Java in a World of Containers

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FnProject

- [http://fnproject.io](http://fnproject.io)
- Open Source Functions-as-a-Service
- “functions” packaged as container images

- Cold Latency MATTERS!
Safe Harbor Statement

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Agenda

Java in a World of Containers
Creating Docker images
Creating Custom JREs
Java + Docker features
Java in a World of Containers
In a World of Containers We Expect...

• Safety and security becoming increasingly more important
• Sprawl
  – Many instances
  – Mix of different applications
  – Heterogeneous machines
  – Heterogeneous container configurations
Java in a World of Containers
Java’s characteristics make it ideal for a container environment

• Managed language/runtime
• Hardware and operating system agnostic
• Safety and security enforced by JVM
• Reliable: Compatibility is a key design goal
• Runtime adaptive: JVM ensures stable execution when environment changes
• Rich eco system
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• Reliable: Compatibility is a key design goal
• Runtime adaptive: JVM ensures stable execution when environment changes
• Rich eco system
• We are committed to keeping Java the first choice for container deployments
Creating Docker images
Docker

<dir/>

  Dockerfile
  jdk-9+181_linux-x64_bin.tar.gz
  HelloWorld.class
Dockerfile

1. FROM oraclelinux:7-slim
2. ADD jdk-9+181_linux-x64_bin.tar.gz /opt/jdk
3. ENV PATH=$PATH:/opt/jdk/jdk-9/bin
4. ADD HelloWorld.class /
5. CMD [ "java", "-showversion", "HelloWorld" ]
Docker

# docker build -t my/jdk9 .
Sending build context to Docker daemon 346.3 MB
Step 1/4 : FROM oraclelinux:7-slim
  ...
Successfully built df05dbf52403

# docker run --rm my/jdk9
java version "9"
Java(TM) SE Runtime Environment (build 9+181)
Java HotSpot(TM) 64-Bit Server VM (build 9+181, mixed mode)
Hello, world!
Creating Custom JREs
Custom JREs

• A Docker image containing the full JDK is large (500+ MB)
  – Contains the stuff you want: `java.{lang,util,...}.*, javax.management.*, …`
  – And all the stuff you don’t: `corba, jaxws, …`

• JDK 9 introduces a module system and tooling for creating custom JREs
  – Only include the modules/functionality needed for the application
  – A minimal JRE only includes the `java.base` module
    • Can be enough for many applications
  – `jdeps` can help identify which modules an application uses
    ```
    # $JAVA_HOME/bin/jdeps lib/tomcat-api.jar
tomcat-api.jar -> java.base
tomcat-api.jar -> java.instrument
tomcat-api.jar -> java.naming
...
    ```
Creating a Custom JRE

• Creating a custom JRE is straightforward
  - jlink <options>
    --module-path <modulepath>
    --add-modules <module> [, <module>] ...

• Example: Creating a java.base (only) JRE
  - $JAVA_HOME/bin/jlink
    --output my-jre
    --module-path $JAVA_HOME/jmods
    --add-modules java.base
  - my-jre/bin/java HelloWorld

• Note: The application does not have to be module aware!
Multi-Stage Dockerfile

• Creation of custom JRE Docker image can be automated using Multi-Stage Dockerfiles

```
# Multi-Stage example using jlink to produce small Java runtime
FROM openjdk:9-jdk AS java-build
WORKDIR /jlink/outputdir
RUN jlink --module-path /docker-java-home/jmods --strip-debug --compress=2 --output java --add-modules java.base

FROM alpine:latest
WORKDIR /root/
COPY --from=java-build /jlink/outputdir /
ENV PATH /root/java/bin:$PATH
CMD ["bash"]
```
Optimizing the Size of the JRE

- **Full JDK**: Default JDK (not jlink:ed)
- **java.base**: `jlink --add-modules` java.base
- **“netty”**: A set of modules expected to be sufficient for many/most Java applications
  - java.base, java.logging, java.management, java.xml, jdk.management, jdk.unsupported
  - Note: Does **not** include the netty application itself
- **Size can be further optimized**
  - `jlink --compress` can reduce size by 25%+
Optimizing the Base Image Size

• Base image is a significant part of the total image size
• With Docker the exact base image matters less
  – As long as it can still run Java

---

Docker image sizes (java.base)

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<th>Size (MB)</th>
<th>oraclelinux:7</th>
<th>oraclelinux:7-slim</th>
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<td>118</td>
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<td>300</td>
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Alpine Linux & musl libc


Alpine Linux is a security-oriented, lightweight Linux distribution based on musl libc and busybox.

- https://www.alpinelinux.org

musl is lightweight, fast, simple, free, and strives to be correct in the sense of standards-conformance and safety.

- https://www.musl-libc.org
OpenJDK Project “Portola”

- OpenJDK project “Portola” provides a port of the JDK to Alpine/musl
  - The Alpine Linux base image weighs in at **4MB**
    - Uses the “musl” C library

http://openjdk.java.net/projects/portola/
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Any interest in an Alpine port?
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Any interest in an Alpine port? Any interest in helping maintain it?
Java + Docker features
Sharing Across Instances

• Micro-services and Docker encourages running **many processes** on the same machine
• Chances are many instances will be running the **exact same application**
• OS shared libraries allows for sharing native data
  - libc, libjvm.so all get shared automatically by the OS & Docker
    – Assuming same layer/file/inode
• What about Java class data?
Class Data Sharing (CDS)

- Like OS shared libraries for Java class data
- Archive is memory-mapped
- RO pages shared, RW pages are shared copy-on-write
- Classes read from mapped memory without overhead of searching, reading & parsing from JAR files
- Archive can be shared across Docker containers
AppCDS Benefits - Startup Time and Footprint
Example: WebLogic Server Base Domain

- Sharing & savings increases with every instance
- With 10 instances there is ~10% saving in total memory footprint
- Can be good to use separate layers
Experimental: Ahead-of-Time Compilation (AOT)

• Like AppCDS, but for JIT compiled code
  – Pre-compiled code stored to archive
  – Allows sharing, footprint reduction, and reduced startup
Honoring Docker/cgroups Resource Limits

• The JVM has plenty of ergonomics which are based on the underlying system
  – Memory, #cpus, exact CPU model, etc.
  – For example, heap size is based on available memory

• Docker allows for specifying resource limits
  – Implemented through cgroups
  – **Not** transparent - requires cooperative application support
  – Explicit support needed for JVM
Honoring Docker/cgroups Resource Limits: CPU

• The JDK honors Docker CPU settings
  —--cpuset-cpus (JDK 9)
  —--cpus, --cpu-shares, --cpu-quota (JDK 10)
  • JDK-8146115: Improve docker container detection and resource configuration usage

• Reflected in
  – Runtime.availableProcessors(), ForkJoin pool, VM internal thread pools
  – Libraries/frameworks such as core.async, ElasticSearch, Netty

Honoring Docker/cgroups Resource Limits: Memory

• Memory settings (JDK 10)
  – `-m<size>`
  – Reflected in
    • Java heap size, GC region sizes, other VM internal structures like code cache, ...

• **JDK-8186248**: Allow more flexibility in selecting Heap % of available RAM
  - `XX:InitialRAMPercentage`
  - `XX:MaxRAMPercentage`
  - `XX:MinRAMPercentage`

Other

• **JDK-8179498**: attach in linux should be relative to /proc/pid/root and namespace aware (JDK 10)

• **JDK-8193710**: jcmd -l and jps commands do not list Java processes running in Docker containers (JDK 11)

• More to come
  – Draft JEP: JDK-8182070: Container aware Java
BACKUP
jshell snippets (snippets.txt)

long javaMaxMem() {
    return Runtime.getRuntime().maxMemory();
}

import java.nio.file.*;

long sysMaxMem() throws IOException {
    return Files.lines(Paths.get("/sys/fs/cgroup/memory/memory.limit_in_bytes"))
        .mapToLong(Long::valueOf)
        .findFirst().getAsLong();
}
jshell in Docker execution commands

# Run without resource restrictions
docker run \
  --rm -it --volume $PWD:/in jdk-9-alpine \
  jshell /in/snippets.txt

# Run with resource restrictions but no Java configuration
docker run -m=384M --cpuset-cpus=0 \
  --rm -it --volume $PWD:/in jdk-9-alpine \
  jshell /in/snippets.txt

# Run with resource restrictions and Java configuration
docker run -m=384M --cpuset-cpus=0 \
  --rm -it --volume $PWD:/in jdk-9-alpine \
  jshell /in/snippets.txt \
  -J-XX:+UnlockExperimentalVMOptions -J-XX:+UseCGroupMemoryLimitForHeap \
  -R-XX:+UnlockExperimentalVMOptions -R-XX:+UseCGroupMemoryLimitForHeap