What's "Native Java"?

A discussion based on the Quarkus native paradigm

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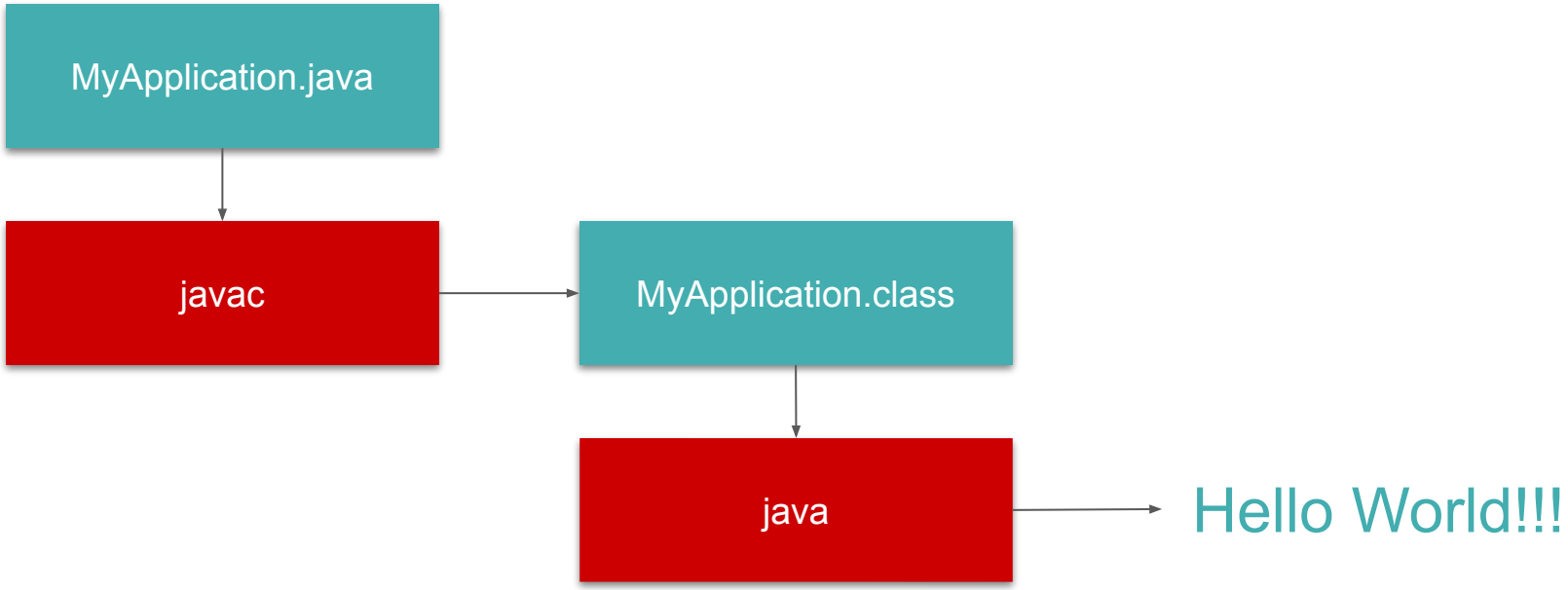
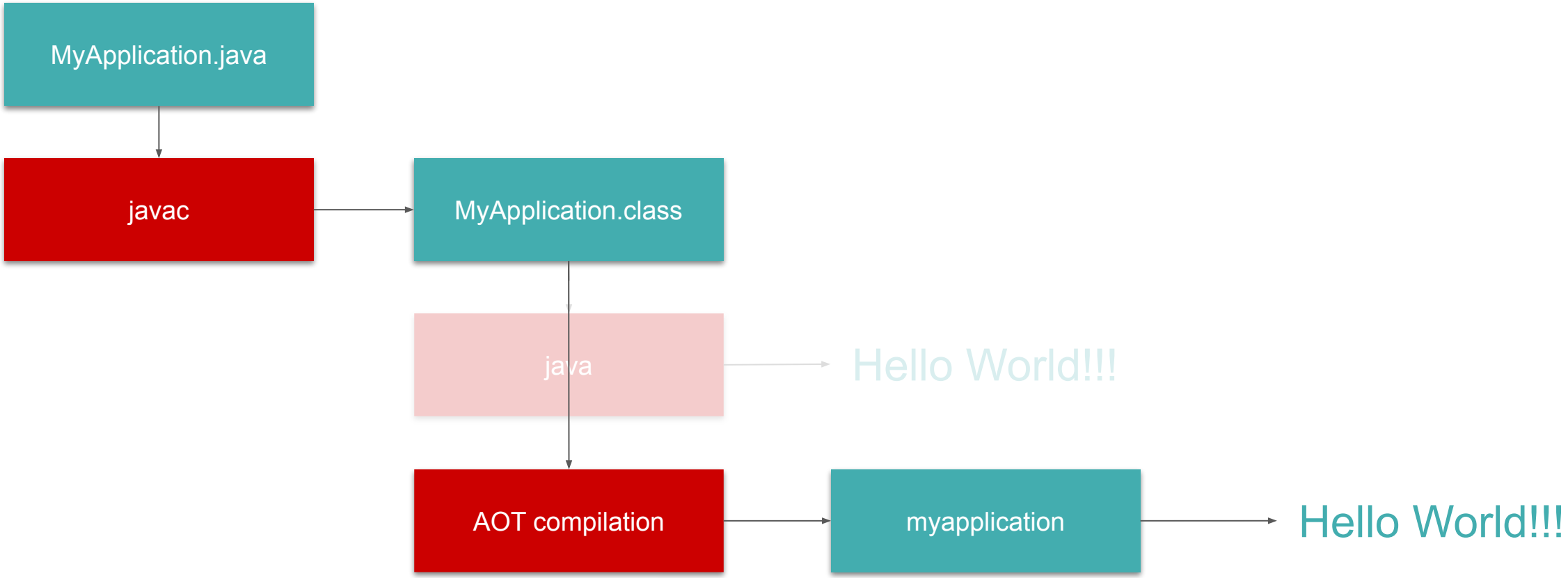
What is Quarkus Native?

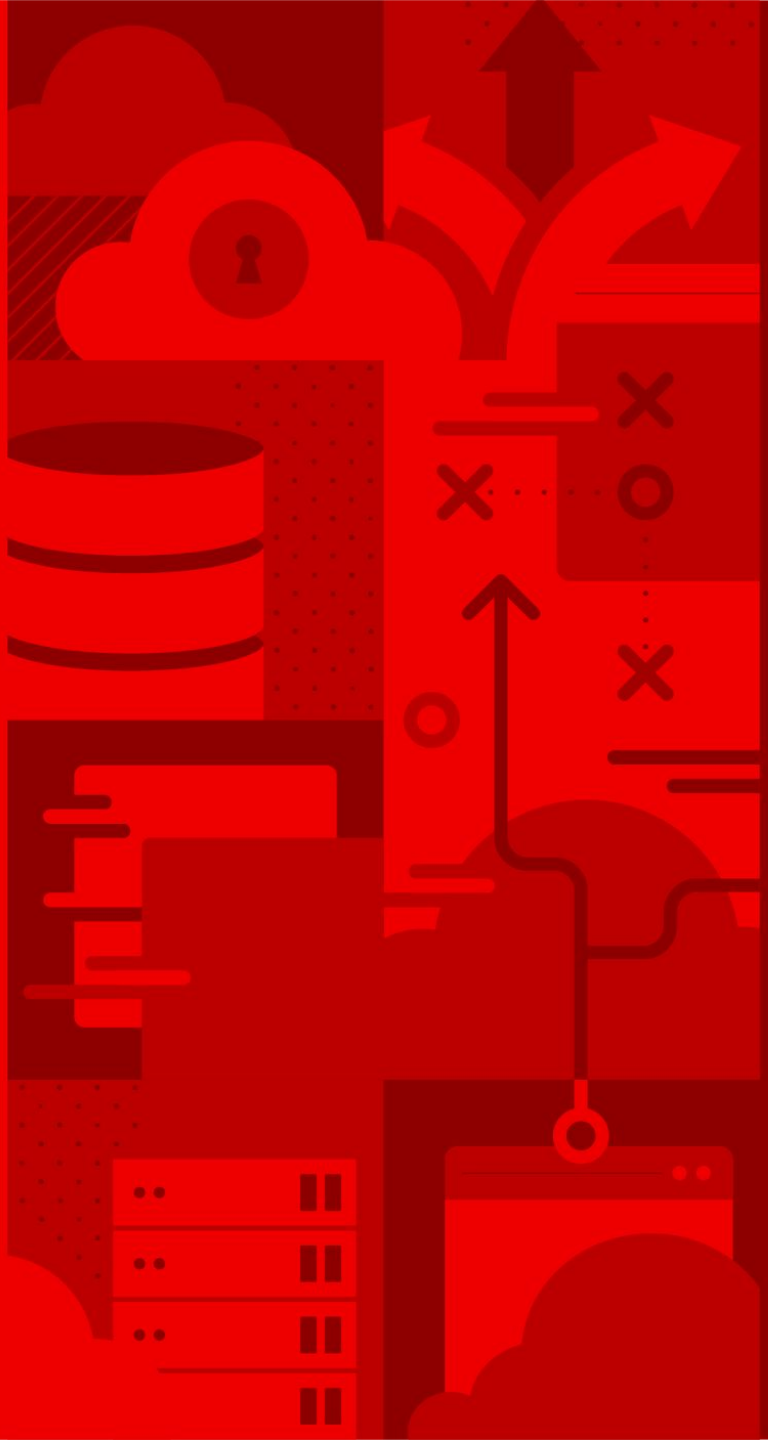
- Ahead of Time (AoT) compilation of Java to binary
- Most Quarkus extensions are:
  - compatible with native-mode “out of the box”
  - optimized to help AOT compilation eliminate dead code and avoid inclusion of unnecessary code/data

The standard Quarkus workflow



The Quarkus Native workflow





Let’s do some side by side comparisons!

Quarkus vs Quarkus Native: Build Time

Quarkus

```
$ ./mvnw clean package
[INFO] Scanning for projects...
[INFO]
[INFO] ---------------------< org.acme:code-with-quarkus >----------------------
[INFO] Building code-with-quarkus 1.0.0-SNAPSHOT
[INFO] --------------------------------[ jar ]---------------------------------
...
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time:  15.928 s
[INFO] Finished at: 2022-05-09T17:08:44+03:00
[INFO] ------------------------------------------------------------------------
```

Quarkus Native

```
$ ./mvnw -Pnative clean package
[INFO] Scanning for projects...
[INFO]
[INFO] ---------------------< org.acme:code-with-quarkus >----------------------
[INFO] Building code-with-quarkus 1.0.0-SNAPSHOT
[INFO] --------------------------------[ jar ]---------------------------------
...
[INFO] ------------------------------------------------------------------------
[INFO] BUILD SUCCESS
[INFO] ------------------------------------------------------------------------
[INFO] Total time:  01:56 min
[INFO] Finished at: 2022-05-09T17:24:35+03:00
[INFO] ------------------------------------------------------------------------
```

Quarkus vs Quarkus Native: Startup Time

Quarkus

```
$ java -jar ./target/quarkus-app/quarkus-run.jar
__  ____  __  _____   ___  __ ____  ______
 --/ __ \/ / / / _ | / _ \/ //_/ / / / __/
 -/ /_/ / /_/ / __ |/ , _/ ,< / /_/ /\ \
--\___\_\____/_/ |_/_/|_/_/|_|\____/___/
2022-05-09 17:11:10,119 INFO  [io.quarkus] (main) code-with-quarkus 1.0.0-SNAPSHOT on JVM (powered by Quarkus 2.8.3.Final) started in 2.580s.
Listening on: http://0.0.0.0:8080
2022-05-09 17:11:10,173 INFO  [io.quarkus] (main) Profile prod activated.
2022-05-09 17:11:10,173 INFO  [io.quarkus] (main) Installed features: [cdi, resteasy, smallrye-context-propagation, vertx]
```

Quarkus Native

```
$ ./target/code-with-quarkus-1.0.0-SNAPSHOT-runner
__  ____  __  _____   ___  __ ____  ______
 --/ __ \/ / / / _ | / _ \/ //_/ / / / __/
 -/ /_/ / /_/ / __ |/ , _/ ,< / /_/ /\ \
--\___\_\____/_/ |_/_/|_/_/|_|\____/___/
2022-05-09 16:55:12,127 INFO  [io.quarkus] (main) code-with-quarkus 1.0.0-SNAPSHOT native (powered by Quarkus 2.8.3.Final) started in 0.039s.
Listening on: http://0.0.0.0:8080
2022-05-09 16:55:12,127 INFO  [io.quarkus] (main) Profile prod activated.
2022-05-09 16:55:12,127 INFO  [io.quarkus] (main) Installed features: [cdi, resteasy, smallrye-context-propagation, vertx]
```

Quarkus vs Quarkus Native: Portability

Quarkus

```
$ file ./target/quarkus-app/quarkus-run.jar
target/quarkus-app/quarkus-run.jar: Zip archive data, at least v1.0 to extract, compression method=store
```

Quarkus Native

```
$ file ./target/code-with-quarkus-1.0.0-SNAPSHOT-runner
./target/code-with-quarkus-1.0.0-SNAPSHOT-runner: ELF 64-bit LSB executable, x86-64, version 1 (SYSV), dynamically linked, interpreter
/lib64/ld-linux-x86-64.so.2, BuildID[sha1]=87022586211d24a49f3e47070c6cfa7c7a2e8396, for GNU/Linux 3.2.0, not stripped
```

Quarkus vs Quarkus Native: Application size

Quarkus

```
$ du -h target/quarkus-app/quarkus-run.jar
4.0K   target/quarkus-app/quarkus-run.jar

$ du -hs /opt/jvms/jdk-11.0.15+10
319M   /opt/jvms/jdk-11.0.15+10
```

Quarkus Native

```
$ du -h ./target/code-with-quarkus-1.0.0-SNAPSHOT-runner
39M    target/code-with-quarkus-1.0.0-SNAPSHOT-runner
```

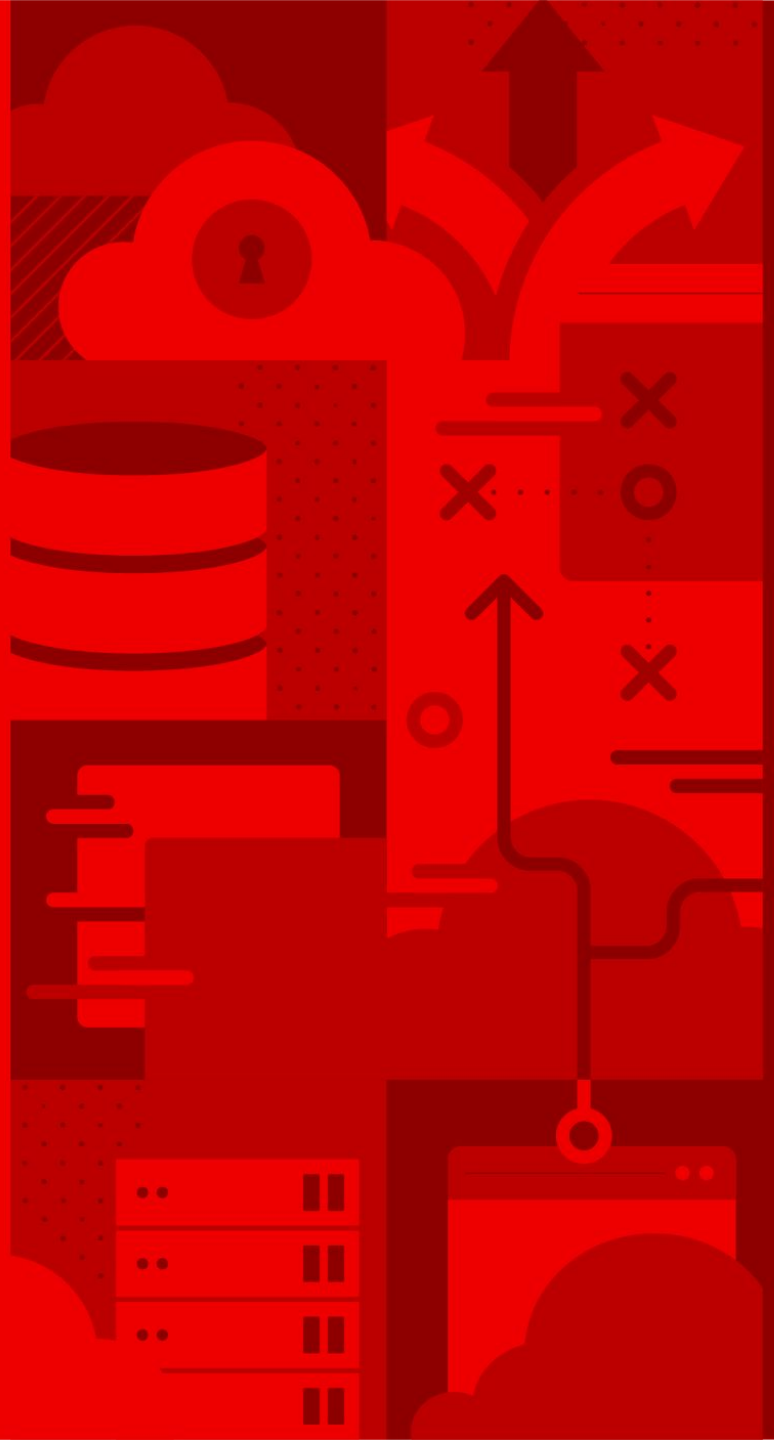
Quarkus vs Quarkus Native: Container size

Quarkus

```
$ ./mvnw quarkus:add-extension -Dextensions="container-image-docker"
...

$ ./mvnw clean package -Dquarkus.container-image.build=true
...
[INFO] Total time:  48.099 s
[INFO] Finished at: 2022-05-10T15:44:58+03:00
[INFO] ------------------------------------------------------------------------

$ docker images
REPOSITORY                                                      TAG                 IMAGE ID       CREATED         SIZE
zakkak/code-with-quarkus                                        1.0.0-SNAPSHOT      80d24a5624bf   3 minutes ago   448MB
```

Quarkus Native

```
$ ./mvnw -Pnative clean package -Dquarkus.container-image.build=true
...
[INFO] Total time:  01:39 min
[INFO] Finished at: 2022-05-10T15:49:59+03:00
[INFO] ------------------------------------------------------------------------


$ docker images
REPOSITORY                                                      TAG                 IMAGE ID       CREATED         SIZE
zakkak/code-with-quarkus                                        1.0.0-SNAPSHOT      2e2d622b2d7c   2 minutes ago   142MB
```



Is Quarkus Native always better?

No!

Quarkus Native Pros

- Fast start up times
  - No JVM start-up overhead
    - No Class loading and verification
    - Build time initialization (BTI)
- Close to peak performance from start
  - No JVM warm up needed
  - No JIT compilation
- Small standalone binary
  - Less dependencies
  - Smaller footprint on disk (does it matter?)
- Smaller Resident Set Size (RSS)
  - native doesn't hold all the metadata that JVM needs at runtime
  - Heap image is shared across multiple instances (copy on write)

See https://github.com/oracle/graal/issues/979#issuecomment-480786612 for more information regarding performance differences

Quarkus Native Cons

- Lower peak performance compared to JVM mode
  - No JIT / dynamic optimizations
  - Worse GC implementation
- Slower development cycle
  - Develop and test in JVM mode
- Lacks behind in terms of tooling
  - Harder to debug and monitor
- Security patches require recompilation
  - Even if the issue is not in the application code
- Not portable
  - Need to build different binaries for different platforms

See https://github.com/oracle/graal/issues/979#issuecomment-480786612 for more information regarding performance differences

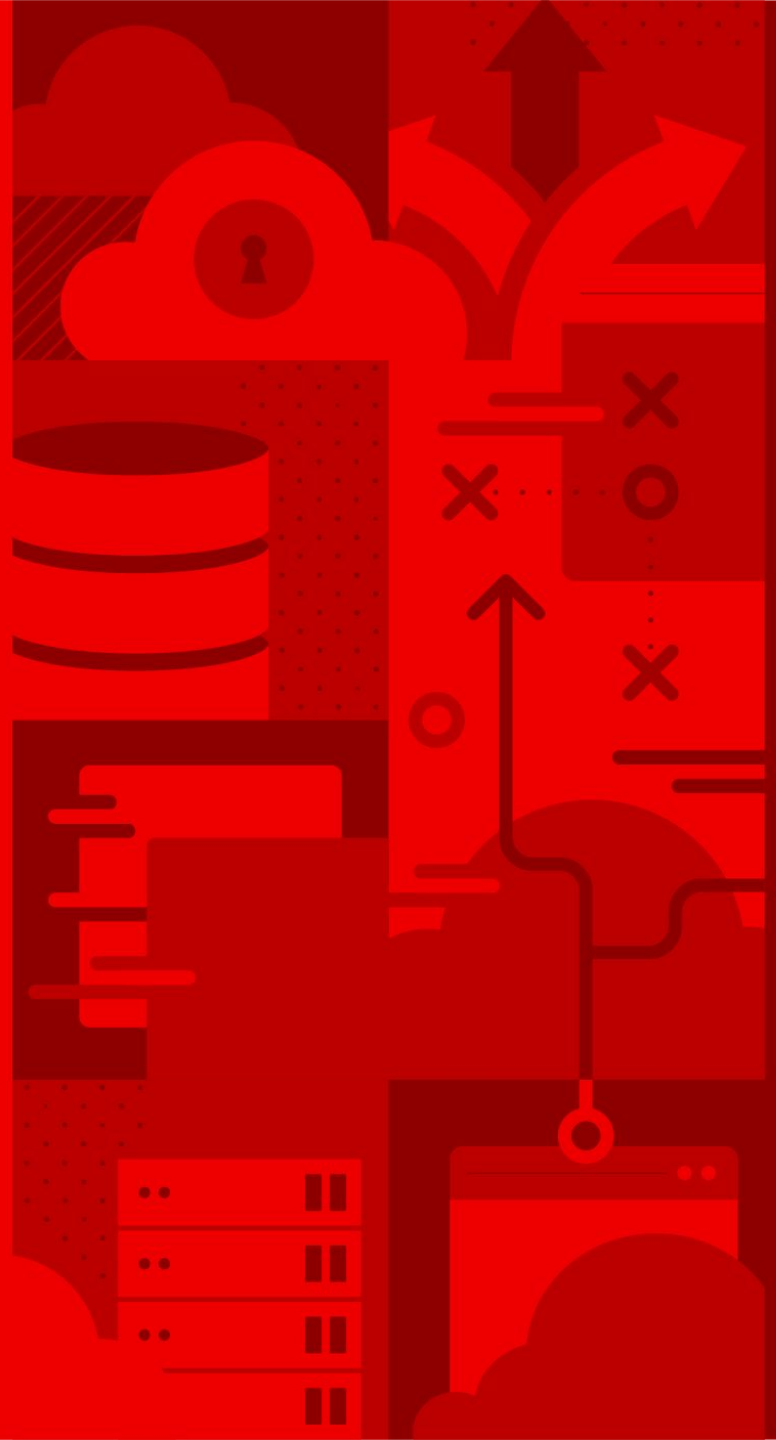
Quakrus Native Limitations

Often require explicit configuration:

- Dynamic Class loading
- Dynamic Proxy
- Reflection
- Java Native Interface
- Serialization

- MethodHandles and invokedynamic bytecode
  - Lambdas are supported
- Tooling support
  - No JDWP, agents, JMX, JVMTI, etc.

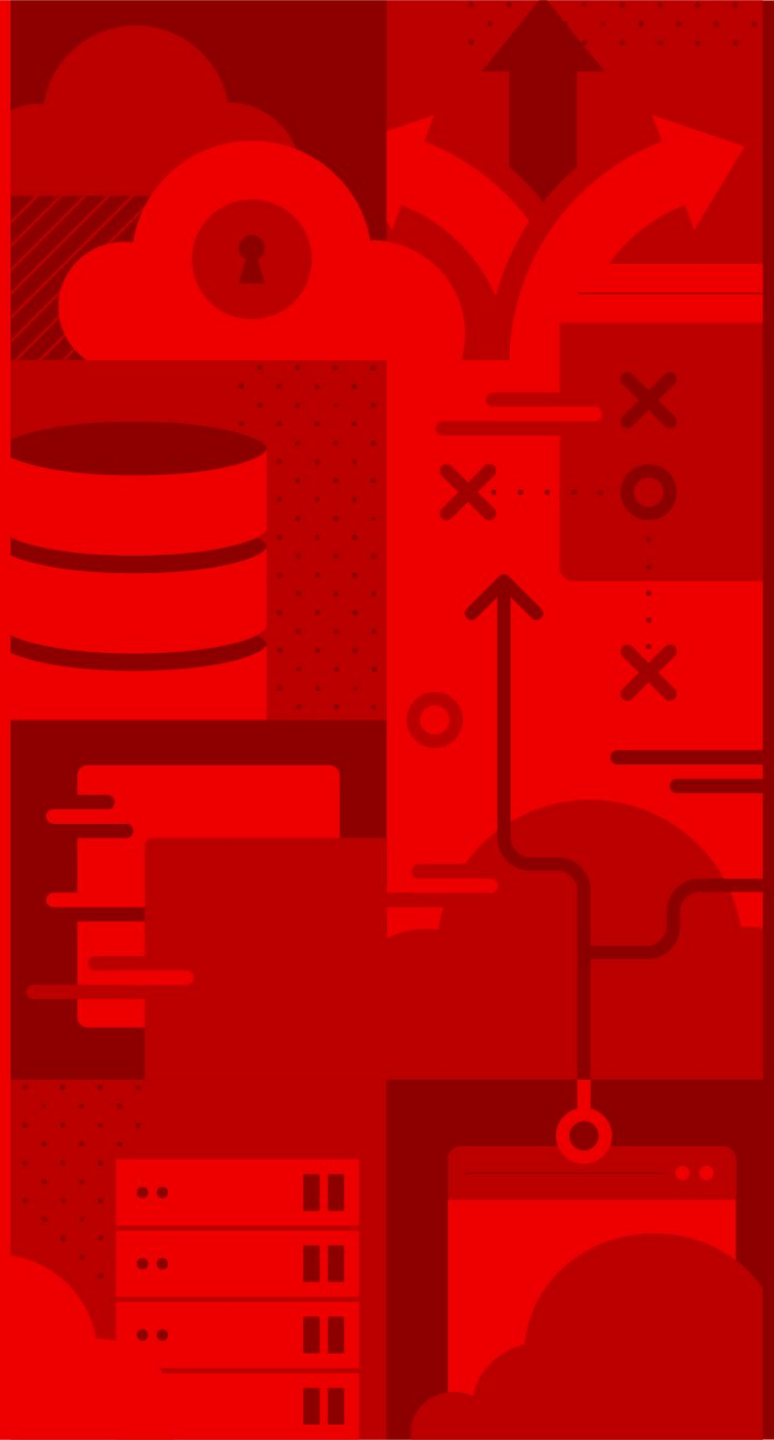
See https://www.graalvm.org/22.1/reference-manual/native-image/Limitations/ for more information



So when should one use Quarkus Native?

When to prefer Quarkus Native

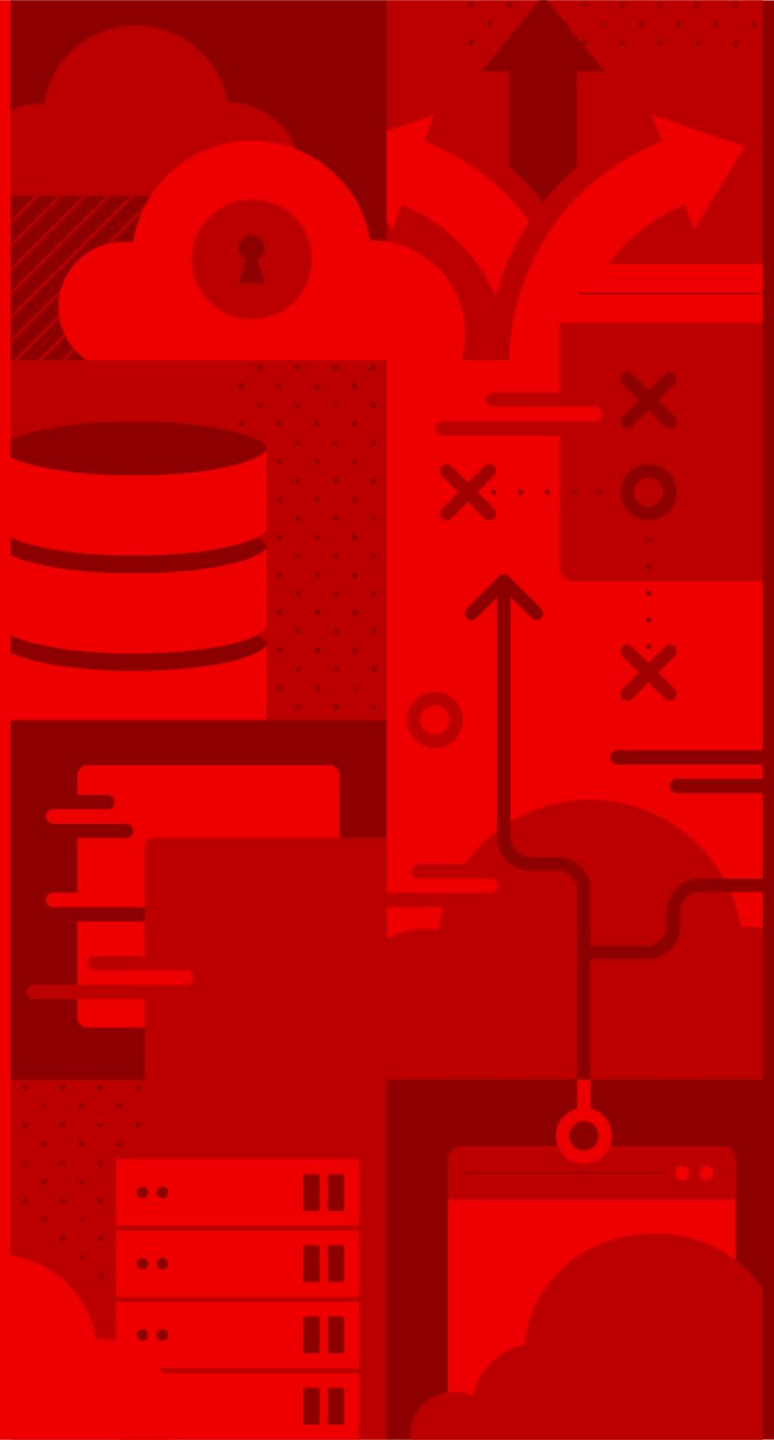
- Typically better for:
  - Short lived processes
  - Processes that require fast startup
  - Non-GC-heavy workloads
- Typically worse for:
  - Highly dynamic workloads
    (using a lot of reflection and dynamic class loading)
  - Processes that can benefit from higher peak performance
    - Usually that means they will also need to run for longer



How does it work?

How does Quarkus Native work?

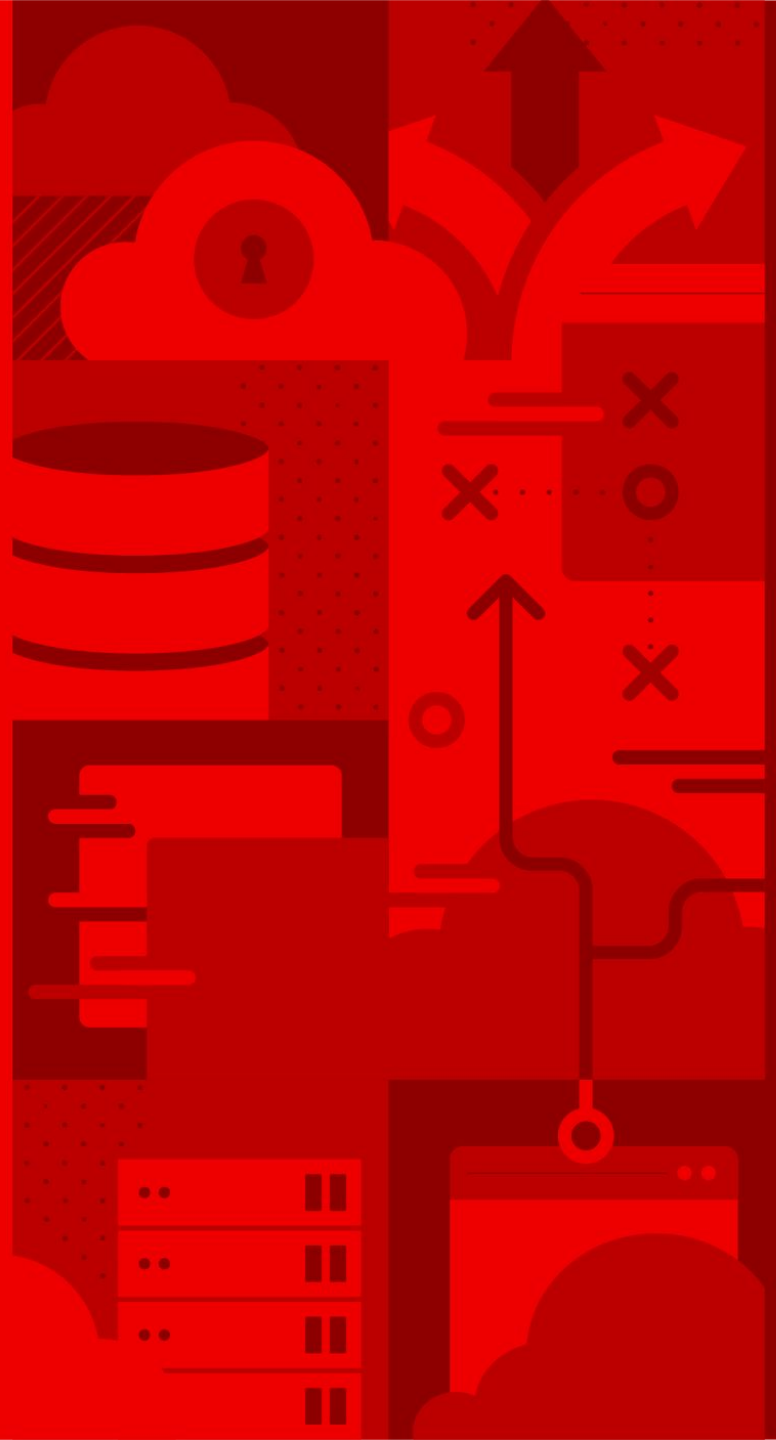
- Takes advantage of GraalVM's native-image
  - Closed world assumption / analysis
    - Identify reachable code and data using static analysis
    - Only compile the reachable part, drop the rest
  - Initialize Once, Start Fast!
    - No need to compile / include code that runs at build time, e.g., Build Time Initialization
- Quarkus extensions handle the biggest part of configuration for indirectly accessed code / data
  - Allows use of "dynamic" class loading, reflection, JNI, etc.
  - Allows the embedding of resources, e.g., configuration files, in the binary
- Quarkus annotations and native-image configuration allow for further configuration



How does it defer?

Quarkus Native Defaults

- Build time initialization of all classes (where possible)
  - Re-initialize when necessary (e.g. random seeds)
  - Reset fields to null to prevent pulling in undesired state or classes
- Doesn't allow incomplete classpaths (`--link-at-build-time`)
  - No unexpected runtime failures due to ClassNotFoundException
- Opinionated native-image support for libraries (due to build time initialization)
  - By default GraalVM offers a metadata repository, which Quarkus doesn't use



Is it future-proof?

Is Quarkus Native future-proof?

- native-image is an existing practical approach to Native Java
  - already widely deployed in production
  - still comes with some gray zones
  - tries to act as much as possible like JVM
    - not always possible
- we need a clear specification for Native Java

Meet project Leyden

- *"Leyden will add static images to the Java Platform Specification, and we expect that GraalVM will evolve to implement that Specification."* - 27 Apr 2020, Mark Reinhold. See https://mail.openjdk.java.net/pipermail/discuss/2020-April/005429.html
- On 20 May 2022 Mark Reinhold posted "Project Leyden: Beginnings" which kick-started some discussions: *"So rather than adopt the closed-world constraint at the start, I propose that we instead pursue a gradual, incremental approach."* See https://openjdk.java.net/projects/leyden/notes/01-beginnings
- Still early to draw conclusions but there is movement towards a specification for Native Java (a.k.a. static images)

https://www.infoq.com/articles/native-java-aligning/

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Key Takeaways

- Native Java is essential for Java to remain relevant in the evolving cloud world.
- Native Java is not a solved problem yet.
- The development lifecycle needs to adapt as well.
- Standardization through Project Leyden is key to the success of native Java.
- Native Java needs to be brought into OpenJDK to enable co-evolution with other ongoing enhancements.

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