Red Hat Data Grid 8.2

Embedding Data Grid

Run Data Grid as an embedded library
Red Hat Data Grid 8.2 Embedding Data Grid

Run Data Grid as an embedded library
Abstract

Set up your project to run Data Grid in your application JVM and use embedded caches.
<table>
<thead>
<tr>
<th>Table of Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>RED HAT DATA GRID</td>
</tr>
<tr>
<td>DATA GRID DOCUMENTATION</td>
</tr>
<tr>
<td>DATA GRID DOWNLOADS</td>
</tr>
<tr>
<td>MAKING OPEN SOURCE MORE INCLUSIVE</td>
</tr>
<tr>
<td>CHAPTER 1. CONFIGURING THE DATA GRID MAVEN REPOSITORY</td>
</tr>
<tr>
<td>1.1. DOWNLOADING THE DATA GRID MAVEN REPOSITORY</td>
</tr>
<tr>
<td>1.2. ADDING RED HAT MAVEN REPOSITORIES</td>
</tr>
<tr>
<td>1.3. CONFIGURING YOUR DATA GRID POM</td>
</tr>
<tr>
<td>CHAPTER 2. ADDING DATA GRID TO YOUR PROJECT</td>
</tr>
<tr>
<td>CHAPTER 3. INITIALIZING EMBEDDED CACHES</td>
</tr>
<tr>
<td>CHAPTER 4. ENABLING DATA GRID STATISTICS</td>
</tr>
<tr>
<td>CHAPTER 5. CONFIGURING DATA GRID TO REGISTER JMX MBEANS</td>
</tr>
<tr>
<td>5.1. ENABLING JMX REMOTE PORTS</td>
</tr>
<tr>
<td>5.2. DATA GRID MBEANS</td>
</tr>
<tr>
<td>CHAPTER 6. SETTING UP DATA GRID CLUSTERS</td>
</tr>
<tr>
<td>6.1. DEFAULT JGROUPS STACKS</td>
</tr>
<tr>
<td>6.2. CLUSTER DISCOVERY PROTOCOLS</td>
</tr>
<tr>
<td>6.2.1. PING</td>
</tr>
<tr>
<td>6.2.2. TCPPING</td>
</tr>
<tr>
<td>6.2.3. MPING</td>
</tr>
<tr>
<td>6.2.4. TCPGOSSIP</td>
</tr>
<tr>
<td>6.2.5. JDBC_PING</td>
</tr>
<tr>
<td>6.2.6. DNS_PING</td>
</tr>
<tr>
<td>6.2.7. Cloud Discovery Protocols</td>
</tr>
<tr>
<td>Providing Dependencies for Cloud Discovery Protocols</td>
</tr>
<tr>
<td>6.3. USING THE DEFAULT JGROUPS STACKS</td>
</tr>
<tr>
<td>6.4. CUSTOMIZING JGROUPS STACKS</td>
</tr>
<tr>
<td>6.4.1. Inheritance Attributes</td>
</tr>
<tr>
<td>6.5. USING JGROUPS SYSTEM PROPERTIES</td>
</tr>
<tr>
<td>6.5.1. Cluster Transport Properties</td>
</tr>
<tr>
<td>6.5.2. System Properties for Cloud Discovery Protocols</td>
</tr>
<tr>
<td>6.5.2.1. Amazon EC2</td>
</tr>
<tr>
<td>6.5.2.2. Google Cloud Platform</td>
</tr>
<tr>
<td>6.5.2.3. Azure</td>
</tr>
<tr>
<td>6.5.2.4. OpenShift</td>
</tr>
<tr>
<td>6.6. USING INLINE JGROUPS STACKS</td>
</tr>
<tr>
<td>6.7. USING EXTERNAL JGROUPS STACKS</td>
</tr>
<tr>
<td>6.8. USING CUSTOM JCHANNELS</td>
</tr>
<tr>
<td>6.9. ENCRYPTING CLUSTER TRANSPORT</td>
</tr>
<tr>
<td>6.9.1. Data Grid Cluster Security</td>
</tr>
<tr>
<td>6.9.2. Configuring Cluster Transport with Asymmetric Encryption</td>
</tr>
<tr>
<td>6.9.3. Configuring Cluster Transport with Symmetric Encryption</td>
</tr>
<tr>
<td>6.10. TCP AND UDP PORTS FOR CLUSTER TRAFFIC</td>
</tr>
<tr>
<td>Cross-Site Replication</td>
</tr>
</tbody>
</table>
RED HAT DATA GRID

Data Grid is a high-performance, distributed in-memory data store.

**Schemaless data structure**
- Flexibility to store different objects as key-value pairs.

**Grid-based data storage**
- Designed to distribute and replicate data across clusters.

**Elastic scaling**
- Dynamically adjust the number of nodes to meet demand without service disruption.

**Data interoperability**
- Store, retrieve, and query data in the grid from different endpoints.
DATA GRID DOCUMENTATION

Documentation for Data Grid is available on the Red Hat customer portal.

- Data Grid 8.2 Documentation
- Data Grid 8.2 Component Details
- Supported Configurations for Data Grid 8.2
- Data Grid 8 Feature Support
- Data Grid Deprecated Features and Functionality
Access the Data Grid Software Downloads on the Red Hat customer portal.

NOTE

You must have a Red Hat account to access and download Data Grid software.
MAKING OPEN SOURCE MORE INCLUSIVE

Red Hat is committed to replacing problematic language in our code, documentation, and web properties. We are beginning with these four terms: master, slave, blacklist, and whitelist. Because of the enormity of this endeavor, these changes will be implemented gradually over several upcoming releases. For more details, see our CTO Chris Wright’s message.
CHAPTER 1. CONFIGURING THE DATA GRID MAVEN REPOSITORY

Data Grid Java distributions are available from Maven.

You can download the Data Grid Maven repository from the customer portal or pull Data Grid dependencies from the public Red Hat Enterprise Maven repository.

1.1. DOWNLOADING THE DATA GRID MAVEN REPOSITORY

Download and install the Data Grid Maven repository to a local file system, Apache HTTP server, or Maven repository manager if you do not want to use the public Red Hat Enterprise Maven repository.

Procedure

1. Log in to the Red Hat customer portal.
2. Navigate to the Software Downloads for Data Grid.
3. Download the Red Hat Data Grid 8.2 Maven Repository.
4. Extract the archived Maven repository to your local file system.
5. Open the README.md file and follow the appropriate installation instructions.

1.2. ADDING RED HAT MAVEN REPOSITORIES

Include the Red Hat GA repository in your Maven build environment to get Data Grid artifacts and dependencies.

Procedure

- Add the Red Hat GA repository to your Maven settings file, typically ~/.m2/settings.xml, or directly in the pom.xml file of your project.

```xml
<repositories>
  <repository>
    <id>redhat-ga-repository</id>
    <name>Red Hat GA Repository</name>
    <url>https://maven.repository.redhat.com/ga/</url>
  </repository>
</repositories>
<pluginRepositories>
  <pluginRepository>
    <id>redhat-ga-repository</id>
    <name>Red Hat GA Repository</name>
    <url>https://maven.repository.redhat.com/ga/</url>
  </pluginRepository>
</pluginRepositories>
```

Reference

- Red Hat Enterprise Maven Repository
1.3. CONFIGURING YOUR DATA GRID POM

Maven uses configuration files called Project Object Model (POM) files to define projects and manage builds. POM files are in XML format and describe the module and component dependencies, build order, and targets for the resulting project packaging and output.

Procedure

1. Open your project pom.xml for editing.

2. Define the version.infinispan property with the correct Data Grid version.

3. Include the infinispan-bom in a dependencyManagement section. The Bill Of Materials (BOM) controls dependency versions, which avoids version conflicts and means you do not need to set the version for each Data Grid artifact you add as a dependency to your project.

4. Save and close pom.xml.

The following example shows the Data Grid version and BOM:

```xml
<properties>
  <version.infinispan>12.1.11.Final-redhat-00001</version.infinispan>
</properties>

<dependencyManagement>
  <dependencies>
    <dependency>
      <groupId>org.infinispan</groupId>
      <artifactId>infinispan-bom</artifactId>
      <version>${version.infinispan}</version>
      <type>pom</type>
      <scope>import</scope>
    </dependency>
  </dependencies>
</dependencyManagement>
```

Next Steps

Add Data Grid artifacts as dependencies to your pom.xml as required.
Add Data Grid to your project to create embedded caches in your applications.

Procedure

- Add the **infinispan-core** artifact as a dependency in your **pom.xml** as follows:

```
<dependencies>
  <dependency>
    <groupId>org.infinispan</groupId>
    <artifactId>infinispan-core</artifactId>
  </dependency>
</dependencies>
```
CHAPTER 3. INITIALIZING EMBEDDED CACHES

Initialize the Cache Manager and add embedded cache in your project to start running Data Grid in your application.

Procedure

- Initialize the default Cache Manager and add an embedded cache named as follows:

```java
GlobalConfigurationBuilder global = GlobalConfigurationBuilder.defaultClusteredBuilder();
DefaultCacheManager cacheManager = new DefaultCacheManager(global.build());
ConfigurationBuilder builder = new ConfigurationBuilder();
builder.clustering().cacheMode(CacheMode.DIST_SYNC);
cacheManager.administration().withFlags(CacheContainerAdmin.AdminFlag.VOLATILE).getOrCreateCache("myCache", builder.build());
```

The preceding code initializes a default, clustered Cache Manager. Cache Managers contain your cache definitions and control cache lifecycles.

Data Grid does not provide a default cache configuration so after initializing the default Cache Manager, you need to add at least one cache instance. This example uses the `ConfigurationBuilder` class to create an embedded cache definition that uses the distributed, synchronous cache mode. You then call the `getOrCreateCache()` method that either creates a cache named "myCache" on all nodes in the cluster or returns it if it already exists.

Next steps

Now that you have a running Cache Manager with a cache created, you can add some more cache definitions, put some data into the cache, or configure Data Grid as needed.

Additional resources

- Configuring Data Grid Programmatically
- `org.infinispan.configuration.global.GlobalConfigurationBuilder`
- `org.infinispan.manager.EmbeddedCacheManager`
- `org.infinispan.Cache`
CHAPTER 4. ENABLING DATA GRID STATISTICS

Configure Data Grid to export statistics for Cache Managers and caches.

Procedure

Modify your configuration to enable Data Grid statistics in one of the following ways:

- **Declarative**: Add the `statistics="true"` attribute.
- **Programmatic**: Call the `.statistics()` method.

**Declarative**

```xml
<!-- Enables statistics for the Cache Manager. -->
<cache-container statistics="true"/>

<!-- Enables statistics for the named cache. -->
<local-cache name="mycache" statistics="true"/>
</cache-container>
```

**Programmatic**

```java
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder()
    //Enables statistics for the Cache Manager.
    .cacheContainer().statistics(true)
    .build();

Configuration config = new ConfigurationBuilder()
    //Enables statistics for the named cache.
    .statistics().enable()
    .build();
```
CHAPTER 5. CONFIGURING DATA GRID TO REGISTER JMX MBEANS

Data Grid can register JMX MBeans that you can use to collect statistics and perform administrative operations. You must enable statistics separately to JMX otherwise Data Grid provides 0 values for all statistic attributes.

Procedure

Modify your cache container configuration to enable JMX in one of the following ways:

- **Declarative**: Add the `<jmx enabled="true"/>` element to the cache container.
- **Programmatic**: Call the `.jmx().enable()` method.

**Declarative**

```xml
<cache-container>
  <jmx enabled="true"/>
</cache-container>
```

**Programmatic**

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

5.1. ENABLING JMX REMOTE PORTS

Provide unique remote JMX ports to expose Data Grid MBeans through connections in JMXServiceURL format.

Procedure

- Pass the following system properties to Data Grid at startup:

  ```
  -Dcom.sun.management.jmxremote
  -Dcom.sun.management.jmxremote.port=9999
  -Dcom.sun.management.jmxremote.authenticate=false
  -Dcom.sun.management.jmxremote.ssl=false
  ```

5.2. DATA GRID MBEANS

Data Grid exposes JMX MBeans that represent manageable resources.

**org.infinispan:type=Cache**

Attributes and operations available for cache instances.

**org.infinispan:type=CacheManager**

Attributes and operations available for cache managers, including Data Grid cache and cluster health statistics.
For a complete list of available JMX MBeans along with descriptions and available operations and attributes, see the *Data Grid JMX Components* documentation.

**Additional resources**

- Data Grid JMX Components
CHAPTER 6. SETTING UP DATA GRID CLUSTERS

Data Grid requires a transport layer so nodes can automatically join and leave clusters. The transport layer also enables Data Grid nodes to replicate or distribute data across the network and perform operations such as re-balancing and state transfer.

6.1. DEFAULT JGROUPS STACKS

Data Grid provides default JGroups stack files, default-jgroups-*.xml, in the default-configs directory inside the infinispan-core-12.1.11.Final-redhat-00001.jar file.

<table>
<thead>
<tr>
<th>File name</th>
<th>Stack name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>default-jgroups-udp.xml</td>
<td>udp</td>
<td>Uses UDP for transport and UDP multicast for discovery. Suitable for larger clusters (over 100 nodes) or if you are using replicated caches or invalidation mode. Minimizes the number of open sockets.</td>
</tr>
<tr>
<td>default-jgroups-tcp.xml</td>
<td>tcp</td>
<td>Uses TCP for transport and the MPING protocol for discovery, which uses UDP multicast. Suitable for smaller clusters (under 100 nodes) only if you are using distributed caches because TCP is more efficient than UDP as a point-to-point protocol.</td>
</tr>
<tr>
<td>default-jgroups-kubernetes.xml</td>
<td>kubernetes</td>
<td>Uses TCP for transport and DNS_PING for discovery. Suitable for Kubernetes and Red Hat OpenShift nodes where UDP multicast is not always available.</td>
</tr>
<tr>
<td>default-jgroups-ec2.xml</td>
<td>ec2</td>
<td>Uses TCP for transport and NATIVE_S3_PING for discovery. Suitable for Amazon EC2 nodes where UDP multicast is not available. Requires additional dependencies.</td>
</tr>
<tr>
<td>default-jgroups-google.xml</td>
<td>google</td>
<td>Uses TCP for transport and GOOGLE_PING2 for discovery. Suitable for Google Cloud Platform nodes where UDP multicast is not available. Requires additional dependencies.</td>
</tr>
<tr>
<td>default-jgroups-azure.xml</td>
<td>azure</td>
<td>Uses TCP for transport and AZURE_PING for discovery. Suitable for Microsoft Azure nodes where UDP multicast is not available. Requires additional dependencies.</td>
</tr>
</tbody>
</table>

Additional resources

- JGroups Protocols

6.2. CLUSTER DISCOVERY PROTOCOLS
Data Grid supports different protocols that allow nodes to automatically find each other on the network and form clusters.

There are two types of discovery mechanisms that Data Grid can use:

- Generic discovery protocols that work on most networks and do not rely on external services.
- Discovery protocols that rely on external services to store and retrieve topology information for Data Grid clusters. For instance, the DNS_PING protocol performs discovery through DNS server records.

**NOTE**

Running Data Grid on hosted platforms requires using discovery mechanisms that are adapted to network constraints that individual cloud providers impose.

Additional resources

- JGroups Discovery Protocols
- JGroups cluster transport configuration for Data Grid 8.x (Red Hat knowledgebase article)

### 6.2.1. PING

PING, or UDPPING, is a generic JGroups discovery mechanism that uses dynamic multicasting with the UDP protocol.

When joining, nodes send PING requests to an IP multicast address to discover other nodes already in the Data Grid cluster. Each node responds to the PING request with a packet that contains the address of the coordinator node and its own address. C=coordinator’s address and A=own address. If no nodes respond to the PING request, the joining node becomes the coordinator node in a new cluster.

**PING configuration example**

```xml
<PING num_discovery_runs="3"/>
```

Additional resources

- JGroups PING

### 6.2.2. TCPPING

TCPPING is a generic JGroups discovery mechanism that uses a list of static addresses for cluster members.

With TCPPING, you manually specify the IP address or hostname of each node in the Data Grid cluster as part of the JGroups stack, rather than letting nodes discover each other dynamically.

**TCPPING configuration example**

```xml
<TCP bind_port="7800"/>
<TCPPING timeout="3000"
    initial_hosts="${jgroups.tcpping.initial_hosts:hostname1[port1],hostname2[port2]}"
```
MPING uses IP multicast to discover the initial membership of Data Grid clusters.

You can use MPING to replace TCPPING discovery with TCP stacks and use multicasing for discovery instead of static lists of initial hosts. However, you can also use MPING with UDP stacks.

**MPING configuration example**

```
<MPING mcast_addr="${jgroups.mcast_addr:228.6.7.8}" 
mcast_port="${jgroups.mcast_port:46655}" 
num_discovery_runs="3" 
ip_ttl="${jgroups.udp.ip_ttl:2}"/>
```

**Additional resources**
- JGroups MPING

### 6.2.4. TCPOSOSSIP

Gossip routers provide a centralized location on the network from which your Data Grid cluster can retrieve addresses of other nodes.

You inject the address (IP:PORT) of the Gossip router into Data Grid nodes as follows:

1. Pass the address as a system property to the JVM; for example, `-DGossipRouterAddress="10.10.2.4[12001]"`.
2. Reference that system property in the JGroups configuration file.

**Gossip router configuration example**

```
<TCP bind_port="7800" />
<TCPOSOSSIP timeout="3000" 
    initial_hosts="${GossipRouterAddress}" 
    num_initial_members="3" /> 
```

**Additional resources**
- JGroups Gossip Router

### 6.2.5. JDBC_PING

JDBC_PING uses shared databases to store information about Data Grid clusters. This protocol supports any database that can use a JDBC connection.
Nodes write their IP addresses to the shared database so joining nodes can find the Data Grid cluster on the network. When nodes leave Data Grid clusters, they delete their IP addresses from the shared database.

**JDBC_PING configuration example**

```xml
<jDBC_PING connection_url="jdbc:mysql://localhost:3306/database_name"
    connection_username="user"
    connection_password="password"
    connection_driver="com.mysql.jdbc.Driver"/>
```

**IMPORTANT**
Add the appropriate JDBC driver to the classpath so Data Grid can use JDBC_PING.

Additional resources
- JDBC_PING
- JDBC_PING Wiki

### 6.2.6. DNS_PING

JGroups DNS_PING queries DNS servers to discover Data Grid cluster members in Kubernetes environments such as OKD and Red Hat OpenShift.

**DNS_PING configuration example**

```xml
<dns.DNS_PING dns_query="myservice.myproject.svc.cluster.local"/>
```

Additional resources
- JGroups DNS_PING
- DNS for Services and Pods (Kubernetes documentation for adding DNS entries)

### 6.2.7. Cloud Discovery Protocols

Data Grid includes default JGroups stacks that use discovery protocol implementations that are specific to cloud providers.

<table>
<thead>
<tr>
<th>Discovery protocol</th>
<th>Default stack file</th>
<th>Artifact</th>
<th>Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>NATIVE_S3_PING</td>
<td>default-jgroups-ec2.xml</td>
<td>org.jgroups.aws.s3:native-s3-ping</td>
<td>1.0.0.Final</td>
</tr>
<tr>
<td>GOOGLE_PING2</td>
<td>default-jgroups-google.xml</td>
<td>org.jgroups.google:jgroups-google</td>
<td>1.0.0.Final</td>
</tr>
<tr>
<td>AZURE_PING</td>
<td>default-jgroups-azure.xml</td>
<td>org.jgroups.azure:jgroups-azure</td>
<td>1.3.0.Final</td>
</tr>
</tbody>
</table>
Providing Dependencies for Cloud Discovery Protocols
To use NATIVE_S3_PING, GOOGLE_PING2, or AZURE_PING cloud discovery protocols, you need to provide dependent libraries to Data Grid.

Procedure

- Add the artifact dependencies to your project pom.xml.

You can then configure the cloud discovery protocol as part of a JGroups stack file or with system properties.

Additional resources

- JGroups NATIVE_S3_PING
- JGroups GOOGLE_PING2
- JGroups AZURE_PING

6.3. USING THE DEFAULT JGROUPS STACKS

Data Grid uses JGroups protocol stacks so nodes can send each other messages on dedicated cluster channels.

Data Grid provides preconfigured JGroups stacks for UDP and TCP protocols. You can use these default stacks as a starting point for building custom cluster transport configuration that is optimized for your network requirements.

Procedure

Do one of the following to use one of the default JGroups stacks:

- Use the **stack** attribute in your **infinispan.xml** file.

```xml
<infinispan>
  <cache-container default-cache="replicatedCache">
    <!-- Use the default UDP stack for cluster transport. -->
    <transport cluster="${infinispan.cluster.name}" stack="udp" node-name="${infinispan.node.name:}"/>
  </cache-container>
</infinispan>
```

- Use the **addProperty()** method to set the JGroups stack file:

```java
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder().transport()
  .defaultTransport()
  .clusterName("qa-cluster")
  //Uses the default-jgroups-udp.xml stack for cluster transport.
  .addProperty("configurationFile", "default-jgroups-udp.xml")
  .build();
```

Verification

Data Grid logs the following message to indicate which stack it uses:
[org.infinispan.CLUSTER] ISPN000078: Starting JGroups channel cluster with stack udp

Additional resources
- JGroups cluster transport configuration for Data Grid 8.x (Red Hat knowledgebase article)

6.4. CUSTOMIZING JGROUPS STACKS

Adjust and tune properties to create a cluster transport configuration that works for your network requirements.

Data Grid provides attributes that let you extend the default JGroups stacks for easier configuration. You can inherit properties from the default stacks while combining, removing, and replacing other properties.

Procedure

2. Add the `extends` attribute and specify a JGroups stack to inherit properties from.
3. Use the `stack.combine` attribute to modify properties for protocols configured in the inherited stack.
4. Use the `stack.position` attribute to define the location for your custom stack.
5. Specify the stack name as the value for the `stack` attribute in the `transport` configuration. For example, you might evaluate using a Gossip router and symmetric encryption with the default TCP stack as follows:

```
<infinispan>
  <jgroups>
    <!-- Creates a custom JGroups stack named “my-stack”. -->
    <!-- Inherits properties from the default TCP stack. -->
    <stack name="my-stack" extends="tcp">
      <!-- Uses TCPGOSSIP as the discovery mechanism instead of MPING -->
      <TCPGOSSIP initial_hosts="${jgroups.tunnel.gossip_router_hosts:localhost[12001]}">
        stack.combine="REPLACE"
        stack.position="MPING" />
      <!-- Removes the FD_SOCK protocol from the stack. -->
      <FD_SOCK stack.combine="REMOVE" />
      <!-- Modifies the timeout value for the VERIFY_SUSPECT protocol. -->
      <VERIFY_SUSPECT timeout="2000"/> 
      <!-- Adds SYM_ENCRYPT to the stack after VERIFY_SUSPECT. -->
      <SYM_ENCRYPT sym_algorithm="AES"
        keystore_name="mykeystore.p12"
        keystore_type="PKCS12"
        store_password="changeit"
        key_password="changeit"
        alias="myKey"
        stack.combine="INSERT_AFTER"
        stack.position="VERIFY_SUSPECT" />
    </stack>
  </jgroups>
  <cache-container name="default" statistics="true">
```

```
6. Check Data Grid logs to ensure it uses the stack.

```
[org.infinispan.CLUSTER] ISPN000078: Starting JGroups channel cluster with stack my-stack
```

Reference

- JGroups cluster transport configuration for Data Grid 8.x  (Red Hat knowledgebase article)

### 6.4.1. Inheritance Attributes

When you extend a JGroups stack, inheritance attributes let you adjust protocols and properties in the stack you are extending.

- **stack.position** specifies protocols to modify.
- **stack.combine** uses the following values to extend JGroups stacks:

<table>
<thead>
<tr>
<th>Value</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>COMBINE</td>
<td>Overrides protocol properties.</td>
</tr>
<tr>
<td>REPLACE</td>
<td>Replaces protocols.</td>
</tr>
<tr>
<td>INSERT_AFTER</td>
<td>Adds a protocol into the stack after another protocol. Does not affect the protocol that you specify as the insertion point. Protocols in JGroups stacks affect each other based on their location in the stack. For example, you should put a protocol such as NAKACK2 after the SYM_ENCRYPT or ASYM_ENCRYPT protocol so that NAKACK2 is secured.</td>
</tr>
<tr>
<td>INSERT_BEFORE</td>
<td>Inserts a protocols into the stack before another protocol. Affects the protocol that you specify as the insertion point.</td>
</tr>
<tr>
<td>REMOVE</td>
<td>Removes protocols from the stack.</td>
</tr>
</tbody>
</table>

### 6.5. USING JGROUPS SYSTEM PROPERTIES

Pass system properties to Data Grid at startup to tune cluster transport.

**Procedure**
Use `-D<property-name>=<property-value>` arguments to set JGroups system properties as required.

For example, set a custom bind port and IP address as follows:

```
$ java -cp ... -Djgroups.bind.port=1234 -Djgroups.bind.address=192.0.2.0
```

**NOTE**

When you embed Data Grid clusters in clustered Red Hat JBoss EAP applications, JGroups system properties can clash or override each other.

For example, you do not set a unique bind address for either your Data Grid cluster or your Red Hat JBoss EAP application. In this case both Data Grid and your Red Hat JBoss EAP application use the JGroups default property and attempt to form clusters using the same bind address.

### 6.5.1. Cluster Transport Properties

Use the following properties to customize JGroups cluster transport.

<table>
<thead>
<tr>
<th>System Property</th>
<th>Description</th>
<th>Default Value</th>
<th>Required/Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>jgroups.bind.address</td>
<td>Bind address for cluster transport.</td>
<td>SITE_LOCAL</td>
<td>Optional</td>
</tr>
<tr>
<td>jgroups.bind.port</td>
<td>Bind port for the socket.</td>
<td>7800</td>
<td>Optional</td>
</tr>
<tr>
<td>jgroups.multicast_addr</td>
<td>IP address for multicast, both discovery and inter-cluster communication.</td>
<td>228.6.7.8</td>
<td>Optional</td>
</tr>
<tr>
<td></td>
<td>The IP address must be a valid &quot;class D&quot; address that is suitable for IP multicast.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>jgroups.multicast_port</td>
<td>Port for the multicast socket.</td>
<td>46655</td>
<td>Optional</td>
</tr>
<tr>
<td>jgroups.ip_ttl</td>
<td>Time-to-live (TTL) for IP multicast packets. The value defines the number of network hops a packet can make before it is dropped.</td>
<td>2</td>
<td>Optional</td>
</tr>
<tr>
<td>jgroups.thread_pool.min_threads</td>
<td>Minimum number of threads for the thread pool.</td>
<td>0</td>
<td>Optional</td>
</tr>
<tr>
<td>System Property</td>
<td>Description</td>
<td>Default Value</td>
<td>Required/Optional</td>
</tr>
<tr>
<td>---------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>---------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>jgroups.thread_pool.max_threads</td>
<td>Maximum number of threads for the thread pool.</td>
<td>200</td>
<td>Optional</td>
</tr>
<tr>
<td>jgroups.join_timeout</td>
<td>Maximum number of milliseconds to wait for join requests to succeed.</td>
<td>2000</td>
<td>Optional</td>
</tr>
<tr>
<td>jgroups.thread_dumps_threshold</td>
<td>Number of times a thread pool needs to be full before a thread dump is logged.</td>
<td>10000</td>
<td>Optional</td>
</tr>
</tbody>
</table>

Reference

- JGroups System Properties
- JGroups Protocol List

6.5.2. System Properties for Cloud Discovery Protocols

Use the following properties to configure JGroups discovery protocols for hosted platforms.

6.5.2.1. Amazon EC2

System properties for configuring **NATIVE_S3_PING**.

<table>
<thead>
<tr>
<th>System Property</th>
<th>Description</th>
<th>Default Value</th>
<th>Required/Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>jgroups.s3.region_name</td>
<td>Name of the Amazon S3 region.</td>
<td>No default value.</td>
<td>Optional</td>
</tr>
<tr>
<td>jgroups.s3.bucket_name</td>
<td>Name of the Amazon S3 bucket. The name must exist and be unique.</td>
<td>No default value.</td>
<td>Optional</td>
</tr>
</tbody>
</table>

6.5.2.2. Google Cloud Platform

System properties for configuring **GOOGLE_PING2**.
<table>
<thead>
<tr>
<th>System Property</th>
<th>Description</th>
<th>Default Value</th>
<th>Required/Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>jgroups.google.bucket_name</td>
<td>Name of the Google Compute Engine bucket. The name must exist and be unique.</td>
<td>No default value.</td>
<td>Required</td>
</tr>
</tbody>
</table>

### 6.5.2.3. Azure

System properties for **AZURE_PING**.

<table>
<thead>
<tr>
<th>System Property</th>
<th>Description</th>
<th>Default Value</th>
<th>Required/Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>jboss.jgroups.azure_ping.storage_account_name</td>
<td>Name of the Azure storage account. The name must exist and be unique.</td>
<td>No default value.</td>
<td>Required</td>
</tr>
<tr>
<td>jboss.jgroups.azure_ping.storage_access_key</td>
<td>Name of the Azure storage access key.</td>
<td>No default value.</td>
<td>Required</td>
</tr>
<tr>
<td>jboss.jgroups.azure_ping.container</td>
<td>Valid DNS name of the container that stores ping information.</td>
<td>No default value.</td>
<td>Required</td>
</tr>
</tbody>
</table>

### 6.5.2.4. OpenShift

System properties for **DNS_PING**.

<table>
<thead>
<tr>
<th>System Property</th>
<th>Description</th>
<th>Default Value</th>
<th>Required/Optional</th>
</tr>
</thead>
<tbody>
<tr>
<td>jgroups.dns.query</td>
<td>Sets the DNS record that returns cluster members.</td>
<td>No default value.</td>
<td>Required</td>
</tr>
</tbody>
</table>

### 6.6. USING INLINE JGROUPS STACKS

You can insert complete JGroups stack definitions into `infinispan.xml` files.

Procedure
Embed a custom JGroups stack declaration in your `infinispan.xml` file.

```xml
<infinispan>
  <!-- Contains one or more JGroups stack definitions. -->
  <jgroups>
    <!-- Defines a custom JGroups stack named "prod". -->
    <stack name="prod">
      <TCP bind_port="7800" port_range="30" recv_buf_size="20000000"
        send_buf_size="640000"/>
      <MPING break_on_coord_rsp="true"
        mcast_addr="${jgroups.mping.mcast_addr:228.2.4.6}" mcast_port="${jgroups.mping.mcast_port:43366}"
        num_discovery_runs="3"
        ip_ttl="${jgroups.udp.ip_ttl:2}"/>
    </stack>
  </jgroups>
  <!-- Creates a "prod-tcp" stack that references an external file. -->
  <stack-file name="prod-tcp" path="prod-jgroups-tcp.xml"/>
</infinispan>

6.7. USING EXTERNAL JGROUPS STACKS

Reference external files that define custom JGroups stacks in `infinispan.xml` files.

**Procedure**

1. Put custom JGroups stack files on the application classpath. Alternatively you can specify an absolute path when you declare the external stack file.

2. Reference the external stack file with the `stack-file` element.

```xml
<infinispan>
  <jgroups>
    <!-- Creates a "prod-tcp" stack that references an external file. -->
    <stack-file name="prod-tcp" path="prod-jgroups-tcp.xml"/>
  </jgroups>
</infinispan>
```
You can also use the `addProperty()` method in the `TransportConfigurationBuilder` class to specify a custom JGroups stack file as follows:

```java
GlobalConfiguration globalConfig = new GlobalConfigurationBuilder().transport()
    .defaultTransport()
    .clusterName("prod-cluster")
    //Uses a custom JGroups stack for cluster transport.
    .addProperty("configurationFile", "my-jgroups-udp.xml")
    .build();
```

In this example, `my-jgroups-udp.xml` references a UDP stack with custom properties such as the following:

**Custom UDP stack example**

```xml
<config xmlns="urn:org:jgroups"
    xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
    xsi:schemaLocation="urn:org:jgroups http://www.jgroups.org/schema/jgroups-4.2.xsd">
  <UDP bind_addr="${jgroups.bind_addr:127.0.0.1}"
    mcast_addr="${jgroups.udp.mcast_addr:192.0.2.0}"
    mcast_port="${jgroups.udp.mcast_port:46655}"
    tos="8"
    ucast_recv_buf_size="20000000"
    ucast_send_buf_size="640000"
    mcast_recv_buf_size="25000000"
    mcast_send_buf_size="640000"
    max_bundle_size="64000"
    ip_ttl="${jgroups.udp.ip_ttl:2}"
    enable_diagnostics="false"
    thread_naming_pattern="pl"
    thread_pool.enabled="true"
    thread_pool.min_threads="2"
    thread_pool.max_threads="30"
    thread_pool.keep_alive_time="5000" />
  <!-- Other JGroups stack configuration goes here. -->
</config>
```

Additional resources
- [org.infinispan.configuration.global.TransportConfigurationBuilder](http://jgroups.infinispan.org/config.html)

### 6.8. USING CUSTOM JCHANNELS

Construct custom JGroups JChannels as in the following example:
NOTE
Data Grid cannot use custom JChannels that are already connected.

Reference
JGroups JChannel

6.9. ENCRYPTING CLUSTER TRANSPORT

Secure cluster transport so that nodes communicate with encrypted messages. You can also configure Data Grid clusters to perform certificate authentication so that only nodes with valid identities can join.

6.9.1. Data Grid Cluster Security

To secure cluster traffic, you configure Data Grid nodes to encrypt JGroups message payloads with secret keys.

Data Grid nodes can obtain secret keys from either:

- The coordinator node (asymmetric encryption).
- A shared keystore (symmetric encryption).

Retrieving secret keys from coordinator nodes

You configure asymmetric encryption by adding the ASYM_ENCRYPT protocol to a JGroups stack in your Data Grid configuration. This allows Data Grid clusters to generate and distribute secret keys.

IMPORTANT
When using asymmetric encryption, you should also provide keystores so that nodes can perform certificate authentication and securely exchange secret keys. This protects your cluster from man-in-the-middle (MitM) attacks.

Asymmetric encryption secures cluster traffic as follows:

1. The first node in the Data Grid cluster, the coordinator node, generates a secret key.
2. A joining node performs certificate authentication with the coordinator to mutually verify identity.
3. The joining node requests the secret key from the coordinator node. That request includes the public key for the joining node.
4. The coordinator node encrypts the secret key with the public key and returns it to the joining node.
5. The joining node decrypts and installs the secret key.

6. The node joins the cluster, encrypting and decrypting messages with the secret key.

**Retrieving secret keys from shared keystores**

You configure symmetric encryption by adding the `SYM_ENCRYPT` protocol to a JGroups stack in your Data Grid configuration. This allows Data Grid clusters to obtain secret keys from keystores that you provide.

1. Nodes install the secret key from a keystore on the Data Grid classpath at startup.

2. Node join clusters, encrypting and decrypting messages with the secret key.

**Comparison of asymmetric and symmetric encryption**

`ASYM_ENCRYPT` with certificate authentication provides an additional layer of encryption in comparison with `SYM_ENCRYPT`. You provide keystores that encrypt the requests to coordinator nodes for the secret key. Data Grid automatically generates that secret key and handles cluster traffic, while letting you specify when to generate secret keys. For example, you can configure clusters to generate new secret keys when nodes leave. This ensures that nodes cannot bypass certificate authentication and join with old keys.

`SYM_ENCRYPT`, on the other hand, is faster than `ASYM_ENCRYPT` because nodes do not need to exchange keys with the cluster coordinator. A potential drawback to `SYM_ENCRYPT` is that there is no configuration to automatically generate new secret keys when cluster membership changes. Users are responsible for generating and distributing the secret keys that nodes use to encrypt cluster traffic.

**6.9.2. Configuring Cluster Transport with Asymmetric Encryption**

Configure Data Grid clusters to generate and distribute secret keys that encrypt JGroups messages.

**Procedure**

1. Create a keystore with certificate chains that enables Data Grid to verify node identity.

2. Place the keystore on the classpath for each node in the cluster.
   For Data Grid Server, you put the keystore in the `$RHDG_HOME` directory.

3. Add the `SSL_KEY_EXCHANGE` and `ASYM_ENCRYPT` protocols to a JGroups stack in your Data Grid configuration, as in the following example:

```xml
<infinispan>
  <jgroups>
    <!-- Creates a secure JGroups stack named "encrypt-tcp" that extends the default TCP stack. -->
    <stack name="encrypt-tcp" extends="tcp">
      <!-- Adds a keystore that nodes use to perform certificate authentication. -->
      <!-- Uses the stack.combine and stack.position attributes to insert SSL_KEY_EXCHANGE into the default TCP stack after VERIFY_SUSPECT. -->
      <SSL_KEY_EXCHANGE keystore_name="mykeystore.jks"
                        keystore_password="changeit"
                        stack.combine="INSERT_AFTER"
                        stack.position="VERIFY_SUSPECT"/>
      <!-- Configures ASYM_ENCRYPT -->
      <!-- Uses the stack.combine and stack.position attributes to insert ASYM_ENCRYPT into the default TCP stack before pbcast.NAKACK2. -->
```

```xml
```
Verification

When you start your Data Grid cluster, the following log message indicates that the cluster is using the secure JGroups stack:

```
<org.infinispan.CLUSTER] ISPN000078: Starting JGroups channel cluster with stack
<encrypted_stack_name>
```

Data Grid nodes can join the cluster only if they use `ASYM_ENCRYPT` and can obtain the secret key from the coordinator node. Otherwise the following message is written to Data Grid logs:

```
[org.jgroups.protocols.ASYM_ENCRYPT] <hostname>: received message without encrypt header from <hostname>; dropping it
```

Reference

The example `ASYM_ENCRYPT` configuration in this procedure shows commonly used parameters. Refer to JGroups documentation for the full set of available parameters.

- JGroups 4 Manual
- JGroups 4.2 Schema

6.9.3. Configuring Cluster Transport with Symmetric Encryption

Configure Data Grid clusters to encrypt JGroups messages with secret keys from keystores that you provide.

Procedure

1. Create a keystore that contains a secret key.

2. Place the keystore on the classpath for each node in the cluster.
   For Data Grid Server, you put the keystore in the `$RHDG_HOME` directory.

3. Add the `SYM_ENCRYPT` protocol to a JGroups stack in your Data Grid configuration.
<infinispan>
  <jgroups>
    <!-- Creates a secure JGroups stack named "encrypt-tcp" that extends the default TCP stack. -->
    <stack name="encrypt-tcp" extends="tcp">
      <!-- Adds a keystore from which nodes obtain secret keys. -->
      <!-- Uses the stack.combine and stack.position attributes to insert SYM_ENCRYPT into the
      default TCP stack after VERIFY_SUSPECT. -->
      <SYM_ENCRYPT keystore_name="myKeystore.p12"
                    keystore_type="PKCS12"
                    store_password="changeit"
                    key_password="changeit"
                    alias="myKey"
                    stack.combine="INSERT_AFTER"
                    stack.position="VERIFY_SUSPECT"/>
    </stack>
  </jgroups>
  <cache-container name="default" statistics="true">
    <!-- Configures the cluster to use the JGroups stack. -->
    <transport cluster="${infinispan.cluster.name}" stack="encrypt-tcp"
               node-name="${infinispan.node.name:}"/>
  </cache-container>
</infinispan>

Verification

When you start your Data Grid cluster, the following log message indicates that the cluster is using the secure JGroups stack:

```
[org.infinispan.CLUSTER] ISPN000078: Starting JGroups channel cluster with stack
<encrypted_stack_name>
```

Data Grid nodes can join the cluster only if they use SYM_ENCRYPT and can obtain the secret key from the shared keystore. Otherwise the following message is written to Data Grid logs:

```
[org.jgroups.protocols.SYM_ENCRYPT] <hostname>: received message without encrypt header from
<hostname>; dropping it
```

Reference

The example SYM_ENCRYPT configuration in this procedure shows commonly used parameters. Refer to JGroups documentation for the full set of available parameters.

- JGroups 4 Manual
- JGroups 4.2 Schema

6.10. TCP AND UDP PORTS FOR CLUSTER TRAFFIC

Data Grid uses the following ports for cluster transport messages:
<table>
<thead>
<tr>
<th>Default Port</th>
<th>Protocol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>7800</td>
<td>TCP/UDP</td>
<td>JGroups cluster bind port</td>
</tr>
<tr>
<td>46655</td>
<td>UDP</td>
<td>JGroups multicast</td>
</tr>
</tbody>
</table>

**Cross-Site Replication**

Data Grid uses the following ports for the JGroups RELAY2 protocol:

**7900**

- For Data Grid clusters running on OpenShift.

**7800**

- If using UDP for traffic between nodes and TCP for traffic between clusters.

**7801**

- If using TCP for traffic between nodes and TCP for traffic between clusters.