Multitenant Java

About me

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- 13 years experience developing, testing and deploying Java SDKs
- Currently testing Multitenancy on IBM Java 7 R1

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- Presenting on behalf of the development team

This session will help you to:

- Understand what multitenancy is
- Understand why it is important
- Find out what it can do for you
- Discover IBM's multitenancy technology in Java 7 R1

Multitenancy == Simplification

- Multitenancy refers to a principle in software architecture where a single instance of the software runs on a server, serving multiple client organizations (tenants).
- Multitenancy is contrasted with a multi-instance architecture where separate software instances (or hardware systems) are set up for different client organizations.
- With a multitenant architecture, a software application is designed to virtually partition its data and configuration, and each client organization works with a customized virtual application instance.

Thanks to

Don't Repeat Yourself: Simplify to save time & $$$

"Every piece of knowledge must have a single, unambiguous, authoritative representation within a system"

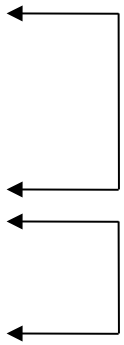
Pragmatic Programmer (Hunt & Thomas)

(or: copy-and-paste encourages problems)

http://www.instructables.com/id/How-To-Create-A-LEGO-Star-Wars-Clone-Army/

Background - Key Trends

- Share more, can do this at different levels in the stack:
  - Hardware partitioning
  - Hypervisor
  - Operating System
  - Containers
  - Runtime
  - Middleware
  - Application

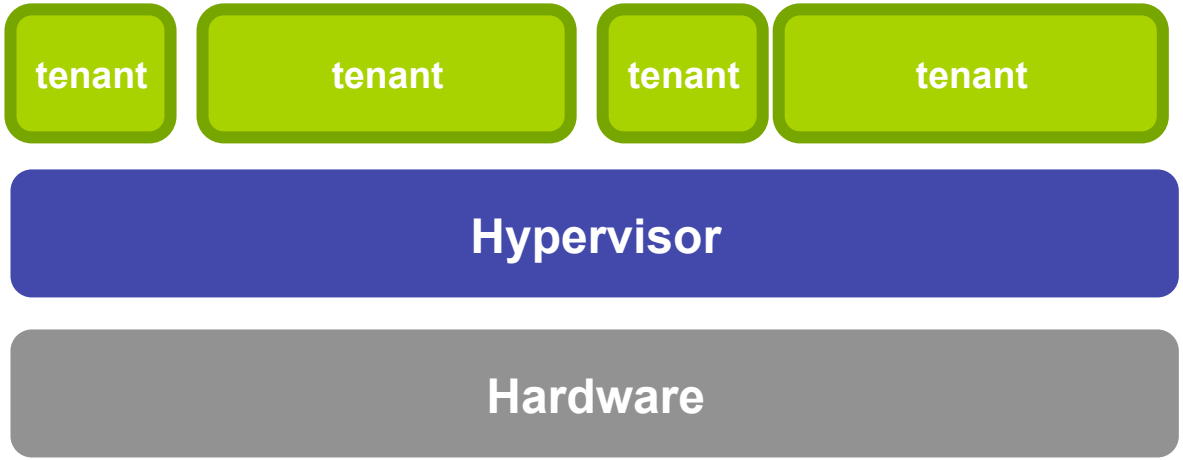


Virtualization – “make it appear as you have dedicated environment/container”

Multitenancy – “share an environment with more than 1 tenant”

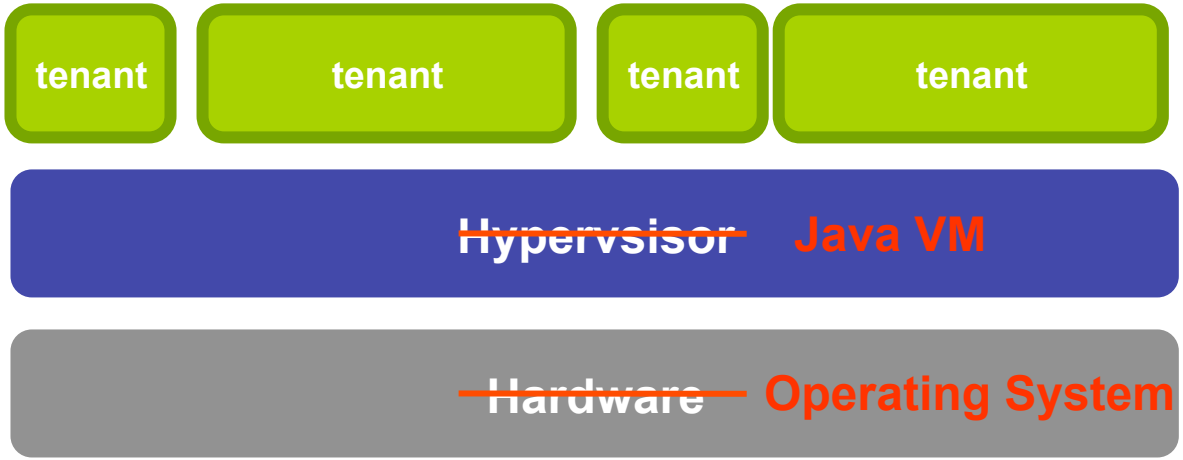
- Continual drive to improve
  - reduce overhead at each level (resource usage, startup)
  - improve isolation at each level
  - more sharing as we move down the stack
- Multitenant Java moves us down one layer in the stack

Hardware Virtualization



- **Hypervisors run multiple applications side-by-side safely**
  - Examples: VMware, kvm, PowerVM, zVM
- **Advantages**
  - Capture idle CPU cycles
  - Automatic de-duplication (RAM)
  - Ability to meter and shift resource toward demand
  - No need to change applications (tenants)

JVM Virtualization



- ~~Hypervisor~~s JVMs can run multiple applications side-by-side safely
- **Advantages**
  - Capture idle CPU cycles
  - Automatic de-duplication (ability to share Java artifacts)
  - Ability to meter and shift resource toward demand
  - No need to change tenant applications

JVM Multitenancy: What is it ?

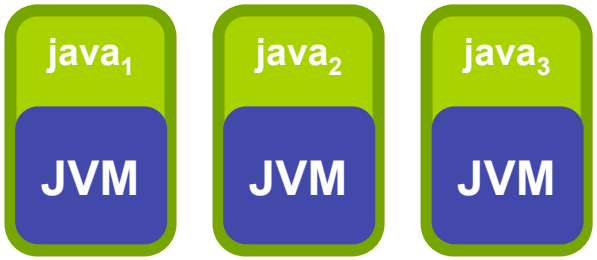
- What we're building: basically a 'virtual JVM'
  - Transparent multitenancy for 100% pure Java applications
  - Opt-in via –Xmt option
  - Shared JVM (javad) process hosts all tenants with in/out/err redirection to launcher
  - JVM-enforced resource controls on Heap, Threads, I/O, and CPU
  - Will behave exactly like a dedicated JVM, only smaller

JVM Multitenancy: What do I get?

- Tech preview in the Java 7.1 release:
  - Full platform evaluation Linux-x86, z/OS, AIX, zLinux, pLinux
- Download from:
  - https://www.ibm.com/developerworks/java/jdk/linux/download.html
- Performance Goals (work in progress)
  - Lower memory usage (classes and JVM internal data structures are shared)
  - 10x density improvement on “Hello World” style applications
  - 3x density improvement on larger OSGi applications (Liberty)
  - Less than 10% throughput degradation on TradeLite
  - Quicker startups: JVM is already up and running
  - Better performance from JIT'd code

Multitenancy: Basics – How does it work

- A standard `java` invocation creates a dedicated (non-shared) JVM in each process



Cost of Dedicated JVM

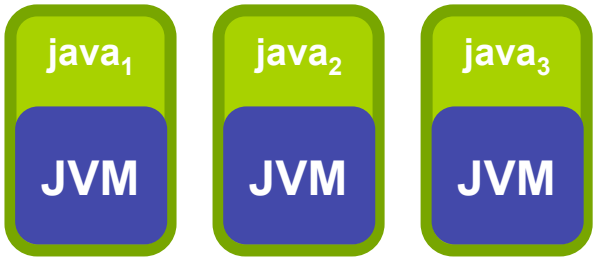
Java Heap consumes 100's of MB of memory
- –Heap objects cannot be shared between JVMs

Just-in-Time Compiler consumes 10's of MB of memory
- –Generated code is private and big
- –Generated code is expensive to produce
  - Steals time from application

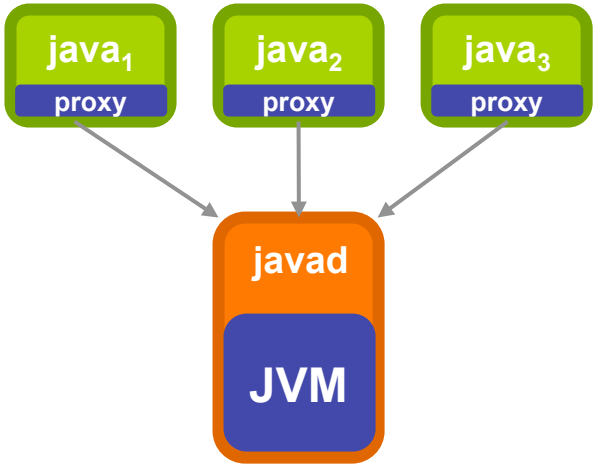
JVM Control structures and threads
- – Heap control structures
- – Multiple compilation threads
- – Multiple GC helper threads

Multitenancy: Basics – How does it work

- A standard **`java`** invocation creates a dedicated (non-shared) JVM in each process



- IBM's Multitenant JVM puts a lightweight 'proxy' JVM in each **`java`** invocation. The 'proxy' knows how to communicate with a shared JVM daemon called **`javad`**.



- **`javad`** is launched and shuts down automatically
- no changes required to the application
- **`javad`** process is where aggressive sharing of runtime artifacts happens

Cost of Virtualized JVM

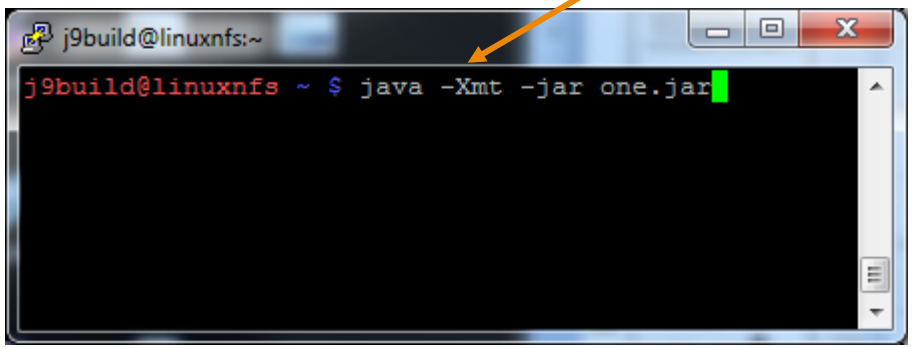
- 1 Heap – no duplication of control structures, helper threads
- 1 JIT – code is compiled once, less memory is used, less CPU used by the JIT
- Shared Classes – Java SDK classes are shared, less memory consumed
- Quicker JVM startup – when a tenant connects, the JVM is already running
- Per tenant instance data is not shared – isolated on the heap by the JVM
- Performance hit for virtualization

Multitenancy: Getting started

- **Multitenancy is an opt-in feature** of IBM JDKs for Java 8 (tech preview 7.1 4Q2013)
  - Just add the `-Xmt` command-line option to opt-in
  - Enables a model very similar to JSR-121: Isolates but doesn't require any new API
- **Daemon startup and communications is handled automatically** by the 'java' launcher
  - One daemon per user to keep permissions aligned between launcher & daemon
  - Launcher:daemon rendezvous accomplished using advertisement files
- **Standard in / out / error streams are connected to daemon**
  - e.g. System.out.println() in the daemon works as expected
  - JVM will multicast messages like dump events to all connected tenants
- **Most standard JVM options are used as-is**
  - -classpath / -jar entries
  - -Dname=value system properties
- **Select JVM options are mapped to tenant-specific values**
  - -Xmx applies to the tenant being launched
  - See documentation for details
- **Daemon-wide options are stored in JAVA_HOME/bin/javad.options file**
- **Documentation available at:**
  - **http://www.ibm.com/support/knowledgecenter/SSYKE2_7.0.0/com.ibm.java.aix.71.doc/diag/preface/changes_71/overview_mt_evaluation.html**

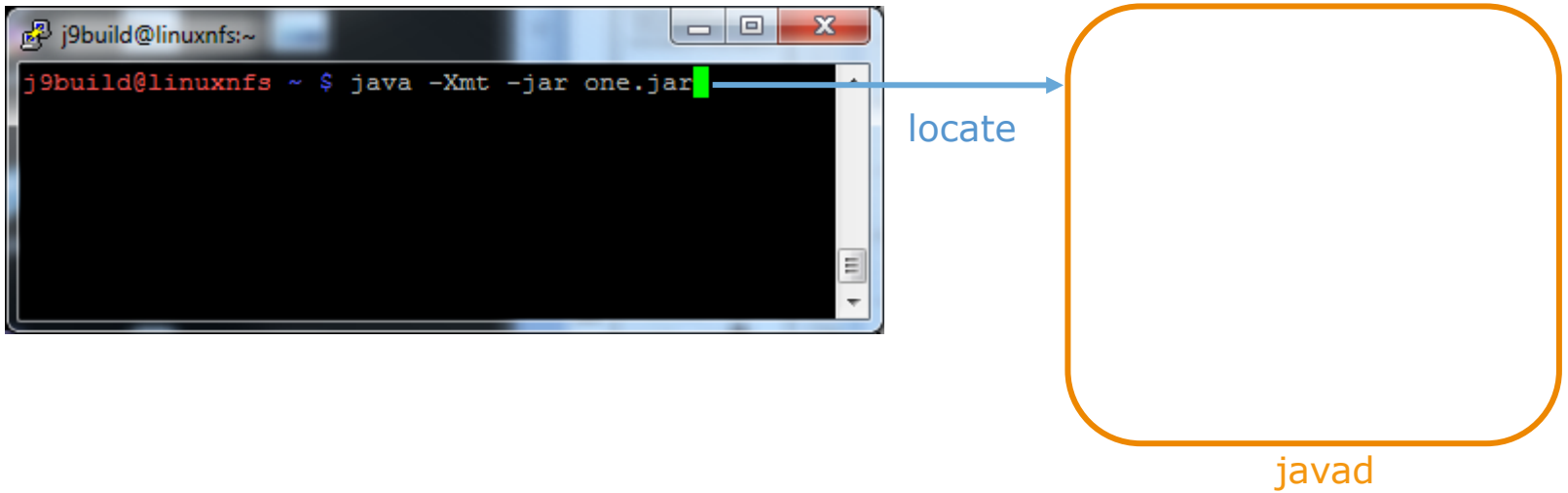
Multitenant JDK: Launch your application

- Opt-in to multitenancy by adding **`-Xmt`**



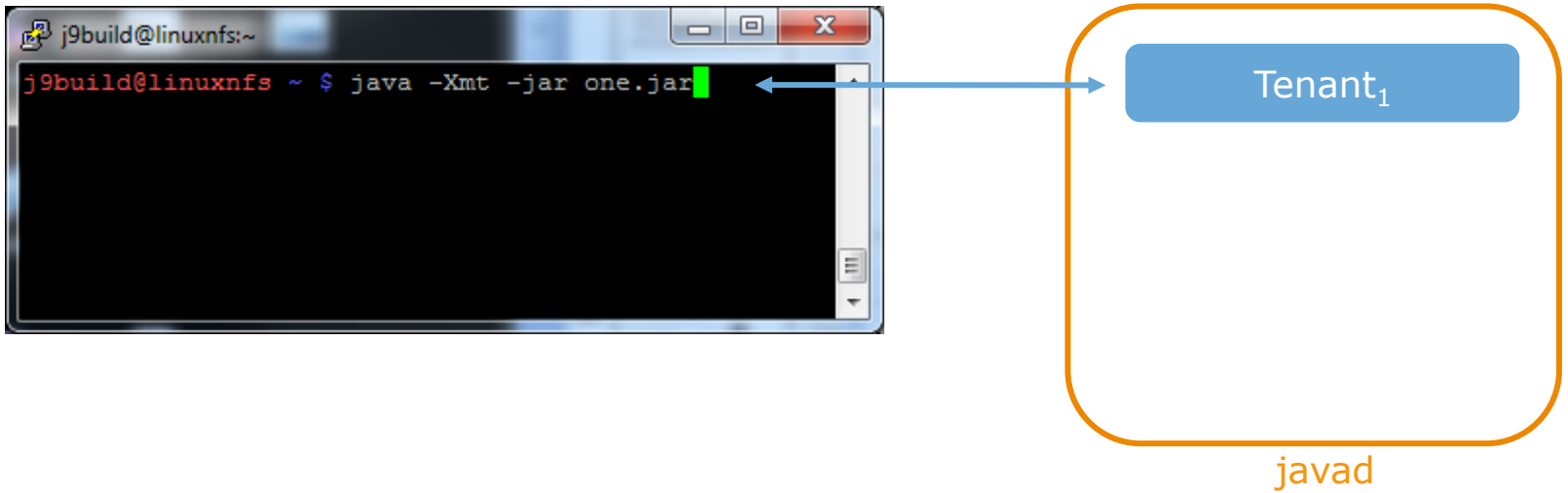
Multitenant JDK: Register with `javad` daemon

- JVM will locate/start daemon automatically



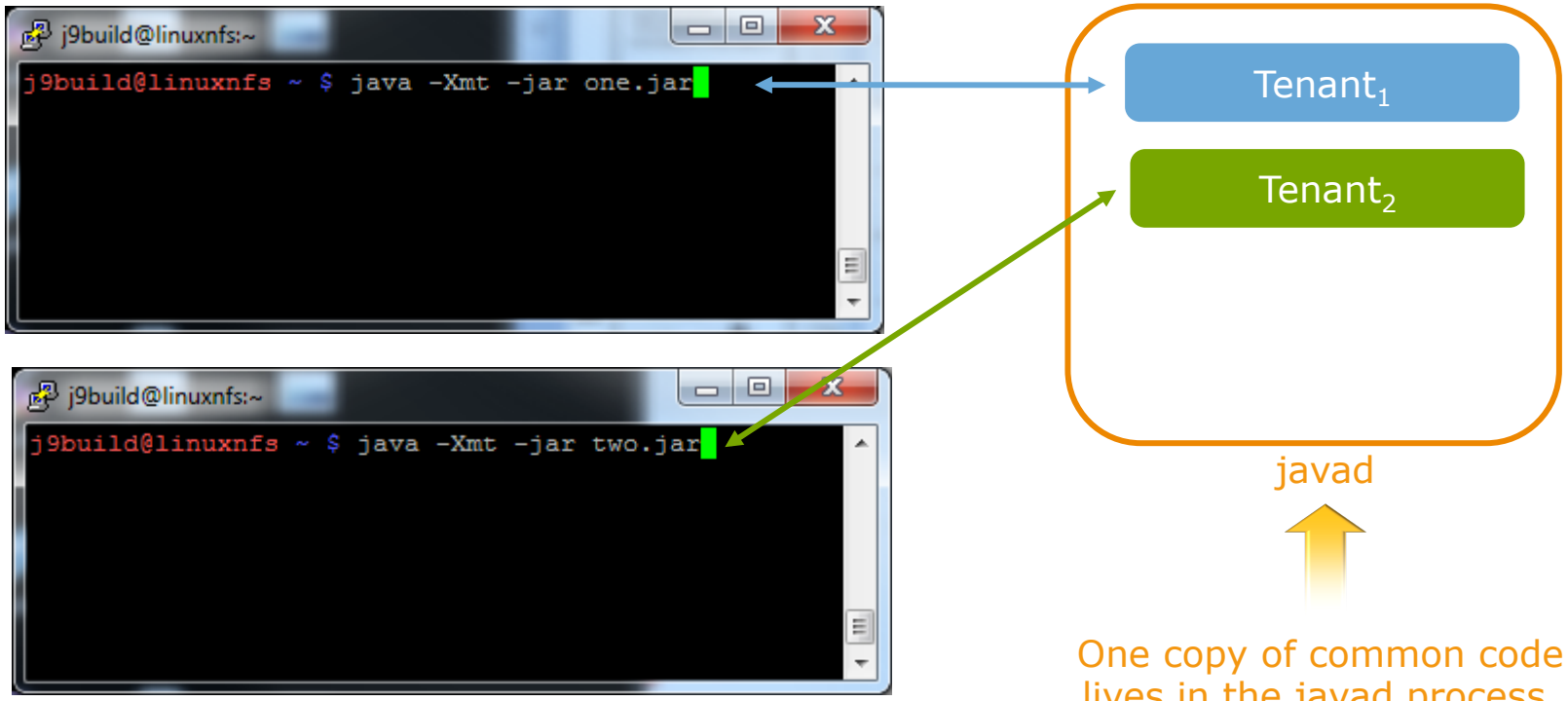
Multitenant JDK: Create a new tenant

- New tenant created inside the **`javad`** daemon



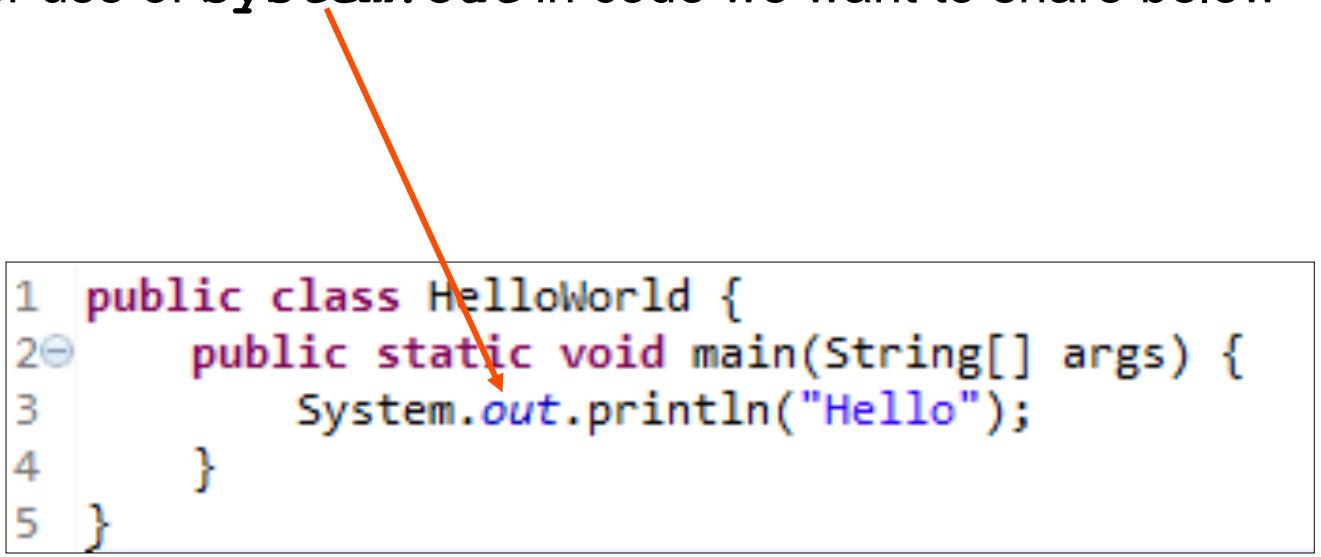
Multitenant JDK: Create a second tenant

- New tenant created inside the **`javad`** daemon



A peek under the covers: Separating State

- Static Variables are a problem for sharing
- Consider use of **`System.out`** in code we want to share below



```
1  public class HelloWorld {
2      public static void main(String[] args) {
3          System.out.println("Hello");
4      }
5  }
```

A peek under the covers: Separating State

```
1  public class HelloWorld {
2      public static void main(String[] args) {
3          System.out.println("Hello");
4      }
5  }
```

```
HelloWorld
// access flags 0x9
public static main([Ljava/lang/String;)V
 L0
  LINENUMBER 3 L0
  GETSTATIC java/lang/System.out : Ljava/io/PrintStream;
  LDC "Hello"
  INVOKEVIRTUAL java/io/PrintStream.println(Ljava/lang/String;)V
 L1
  LINENUMBER 4 L1
  RETURN
```

`getstatic` does 2 things

1. Triggers class initialization on first contact
   - Notable: Each 'tenant' needs to do this
2. Resolves a name (`out`) to a storage location and reads from it
   - Notable : Each tenant needs dedicated storage

Multitenancy: Controlling Resource Consumption

- An opportunity!
- Problem – multiple applications on a single server, one misbehaved app can break all the rest
- Allow the JVM to limit resource consumption of your tenants

Multitenancy: Controlling Resource Consumption

- The second key feature for safe multitenancy is **resource control**
  - Based on JSR-284 for resource configuration management
  - Internally uses a token-bucket algorithm commonly applied to network traffic shaping
- Resources that can be throttled:
  - **CPU** & **Threads**
  - **Heap** memory consumption
  - Disk and Network **I/O**

Multitenancy: Controlling Resource Consumption

- Throttling is controlled using a new **`-Xlimit`** command-line option
  - General form is: **`-Xlimit:`**`<resource_name>=<min_limit>-<max_limit>`
  - `<min_limit>`: Specifies the minimum amount of the resource that must be available for the tenant to start. This value is optional.
  - `<max_limit>`: Specifies the maximum amount of the resource that the tenant is allowed to use.
- Examples:
  - **`-Xlimit:cpu=10-30`**
    - requires a 10% share of the processor to start and limits processor consumption to 30%.
  - **`-Xlimit:threads=5-20`**
    - requires a minimum reservation of five threads and an upper limit of 20
  - **`-Xmx20m`**
    - Limit heap consumption to 20 megabytes

Multitenancy – When and Where?

- Advantages
- Disadvantages
- Possible use cases

Multitenancy Sweet spot

- **How low can you go?**
  - Simple ('Hello World') applications showing per-tenant sizes of ~170 KB of heap
  - This equates to a **5-6x** more applications running on the same hardware
- **Performance**
  - Target is 10% overhead, still a work in progress
- **Second-run start-up times are significantly better**
  - Faster because the JVM is already up and running
- **Application Sweet spot:**
  - **One of:**
    - Relatively large class:heap ratio (JRuby and other JVM languages)
    - Require fast startup: run-and-done / batch
    - Workloads with varying busy:idle cycles – MT JDK is better at shifting resource between tenants
  - **100% pure Java Code**

Multitenancy: Caveats & Limitations

- **Main Limitations of the MT Model**

  JNI Natives
  - The operating system allows the shared JVM process to load only one copy of a shared library. Only native libraries present on the bootclasspath of the JVM usable.

  JVMTI
  - Because debugging and profiling activities impact all tenants that share the JVM daemon process, these features are not supported in the multitenant JVM process model. Note: we do have per-tenant -javaagent: support.

  GUI programs
  - Libraries such as the Standard Widget Toolkit (SWT) are not supported in the multitenant JVM process model because the libraries maintain a global state in the native layer.

– Full list available at:
http://www-01.ibm.com/support/knowledgecenter/SSYKE2_7.0.0/com.ibm.java.aix.71.doc/user/mt_limitations.html

Use Cases

- **MT-UC1 – Small Application Consolidation**
- MT-UC2 – Run and Done
- **MT-UC3 – Resource Time Sharing**
- MT-UC4 – Resource Limiting based on SLA
- **MT-UC5 – Resource Limiting for Safety**
- MT-UC6 – Memory Cost Sensitive Environments
- **MT-UC7 – Health Monitoring and Recovery**

MT-UC1 – Small Application Consolidation

- Key attributes
  - Customer has multiple small applications
  - Non EE deployment OR more isolation needed between applications than provided by EE deployment OR need per application Middleware instances (ex liberty) due to management/operational requirements
  - Application memory/CPU overhead low compared to JVM overhead
- MT Benefit:
  - Lower total footprint/memory requirements
    - Limit overhead to that of 1 JVM versus many
    - Limit heap to 1 shared head heap

MT-UC2 – Run and Done

- Key attributes
  - Short running application with multiple invocations
  - Startup/Shutdown dominates run time
  - Need Isolation between invocations
  - Examples: Ant scripts, compilation with javac, IMS, Z Batch, JRuby scripts, Jython scripts etc.
- MT Benefit:
  - Faster startup/shutdown
    - Avoid full JVM startup/shutdown for each invocation

MT-UC3 – Resource Time Sharing

- Key attributes
  - Customer has multiple applications that have load at different times
  - Non EE deployment OR more isolation needed between applications than provided by EE deployment OR need per application Middleware instances (ex liberty) due to management/operational requirements
- MT Benefit:
  - Lower total footprint/memory requirements
    - Limit overhead to that of 1 JVM versus many
    - Shared heap sized to match concurrent maximum instead of sum of all application maximums

MT-UC4 – Resource Limiting based on SLA

- Key attributes
  - Customer has multiple applications sharing same OS instance
  - Some applications have higher SLA levels than others
- MT Benefit:
  - Able to control CPU, Network IO , File IO resource usage to favor application with higher SLA

MT-UC5 – Resource Limiting for Safety

- Key attributes
  - Customer has multiple applications sharing same OS instance
  - Some applications un-trusted or buggy, concern they will affect performance of other applications.
- MT Benefit:
  - Able to control CPU, Network IO , File IO resource usage to limit maximum impact of “runaway” application

MT-UC6 – Memory Cost Sensitive Environments

- Key attributes
  - Memory is costly for environment (e.g. Legacy hardware)
  - Shares attributes of one of earlier use cases
- MT Benefits
  - Footprint savings more compelling than in other environments.

MT-UC7 – Health monitoring and recovery

- Key attributes
  - Health monitoring/recovery runs in JVM with application
  - Application failures should not affect health monitoring (ex OOM on app)
- MT Benefits
  - Ability to ensure minimum amount of memory available to health monitoring/recovery components

Demo - Scenario

- JVM Health monitoring
  - Want heartbeat to track “liveness” of server
  - Need this to run reliably as long as application is still running
  - Requires some memory and cpu to generate heartbeat
  - Simulate in demo with thread that prints out “heartbeat” at 2 second interval
- Application Transactions
  - Transactions submitted from external system
  - Use variable amount of cpu depending on request
  - If transaction uses too much memory it can starve heartbeat thread
  - Simulate with thread(s) that uses as much cpu as they can

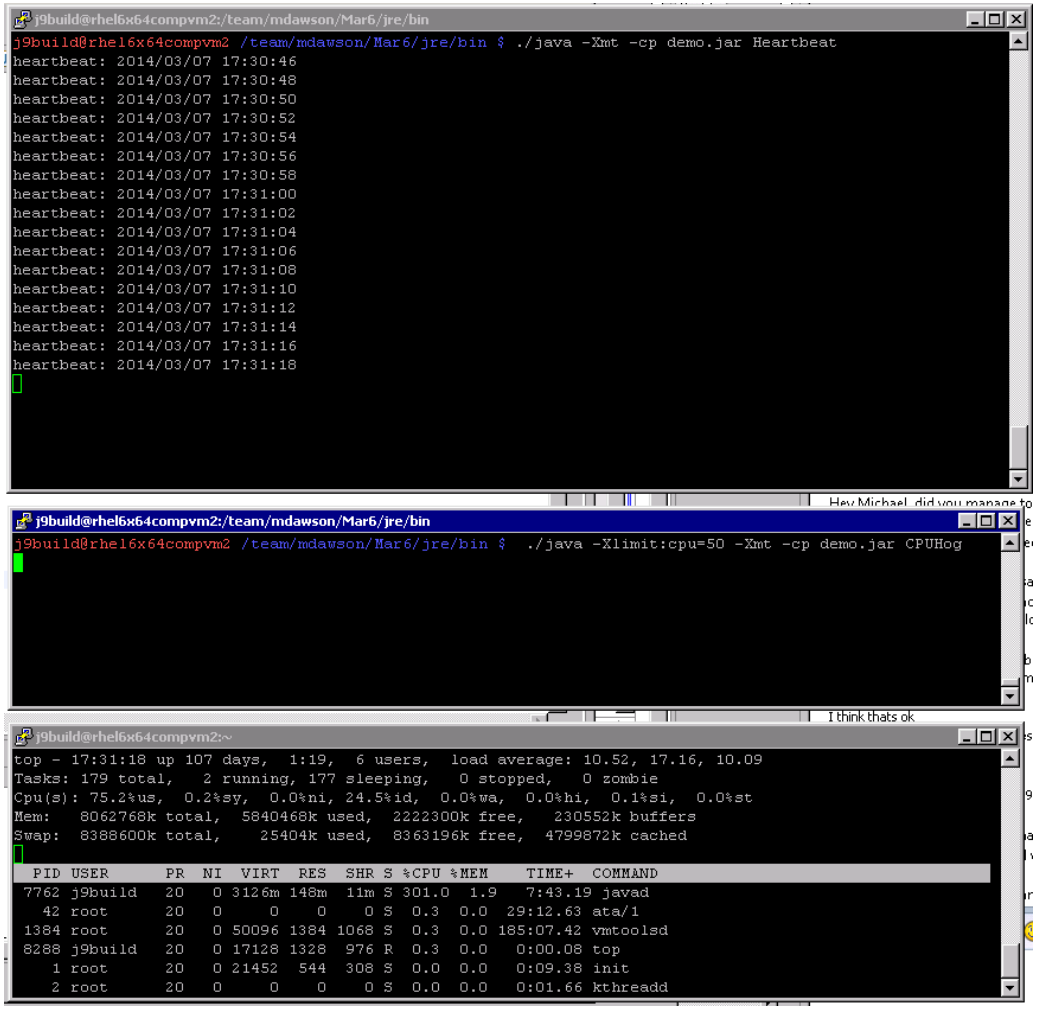
Demo – what happens today

- Run HeartbeatAndCPUHog
- ./java -cp demo.jar HeartbeatAndCPUHog
- Shows running both heartbeat thread and transaction in regular jvm
- Note that times between heartbeat messages stretch out once cpu hog starts

```
j9build@rhel6x64compvm2 /team/mdawson/Mar6/jre/bin $ cat javad.options^C
j9build@rhel6x64compvm2 /team/mdawson/Mar6/jre/bin $ ./java -cp demo.jar HeartbeatAndCPUHog
heartbeat: 2014/03/07 17:23:26
heartbeat: 2014/03/07 17:23:28
heartbeat: 2014/03/07 17:23:30
heartbeat: 2014/03/07 17:23:32
heartbeat: 2014/03/07 17:23:34
CPU Hog starting
heartbeat: 2014/03/07 17:23:36
heartbeat: 2014/03/07 17:23:44
heartbeat: 2014/03/07 17:23:53
heartbeat: 2014/03/07 17:24:03
heartbeat: 2014/03/07 17:24:12
heartbeat: 2014/03/07 17:24:22
heartbeat: 2014/03/07 17:24:33
```

Demo with MT

- ./java -Xmt -cp demo.jar Heartbeat in one window
- ./java -Xlimit:cpu=50 -Xmt -cp demo.jar CPUHog in another window
- Top in third window
- Note that heartbeat remains consistent even after hog starts
- Top shows that cpu varies, but average looks to be around 50%
- You might have to play with limit depending on your machine as heartbeat task does use reasonable amount of cpu to show affect.



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