What’s Hot in IBM’s Virtual Machine for the Java™ Platform?

Trent Gray-Donald

Java SE JVM Lead
IBM
www.ibm.com

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Goal

What's in it for you?

Learn about IBM's Java™ Virtual Machine offerings, the underlying design philosophy that enables scaling from a watch to a mainframe, and some of the core technology, including JIT and GC.

Agenda

Design Philosophy and History

JIT—Scalable Performance

GC—Flexible Collection Policies

Shared Classes—Smarter Resource Use

RAS—Reliability, Availability, Serviceability

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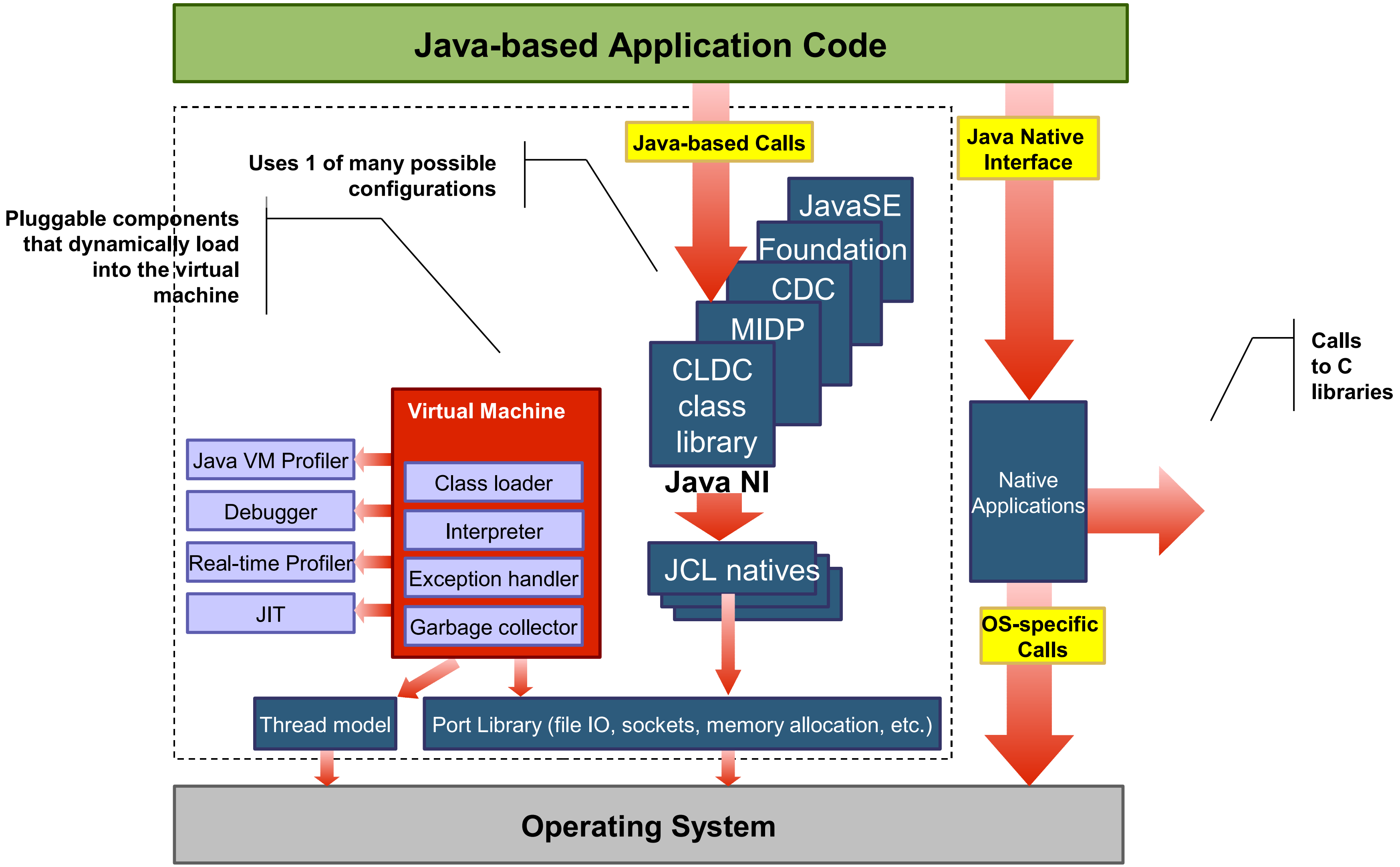
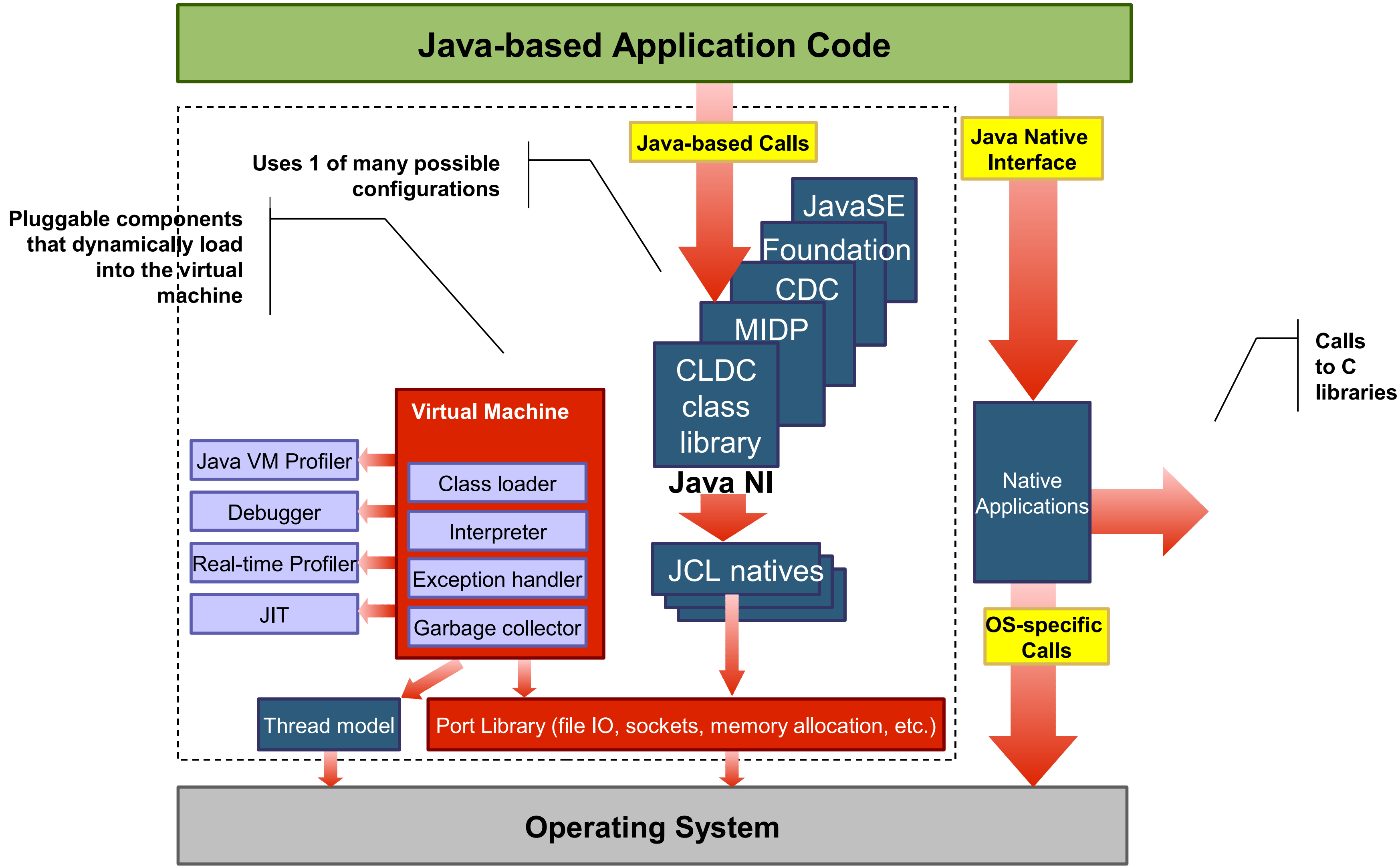
Design Philosophy and History

- Current offerings based on the J9 Virtual Machine
  - 3rd generation Java VM from IBM
  - Designed from the ground up to be a scalable solution for embedded, desktop, and server class hardware
- Common code base for all Java ME and Java SE products
  - Highly configurable—pluggable interfaces with different implementations depending on the target market
- Class library independence
- Supports latest language features (Java SE 5)
- Scaling to available hardware
  - Wide range—“From a watch to a mainframe”
    - Portable, configurable, flexible

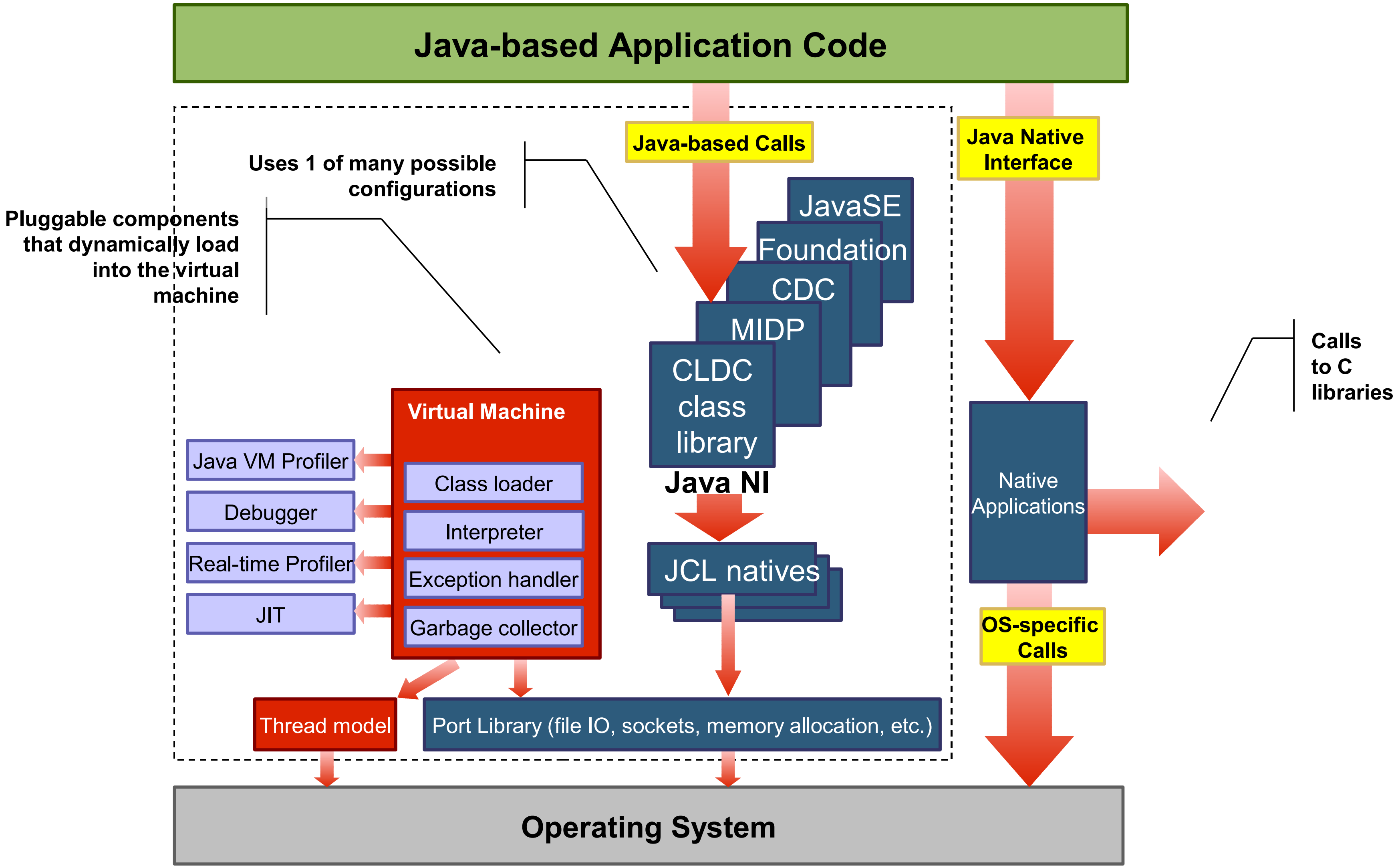
Java VM Architecture



Java VM Architecture



Java VM Architecture



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JIT Design Goals

- Java technology-centric design
- Flexible to meet different footprint goals
- Configurable optimization framework
- High-performance code with deep platform exploitation
- Complete solution: optimizing transformations fully operational in the presence of exception handling, security manager, stack trace, unresolved or volatile entities, etc.
- Dynamic recompilation with profile-directed feedback
- Fast Startup Times
- Support for Hot Code Replace and Full-speed Debug

Flexible JIT Configurations

- 3 ways to build the JIT
  - Full JIT 1–3M
    - Used with all the Java SE builds
  - Small JIT 300–600K
    - Generally bundled with the Java ME CDC offerings
    - Subset of the Full JIT
      - Optimizations from the Full JIT can easily be added to the Small JIT as small devices increase the amount of memory they have
  - Micro JIT 50–100K
    - Generally bundled with the Java ME CLDC offerings
    - Direct bytecode to native code (no intermediate language)

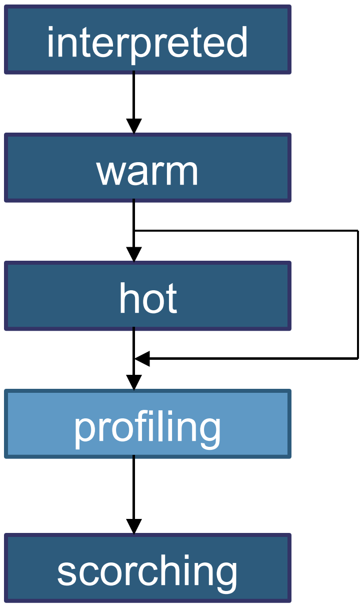
Configurable Optimization Framework

- Complete suite of classical and Java technology optimizations
- Platform neutral optimizer performs IL-IL transformations
  - Parameterized by platform-specific code to handle different CPU capabilities (e.g., number of registers)
- Multiple optimization strategies for different code quality/compile-time tradeoffs
  - Used to compose optimizations into a collection of transformations
  - Spend compile time where it makes biggest difference
  - Extremely flexible solutions and infrastructure
- Target processor optimizations

Subset of Classical Optimizations

- Loop versioning, loop unrolling
- Local and global register assigning
- Escape Analysis
- Devirtualization
- Scheduling technology shared with IBM's static compilers
- Class hierarchy optimizations

Adaptive Compilation in TR JIT



- Methods start out being interpreted
- After N invocations methods get compiled at ‘warm’ level
- Sampling thread used to identify hot methods
- Methods may get recompiled at ‘hot’ or ‘scorching’ levels
- Transition to ‘scorching’ goes through a temporary profiling step

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Garbage Collection

- Workloads
  - Transactional (e.g., web)
  - Batch (javac/Eclipse workspace build)
- Hardware varies tremendously
  - 1MB to 128GB
  - Single hardware thread up to 128-way multi-core Simultaneous MultiThreading (SMT) hardware
  - Memory Consistency differences
    - z/Series®
    - p/Series®

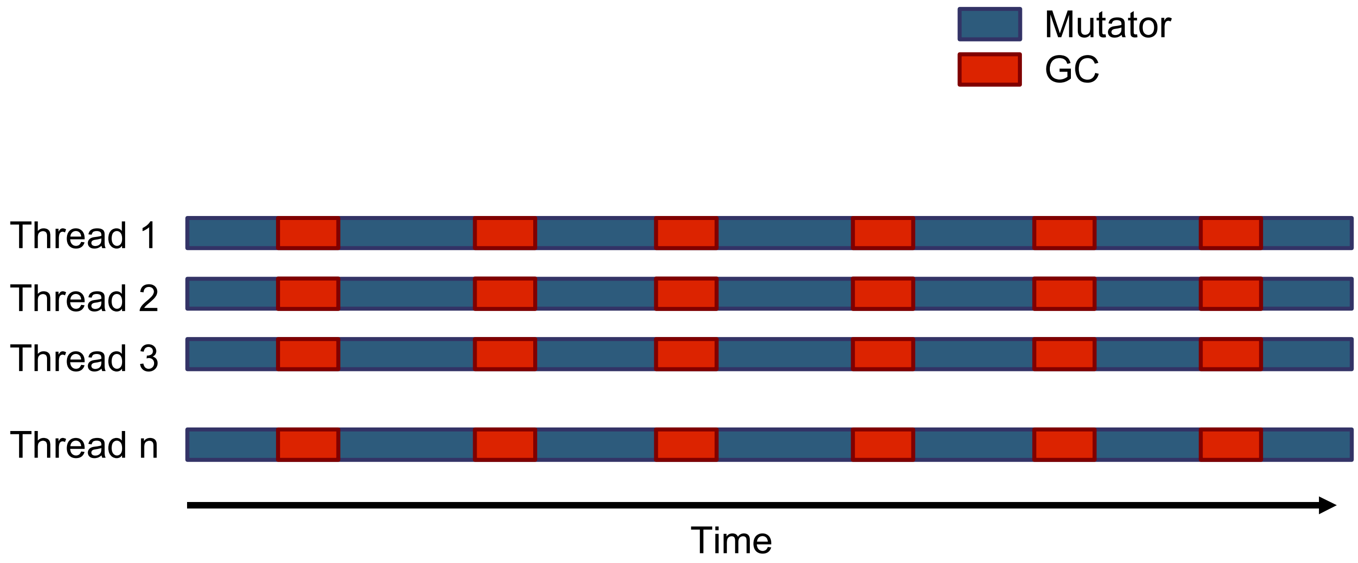
GC Policies in IBM SDK 5.0

- Optimize for Throughput –Xgcpolicy:optthruput (default)
  - Mark-Sweep-Compact tracing collector
- Optimize for PauseTime –Xgcpolicy:optavgpause
  - Concurrent Mark and Sweep
- Subpooling –Xgcpolicy:subpool
  - Mark-Sweep-Compact tracing collector
  - Designed to reduce heap lock contention on SMP systems
- Generational Concurrent –Xgcpolicy:gencon
  - Generational Copy-Collector with concurrent collection

GC Policies in IBM SDK 5.0

How do the policies compare?

-Xgcpolicy:optthruput *(and –Xgcpolicy:subpool)*

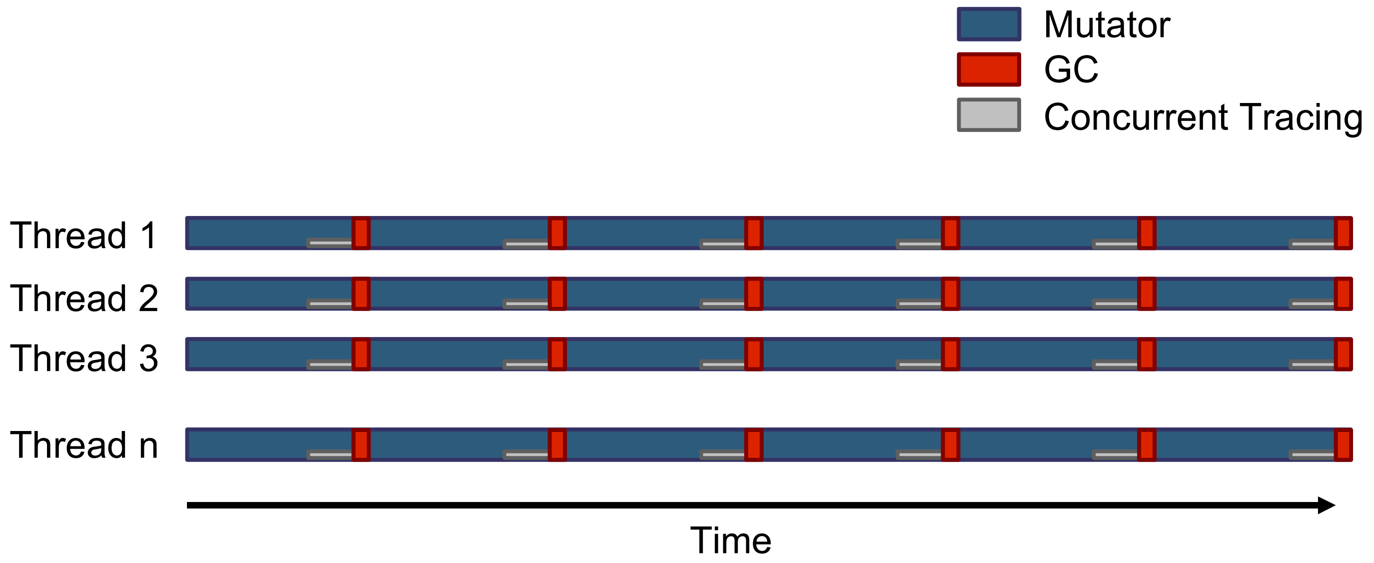


Picture is only illustrative and doesn't reflect any particular real-life application. The purpose is to show theoretical differences in pause times between GC policies.

GC Policies in IBM SDK 5.0

How do the policies compare?

-Xgcpolicy:optavgpause



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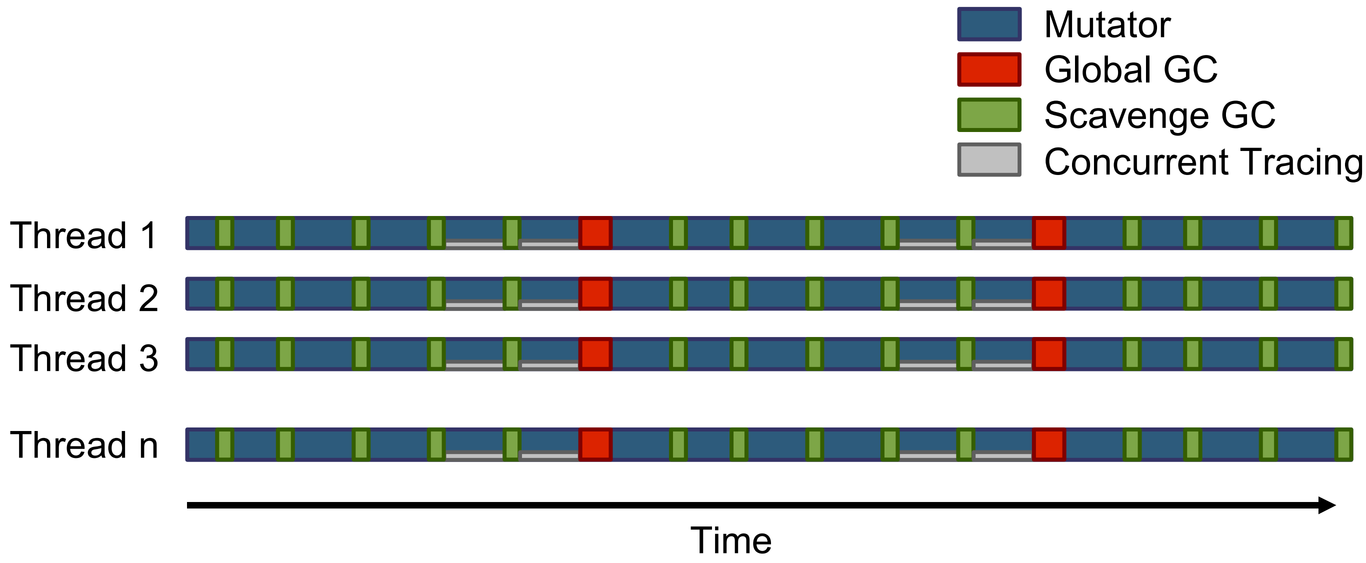
GC Policies in IBM SDK 5.0

How do the policies compare?

-Xgcpolicy:gencon



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Tuning

Allocation request details, time it took to stop all mutator threads.

Heap occupancy details before GC.

Details about the scavenge.

Heap occupancy details after GC.

```
<af type="nursery" id="1134" timestamp="Fri May 05 17:10:32 2006" intervalms="1882.416">
  <minimum requested_bytes="88" />
  <time exclusiveaccessms="0.109" />
  <nursery freebytes="0" totalbytes="56465408" percent="0" />
  <tenured freebytes="629133648" totalbytes="1191182336" percent="52" >
    <soa freebytes="617221968" totalbytes="1179270656" percent="52" />
    <loa freebytes="11911680" totalbytes="11911680" percent="100" />
  </tenured>
  <gc type="scavenger" id="1134" totalid="1142" intervalms="1882.915">
    <flipped objectcount="309209" bytes="10003828" />
    <tenured objectcount="150595" bytes="4840096" />
    <refs_cleared soft="234" weak="0" phantom="0" />
    <finalization objectsqueued="7" />
    <scavenger tiltratio="84" />
    <nursery freebytes="45832192" totalbytes="56475648" percent="81" tenureage="2" />
    <tenured freebytes="624027856" totalbytes="1191182336" percent="52" >
      <soa freebytes="612116176" totalbytes="1179270656" percent="51" />
      <loa freebytes="11911680" totalbytes="11911680" percent="100" />
    </tenured>
    <time totalms="86.619" />
  </gc>
  <nursery freebytes="45830144" totalbytes="56475648" percent="81" />
  <tenured freebytes="624027856" totalbytes="1191182336" percent="52" >
    <soa freebytes="612116176" totalbytes="1179270656" percent="51" />
    <loa freebytes="11911680" totalbytes="11911680" percent="100" />
  </tenured>
  <time totalms="87.229" />
</af>
```

What Policy Should I Choose?

I want my application to run to completion as quickly as possible.

-Xgcpolicy:optthruput

My application requires good response time to unpredictable events.

-Xgcpolicy:optavgpause

What Policy Should I Choose?

My application has a high allocation and death rate.

-Xgcpolicy:gencon

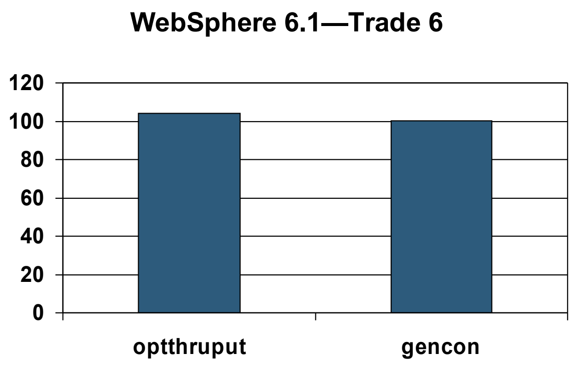
My application is running on big metal and has high allocation rates on many threads.

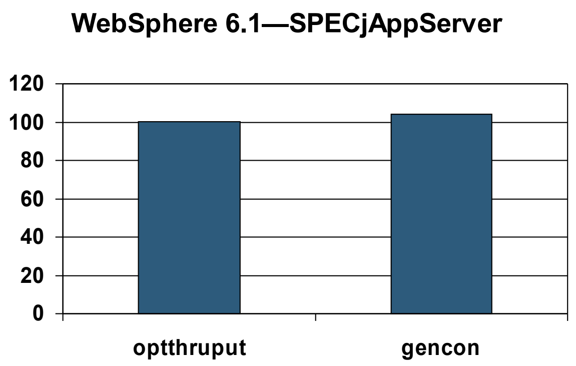
-Xgcpolicy:subpool

Danger! Caveat Emptor…

- Some WebSphere® applications perform better with gencon—however, some applications degrade in performance

- Peak throughput performance versus lower GC pause times tradeoffs possible





Numbers are approximate and only intended to show a general behaviour seen when running Trade6 compared to SPECjAppServer.

Garbage Collection FAQ

- "I want to reduce my maximum pause time."
  - Lock the new generation size to a fixed value
    - Fixed number of possible live objects per collect
  - Adjust the taxation rate of the concurrent collector
    - Amortize the cost of collection over longer periods
  - Disable compaction
    - Reduced large pauses at the expense of increased fragmentation

Garbage Collection FAQ

- "I want my system to handle occasional large objects allocations without Garbage Collecting every time."
  - Increase the size of the large object area
    - Reduce need for garbage collector to create space by pre-reserving heap
  - Adjust concurrent collector metering against regular allocates, large object allocates, or both
    - Determined by frequency of large object allocates

Garbage Collection—Tuning gencon

- Balancing nursery and the tenured space
- Automatic
  - Specify the minimum and maximum heap size (e.g., –Xms512m –Xmx1024m)
  - JDK 5 nursery will not automatically grow beyond 64MB
- Hand Tuning
  - Main factors are new object death rates, tenure space used
  - Recommended approach for performance-sensitive, server-side applications

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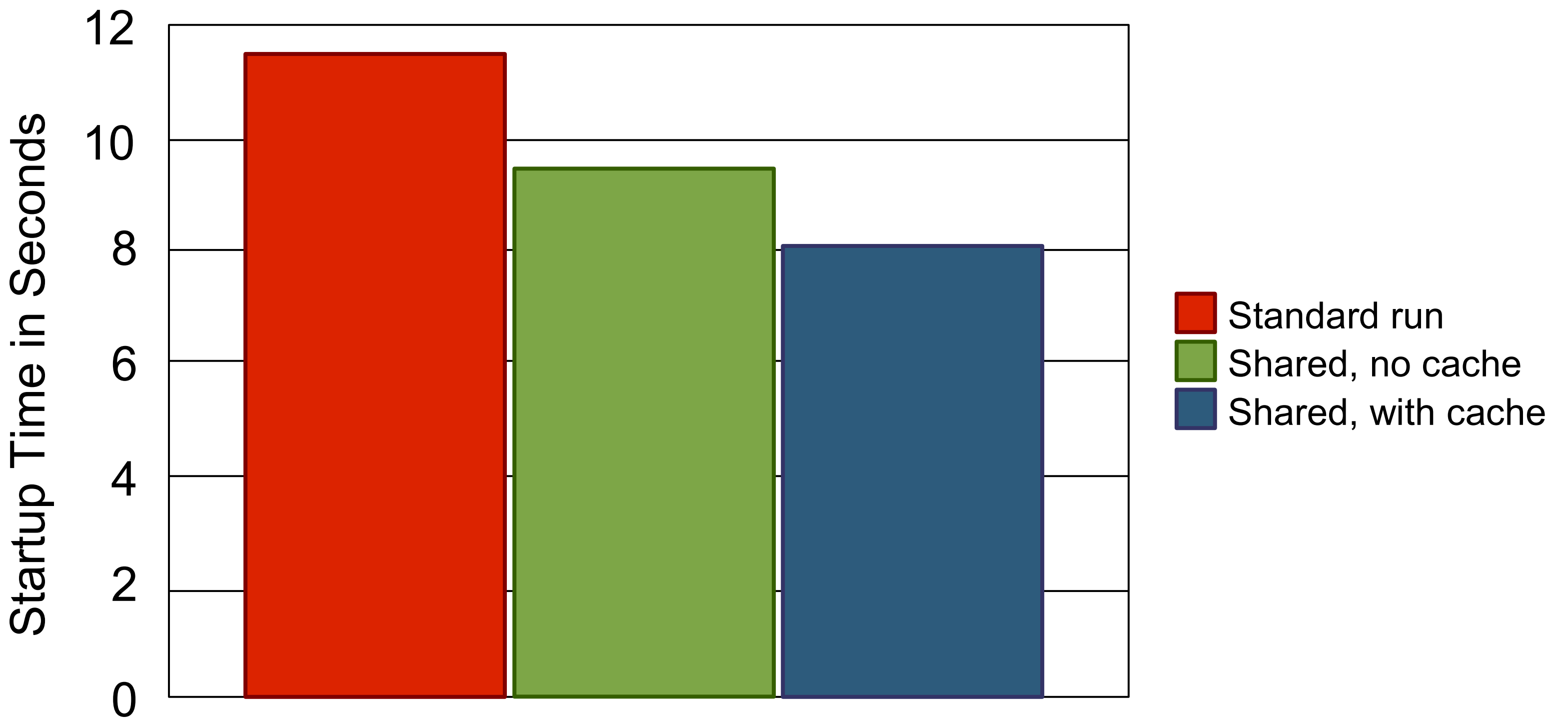
Shared Classes

- Server environments where multiple JVMs exist on the same box
- Improves startup time and memory footprint
- Sharing of class data—granularity is .class file
- Multiple sharing strategies
  - Standard classloaders (including Application Classloader) exploit the feature when enabled
  - API to extend custom ClassLoaders available

Shared Classes Performance



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Reliability, Availability, Serviceability (RAS)

- Top IBM focus
  - Necessary for effective support of over 1,800 IBM products on top of Java
- Problem types are varied
  - Hangs
  - Spins
  - Unexpected Java code exceptions/errors
  - Crashes (because of user Java NI code or Java VM code)
  - Performance issues

RAS Tools—Java NI

- Difficult problem area
  - Different Java VM behaviours
    - Arrays—copy vs. pin
    - References (reuse, lifetimes)
  - Non-Java technology paradigm
    - Explicit exception checks
    - Allocation failures
- -Xcheck:jni
  - Validates a full range of Java NI errors seen internally and in customer code
  - Range from critical to pedantic

RAS Tools –Xdump and DTFJ

- Trigger informative dumps (Java based/ system/heap) on a multitude of events
  - e.g., OutOfMemoryError produces javacore.txt and a heap dump
- Events include class load, exception throw, thread start/stop, GC
- Dump Tools Framework for Java Technology (DTFJ)
  - Toolkit to allow programmatic introspection into different RAS artifacts (system dumps, etc.)
  - TS-3881 for a deep dive

RAS Tools –Xdump File Types

- Javacore.txt (human and machine readable)
  - Java VM version
  - Java VM arguments, OS paths
  - Major Java VM structure addresses
  - Java-based Threads with stack trace
  - Monitors with owners, blockers, waiters
  - Classloaders and classes
- Heapdump.phd (machine readable)
  - Dense Java-based heap contents
- System dumps (OS specific)

RAS Tools –Xdump Examples

- -Xdump:java:events=throw,filter=MyException
- -Xdump:heap:events=unload,filter=MyClass
- -Xdump:java:events=load,range=4..7

```
JVMDUMP006I Processing Dump Event "load", detail "java/lang/reflect/GenericDeclaration" -
Please Wait.
JVMDUMP007I JVM Requesting Java Dump using C:\150\jre\bin\javacore.20060425.010831.2720.txt
JVMDUMP010I Java Dump written to C:\150\jre\bin\javacore.20060425.010831.2720.txt
JVMDUMP013I Processed Dump Event "load", detail "java/lang/reflect/GenericDeclaration".
```

RAS Tools –Xtrace

- Provides tiered tracing of Java VM internal program flow and Java technology-level method execution
- Always on for some internal trace in JDK™ 5.0 software
  - Very useful for First Fail Data Capture (FFDC) purposes
- GC statistics kept in separate rolling trace buffer and dumped into javacore*.txt files whenever triggered

Observations on the Future

(NB: No guarantee re: future products or research)

- Quality of service
  - Pause time (not just GC!)
  - Performance
  - RAS
- Real-time GC
  - Metronome (1ms max pause time)
- Multi-core CPUs
- NUMA
- 64-bit Java VMs and hybrid solutions

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