Red Hat build of Quarkus 1.11

Compiling your Quarkus applications to native executables
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Abstract

This guide shows you how to compile the Quarkus Getting Started project into a native executable and how to configure and test the native executable.
# Table of Contents

- **PREFACE** .......................................................... 3
- **PROVIDING FEEDBACK ON RED HAT DOCUMENTATION** ........................................... 4
- **MAKING OPEN SOURCE MORE INCLUSIVE** ................................................................. 5
- **CHAPTER 1. PRODUCING A NATIVE EXECUTABLE** ....................................................... 6
- **CHAPTER 2. CREATING A CUSTOM CONTAINER IMAGE** .............................................. 8
  - 2.1. CREATING A CONTAINER MANUALLY ...................................................................... 8
  - 2.2. CREATING A CONTAINER USING THE OPENSHIFT DOCKER BUILD ......................... 9
- **CHAPTER 3. NATIVE EXECUTABLE CONFIGURATION PROPERTIES** ............................. 11
  - 3.1. CONFIGURING MEMORY CONSUMPTION FOR QUARKUS NATIVE COMPILATION .......... 14
- **CHAPTER 4. TESTING THE NATIVE EXECUTABLE** ....................................................... 16
  - 4.1. EXCLUDING TESTS WHEN RUNNING AS A NATIVE EXECUTABLE ............................ 17
  - 4.2. TESTING AN EXISTING NATIVE EXECUTABLE ...................................................... 18
- **CHAPTER 5. ADDITIONAL RESOURCES** ...................................................................... 19
As an application developer, you can use Red Hat build of Quarkus to create microservices written in Java that run on OpenShift and serverless environments. Applications compiled to native executables have small memory footprints and fast startup times.

This guide shows you how to compile the Quarkus Getting Started project into a native executable and how to configure and test the native executable. You will need the application created in *Getting started with Quarkus*.

**Building a native executable with Red Hat build of Quarkus covers:**

- Building a native executable with a single command using a container runtime such as Podman or Docker
- Creating a custom container image using the produced native executable
- Creating a container image using the OpenShift Docker build strategy
- Deploying the Quarkus native application to OpenShift
- Configuring the native executable
- Testing the native executable

**Prerequisites**

- Have OpenJDK (JDK) 11 installed and the `JAVA_HOME` environment variable set to specify the location of the Java SDK.
  - Log in to the Red Hat Customer Portal to download Red Hat build of Open JDK from the [Software Downloads](#) page.
- An OCI (Open Container Initiative) compatible container runtime, such as Podman or Docker.
- A completed Quarkus Getting Started project.
  - To learn how to build the Quarkus Getting Started project, see *Getting started with Quarkus*.
  - Alternatively, you can download the [*Quarkus quickstart archive*](#) or clone the [*Quarkus Quickstarts*](#) Git repository. The sample project is in the `getting-started` directory.
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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. PRODUCING A NATIVE EXECUTABLE

You can produce a native executable from your Quarkus application using a container runtime such as Podman or Docker. Quarkus produces a binary executable using a builder image, which you can use together with the Red Hat Universal Base Images RHEL8-UBI and RHEL8-UBI minimal. Red Hat build of Quarkus 1.11 uses registry.access.redhat.com/quarkus/mandrel-20-rhel8:20.3 as a default for the quarkus.native.builder-image property.

The native executable for your application contains the application code, required libraries, Java APIs, and a reduced version of a virtual machine (VM). The smaller VM base improves the startup time of the application and produces a minimal disk footprint.

Procedure

1. Open the Getting Started project pom.xml file and verify that it includes the native profile:

   ```xml
   <profiles>
     <profile>
       <id>native</id>
       <properties>
         <quarkus.package.type>native</quarkus.package.type>
       </properties>
     </profile>
   </profiles>
   ```

   **NOTE**
   Using Quarkus native profile allows you to run both the native executable and the native image tests.

2. Build a native executable using one of the following methods:
   
   a. Build a native executable with Docker:

   ```
   ./mvnw package -Pnative -Dquarkus.native.container-build=true
   ```

   b. Build a native executable with Podman:

   ```
   ./mvnw package -Pnative -Dquarkus.native.container-build=true -Dquarkus.native.container-runtime=podman
   ```

   These commands create the getting-started-*-runner binary in the target directory.

   **IMPORTANT**
   Compiling a Quarkus application to a native executable consumes a lot of memory during analysis and optimization. You can limit the amount of memory used during native compilation by setting the quarkus.native.native-image-xmx configuration property. Setting low memory limits might increase the build time. For more details, refer to Native executable configuration properties.

3. Run the native executable:
When you build the native executable the `prod` profile is enabled and the Quarkus native tests run using the `prod` profile. You can change this using the `quarkus.test.native-image-profile` property.

```
./target/getting-started-*-runner
```
CHAPTER 2. CREATING A CUSTOM CONTAINER IMAGE

You can create a container image from your Quarkus application using one of the following methods:

- Creating a container manually
- Creating a container using the OpenShift Docker build

IMPORTANT

Compiling a Quarkus application to a native executable consumes a lot of memory during analysis and optimization. You can limit the amount of memory used during native compilation by setting the `quarkus.native.native-image-xmx` configuration property. Setting low memory limits might increase the build time.

2.1. CREATING A CONTAINER MANUALLY

This section shows you how to manually create a container image with your application for Linux X86_64. When you produce a native image using the Quarkus Native container it creates an executable that targets the Linux X86_64 operating system. If your host operating system is different from this, you will not be able to run the binary directly and you will need to create a container manually.

Your Quarkus Getting Started project includes a `Dockerfile.native` in the `src/main/docker` directory with the following content:

```
FROM registry.access.redhat.com/ubi8/ubi-minimal:8.3
WORKDIR /work/
RUN chown 1001 /work 
  && chmod "g+rwX" /work 
  && chown 1001:root /work
COPY --chown=1001:root target/*-runner /work/application
EXPOSE 8080
USER 1001
CMD ["./application", "-Dquarkus.http.host=0.0.0.0"]
```

UNIVERSAL BASE IMAGE (UBI)

The `Dockerfiles` use UBI as a base image. This base image was designed to work in containers. The `Dockerfiles` use the minimal version of the base image to reduce the size of the produced image.

Procedure

1. Build a native Linux executable using one of the following methods:
   a. Build a native executable with Docker:
      ```
      ./mvnw package -Pnative -Dquarkus.native.container-build=true
      ```
   b. Build a native executable with Podman:
2. Build the container image using one of the following methods:
   a. Build the container image with Docker:
      ```bash
docker build -f src/main/docker/Dockerfile.native -t quarkus-quickstart/getting-started .
      ```
   b. Build the container image with Podman
      ```bash
      podman build -f src/main/docker/Dockerfile.native -t quarkus-quickstart/getting-started .
      ```

3. Run the container:
   a. Run the container with Docker:
      ```bash
docker run -i --rm -p 8080:8080 quarkus-quickstart/getting-started
      ```
   b. Run the container with Podman:
      ```bash
      podman run -i --rm -p 8080:8080 quarkus-quickstart/getting-started
      ```

### 2.2. CREATING A CONTAINER USING THE OPENSSHIFT DOCKER BUILD

You can create a container image for your Quarkus application using the OpenShift Docker build strategy. This strategy creates a container using a build configuration in the cluster.

#### Prerequisites
- You have access to a Red Hat OpenShift Container Platform cluster and the latest version of the OpenShift CLI (oc) is installed. For information about installing oc, see the "Installing the CLI" section of the [Installing and configuring OpenShift Container Platform clusters](https://openshift.redhat.com) guide.
- A URL for the OpenShift API endpoint.

#### Procedure
1. Log in to the OpenShift CLI:
   ```bash
   oc login -u <username_url>
   ```
2. Create a new project in OpenShift:
   ```bash
   oc new-project <project_name>
   ```
3. Create a build config based on the `src/main/docker/Dockerfile.native` file:
   ```bash
   cat src/main/docker/Dockerfile.native | oc new-build --name <build_name> --strategy=docker --dockerfile -
   ```
4. Build the project:
5. Deploy the project to OpenShift:
   ```bash
   oc new-app <build_name>
   ```

6. Expose the services:
   ```bash
   oc expose svc/<build_name>
   ```
CHAPTER 3. NATIVE EXECUTABLE CONFIGURATION PROPERTIES

Configuration properties define how the native executable is generated. You can configure your Quarkus application using the `application.properties` file.

Configuration properties

The following table lists the configuration properties that you can set to define how the native executable is generated:

<table>
<thead>
<tr>
<th>Property</th>
<th>Description</th>
<th>Type</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>quarkus.native.additional-build-args</code></td>
<td>Additional arguments to pass to the build process.</td>
<td>list of string</td>
<td></td>
</tr>
<tr>
<td><code>quarkus.native.enable-http-url-handler</code></td>
<td>Enables HTTP URL handler. This allows you to do <code>URL.openConnection()</code> for HTTP URLs.</td>
<td>boolean</td>
<td>true</td>
</tr>
<tr>
<td><code>quarkus.native.enable-https-url-handler</code></td>
<td>Enables HTTPS URL handler. This allows you to do <code>URL.openConnection()</code> for HTTPS URLs.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td><code>quarkus.native.enable-all-security-services</code></td>
<td>Adds all security services to the native image.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td><code>quarkus.native.add-all-charsets</code></td>
<td>Adds all character sets to the native image. This increases image size.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td><code>quarkus.native.graalvm-home</code></td>
<td>Contains the path of the Graal distribution.</td>
<td>string</td>
<td><code>${GRAALVM_HOME:}</code></td>
</tr>
<tr>
<td><code>quarkus.native.java-home</code></td>
<td>Contains the path of the JDK.</td>
<td>File</td>
<td><code>${java.home}</code></td>
</tr>
<tr>
<td><code>quarkus.native.native-image-xmx</code></td>
<td>The maximum Java heap used to generate the native image.</td>
<td>string</td>
<td></td>
</tr>
<tr>
<td><code>quarkus.native.debug-build-process</code></td>
<td>Waits for a debugger to attach to the build process before running the native image build. This is an advanced option for those familiar with GraalVM internals.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td><code>quarkus.native.publish-debug-build-process-port</code></td>
<td>Publishes the debug port when building with docker and debug-build-process is true.</td>
<td>boolean</td>
<td>true</td>
</tr>
<tr>
<td>Property</td>
<td>Description</td>
<td>Type</td>
<td>Default</td>
</tr>
<tr>
<td>---------------------------------------</td>
<td>-----------------------------------------------------------------------------</td>
<td>-----------</td>
<td>---------</td>
</tr>
<tr>
<td>quarkus.native.cleanup-server</td>
<td>restarts the native image server.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td>quarkus.native.enable-isolates</td>
<td>enables isolates to improve the memory management.</td>
<td>boolean</td>
<td>true</td>
</tr>
<tr>
<td>quarkus.native.enable-fallback-images</td>
<td>creates a JVM based fallback image if native image fails.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td>quarkus.native.enable-server</td>
<td>uses native image server. This can speed up compilation but can cause changes to drop due to cache invalidation issues.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td>quarkus.native.auto-service-loader-registration</td>
<td>automatically registers all META-INF/services entries.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td>quarkus.native.dump-proxies</td>
<td>dumps the bytecode of all proxies for inspection.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td>quarkus.native.container-build</td>
<td>builds using a container runtime. Docker is used by default.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td>quarkus.native.builder-image</td>
<td>the docker image to build the image.</td>
<td>string</td>
<td>registry.access.redhat.com/qua rkus/mandrel-20-rhel8:20.3</td>
</tr>
<tr>
<td>quarkus.native.container-runtime</td>
<td>the container runtime used build the image. For example, Docker.</td>
<td>string</td>
<td></td>
</tr>
<tr>
<td>quarkus.native.container-runtime-options</td>
<td>options to pass to the container runtime.</td>
<td>list of string</td>
<td></td>
</tr>
<tr>
<td>quarkus.native.enable-vm-inspection</td>
<td>enables VM introspection in the image.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td>quarkus.native.full-stack-traces</td>
<td>enables full stack traces in the image.</td>
<td>boolean</td>
<td>true</td>
</tr>
<tr>
<td>quarkus.native.enable-reports</td>
<td>generates reports on call paths and included packages/classes/methods.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td>quarkus.native.report-exception-stack-traces</td>
<td>reports exceptions with a full stack trace.</td>
<td>boolean</td>
<td>true</td>
</tr>
<tr>
<td>Property</td>
<td>Description</td>
<td>Type</td>
<td>Default</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
<td>-------</td>
<td>---------</td>
</tr>
<tr>
<td><code>quarkus.native.report-errors-at-runtime</code></td>
<td>Reports errors at runtime. This may cause your application to fail at runtime if you are using unsupported feature.</td>
<td>boolean</td>
<td>false</td>
</tr>
<tr>
<td><code>quarkus.native.resources.includes</code></td>
<td>A comma separated list of globs to match resource paths that should be added to the native image. Use slash (/) as a path separator on all platforms. Globs must not start with slash. For example you have <code>src/main/resources/ignored.png</code> and <code>src/main/resources/foo/selected.png</code> in your source tree and one of your dependency JARs contains <code>bar/some.txt</code> file, with the following configuration <code>quarkus.native.resources.includes = foo/,bar/*.*.txt</code> the files <code>src/main/resources/foo/selected.png</code> and <code>bar/some.txt</code> will be included in the native image, while <code>src/main/resources/ignored.png</code> will not be included. To find out more about the glob features see the <a href="#">Supported glob features and its description.</a></td>
<td>list of</td>
<td>string</td>
</tr>
<tr>
<td><code>quarkus.native.debug.enabled</code></td>
<td>Enables debug and generates debug symbols in a separate .debug file. When used with <code>quarkus.native.container-build</code>, Red Hat build of Quarkus only supports Red Hat Enterprise Linux or other Linux distributions as they contain the <code>binutils</code> package that installs the <code>objcopy</code> utility to split the debug info from the native image.</td>
<td>boolean</td>
<td>false</td>
</tr>
</tbody>
</table>

**Supported glob features and its description**

The following table lists the supported glob features and its description:

<table>
<thead>
<tr>
<th>Character</th>
<th>Feature description</th>
</tr>
</thead>
<tbody>
<tr>
<td>*</td>
<td>Matches a possibly empty sequence of characters that does not contain slash (/).</td>
</tr>
</tbody>
</table>
** Matches a possibly empty sequence of characters that might contain slash (/).

? Matches one character, but not slash.

[abc] Matches one character from the range specified in the bracket, but not slash.

[a-zA-Z] Matches one character from the range specified in the bracket, but not slash.

![abc] Matches one character not specified in the bracket; does not match slash.

[a-zA-Z] Matches one character outside the range specified in the bracket; does not match slash.

{one,two,three} Matches any of the alternating tokens separated by comma; the tokens may contain wildcards, nested alternations and ranges.

\ The escape character. There are three levels of escaping: application.properties parser, MicroProfile Config list converter, and Glob parser. All three levels use the backslash as the escaping character.

### Additional resources

- [Configuring your Quarkus applications](#)

### 3.1. CONFIGURING MEMORY CONSUMPTION FOR QUARKUS NATIVE COMPILATION

Compiling a Quarkus application to a native executable consumes a lot of memory during analysis and optimization. You can limit the amount of memory used during native compilation by setting the `quarkus.native.native-image-xmx` configuration property. Setting low memory limits might increase the build time.

#### Procedure

- Use one of the following methods to set a value for the `quarkus.native.native-image-xmx` property to limit the memory consumption during the native image build time:
  
  - Using the `application.properties` file:
    ```
    quarkus.native.native-image-xmx=<maximum_memory>
    ```
  
  - Setting system properties:
    ```
    mvn -Pnative -Dquarkus.native.container-build=true -Dquarkus.native.native-image-xmx=<maximum_memory>
    ```

    This command builds the native executable with Docker. Add `-Dquarkus.native.container-runtime=podman` argument to use Podman.
NOTE

For example, to set the memory limit to 6 GB, enter `quarkus.native.native-image-xmx=6g`. The value must be a multiple of 1024 greater than 2MB. Append the letter m or M to indicate megabytes, or g or G to indicate gigabytes.
CHAPTER 4. TESTING THE NATIVE EXECUTABLE

Test the application running in the native mode to test the functionality of the native executable. Use `@NativeImageTest` annotation to build the native executable and run test against the http endpoints.

Procedure

1. Open the `pom.xml` file and verify that the `native` profile contains the following elements:

```xml
<plugin>
  <groupId>org.apache.maven.plugins</groupId>
  <artifactId>maven-failsafe-plugin</artifactId>
  <version>${surefire-plugin.version}</version>
  <executions>
    <execution>
      <goals>
        <goal>integration-test</goal>
        <goal>verify</goal>
      </goals>
      <configuration>
        <systemPropertyVariables>
          <native.image.path>${project.build.directory}/${project.build.finalName}-runner</native.image.path>
        </systemPropertyVariables>
      </configuration>
    </execution>
  </executions>
</plugin>
```

The `failsafe-maven-plugin` runs integration test and indicates the location of the produced native executable.

2. Open the `src/test/java/org/acme/quickstart/NativeGreetingResourceIT.java` file and verify that it includes the following content:

```java
package org.acme.quickstart;

import io.quarkus.test.junit.NativeImageTest;

@NativeImageTest
public class NativeGreetingResourceIT extends GreetingResourceTest {

  // Run the same tests

}
```

1. Use another test runner that starts the application from the native file before the tests. The executable is retrieved using the `native.image.path` system property configured in the Failsafe Maven Plugin.

2. This example extends the `GreetingResourceTest`, but you can also create a new test.
3. Run the test:

```bash
./mvnw verify -Pnative
```

The following example shows the output of this command:

```bash
./mvnw verify -Pnative
... 
[getting-started-1.0-SNAPSHOT-runner:18820] universe: 587.26 ms 
[getting-started-1.0-SNAPSHOT-runner:18820] (parse): 2,247.59 ms 
[getting-started-1.0-SNAPSHOT-runner:18820] (inline): 1,985.70 ms 
[getting-started-1.0-SNAPSHOT-runner:18820] (compile): 14,922.77 ms 
[getting-started-1.0-SNAPSHOT-runner:18820] compile: 20,361.28 ms 
[getting-started-1.0-SNAPSHOT-runner:18820] image: 2,228.30 ms 
[getting-started-1.0-SNAPSHOT-runner:18820] write: 364.35 ms 
[getting-started-1.0-SNAPSHOT-runner:18820] [total]: 52,777.76 ms 
INFO ] INFO] --- maven-failsafe-plugin:2.22.1:integration-test (default) @ getting-started --- 
INFO ] INFO] ------------------------------------------------------- 
INFO] T E S T S 
INFO] ------------------------------------------------------- 
INFO] Running org.acme.quickstart.NativeGreetingResourceIT 
Executing [/data/home/gsmet/git/quarkus-quickstarts/getting-started/target/getting-started- 
1.0-SNAPSHOT-runner, -Dquarkus.http.port=8081, -Dtest.url=http://localhost:8081, - 
Dquarkus.log.file.path=build/quarkus.log] 
2019-04-15 11:33:20,348 INFO [io.quarkus] (main) Quarkus 999-SNAPSHOT started in 
0.002s. Listening on: http://[::]:8081 
[INFO] Tests run: 2, Failures: 0, Errors: 0, Skipped: 0, Time elapsed: 1.387 s - in 
org.acme.quickstart.NativeGreetingResourceIT 
... 
```

**NOTE**

Quarkus waits for 60 seconds for the native image to start before automatically failing the native tests. You can change this duration using the `quarkus.test.native-image-wait-time` system property.

You can extend the wait time using the following command where `<duration>` is the wait time in seconds:

```bash
./mvnw verify -Pnative -Dquarkus.test.native-image-wait-time=<duration>
```

### 4.1. EXCLUDING TESTS WHEN RUNNING AS A NATIVE EXECUTABLE

When you run tests against your native application, you can only interact with its HTTP endpoints. Tests do not run natively, therefore they cannot link against your application’s code like they can when running on the JVM.

You can share your test class between JVM and native executions and exclude certain tests with the `@DisabledOnNativeImage` annotation to run them only on the JVM.
4.2. TESTING AN EXISTING NATIVE EXECUTABLE

You can test against the existing executable build. This allows you to run multiple sets of tests in stages on the binary after it has been built.

Procedure

- Run a test against an already built native executable:

  ```bash
  ./mvnw test-compile failsafe:integration-test
  ```

  This command runs the test against the existing native image using Failsafe Maven Plugin.

- Alternatively, you can specify the path to the native executable with the following command where `<path>` is the native image path:

  ```bash
  ./mvnw test-compile failsafe:integration-test -Dnative.image.path=<path>
  ```
CHAPTER 5. ADDITIONAL RESOURCES

- Testing your Quarkus applications
- Deploying your Quarkus applications to OpenShift
- Developing and compiling your Quarkus applications with Apache Maven
- Apache Maven Project
- The UBI Image Page
- The UBI-minimal Image Page
- The List of UBI-minimal Tags

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