sites, followed by a description of individual elements present in the deployment. Options are then explained at large in future paragraphs. Comments on the diagram above:



- there are 3 sites: LON, NYC and SFO.
- in each site there is a running Red Hat Data Grid cluster with a (potentially) different number of physical nodes: 3 nodes in LON, 4 nodes in NYC and 3 nodes in SFO

- the "users" cache is active in LON, NYC and SFO. Updates on the "users" cache in any of these sites gets replicated to the other sites as well
- it is possible to use different replication mechanisms between sites. E.g. One can configure SFO to backup data synchronously to NYC and asynchronously to LON
- the "users" cache can have a different configuration from one site to the other. E.g. it might be configured as distributed with numOwners=2 in the LON site, REPL in the NYC site and distributed with numOwners=1 in the SFO site
- JGroups is used for both inter-site and intra-site communication. RELAY2 is used for inter-site communication
- "orders" is a site local to LON, i.e. updates to the data in "orders" don't get replicated to the remote sites The following sections discuss specific aspects of cross site replication into more detail. The foundation of the cross-site replication functionality is RELAY2 so it highly recommended to read JGroups' RELAY2 documentation before moving on into cross-site. Configuration

The cross-site replication configuration spreads over the following files:

1. the backup policy for each individual cache is defined in the Red Hat Data Grid .xml configuration file (infinispan.xml)
2. cluster's JGroups xml configuration file: RELAY2 protocol needs to be added to the JGroups protocol stack (jgroups.xml)
3. RELAY2 configuration file: RELAY2 has an own configuration file (relay2.xml)
4. the JGroups channel that is used by RELAY2 has its own configuration file (jgroups-relay2.xml) Red Hat Data Grid XML configuration file

The local site is defined in the the global configuration section. The local is the site where the node using this configuration file resides (in the example above local site is "LON").

infinispan.xml

```
<transport site="LON" />
```

The same setup can be achieved programatically:

```
GlobalConfigurationBuilder lonGc = GlobalConfigurationBuilder.defaultClusteredBuilder();
lonGc.site().localSite("LON");
```

The names of the site (case sensitive) should match the name of a site as defined within JGroups' RELAY2 protocol configuration file. Besides the global configuration, each cache specifies its backup policy in the "site" element:

infinispan.xml

```
<distributed-cache name="users">
  <backups>
    <backup site="NYC" failure-policy="WARN" strategy="SYNC" timeout="12000"/>
    <backup site="SFO" failure-policy="IGNORE" strategy="ASYNC"/>
    <backup site="LON" strategy="SYNC" enabled="false"/>
  </backups>
</distributed-cache>
```

The "users" cache backups its data to the "NYC" and "SFO" sites. Even though the "LON" appears as a backup site, it has the "enabled" attribute set to *false* so it will be ignored . For each site backup, the following configuration attributes can be specified:

- *strategy* - the strategy used for backing up data, either "SYNC" or "ASYNC". Defaults to "ASYNC".
- *failure-policy* - Decides what the system would do in case of failure during backup. Possible values are:
  - *IGNORE* - allow the local operation/transaction to succeed
  - *WARN* - same as IGNORE but also logs a warning message. Default.
  - *FAIL* - only in effect if "strategy" is "SYNC" - fails local cluster operation/transaction by throwing an exception to the user
  - *CUSTOM* - user provided, see "failurePolicyClass" below
- failurePolicyClass - If the 'failure-policy' is set to 'CUSTOM' then this attribute is required and should contain the fully qualified name of a class implementing org.infinispan.xsite.CustomFailurePolicy
- timeout - The timeout(milliseconds) to be used when backing up data remotely. Defaults to 10000 (10 seconds)

The same setup can be achieved programatically:

```
ConfigurationBuilder lon = new ConfigurationBuilder();
lon.sites().addBackup()
      .site("NYC")
      .backupFailurePolicy(BackupFailurePolicy.WARN)
      .strategy(BackupConfiguration.BackupStrategy.SYNC)
      .replicationTimeout(12000)
      .sites().addInUseBackupSite("NYC")
    .sites().addBackup()
      .site("SFO")
      .backupFailurePolicy(BackupFailurePolicy.IGNORE)
      .strategy(BackupConfiguration.BackupStrategy.ASYNC)
      .sites().addInUseBackupSite("SFO")
```

The "users" cache above doesn’t know on which cache on the remote sites its data is being replicated. By default the remote site writes the backup data to a cache having the same name as the originator, i.e. "users". This behaviour can be overridden with an "backupFor" element. For example the following configuration in SFO makes the "usersLONBackup" cache act as the backup cache for the "users" cache defined above in the LON site:

infinispan.xml

```
<infinispan>
  <cache-container default-cache="">
    <distributed-cache name="usersLONBackup">
```

```
        <backup-for remote-cache="users" remote-site="LON"/>
      </distributed-cache>
   </cache-container>
</infinispan>
```

The same setup can be achieved programatically:

```
ConfigurationBuilder cb = new ConfigurationBuilder();
cb.sites().backupFor().remoteCache("users").remoteSite("LON");
```

25.1.1. Local cluster's jgroups .xml configuration

This is the configuration file for the local (intra-site) Red Hat Data Grid cluster. It is referred from the Red Hat Data Grid configuration file, see "configurationFile" below:

infinispan.xml

```
<infinispan>
  <jgroups>
     <stack-file name="external-file" path="jgroups.xml"/>
  </jgroups>
  <cache-container>
    <transport stack="external-file" />
  </cache-container>

  ...

</infinispan>
```

In order to allow inter-site calls, the RELAY2 protocol needs to be added to the protocol stack defined in the jgroups configuration (see attached jgroups.xml for an example).

25.1.2. RELAY2 configuration file

The RELAY2 configuration file is linked from the jgroups.xml (see attached relay2.xml). It defines the sites seen by this cluster and also the JGroups configuration file that is used by RELAY2 in order to communicate with the remote sites.

25.2. DATA REPLICATION

For both transactional and non-transactional caches, the backup calls are performed in parallel with local cluster calls, e.g. if we write data to node N1 in LON then replication to the local nodes N2 and N3 and remote backup sites SFO and NYC happen in parallel.

25.2.1. Non transactional caches

In the case of non-transactional caches the replication happens during each operation. Given that data is sent in parallel to backups and local caches, it is possible for the operations to succeed locally and fail remotely, or the other way, causing inconsistencies

25.2.2. Transactional caches

For synchronous transactional caches, Red Hat Data Grid internally uses a two phase commit protocol:

lock acquisition during the 1st phase (prepare) and apply changes during the 2nd phase (commit). For asynchronous caches the two phases are merged, the "apply changes" message being sent asynchronously to the owners of data. This 2PC protocol maps to 2PC received from the JTA transaction manager. For transactional caches, both optimistic and pessimistic, the backup to remote sites happens during the prepare and commit phase only.

25.2.2.1. Synchronous local cluster with async backup

In this scenario the backup call happens during local commit phase(2nd phase). That means that if the local prepare fails, no remote data is being sent to the remote backup.

25.2.2.2. Synchronous local cluster with sync backup

In this case there are two backup calls:

- during prepare a message is sent across containing all the modifications that happened within this transaction
- if the remote backup cache is transactional then a transaction is started remotely and all these modifications are being written within this transaction’s scope. The transaction is not committed yet (see below)
- if the remote backup cache is not transactional, then the changes are applied remotely
- during the commit/rollback, a commit/rollback message is sent across
- if the remote backups cache is transactional then the transaction started at the previous phase is committed/rolled back
- if the remote backup is not transactional then this call is ignored

Both the local and the backup call(if the "backupFailurePolicy" is set to "FAIL") can veto transaction’s prepare outcome

25.2.2.3. Asynchronous local cluster

In the case of asynchronous local clusters, the backup data is sent during the commit phase. If the backup call fails and the "backupFailurePolicy" is set to "FAIL" then the user is notified through an exception.

25.2.3. Replication of expired cache entries across sites

You can configure Red Hat Data Grid to expire entries, which controls the amount of time entries remain in the cache.

- **lifespan** expiration is suitable for cross-site replication because entries expire without the need for Red Hat Data Grid to determine if the entries have expired in clusters on other sites.
- **max-idle** expiration does not work with cross-site replication because Red Hat Data Grid cannot determine if cache entries have reached the idle timeout in clusters on other sites.

25.2.4. Deadlocks and Conflicting Entries

In active/active configurations, concurrent writes to the same key results in deadlocks or conflicts.

Active/active configurations are those in which both the local and the backup sites replicate data to each other. For example, "SiteA" backs up to "SiteB" and "SiteB" also backs up to "SiteA".

In synchronous mode (**SYNC**), concurrent writes result in deadlocks because both sites lock the same key in different orders. To resolve deadlocks, client applications must wait until the locks time out.

In asynchronous mode (**ASYNC**), concurrent writes result in conflicting values because sites replicate after entries are modified locally. There is no guaranteed order for asynchronous replication operations so the following outcomes are possible:

- Keys have different values each site. For example, **k=1** on "SiteA" and **k=2** on "SiteB". Asynchronous replication occurs at some point after the client writes to **k** with the result that **x=2** is replicated to "SiteA" and **x=1** is replicated to "SiteB".
- One of the conflicting values is overwritten if sites do not replicate values at the same time. In this case, one of the values is lost and there is no guarantee which value is saved.

In all cases, inconsistencies in key values are resolved after the next non-conflicting **PUT** operation updates the value.

NOTE

There currently is no conflict resolution policy that client applications can use to handle conflicts in asynchronous mode. However, conflict resolution techniques are planned for a future Red Hat Data Grid version.

25.3. TAKING A SITE OFFLINE

If backing up to a site fails for a certain number of times during a time interval, then it is possible to automatically mark that site as offline. When a site is marked as offline the local site won’t try to backup data to it anymore. In order to be taken online a system administrator intervention being required.

25.3.1. Configuration

The following configuration provides an example for taking sites offline:

infinispan.xml

```
<replicated-cache name="bestEffortBackup">
  ...
  <backups>
    <backup site="NYC" strategy="SYNC" failure-policy="FAIL">
      <take-offline after-failures="500" min-wait="10000"/>
    </backup>
  </backups>
   ...
</replicated-cache>
```

The *take-offline* element under the *backup* configures the taking offline of a site:

- *after-failures* - the number of failed backup operations after which this site should be taken offline. Defaults to 0 (never). A negative value would mean that the site will be taken offline after *minTimeToWait*

- *min-wait* - the number of milliseconds in which a site is not marked offline even if it is unreachable for 'afterFailures' number of times. If smaller or equal to 0, then only *afterFailures* is considered.

The equivalent programmatic configuration is:

```
lon.sites().addBackup()
      .site("NYC")
      .backupFailurePolicy(BackupFailurePolicy.FAIL)
      .strategy(BackupConfiguration.BackupStrategy.SYNC)
      .takeOffline()
         .afterFailures(500)
         .minTimeToWait(10000);
```

25.3.2. Bringing Sites Back Online

After taking sites offline, invoke the **bringSiteOnline(siteName)** operation via the following JMX MBeans to bring sites back online:

- **XSiteAdmin** enables replication on caches across clusters in a remote site.
- **GlobalXSiteAdminOperations** enables replication on cache containers across clusters in a remote site.

The **bringSiteOnline(siteName)** operation enables replication only and does not do a full update. For this reason, when you bring sites back online, they only contain new entries. You should push transfer to sites after you bring them online to synchronize the most recent data.

TIP

Pushing state transfer brings sites back online. You can do that instead of invoking **bringSiteOnline(siteName)**.

25.4. PUSHING STATE TRANSFER TO SITES

Transferring state from one site to another synchronizes the data between the two sites.

You should always transfer state from the currently active site, which contains the most up-to-date data, to another site. The site to which you push state transfer can be online or offline. If you push state transfer to an offline site, it brings that site back online.

Caches on sites to which you transfer state from another site do not need to be empty. However, state transfer only overwrites existing keys on receiving sites and does not delete keys.

For example, key K exists on site A and site B. You transfer state from site A to site B. In this case, Red Hat Data Grid overwrites key K. However, key Y exists on site B but not site A. After you transfer state from site A to site B, key Y still exists on site B.

NOTE

You can receive state transfer from only one site at a time. Likewise, if you invoke a state transfer operation on a site, Red Hat Data Grid ignores subsequent invocations on that site.

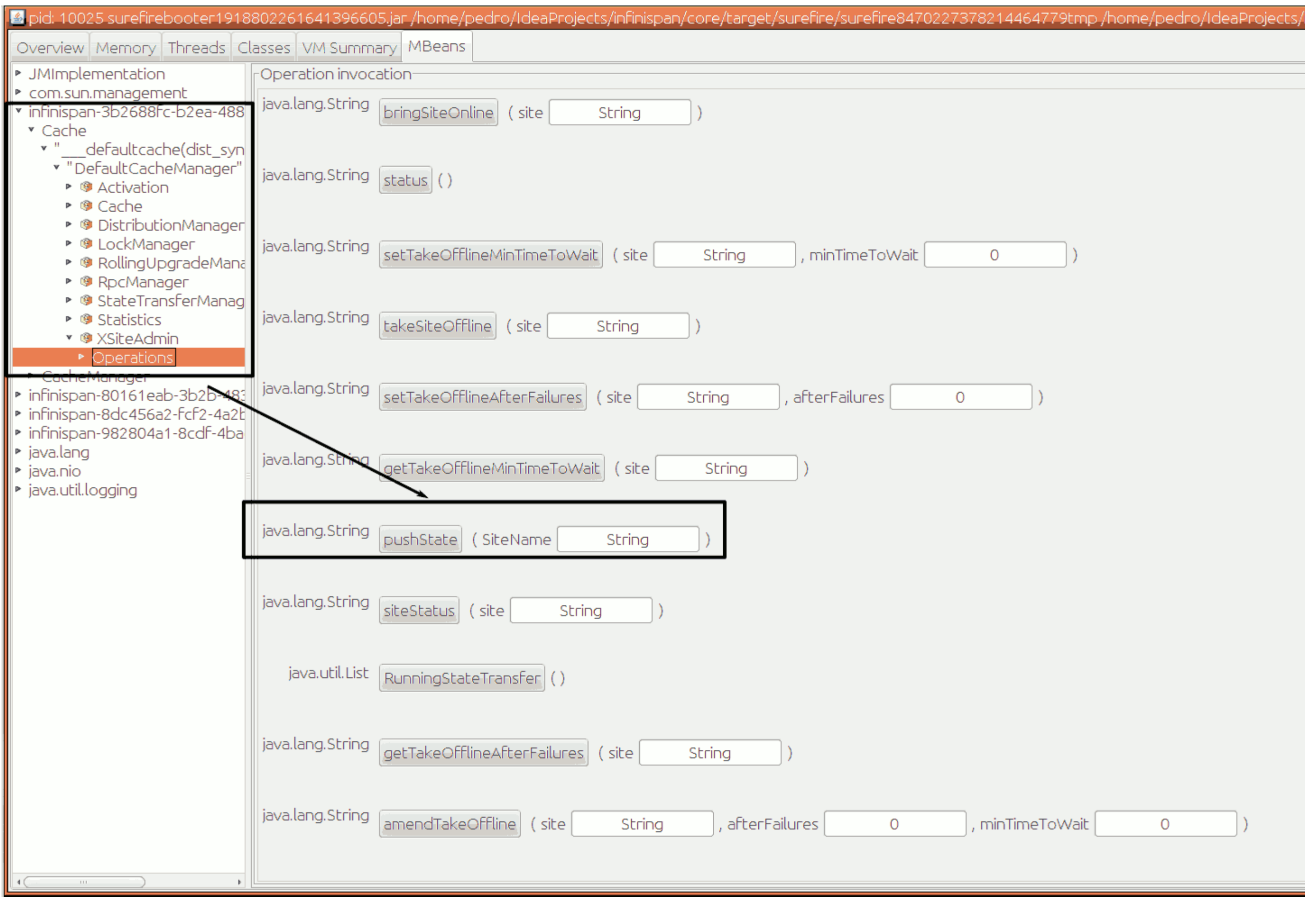
Invoke the **pushState(String)** operation via the following JMX MBeans to bring sites back online:

- **XSiteAdminOperations** synchronizes state for caches between the site on which you invoke the operation and a remote site. Brings the site online if it is offline.
- **GlobalXSiteAdminOperations** synchronizes state for cache containers between the site on which you invoke the operation and a remote site. Brings the site online if it is offline.

When you invoke the **pushState(String)** operation on the site that transfers state, you specify the name of the site that receives the state.

The following figure shows the pushState(String) operation in JConsole:

Figure 25.1. Pushing state via JConsole


pid: 10025 surefirebooter1918802261641396605.jar /home/pedro/IdeaProjects/infinispan/core/target/surefire/surefire8470227378214464779tmp /home/pedro/IdeaProjects/
Overview
Memory
Threads
Classes
VM Summary
MBeans
JMImplementation
com.sun.management
infinispan-3b2688fc-b2ea-488
Cache
"___defaultcache(dist_syn
"DefaultCacheManager"
Activation
Cache
DistributionManager
LockManager
RollingUpgradeMana
RpcManager
StateTransferManag
Statistics
XSiteAdmin
Operations
CacheManager
infinispan-80161eab-3b2b-483
infinispan-8dc456a2-fcf2-4a2b
infinispan-982804a1-8cdf-4ba
java.lang
java.nio
java.util.logging
Operation invocation
java.lang.String bringSiteOnline (site String)
java.lang.String status ( )
java.lang.String setTakeOfflineMinTimeToWait (site String , minTimeToWait 0)
java.lang.String takeSiteOffline (site String)
java.lang.String setTakeOfflineAfterFailures (site String , afterFailures 0)
java.lang.String getTakeOfflineMinTimeToWait (site String)
java.lang.String pushState (SiteName String)
java.lang.String siteStatus (site String)
java.util.List RunningStateTransfer ( )
java.lang.String getTakeOfflineAfterFailures (site String)
java.lang.String amendTakeOffline (site String , afterFailures 0 , minTimeToWait 0)

25.4.1. Handling join/leave nodes

The current implementation automatically handles the topology changes in producer or consumer site. Also, the cross-site state transfer can run in parallel with a local site state transfer.

25.4.2. Handling broken link between sites

A System Administrator action is needed if the link between the producer and consumer site is broken during the cross-site state transfer (data consistency is not ensured in consumer site). The producer site retries for a while before giving up. Then, it gets back to normal state. However, the consumer site is not able to get back to normal state and, here, an action from System Administrator is need. The System Administrator should use the operation cancelReceiveState(String siteName) to bring the consumer site to normal state.

25.4.3. System Administrator Operations

A set of operations can be performed to control the cross-site state transfer:

- pushState(String siteName) - It starts the cross-site state transfer to the site name specified;
- cancelPushState(String siteName) - It cancels the cross-site state transfer to the site name specified;
- getRunningStateTransfer() - It returns a list of site name to which this site is pushing the state;
- getSendingSiteName() - It returns the site name that is pushing state to this site;
- cancelReceiveState(String siteName) - It restores the site to normal state. Should be used when the link between the sites is broken during the state transfer (as described above);
- getPushStateStatus() - It returns the status of completed cross-site state transfer;
- clearPushStateStatus() - It clears the status of completed cross-site state transfer.

For more technical information, you can check the Cross Site design document. See Reference.

25.4.4. Configuration

State transfer between sites cannot be enabled or disabled but it allows to tune some parameters. The values shown below are the default values:

infinispan.xml

```
<replicated-cache name="xSiteStateTransfer">
  ...
  <backups>
    <backup site="NYC" strategy="SYNC" failure-policy="FAIL">
      <state-transfer chunk-size="512" timeout="1200000" max-retries="30" wait-time="2000" />
    </backup>
  </backups>
   ...
</replicated-cache>
```

The equivalent programmatic configuration is:

```
lon.sites().addBackup()
      .site("NYC")
      .backupFailurePolicy(BackupFailurePolicy.FAIL)
      .strategy(BackupConfiguration.BackupStrategy.SYNC)
      .stateTransfer()
         .chunkSize(512)
         .timeout(1200000)
         .maxRetries(30)
         .waitingTimeBetweenRetries(2000);
```

Below, it is the parameters description:

- *chunk-size* - The number of keys to batch before sending them to the consumer site. A negative or a zero value is **not** a valid value. Default value is 512 keys.

- *timeout* - The time (in milliseconds) to wait for the consumer site acknowledge the reception and appliance of a state chunk. A negative or zero value is **not** a valid value. Default value is 20 minutes.
- *max-retries* - The maximum number of retries when a push state command fails. A negative or a zero value means that the command will not retry in case of failure. Default value is 30.
- *wait-time* - The waiting time (in milliseconds) between each retry. A negative or a zero value is **not** a valid value. Default value is 2 seconds.

25.5. REFERENCE

This document describes the technical design of cross site replication in more detail.

CHAPTER 26. PERFORMING ROLLING UPGRADES

Upgrade Red Hat Data Grid without downtime or data loss. You can perform rolling upgrades in Remote Client/Server Mode to start using a more recent version of Red Hat Data Grid.

NOTE

This section explains how to upgrade Red Hat Data Grid servers, see the appropriate documentation for your Hot Rod client for upgrade procedures.

From a high-level, you do the following to perform rolling upgrades:

1. Set up a target cluster. The target cluster is the Red Hat Data Grid version to which you want to migrate data. The source cluster is the Red Hat Data Grid deployment that is currently in use. After the target cluster is running, you configure all clients to point to it instead of the source cluster.

2. Synchronize data from the source cluster to the target cluster.

26.1. SETTING UP A TARGET CLUSTER

1. Start the target cluster with unique network properties or a different JGroups cluster name to keep it separate from the source cluster.

2. Configure a **RemoteCacheStore** on the target cluster for each cache you want to migrate from the source cluster.

   RemoteCacheStore settings

   - **remote-server** must point to the source cluster via the **outbound-socket-binding** property.
   - **remoteCacheName** must match the cache name on the source cluster.
   - **hotrod-wrapping** must be **true** (enabled).
   - **shared** must be **true** (enabled).
   - **purge** must be **false** (disabled).
   - **passivation** must be **false** (disabled).
   - **protocol-version** matches the Hot Rod protocol version of the source cluster.

     Example RemoteCacheStore Configuration

     ```
     <distributed-cache>
       <remote-store cache="MyCache" socket-timeout="60000" tcp-no-delay="true"
     protocol-version="2.5" shared="true" hotrod-wrapping="true" purge="false"
     passivation="false">
         <remote-server outbound-socket-binding="remote-store-hotrod-server"/>
       </remote-store>
     </distributed-cache>
     ...
     <socket-binding-group name="standard-sockets" default-interface="public" port-
     ```

```
offset="${jboss.socket.binding.port-offset:0}">
  ...
  <outbound-socket-binding name="remote-store-hotrod-server">
    <remote-destination host="198.51.100.0" port="11222"/>
  </outbound-socket-binding>
  ...
</socket-binding-group>
```

3. Configure the target cluster to handle all client requests instead of the source cluster:

    a. Configure all clients to point to the target cluster instead of the source cluster.

    b. Restart each client node.
    The target cluster lazily loads data from the source cluster on demand via **RemoteCacheStore**.

26.2. SYNCHRONIZING DATA FROM THE SOURCE CLUSTER

1. Call the **synchronizeData()** method in the **TargetMigrator** interface. Do one of the following on the target cluster for each cache that you want to migrate:

    JMX

    Invoke the **synchronizeData** operation and specify the **hotrod** parameter on the **RollingUpgradeManager** MBean.

    CLI

    ```
    $ bin/cli.sh --connect controller=127.0.0.1:9990 -c "/subsystem=datagrid-infinispan/cache-container=clustered/distributed-cache=MyCache:synchronize-data(migrator-name=hotrod)"
    ```

    Data migrates to all nodes in the target cluster in parallel, with each node receiving a subset of the data.

    Use the following parameters to tune the operation:

    - **read-batch** configures the number of entries to read from the source cluster at a time. The default value is **10000**.
    - **write-threads** configures the number of threads used to write data. The default value is the number of processors available.
    For example:

        synchronize-data(migrator-name=hotrod, read-batch=100000, write-threads=3)

2. Disable the **RemoteCacheStore** on the target cluster. Do one of the following:

    JMX

    Invoke the **disconnectSource** operation and specify the **hotrod** parameter on the **RollingUpgradeManager** MBean.

    CLI

```
$ bin/cli.sh --connect controller=127.0.0.1:9990 -c "/subsystem=datagrid-infinispan/cache-
container=clustered/distributed-cache=MyCache:disconnect-source(migrator-
name=hotrod)"
```

3. Decommission the source cluster. == Extending Red Hat Data Grid Red Hat Data Grid can be extended to provide the ability for an end user to add additional configurations, operations and components outside of the scope of the ones normally provided by Red Hat Data Grid.

26.3. CUSTOM COMMANDS

Red Hat Data Grid makes use of a command/visitor pattern to implement the various top-level methods you see on the public-facing API. This is explained in further detail in the Architectural Overview section. While the core commands - and their corresponding visitors - are hard-coded as a part of Red Hat Data Grid's core module, module authors can extend and enhance Red Hat Data Grid by creating new custom commands.

As a module author (such as infinispan-query, etc.) you can define your own commands.

You do so by:

1. Create a **META-INF/services/org.infinispan.commands.module.ModuleCommandExtensions** file and ensure this is packaged in your jar.
2. Implementing **ModuleCommandFactory**, **ModuleCommandInitializer** and **ModuleCommandExtensions**
3. Specifying the fully-qualified class name of the **ModuleCommandExtensions** implementation in **META-INF/services/org.infinispan.commands.module.ModuleCommandExtensions**.
4. Implement your custom commands and visitors for these commands

26.3.1. An Example

Here is an example of an **META-INF/services/org.infinispan.commands.module.ModuleCommandExtensions** file, configured accordingly:

org.infinispan.commands.module.ModuleCommandExtensions

```
org.infinispan.query.QueryModuleCommandExtensions
```

For a full, working example of a sample module that makes use of custom commands and visitors, check out Red Hat Data Grid Sample Module .

26.3.2. Preassigned Custom Command Id Ranges

This is the list of **Command** identifiers that are used by Red Hat Data Grid based modules or frameworks. Red Hat Data Grid users should avoid using ids within these ranges. (RANGES to be finalised yet!) Being this a single byte, ranges can't be too large.

Red Hat Data Grid Query:	100 - 119

Hibernate Search:	120 - 139
Hot Rod Server:	140 - 141

26.4. EXTENDING THE CONFIGURATION BUILDERS AND PARSERS

If your custom module requires configuration, it is possible to enhance Red Hat Data Grid's configuration builders and parsers. Look at the custom module tests for a detail example on how to implement this.

CHAPTER 27. ARCHITECTURAL OVERVIEW

This section contains a high level overview of Red Hat Data Grid's internal architecture. This document is geared towards people with an interest in extending or enhancing Red Hat Data Grid, or just curious about Red Hat Data Grid's internals.

27.1. CACHE HIERARCHY

Red Hat Data Grid's Cache interface extends the JRE's ConcurrentMap interface which provides for a familiar and easy-to-use API.

```
---
public interface Cache<K, V> extends BasicCache<K, V> {
 ...
}
```

public interface BasicCache<K, V> extends ConcurrentMap<K, V> { … } ---

Caches are created by using a CacheContainer instance - either the EmbeddedCacheManager or a RemoteCacheManager. In addition to their capabilities as a factory for Caches, CacheContainers also act as a registry for looking up Caches.

EmbeddedCacheManagers create either clustered or standalone Caches that reside in the same JVM. RemoteCacheManagers, on the other hand, create RemoteCaches that connect to a remote cache tier via the Hot Rod protocol.

27.2. COMMANDS

Internally, each and every cache operation is encapsulated by a command. These command objects represent the type of operation being performed, and also hold references to necessary parameters. The actual logic of a given command, for example a ReplaceCommand, is encapsulated in the command's perform() method. Very object-oriented and easy to test.

All of these commands implement the VisitableCommand inteface which allow a Visitor (described in next section) to process them accordingly.

```
---
public class PutKeyValueCommand extends VisitableCommand {
  ...
}
```

public class GetKeyValueCommand extends VisitableCommand { … }

i. etc … ---

27.3. VISITORS

Commands are processed by the various Visitors. The visitor interface, displayed below, exposes methods to visit each of the different types of commands in the system. This gives us a type-safe mechanism for adding behaviour to a call.Commands are processed by `Visitor`s. The visitor interface, displayed below, exposes methods to visit each of the different types of commands in the system. This gives us a type-safe mechanism for adding behaviour to a call.

> ---
> public interface Vistor {
>   Object visitPutKeyValueCommand(InvocationContext ctx, PutKeyValueCommand command) throws Throwable;

> Object visitRemoveCommand(InvocationContext ctx, RemoveCommand command) throws Throwable;

> Object visitReplaceCommand(InvocationContext ctx, ReplaceCommand command) throws Throwable;

> Object visitClearCommand(InvocationContext ctx, ClearCommand command) throws Throwable;

> Object visitPutMapCommand(InvocationContext ctx, PutMapCommand command) throws Throwable;

i. etc … } ---

An **AbstractVisitor** class in the **org.infinispan.commands** package is provided with no-op implementations of each of these methods. Real implementations then only need override the visitor methods for the commands that interest them, allowing for very concise, readable and testable visitor implementations.

27.4. INTERCEPTORS

Interceptors are special types of Visitors, which are capable of visiting commands, but also acts in a chain. A chain of interceptors all visit the command, one in turn, until all registered interceptors visit the command.

The class to note is the CommandInterceptor. This abstract class implements the interceptor pattern, and also implements Visitor. Red Hat Data Grid's interceptors extend CommandInterceptor, and these add specific behaviour to specific commands, such as distribution across a network or writing through to disk.

There is also an experimental asynchronous interceptor which can be used. The interface used for asynchronous interceptors is AsyncInterceptor and a base implementation which should be used when a custom implementation is desired BaseCustomAsyncInterceptor. Note this class also implements the **Visitor** interface.

27.5. PUTTING IT ALL TOGETHER

So how does this all come together? Invocations on the cache cause the cache to first create an invocation context for the call. Invocation contexts contain, among other things, transactional characteristics of the call. The cache then creates a command for the call, making use of a command factory which initialises the command instance with parameters and references to other subsystems.

The cache then passes the invocation context and command to the InterceptorChain, which calls each and every registered interceptor in turn to visit the command, adding behaviour to the call. Finally, the command's perform() method is invoked and the return value, if any, is propagated back to the caller.

27.6. SUBSYSTEM MANAGERS

The interceptors act as simple interception points and don't contain a lot of logic themselves. Most behavioural logic is encapsulated as managers in various subsystems, a small subset of which are:

27.6.1. DistributionManager

Manager that controls how entries are distributed across the cluster.

27.6.2. TransactionManager

Manager than handles transactions, usually supplied by a third party.

27.6.3. RpcManager

Manager that handles replicating commands between nodes in the cluster.

27.6.4. LockManager

Manager that handles locking keys when operations require them.

27.6.5. PersistenceManager

Manager that handles persisting data to any configured cache stores.

27.6.6. DataContainer

Container that holds the actual in memory entries.

27.6.7. Configuration

A component detailing all of the configuration in this cache.

27.7. COMPONENTREGISTRY

A registry where the various managers above and components are created and stored for use in the cache. All of the other managers and crucial componanets are accesible through the registry.

The registry itself is a lightweight dependency injection framework, allowing components and managers to reference and initialise one another. Here is an example of a component declaring a dependency on a DataContainer and a Configuration, and a DataContainerFactory declaring its ability to construct DataContainers on the fly.

```
---
  @Inject
  public void injectDependencies(DataContainer container, Configuration configuration) {
    this.container = container;
    this.configuration = configuration;
  }
```

```
  @DefaultFactoryFor
  public class DataContainerFactory extends AbstractNamedCacheComponentFactory {
---
```

Components registered with the ComponentRegistry may also have a lifecycle, and methods annotated with @Start or @Stop will be invoked before and after they are used by the component registry.

```
---
  @Start
  public void init() {
    useWriteSkewCheck = configuration.locking().writeSkewCheck();
  }
```

```
  @Stop(priority=20)
  public void stop() {
    notifier.removeListener(listener);
    executor.shutdownNow();
  }
---
```

In the example above, the optional priority parameter to @Stop is used to indicate the order in which the component is stopped, in relation to other components. This follows a Unix Sys-V style ordering, where smaller priority methods are called before higher priority ones. The default priority, if not specified, is 10.