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Running Java on Linux on System z

Session # 12378

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Content

- IBM Java on Z
  - History, overview and roadmap

- IBM J9 Virtual Machine and IBM Testarossa JIT
  - IBM Monitoring and Diagnostic Tools for Java

- Java 7 SR3
  - zEC12 exploitation and performance

IBM and Java

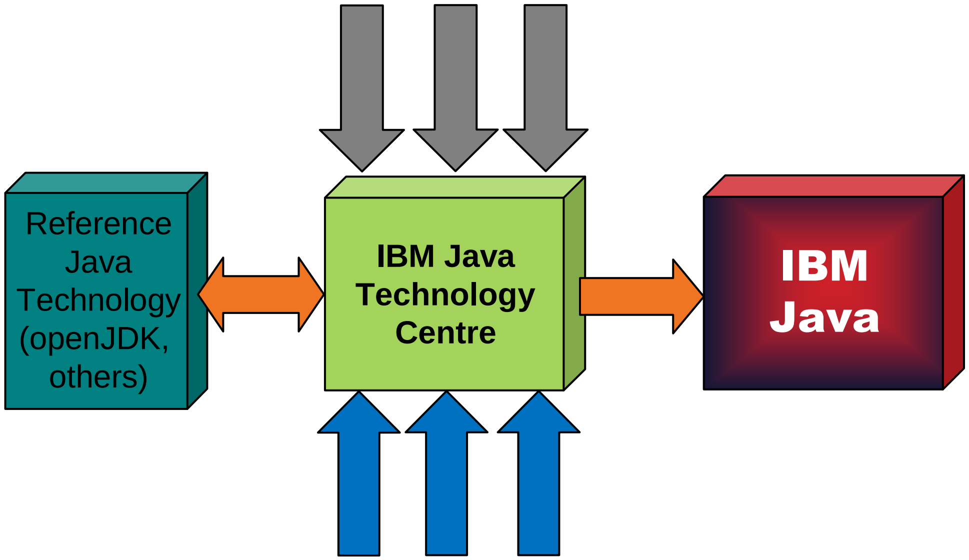
- **Java is critically important to IBM**
  - Fundamental infrastructure for IBM's software portfolio
  - WebSphere, Lotus, Tivoli, Rational, Information Management (IM)

- **IBM is investing strategically for Java in Virtual Machines**
  - As of Java 5.0, single JVM support
    - JME, JSE, JEE
  - New technology base (J9/TR Compiler) on which to deliver improved performance, reliability, serviceability

- **IBM also invests in, and supports public innovation in Java**
  - OpenJDK, Eclipse, Apache (XML, Aries, Derby, Geronimo, Harmony, Tuscany, Hadoop …)
  - Broad participation in relevant open standards (JCP, OSGi)

IBM’s Approach to Java Technology

Quality Engineering
Performance
Security
Reliability
Serviceability



Reference Java Technology (openJDK, others)

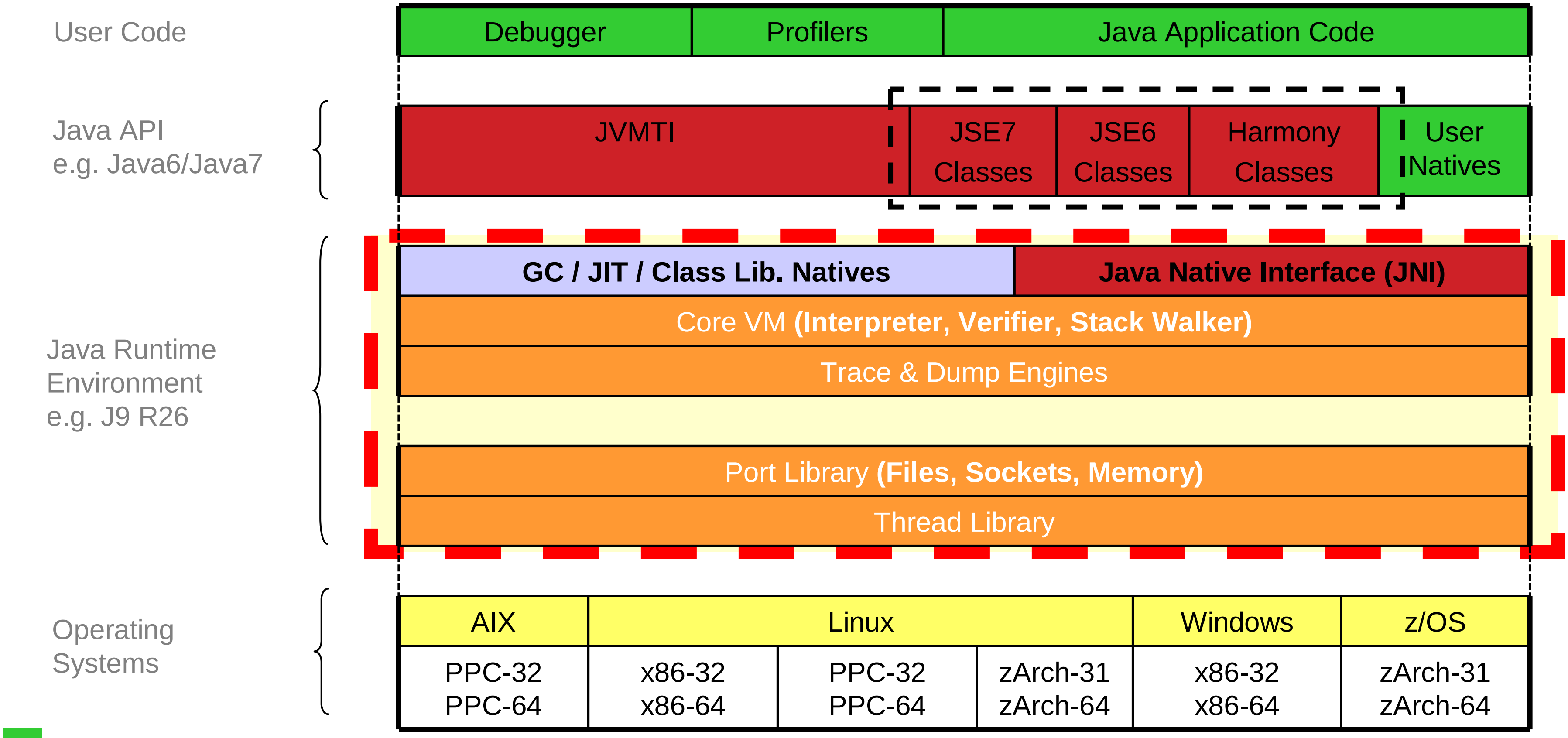
IBM Java Technology Centre

IBM Java

Production Requirements
IBM Software Group
IBM *eServer*
ISVs
IBM Clients

- ✓ *Listen to and act upon market requirements*
- ✓ *World class service and support*
- ✓ *Available on more platforms than any other Java implementation*
- ✓ *Highly optimized*
- ✓ *Embedded in IBM’s middleware portfolio and available to ISV partners*

JVM Architectural Overview



User Code

Debugger | Profilers | Java Application Code

Java API
e.g. Java6/Java7

JVMTI | JSE7 Classes | JSE6 Classes | Harmony Classes | User Natives

Java Runtime
Environment
e.g. J9 R26

GC / JIT / Class Lib. Natives | **Java Native Interface (JNI)**

Core VM **(Interpreter, Verifier, Stack Walker)**

Trace & Dump Engines

Port Library **(Files, Sockets, Memory)**

Thread Library

Operating
Systems

AIX	Linux			Windows	z/OS
PPC-32 PPC-64	x86-32 x86-64	PPC-32 PPC-64	zArch-31 zArch-64	x86-32 x86-64	zArch-31 zArch-64

🟩 = User Code

🟥 = Java Platform API

🟪 = VM-aware

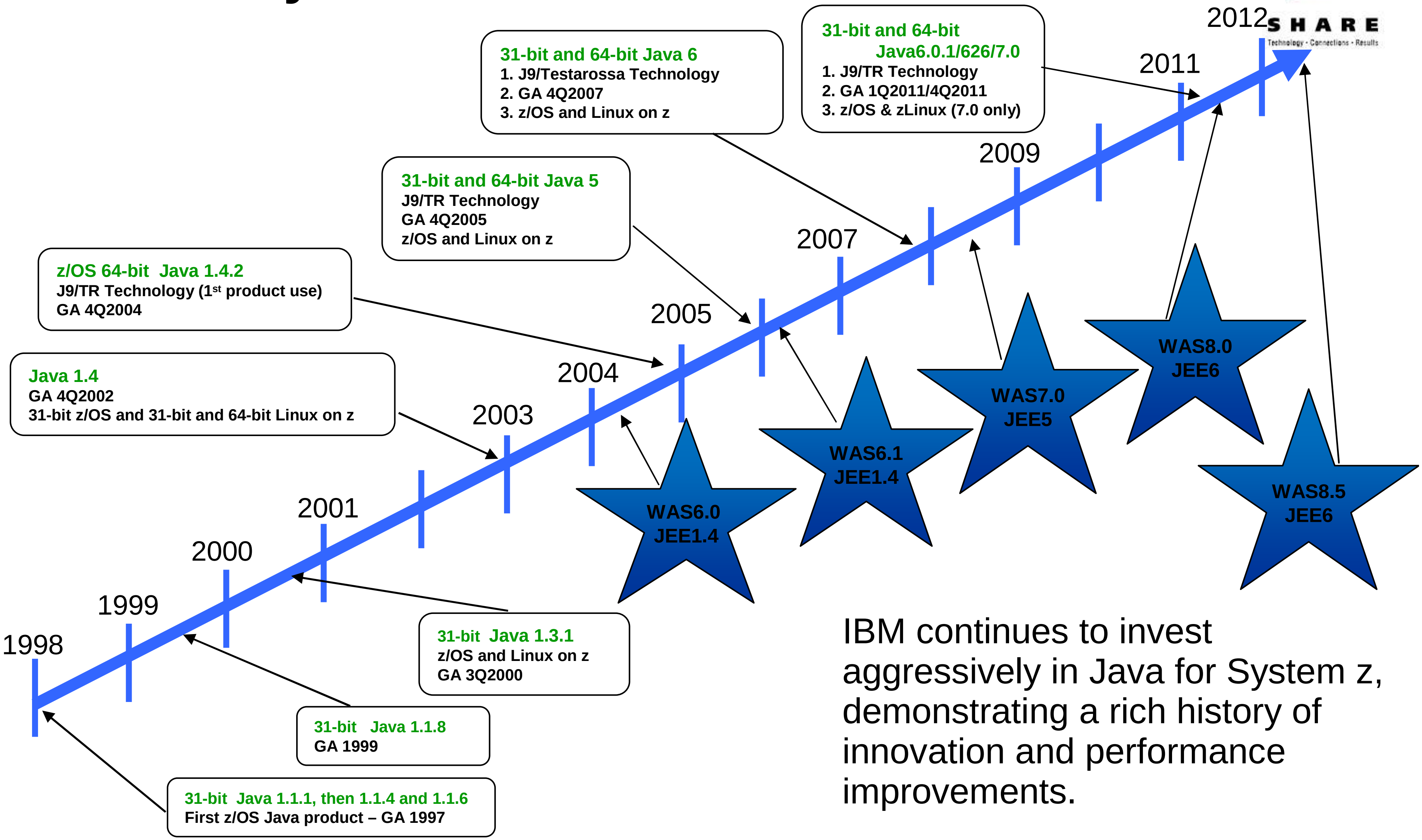
🟧 = Core VM

Key Differences between Oracle and IBM Java

- IBM and Oracle use the same reference implementation of Java Class Libraries (e.g. OpenJDK)
  - Key differences to be aware of:
    1. Security: Standards do not impose strong separation of interest
    2. ORB: OMG CORBA standard rules
    3. XML: Xerces/Xalan used by both vendors as of Java5, although different levels may be used.

- IBM uses the J9/TR runtime, Oracle uses Hotspot
  - Different JIT/GC/VM tuning and controls
  - Tooling is distinct (e.g. IBM's Health Center)

Java on System z – 15 Years of Innovation



31-bit Java 1.1.1, then 1.1.4 and 1.1.6
First z/OS Java product – GA 1997

31-bit Java 1.1.8
GA 1999

31-bit Java 1.3.1
z/OS and Linux on z
GA 3Q2000

Java 1.4
GA 4Q2002
31-bit z/OS and 31-bit and 64-bit Linux on z

z/OS 64-bit Java 1.4.2
J9/TR Technology (1st product use)
GA 4Q2004

31-bit and 64-bit Java 5
J9/TR Technology
GA 4Q2005
z/OS and Linux on z

31-bit and 64-bit Java 6
1. J9/Testarossa Technology
2. GA 4Q2007
3. z/OS and Linux on z

31-bit and 64-bit
Java6.0.1/626/7.0
1. J9/TR Technology
2. GA 1Q2011/4Q2011
3. z/OS & zLinux (7.0 only)

IBM continues to invest aggressively in Java for System z, demonstrating a rich history of innovation and performance improvements.

Testimonials: http://www-01.ibm.com/software/os/systemz/testimonials/
http://www.centerline.net/review/#/3332_B

Timelines and deliveries are subject to change.

Java Road Map

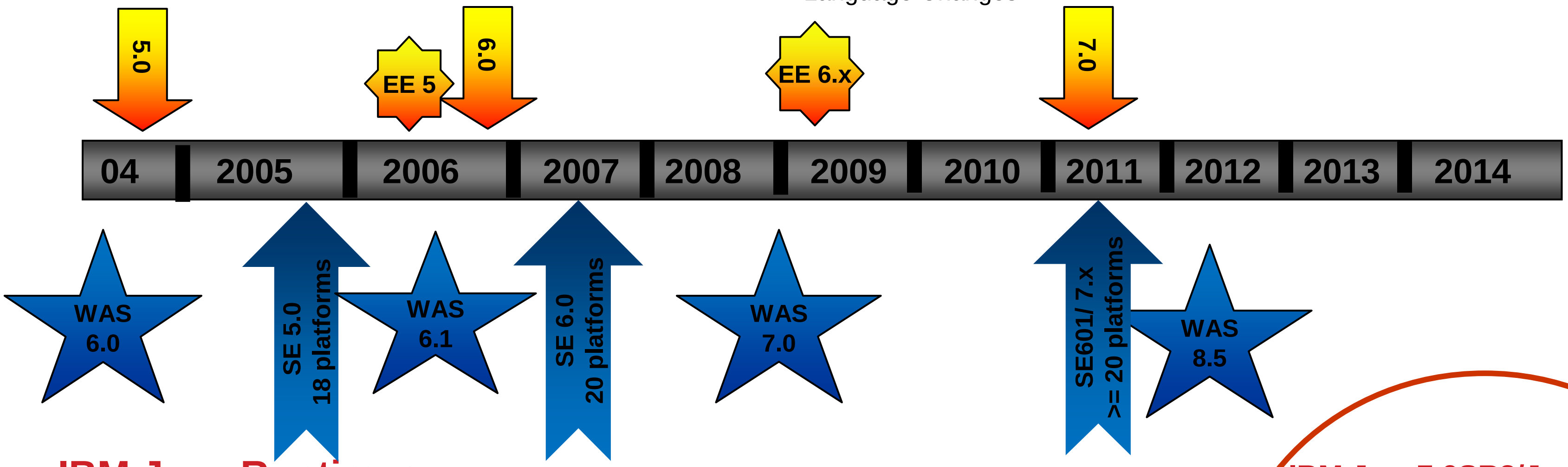
Language Updates

Java 5.0
- New Language features:
  - Autoboxing
  - Enumerated types
  - Generics
  - Metadata

Java 6.0
- Performance Improvements
- Client WebServices Support

Java 7.0
- Support for dynamic languages
- Improve ease of use for SWING
- New IO APIs (NIO2)
- Java persistence API
- JMX 2.x and WS connection for JMX agents
- Language Changes

Java 8.0**
- Language improvements
- Closures for simplified fork/join



IBM Java Runtimes

IBM Java 5.0 (J9 R23)
- Improved performance
  - Generational Garbage Collector
  - Shared classes support
  - New J9 Virtual Machine
  - New Testarossa JIT technology
- First Failure Data Capture
- Full Speed Debug
- Hot Code Replace
- Common runtime technology
  - ME, SE, EE

IBM Java 6.0 (J9 R24)
- Improvements in
  - Performance
  - Serviceability tooling
  - Class Sharing
- XML parser improvements
- z10™ Exploitation
  - DFP exploitation for BigDecimal
  - Large Pages
  - New ISA features

IBM Java 6.0.1/Java7.0 (J9 R26)
- Improvements in
  - Performance
  - GC Technology
- z196™ Exploitation
  - OOO Pipeline
  - 70+ New Instructions
- JZOS/Security Enhancements

IBM Java7.0SR3/Java.Vnext**
- Improvements in
  - Performance
  - GC Technology
- zEC12™ Exploitation
  - Transactional Execution
  - Runtime Instrumentation
  - Flash 1Meg pageable LPs
  - 2G large pages
  - Hints/traps
- Data Access Accelerator
- **Cloud:** Multi-tenancy/Virtualization

**Timelines and deliveries are subject to change.

Java 7.0 – What to look for

New I/O

- Meets the increasingly I/O intensive demands of data mining and analytics workloads
- Significant performance and footprint gains from async I/O

Concurrency Libraries

- Exploit larger multi-core systems, such as next generation Power and System z, by providing better scalability, higher throughput and lower total cost of ownership from server consolidations

Dynamic language support

- Leverage the advantages of a single runtime for dynamic language applications written in PHP, Groovy, jRuby and jython

Language improvements

- Improved efficiency through simplified day-to-day programming tasks
- Protect developer commitment to, and customer/ISV investment in, the Java ecosystem.

Java8-Beta Program

- **Provides Java SE 8 compatibility, while exploiting the unique capabilities of IBM platforms to achieve performance and usability improvements**
  - To provide early technology access during the development cycle
  - To assist Java 8 in satisfying customer requirements
  - To provide feedback to IBM

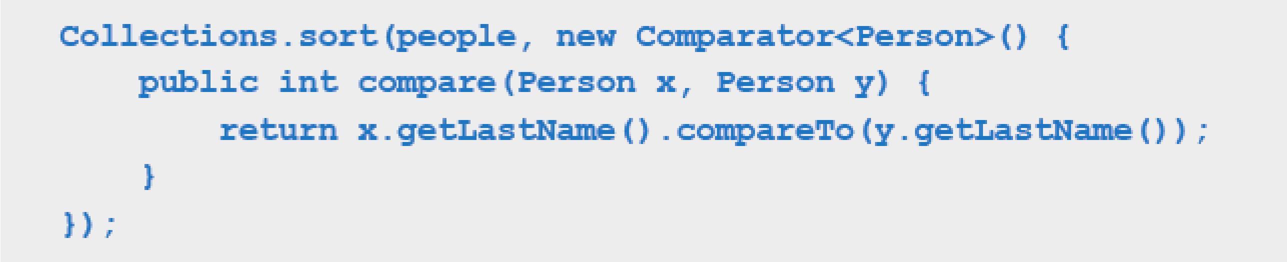
- **New in IBM SDK, Java Technology Edition, Version 8:**
  - Compatibility with the new Java SE 8
  - Leveraging new IBM hardware (e.g. IBM zEnterprise EC12)
  - Improved performance for workload optimized runtimes, which delivers better application throughput without changes to application code
  - Enhanced support for Cloud & Multi-tenancy environments
  - Improved efficiency of manipulating native data records/types directly from Java code

- **Managed and Open Beta**
  - http://www.ibm.com/developerworks/java/jdk/beta/index.html

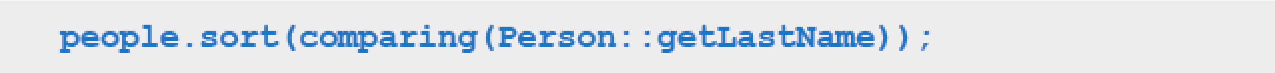
Java8: Language Innovation -- Lambdas

New syntax to allow concise code snippets and expression

- Useful for sending code to java.lang.concurrent
- On the path to enabling more parallelisms



```
Collections.sort(people, new Comparator<Person>() {
    public int compare(Person x, Person y) {
        return x.getLastName().compareTo(y.getLastName());
    }
});
```



```
people.sort(comparing(Person::getLastName));
```

http://www.dzone.com/links/presentation_languagelibraryvm_coevolution_in_jav.html

Java8: Data Access Accelerator

A Java library for bare-bones data conversion and arithmetic

Operates directly on byte arrays

No Java object tree created

Orchestrated with JIT for deep platform opt.

Avoids expensive Java object instantiation

Library is platform and JVM-neutral

Marshalling and Un-marshalling

Transform primitive type (short, int, long, float, double) ⇔ byte array

Support both big/little endian byte arrays

Packed Decimal (PD) Operations

Arithmetic:	+, -, *, /, % on 2 PD operands
Relation:	>,<,>=,<=,==,!= on 2 PD operands
Error checking: checks if PD operand is well-formed	
Other:	shifting, and moving ops on PD operand

Decimal Data Type Conversions

Decimal ⇔ Primitive:	Convert Packed Decimal(PD), External Decimal(ED), Unicode Decimal(UD) ⇔ primitive types (int, long)
Decimal ⇔ Decimal:	Convert between dec. types (PD, ED, UD)
Decimal ⇔Java:	Convert dec. types (PD, ED, UD) ⇔ BigDecimal, BigInteger

Current Approach:

```
byte[] addPacked(array a[], array b[]) {
      BigDecimal a_bd = convertPackedToBd(a[]);
      BigDecimal b_bd = convertPackedToBd(b[]);
      a_bd.add(b_bd);
return (convertBDtoPacked(a_bd));
}
```

Proposed Solution:

```
byte[] addPacked(array a[], array b[]) {
      DAA.addPacked(a[], b[]);
return (a[]);
}
```

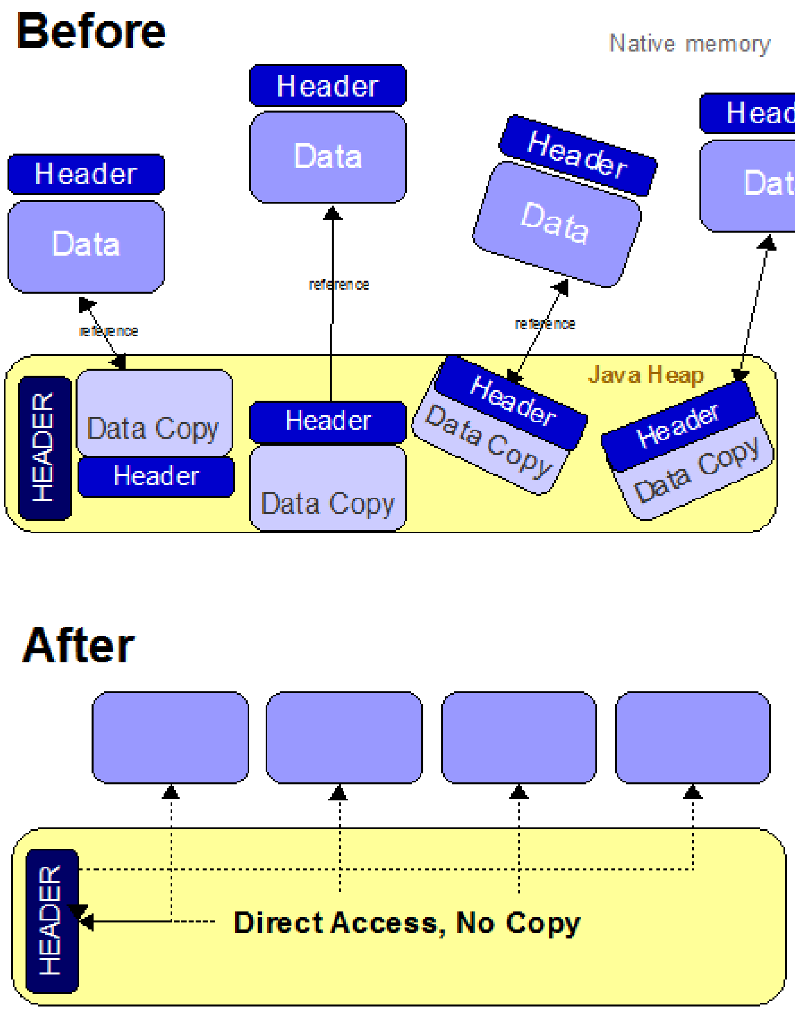
Looking Ahead: PackedObjects with IBM Java

PackedObjects

Experimental feature in the IBM JVM. Introduces a new Java type that implements an explicit object model which tightly packs fields allowing for natural and efficient direct mapping of structured data.

Goals

- Allow for explicit source-level representation of structured data in Java
- Improve serialization and I/O performance
- Allow direct access to “native” (off-heap) data

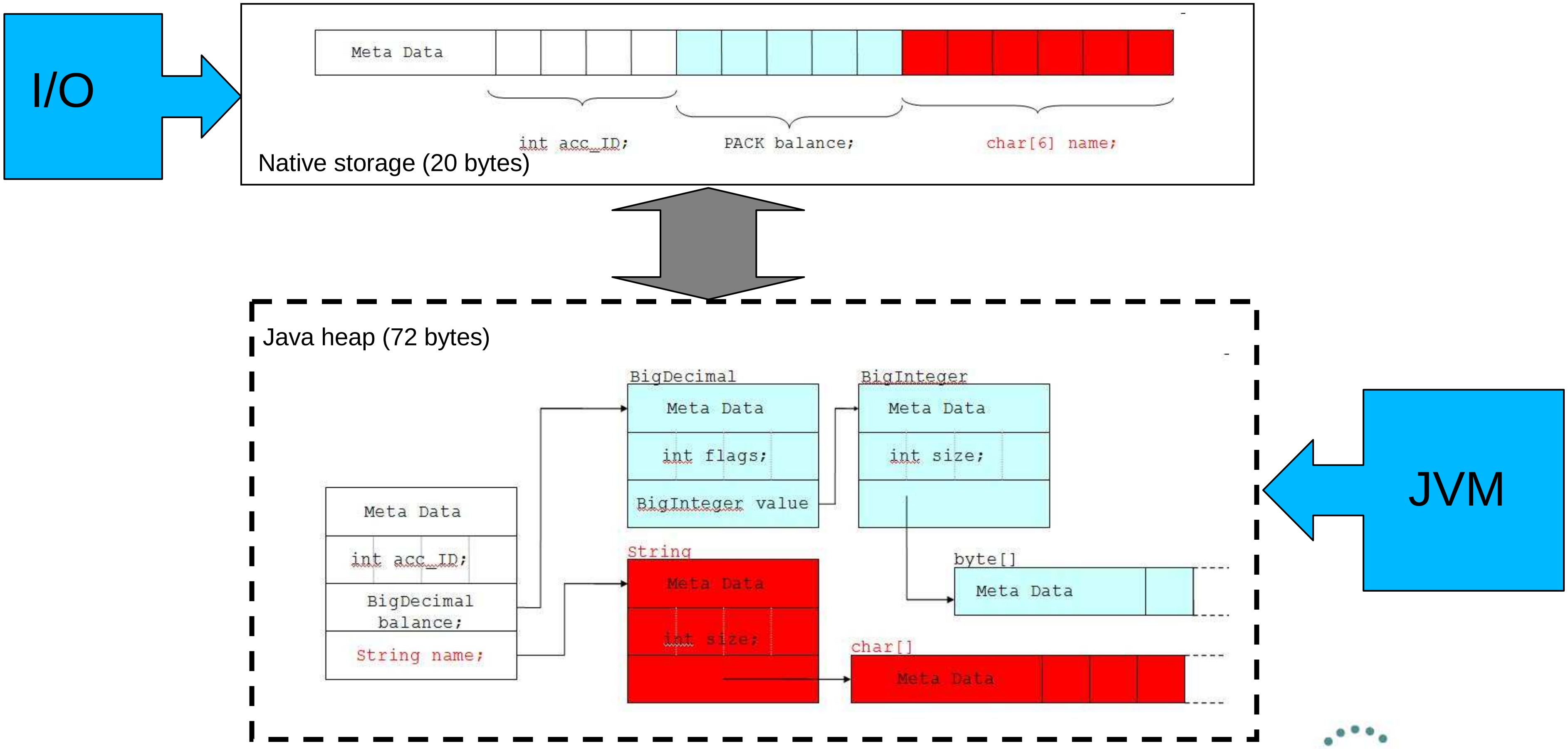


http://www.slideshare.net/mmitran/ibm-java-packed-objects-mmit-20121120
http://duimovich.blogspot.ca/2012/11/packed-objects-in-java.html

Timelines and deliveries are subject to change.

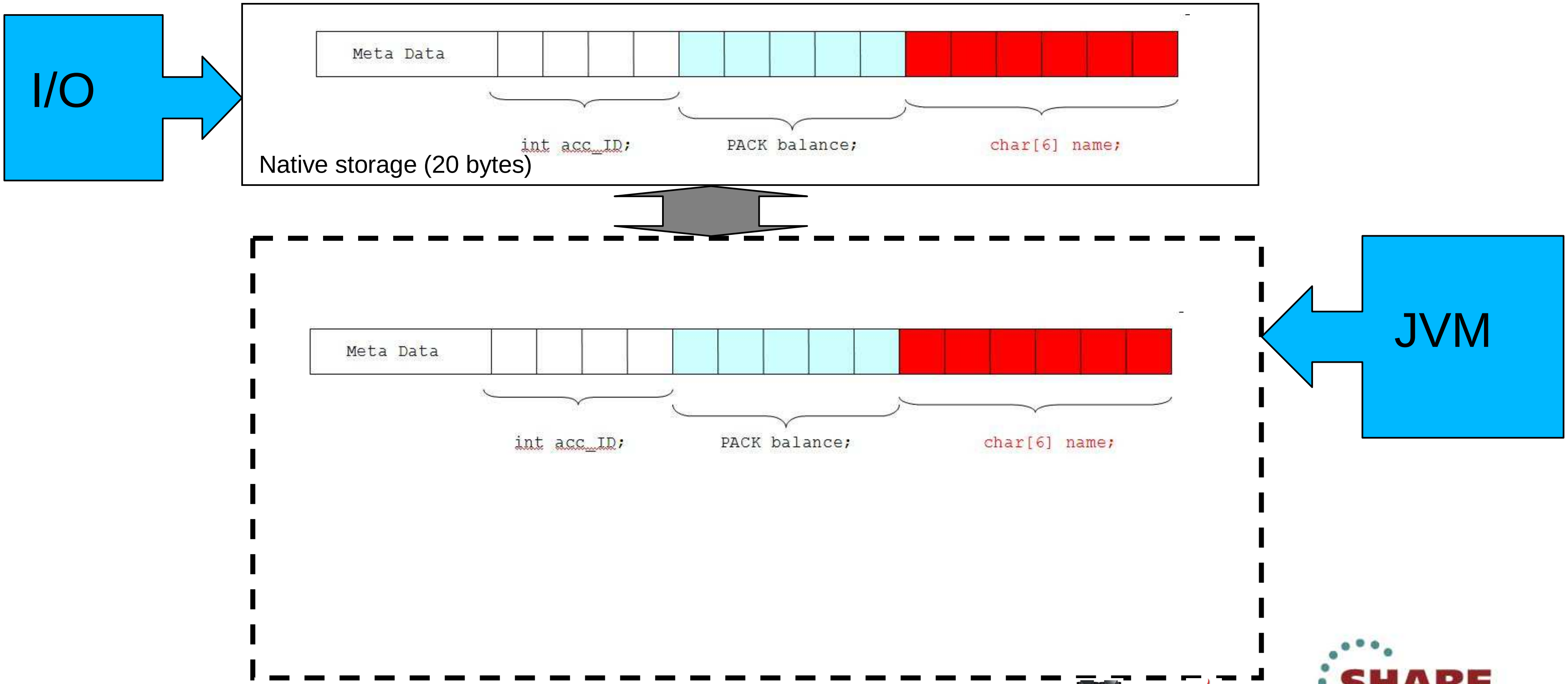
Speak to me in ‘Java’

- Java only speaks ‘Java’…
  - Data typically must be copied/re-formatted onto/off Java heap
  - Costly in path-length and footprint



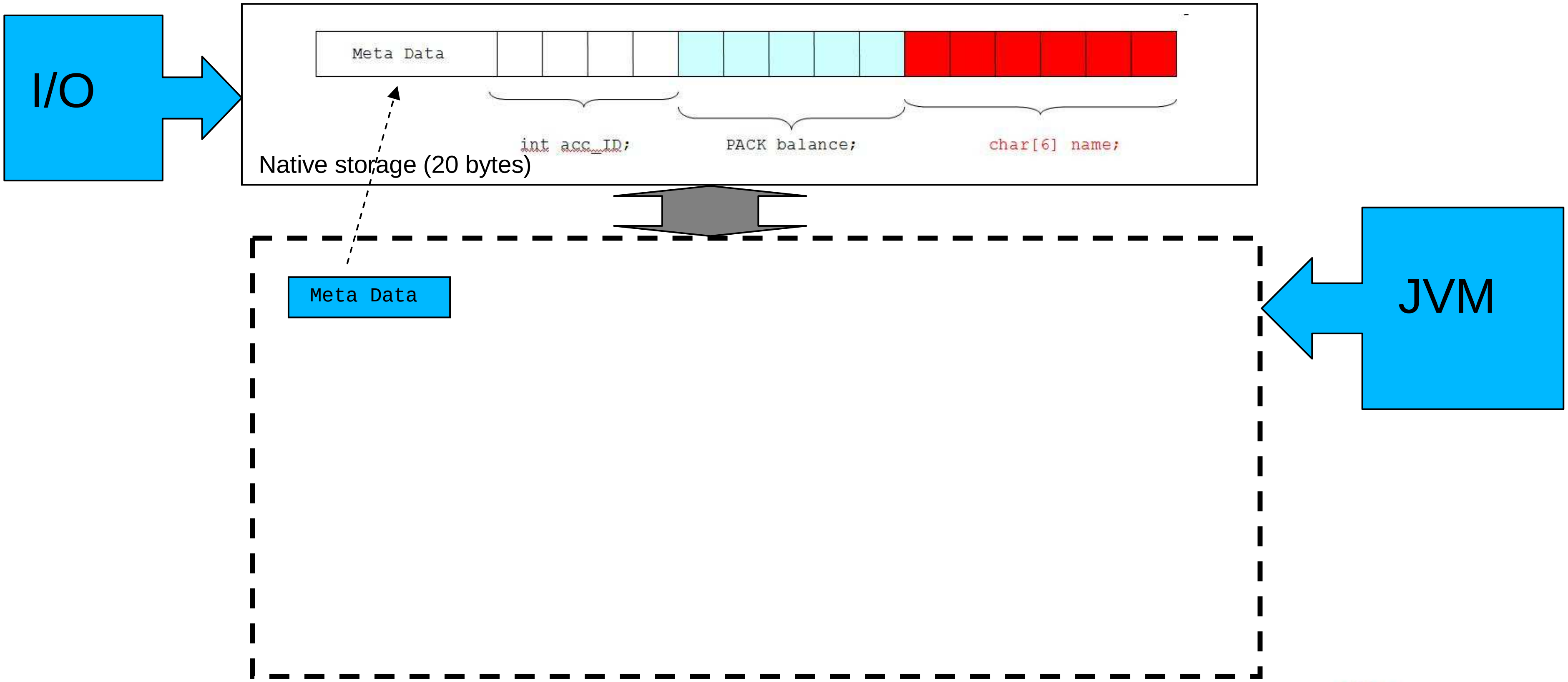
On-Heap PackedObject

- Allows controlled layout of storage of data structures on the Java heap
  - Reduces footprint of data on Java heap
  - No (de)serialization required



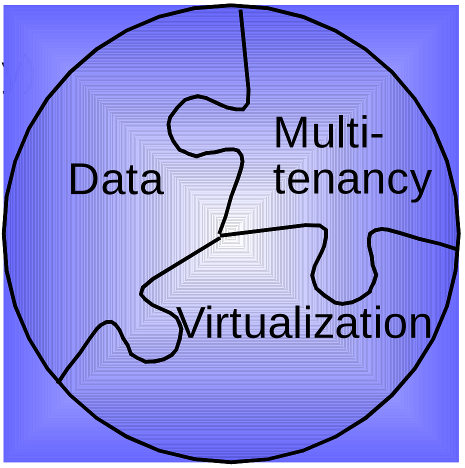
Off-Heap PackedObject

- Enable Java to talk directly to the native data structure
  - Avoid overhead of data copy onto/off Java heap
  - No (de)serialization required



Looking Ahead: Cloud with IBM Java

- **Multi-tenancy support will allow multiple applications to run in a single shared JVM for high-density deployments.**
  - *Win*: Footprint reduction enabled by sharing runtime and JVM artifacts while enforcing resource consumption quotas
  - *Platform Coverage*: 64-bit, balanced GC policy only
  - *Ergonomics*: Single new command-line flag (**-Xmt** = **m**ulti **t**enanc

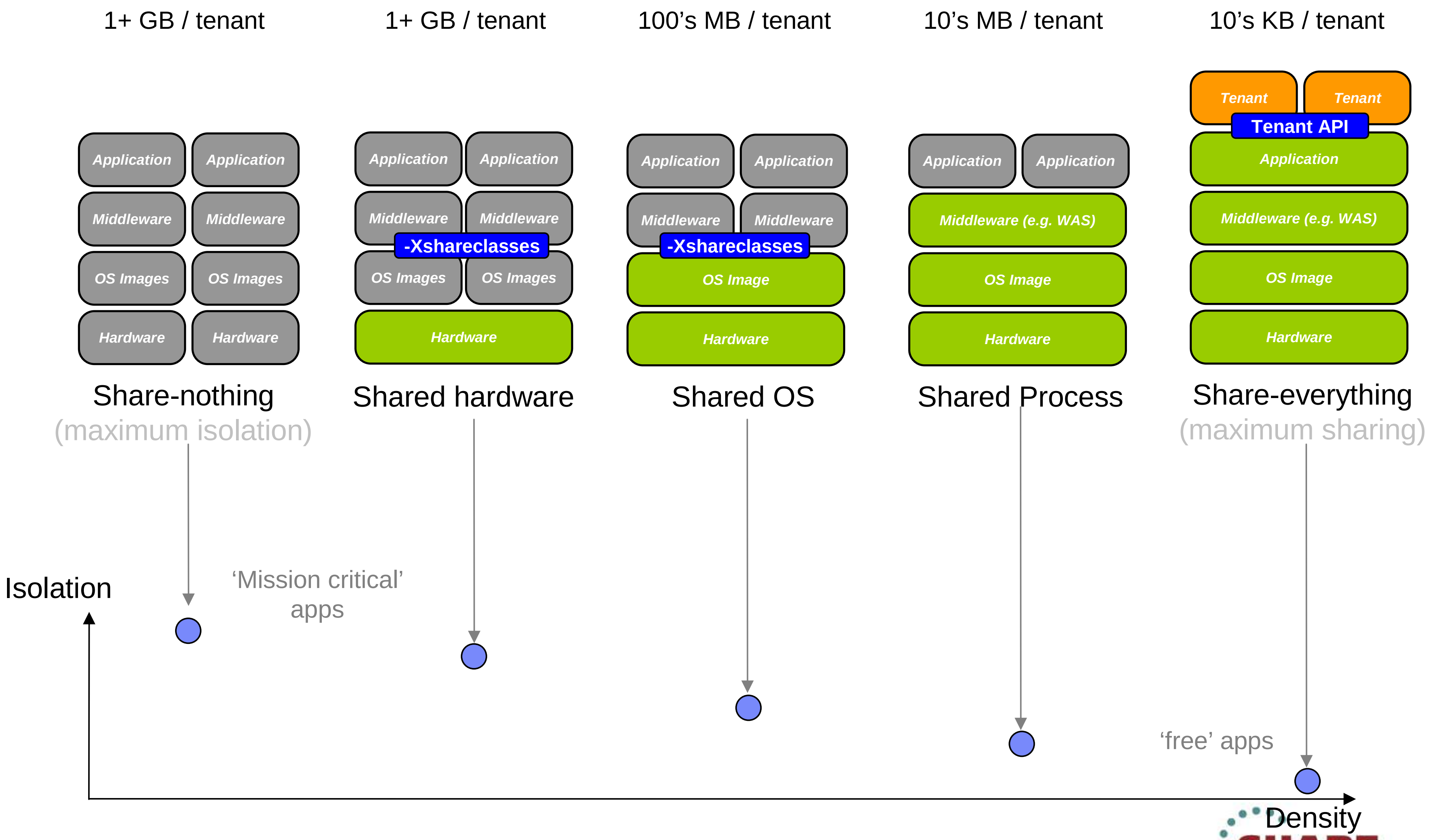


- **Runtime Adjustable Heap Size (-Xsoftmx)**
  - JMX beans allow for dynamically adjusting heap size
  - Allows users to take advantage of hot-add of memory

- **Hypervisor, Virtual Guest, and Extended-OS JMX Beans**
  - Allows applications to detect and identify the installed hypervisor and query attributes of LPAR
  - Provides richer access to operating system performance statistics

Timelines and deliveries are subject to change.

Multitenancy: Isolation and Density



1+ GB / tenant

Application | Application
Middleware | Middleware
OS Images | OS Images
Hardware | Hardware

Share-nothing
(maximum isolation)

1+ GB / tenant

Application | Application
Middleware | Middleware
-Xshareclasses
OS Images | OS Images
Hardware

Shared hardware

100's MB / tenant

Application | Application
Middleware | Middleware
-Xshareclasses
OS Image
Hardware

Shared OS

10's MB / tenant

Application | Application
Middleware (e.g. WAS)
OS Image
Hardware

Shared Process

10's KB / tenant

Tenant | Tenant
Tenant API
Application
Middleware (e.g. WAS)
OS Image
Hardware

Share-everything
(maximum sharing)

Isolation

'Mission critical' apps

'free' apps

Density

IBM Java Runtime Environment

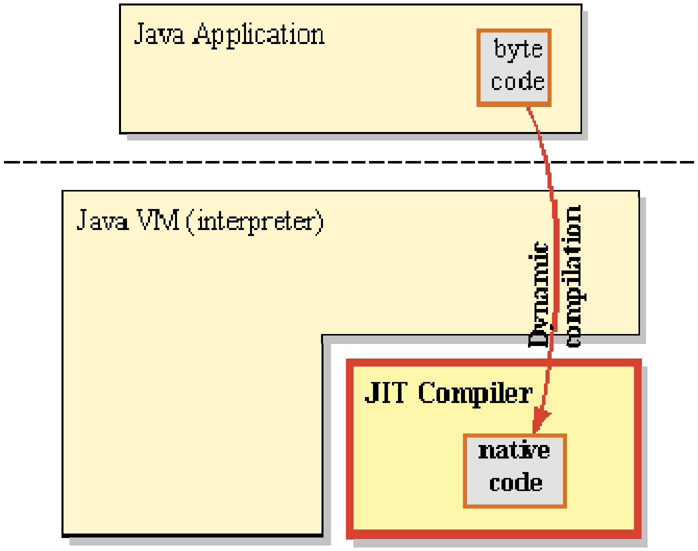
- IBM's implementation of Java 5, Java 6 and Java 7 are built with **IBM J9 Virtual Machine** and **IBM Testarossa JIT Compiler** technology
  - Independent clean-room JVM runtime & JIT compiler

- Combines best-of breed from embedded, development and server environments… from a cell-phone to a mainframe!
  - Lightweight flexible/scalable technology
  - World class garbage collection – gencon, balanced GC policies
  - Startup & Footprint - Shared classes, Ahead-of-time (AOT) compilation
  - 64-bit performance - Compressed references & Large Pages
  - Deep System z exploitation – zEC12/z196/z10/z9/z990 exploitation

- Millions of instances of J9/TR compiler

IBM Testarossa JIT Compiler – Introduction

- IBM Testarossa JIT is IBM's Production JIT on all Platforms since SDK5
- Developed at the IBM Toronto Lab
- The Toronto Lab has 30+ years of expertise in compilation and optimization technologies



- Close relationships with:
  - Research: productizing innovative ideas and experimental technologies.

    (Tokyo/Watson Research Lab)
  - Hardware: best possible performance with the underlying system and processor.

    (Poughkeepsie, Austin, xSeries)
  - IBM Middleware: work with DB2® , WAS to provide strong performance

    (SVL, Toronto, Raleigh)

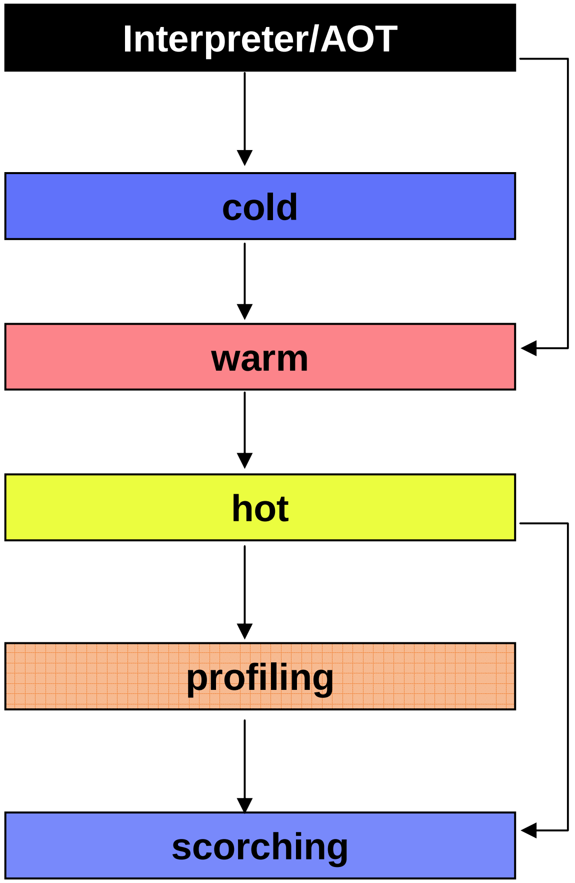
IBM Testarossa JIT – Dynamic, adaptive, optimizing compiler

- **Dynamic**
  - Triggered at runtime based on projected profitability of compilation
  - Compiled methods can be freely intermixed with interpreted callers/callees
  - May have multiple versions of methods built with different levels of optimization
- **Adaptive**
  - Sensitive to need for program to have CPU (e.g. throttled during startup, runs on asynchronous thread)
  - Able to profile program to retrieve common control paths or data values
  - Profile information used in subsequent re-optimizing compilation step
- **Optimizing**
  - Comprehensive collection of conventional optimizations
    - control flow simplification, data flow analysis, etc
  - Speculative and Java-specific optimizations
    - de-virtualization, partial inlining, lock coarsening, etc
  - Deep exploitation of System z micro-architecture

IBM Testarossa JIT – Compilation Strategy

Goals

- Focus compilation CPU time where it matters
  - Stager investment over time to amortize cost
- Methods start as interpreted
  - Interpreter does first level profiling
- 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
  - Global optimizations are directed using profiling data
  - Hot paths through methods are identified
    - register allocation, branch straightening, etc
  - Values/types are profiled, hot paths are specialized/versioned
  - Virtual calls are profiled, hot targets are in-lined



IBM Testarossa JIT – System z Support

- Idioms are recognized in Java source/bytecodes
- Bytecodes converted to CISC instructions**
- CISC Instructions:
  - TROT, TRTO, TRTT, TROO (TR = Translate, O = One Byte, T = Two bytes)
  - SRST (search string)
  - MVC (move character)
  - XC (exclusive-or)
  - CLC (compare-logical)

- Example:

```
while (i < end) {
   value = table[arrB[i+offsetB]];
   if (value == termChar) break;
   arrA[i+offsetA] = value;
   ++i;
}
```

```
LB:  DS 0H
        TRxx       //  xx depends on arrA/B types
        BRC LB  //  re-drive long xlate
```

** M. Kawahito, *et al.*, A new idiom recognition framework for exploiting hardware-assist instructions, ASPLOS-XII: Proceedings of the 12th international conference on Architectural support for programming languages and operating systems. 2006

IBM J9 Garbage Collector

- **IBM J9 VM garbage collector family**

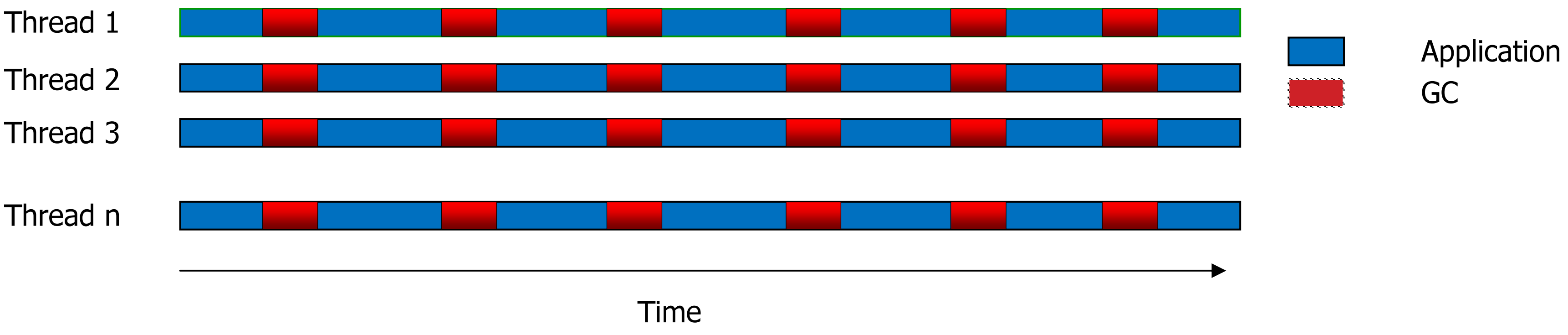
Policy	Recommended usage	Notes
`optThroughput`	optimized for throughput	default in Java5 and Java6
`optAveragePause`	optimized to reduce pause times	
`gencon`	optimized for transactional workloads	default in Java601/Java7
~~`subPools`~~	~~optimized for large MP systems~~	~~deprecated in Java601/Java7~~
`balanced`	optimized for large heaps	added in Java601/Java7

- Why have many policies? Why not just “the best”?
  - Cannot always dynamically determine what tradeoffs the user/application are willing to make
  - ***Pause time vs. Throughput***
    - *Trade off frequency and length of pauses vs. throughput*
  - ***Footprint vs. Frequency***
    - *Trade off smaller footprint vs. frequency of GC pauses/events*

IBM J9 Garbage Collector: -Xgcpolicy:optthruput

The default policy in Java5 and Java6.

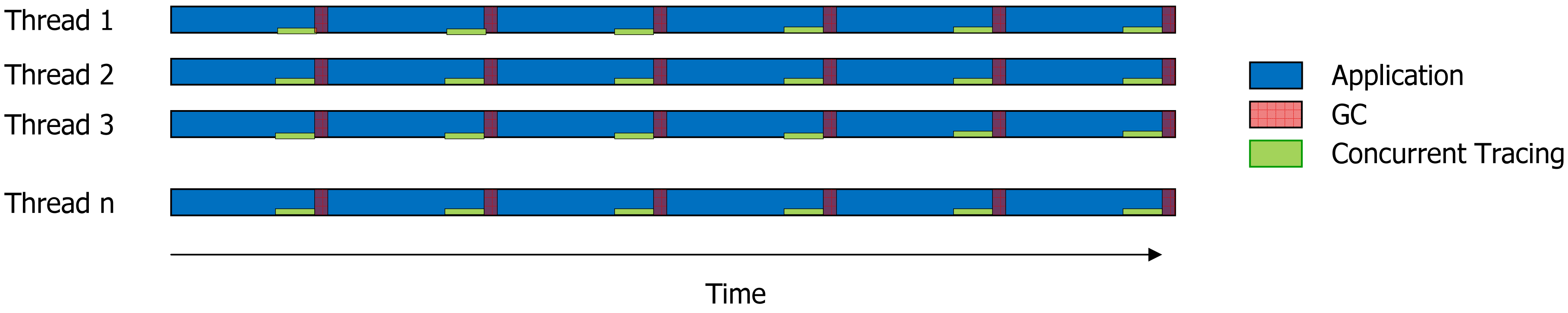
Used for applications where raw throughput is more important than short GC pauses. The application is stopped each time that garbage is collected.



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.

IBM J9 Garbage Collector: -Xgcpolicy:optavgpause

Trades high throughput for shorter GC pauses by performing some of the garbage collection concurrently. The application is paused for shorter periods.



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.

IBM J9 Garbage Collector: -Xgcpolicy:gencon

- Best of both worlds
  - Throughput + Small Pause Times
  - Shown most value with customers

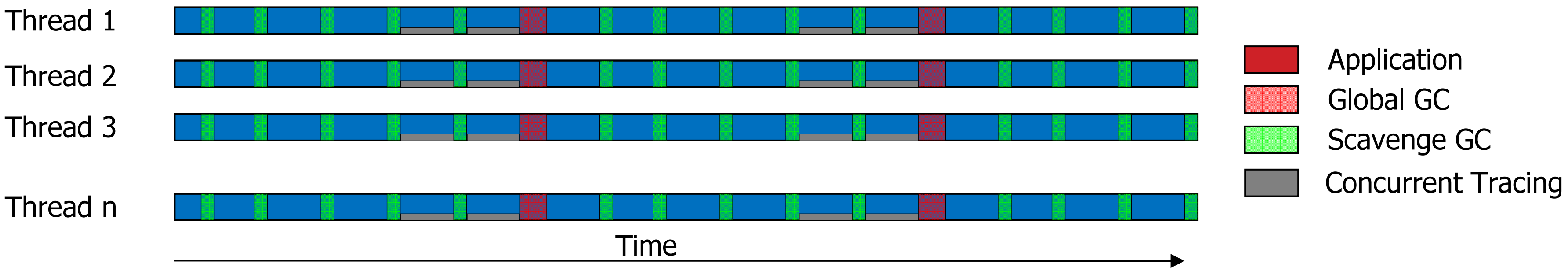
- Two types of collection:
  - Generational nursery (local) collection
  - Partially concurrent nursery & tenured (global) collection

- Why a generational + concurrent solution?
  - For most workloads objects die young
    - Generational allows a better return on investment (less effort, better reward)
    - Performance can be close or even better than standard configuration
  - Reduce large pause times
    - Partially concurrent with application thread (application thread is 'taxed')
    - Mitigates cost of object movement, and cache misses

IBM J9 Garbage Collector: -Xgcpolicy:gencon

Default policy in Java6.0.1/Java7

Handles short-lived objects differently than objects that are long-lived. Applications that have many short-lived objects can see shorter pause times with this policy while still producing good throughput.

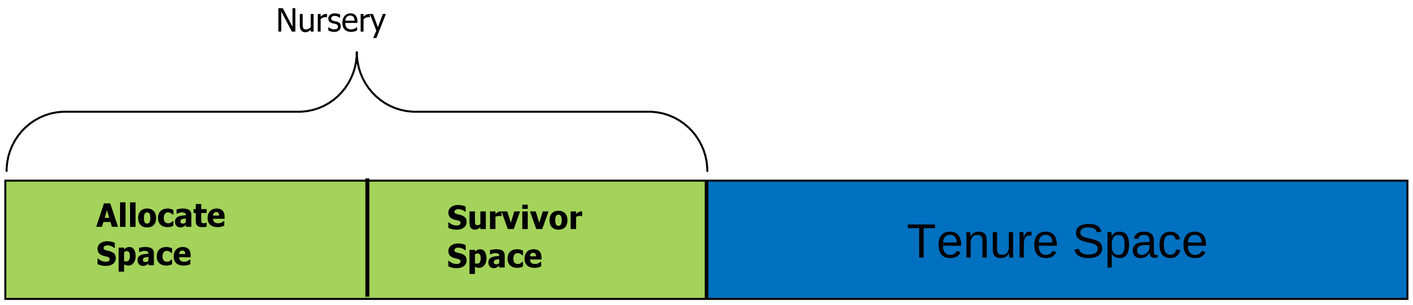


Picture is only illustrative and doesn't reflect any particular real-life application. The purpose is to show theoretical differences in pause times between GC policies.

IBM J9 Garbage Collector: A closer look into gencon

- Heap is split into two areas:
  - Objects created in the nursery (a *small but frequently collected area)*
  - Objects that survive a number of collections are promoted to tenured area (*less frequently collected*)

- Nursery is further split into two spaces: ‘allocate’ and ‘survivor’
- A collection in the nursery (scavenge) copies objects from the ‘allocate’ space to the ‘survivor’ space
  - Reduces fragmentation, improves data locality, speeds up future allocations
- If an object survive X number of scavenges it gets promoted to the ‘tenure’ space



The division between allocate and survivor space is dynamic.

It will be adjusted depending on the survival rate.

IBM J9 2.6 Technology Enhancements:
Garbage Collection: Balanced Policy

Improved responsiveness in application behavior

- Reduced maximum pause times to achieve more consistent behavior
- Incremental result-based heap collection targets best ROI areas of the heap
- Native memory aware approach reduces non-object heap consumption

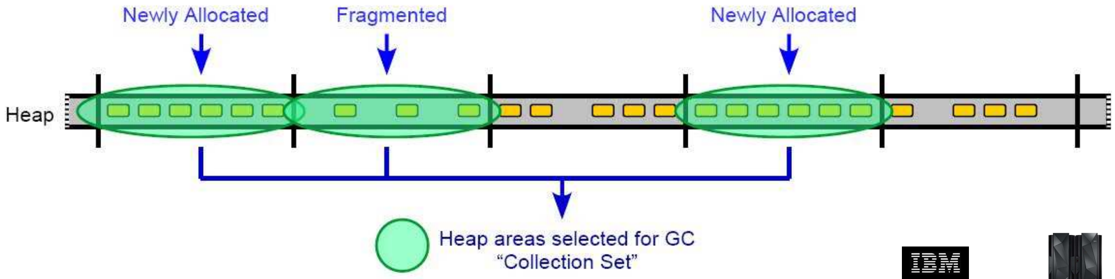
Next generation technology expands platform exploitation possibilities

- Virtualization – Group heap data by frequency of access, direct OS paging decisions
- Dynamic reorganization of data structures to improve memory hierarchy utilization (performance)

Recommended deployment scenarios

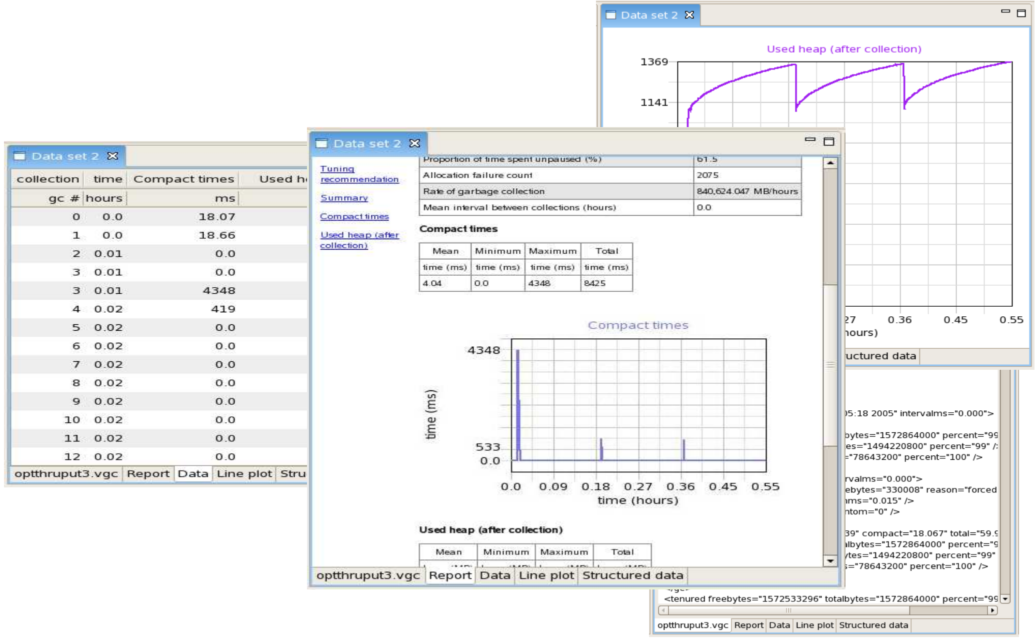
- Large (>4GB) heaps
- Frequent global garbage collections
- Excessive time spent in global compaction
- Relatively frequent allocation of large (>1MB) arrays

Input welcome: Help set directions by telling us your needs



IBM J9 Garbage Collector: Tuning

- GC Tuning documentation
  - http://www.ibm.com/developerworks/views/java/libraryview.jsp?search_by=java+technology+ibm+style:
  - http://www-01.ibm.com/support/docview.wss?uid=swg27013824&aid=1
  - http://proceedings.share.org/client_files/SHARE_in_San_Jose/S1448KI161816.pdf
  - http://www.redbooks.ibm.com/redpapers/pdfs/redp3950.pdf
- GC and Memory Visualizer – Views on verbose GC
- Typical configuration
  - Pick a policy based on desired application behaviour
  - Tune heap sizes (use tooling)
  - Helper threads (-Xgcthreads)
  - Avoid finalizers
  - Don't use System.gc()
  - Lots of other tuning knobs, suggest try hard to ignore, to avoid over-tuning
- Memory leaks are possible even with a garbage collector



collection	time	Compact times	Used h
gc #	hours	ms	
0	0.0	18.07	
1	0.0	18.66	
2	0.01	0.0	
3	0.01	0.0	
3	0.01	4348	
4	0.02	419	
5	0.02	0.0	
6	0.02	0.0	
7	0.02	0.0	
8	0.02	0.0	
9	0.02	0.0	
10	0.02	0.0	
11	0.02	0.0	
12	0.02	0.0	

Proportion of time spent unpaused (%)	61.5
Allocation failure count	2075
Rate of garbage collection	840,624.047 MB/hours
Mean interval between collections (hours)	0.0

Compact times

Mean	Minimum	Maximum	Total
time (ms)	time (ms)	time (ms)	time (ms)
4.04	0.0	4348	8425

Used heap (after collection)

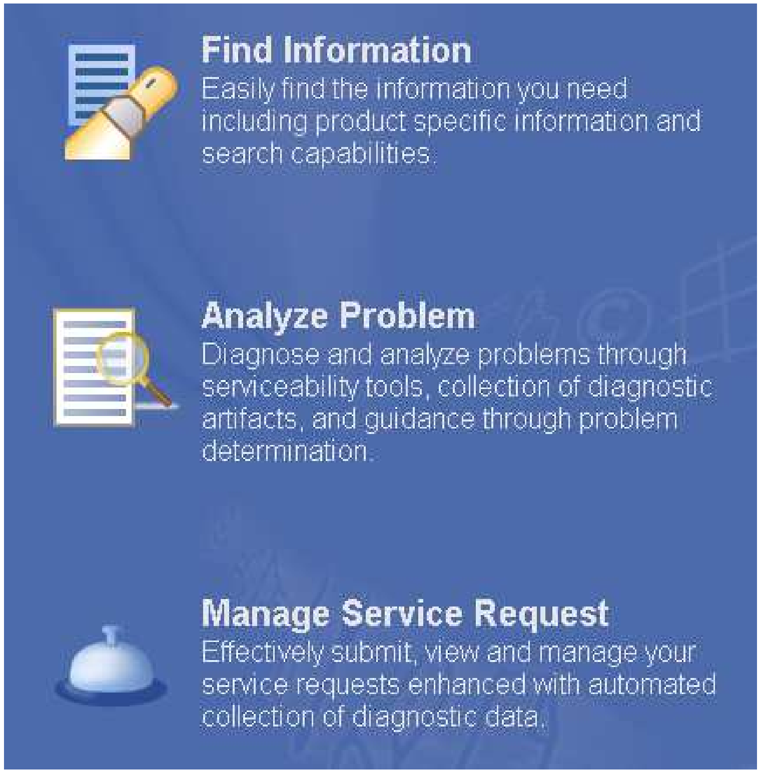
Mean	Minimum	Maximum	Total

```
05:18 2005" intervalms="0.000">
bytes="1572864000" percent="99
es="1494220800" percent="99" /:
="78643200" percent="100" />
rvalms="0.000">
ebytes="330008" reason="forced
ms="0.015" />
ntom="0" />
39" compact="18.067" total="59.9
albytes="1572864000" percent="9
ytes="1494220800" percent="99"
s="78643200" percent="100" />
<tenured freebytes="1572533296" totalbytes="1572864000" percent="99
```

What is IBM Support Assistant?

- **IBM Support Assistant**
  - A free application that simplifies and automates software support
  - Helps customers analyze and resolve questions and problems with IBM software products.
  - Includes rich features and serviceability tools for quick resolution to problems

- **Meant for diagnostics and problem determination**
  - Not a monitoring tool

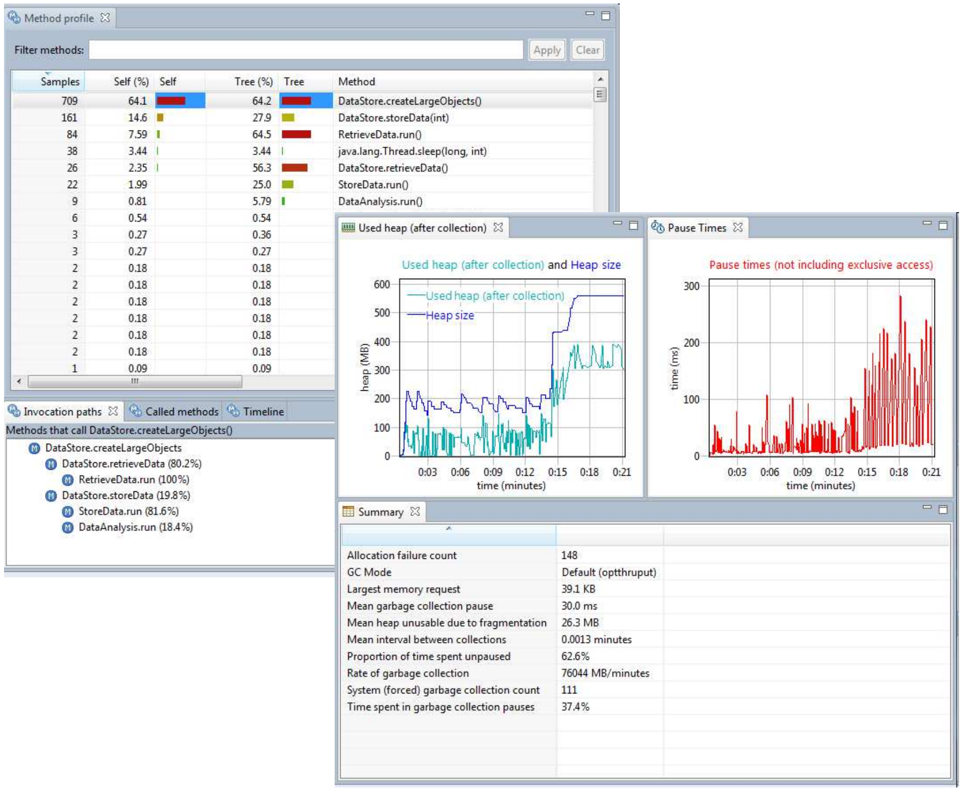


Find Information
Easily find the information you need including product specific information and search capabilities.

Analyze Problem
Diagnose and analyze problems through serviceability tools, collection of diagnostic artifacts, and guidance through problem determination.

Manage Service Request
Effectively submit, view and manage your service requests enhanced with automated collection of diagnostic data.

IBM Monitoring and Diagnostic Tools for Java - Health Center



Samples	Self (%)	Self	Tree (%)	Tree	Method
709	64.1		64.2		DataStore.createLargeObjects()
161	14.6		27.9		DataStore.storeData(int)
84	7.59		64.5		RetrieveData.run()
38	3.44		3.44		java.lang.Thread.sleep(long, int)
26	2.35		56.3		DataStore.retrieveData()
22	1.99		25.0		StoreData.run()
9	0.81		5.79		DataAnalysis.run()
6	0.54		0.54		
3	0.27		0.36		
3	0.27		0.27		
2	0.18		0.18		
2	0.18		0.18		
2	0.18		0.18		
2	0.18		0.18		
2	0.18		0.18		
2	0.18		0.18		
1	0.09		0.09		

Methods that call DataStore.createLargeObjects()

- DataStore.createLargeObjects
  - DataStore.retrieveData (80.2%)
    - RetrieveData.run (100%)
  - DataStore.storeData (19.8%)
    - StoreData.run (81.6%)
    - DataAnalysis.run (18.4%)

Allocation failure count	148
GC Mode	Default (optthruput)
Largest memory request	39.1 KB
Mean garbage collection pause	30.0 ms
Mean heap unusable due to fragmentation	26.3 MB
Mean interval between collections	0.0013 minutes
Proportion of time spent unpaused	62.6%
Rate of garbage collection	76044 MB/minutes
System (forced) garbage collection count	111
Time spent in garbage collection pauses	37.4%

What problem am I solving

- •What is my JVM doing? Is everything ok?
- •Why is my application running slowly?
- •Why is it not scaling?
- •Am I using the right options?

Overview

- •Lightweight live monitoring tool with very low overhead
- •Understand how your application is behaving, diagnose potential problems with recommendations.
- •Visualize garbage collection, method profiling, class loading, lock analysis, file I/O and native memory usage
- •Suitable for all Java applications running on IBM's JVM

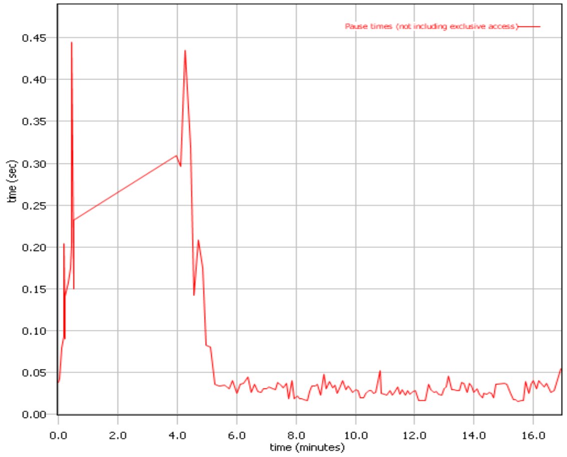
IBM Monitoring and Diagnostic Tools for Java - GCMV

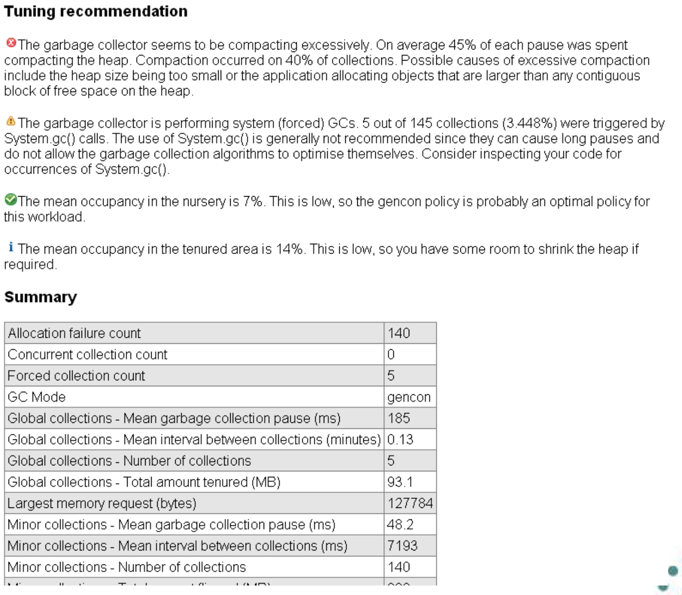
What problem am I solving

- How is the Garbage Collector (GC) behaving? Can I do better?
- How much time is GC taking?
- How much free memory does my JVM have?

Overview

- Analyse Java verbose GC logs, providing insight into application behaviour
- Visualize a wide range of garbage collection data and Java heap statistics over time
- Provides the ability to detect memory leaks and optimized garbage collection
- Recommendations use heuristics to guide you towards GC performance tuning





Tuning recommendation

⊗ The garbage collector seems to be compacting excessively. On average 45% of each pause was spent compacting the heap. Compaction occurred on 40% of collections. Possible causes of excessive compaction include the heap size being too small or the application allocating objects that are larger than any contiguous block of free space on the heap.

⚠ The garbage collector is performing system (forced) GCs. 5 out of 145 collections (3.448%) were triggered by System.gc() calls. The use of System.gc() is generally not recommended since they can cause long pauses and do not allow the garbage collection algorithms to optimise themselves. Consider inspecting your code for occurrences of System.gc().

✓ The mean occupancy in the nursery is 7%. This is low, so the gencon policy is probably an optimal policy for this workload.

ℹ The mean occupancy in the tenured area is 14%. This is low, so you have some room to shrink the heap if required.

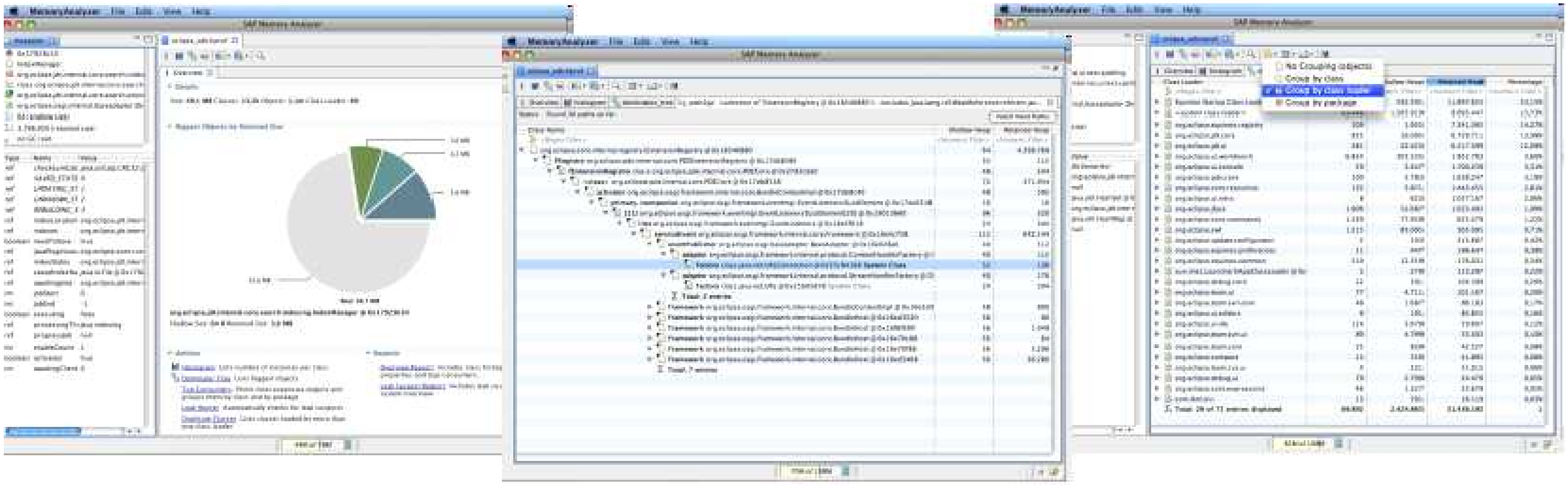
Summary

Allocation failure count	140
Concurrent collection count	0
Forced collection count	5
GC Mode	gencon
Global collections - Mean garbage collection pause (ms)	185
Global collections - Mean interval between collections (minutes)	0.13
Global collections - Number of collections	5
Global collections - Total amount tenured (MB)	93.1
Largest memory request (bytes)	127784
Minor collections - Mean garbage collection pause (ms)	48.2
Minor collections - Mean interval between collections (ms)	7193
Minor collections - Number of collections	140

IBM Monitoring and Diagnostic Tools for Java - Memory Analyzer

What problem am I solving

- Why did I run out of Java memory?
- What's in my Java heap? How can I explore it and get new insights?



Overview

- Tool for analyzing heap dumps and identifying memory leaks from JVMs
- Works with IBM system dumps, heapdumps and Sun HPROF binary dumps
- Provides memory leak detection, footprint analysis and insight into wasted space
- Objects by Class, Dominator Tree Analysis, Path to GC Roots, Dominator Tree by Class Loader
- Provides SQL like object query language (OQL)

zEC12 – More Hardware for Java

Continued aggressive investment in Java on Z

Significant set of new hardware features tailored and co-designed with Java

Hardware Transaction Memory (HTM) *(no zVM)*

Better concurrency for multi-threaded applications

eg. ~2X improvement to juc.ConcurrentLinkedQueue

Run-time Instrumentation (RI)

Innovation new h/w facility designed for managed runtimes

Enables new expanse of JRE optimizations

2GB page frames *(only on z/OS)*

Improved performance targeting 64-bit heaps

Pageable 1MB large pages using flash *(only on z/OS)*

Better versatility of managing memory

New software hints/directives

Data usage intent improves cache management

Branch pre-load improves branch prediction

New trap instructions

Reduce over-head of implicit bounds/null checks

New 5.5 GHz 6-Core Processor Chip

Large caches to optimize data serving

Second generation OOO design

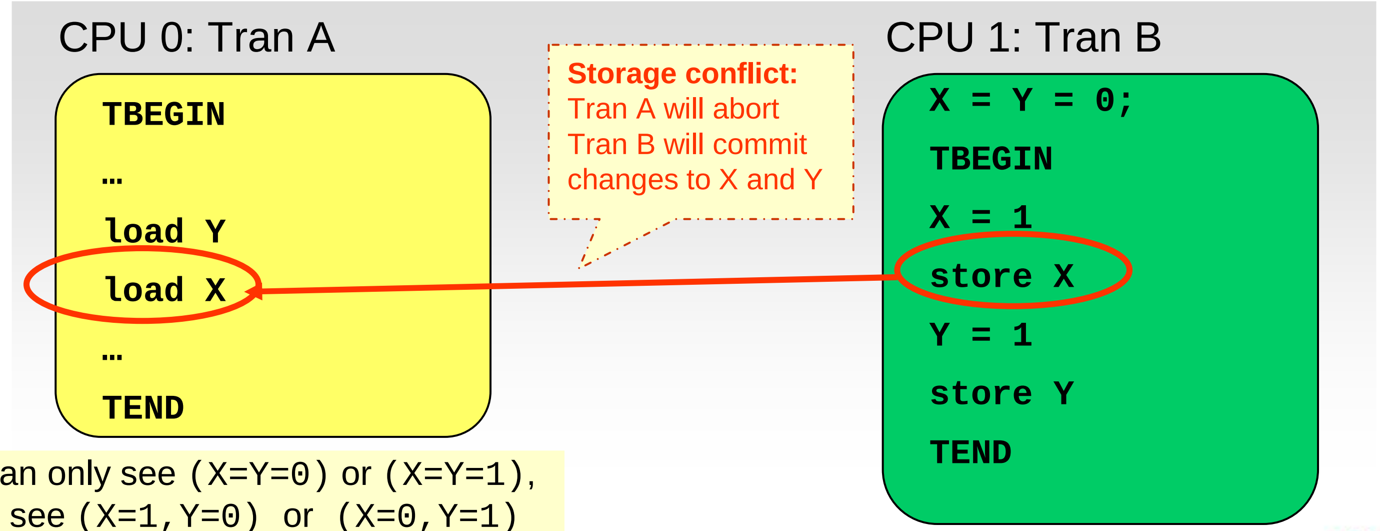
*Up-to **60%** improvement in throughput amongst Java workloads measured with zEC12 and Java7SR3*

Engineered Together—IBM Java and zEC12 Boost Workload Performance
http://www.ibmsystemsmag.com/mainframe/trends/whatsnew/java_compiler/

Timelines and deliveries are subject to change.

Hardware Transactional Memory (HTM)

- ***Allow lockless interlocked execution of a block of code called a ‘transaction’***
  - **Transaction:** *Segment of code that appears to execute ‘atomically’ to other CPUs*
    - Other processors in the system will either see **all-or-none** of the storage up-dates of transaction
- ***How it works:***
  - TBEGIN instruction starts speculative execution of ‘transaction’
  - Storage conflict is detected by hardware if another CPU writes to storage used by the transaction
  - Conflict triggers hardware to roll-back state (storage and registers)
    - transaction can be re-tried, or
    - a fall-back software path that performs locking can be used to guarantee forward progress
  - Changes made by transaction become visible to other CPUs after TEND



CPU 0: Tran A

```
TBEGIN
…
load Y
load X
…
TEND
```

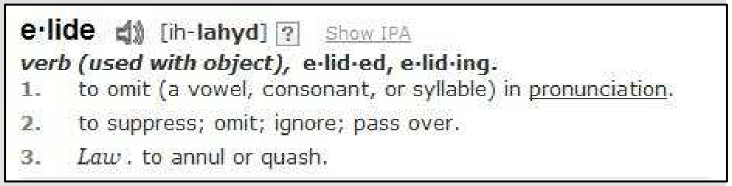
Storage conflict:
Tran A will abort
Tran B will commit
changes to X and Y

CPU 1: Tran B

```
X = Y = 0;
TBEGIN
X = 1
store X
Y = 1
store Y
TEND
```

CPU 0 can only see `(X=Y=0)` or `(X=Y=1)`,
cannot see `(X=1,Y=0)` or `(X=0,Y=1)`

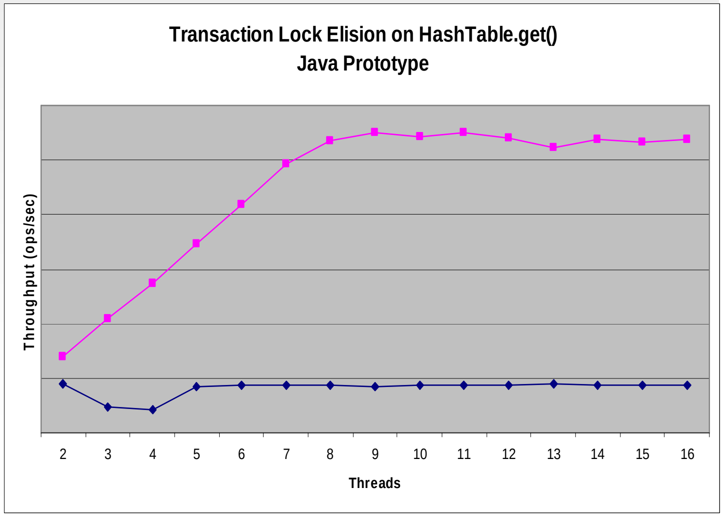
HTM Example: Transactional Lock Elision (TLE)



e·lide [ih-lahyd] [?] Show IPA

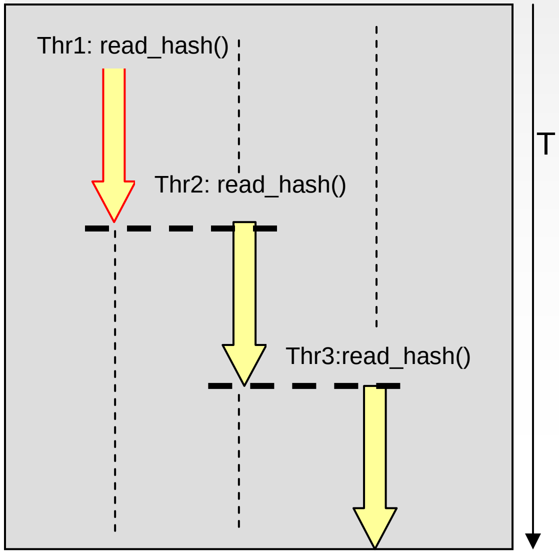
verb (used with object), **e·lid·ed, e·lid·ing.**

1. to omit (a vowel, consonant, or syllable) in pronunciation.
2. to suppress; omit; ignore; pass over.
3. *Law* . to annul or quash.



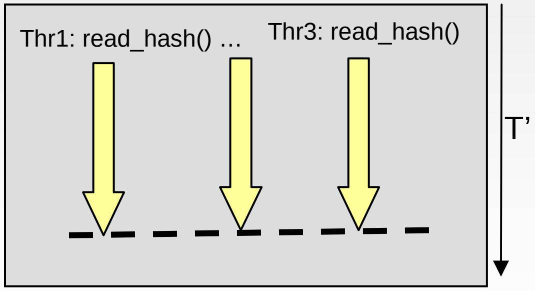
Threads must serialize despite only reading… just in-case a writer updates the hash

```
read_hash(key) {
  Wait_for_lock();
  read(hash, key);
  Release_lock();
}
```



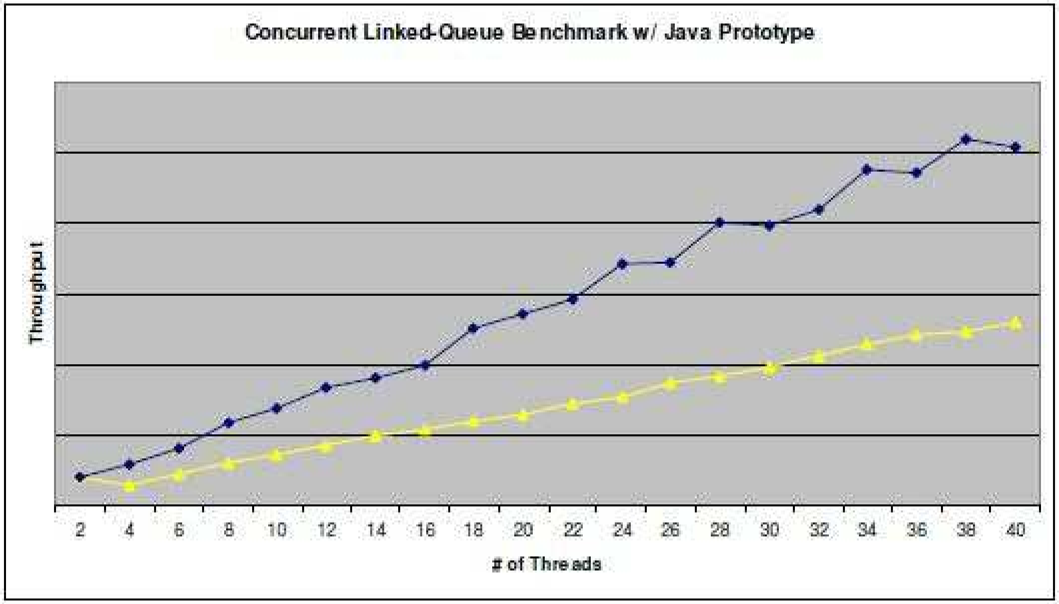
Lock elision allows readers to execute in parallel, and safely back-out should a writer update hash

```
read_hash(key)
  TRANSACTION_BEGIN
  read hash.lock;
  BRNE serialize_on_hash_lock
  read (hash, key);
  TRANSACTION_END
```



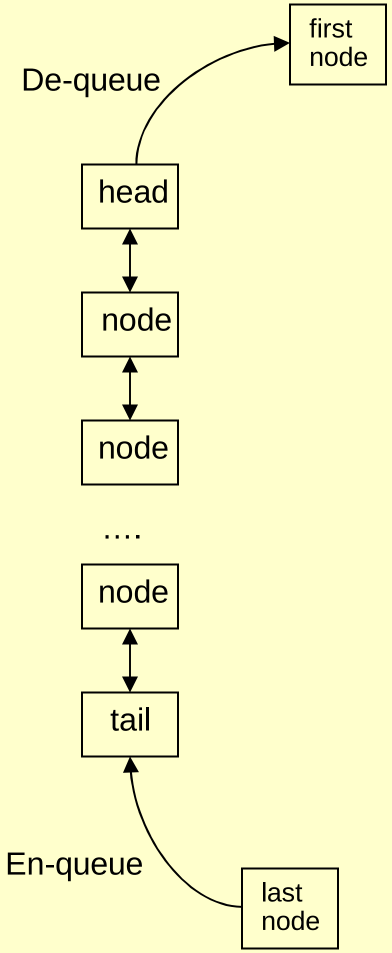
Transactional Execution: Concurrent Linked Queue

- ***~2x improved scalability of juc.ConcurrentLinkedQueue***
- ***Unbound Thread-Safe LinkedQueue***
  - First-in-first-out (FIFO)
  - Insert elements into tail (en-queue)
  - Poll elements from head (de-queue)
  - No explicit locking required
- ***Example usage: a multi-threaded work queue***
  - Tasks are inserted into a concurrent linked queue as multiple worker threads poll work from it concurrently



🟦 **New TX-base implementation**

🟨 **Traditional CAS-base implementation**


De-queue

first node

head

node

node

....

node

tail

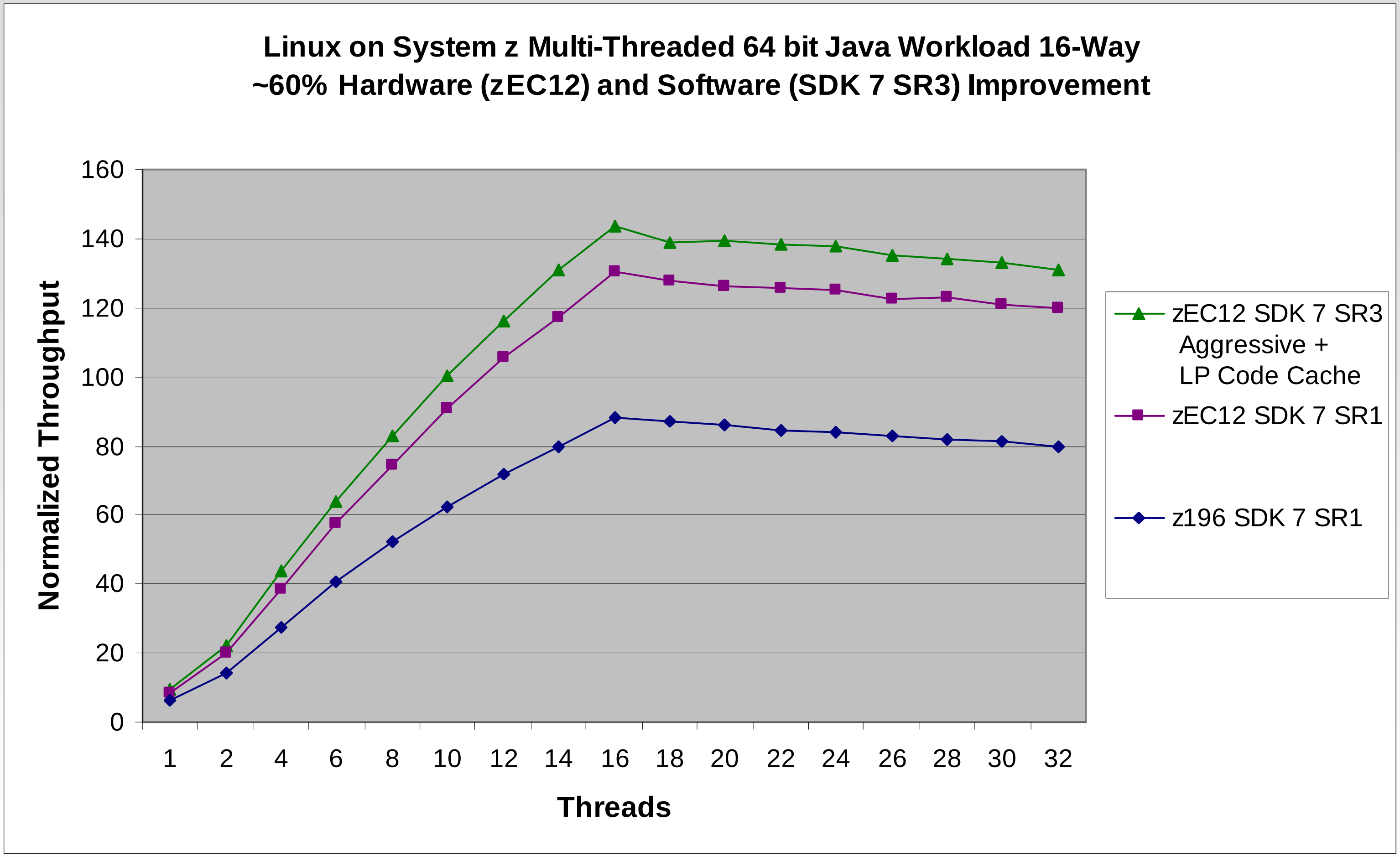
En-queue

last node

(Controlled measurement environment, results may vary)

Linux on System z and Java7SR3 on zEC12:

64-Bit Java Multi-threaded Benchmark on 16-Way


Linux on System z Multi-Threaded 64 bit Java Workload 16-Way
~60% Hardware (zEC12) and Software (SDK 7 SR3) Improvement

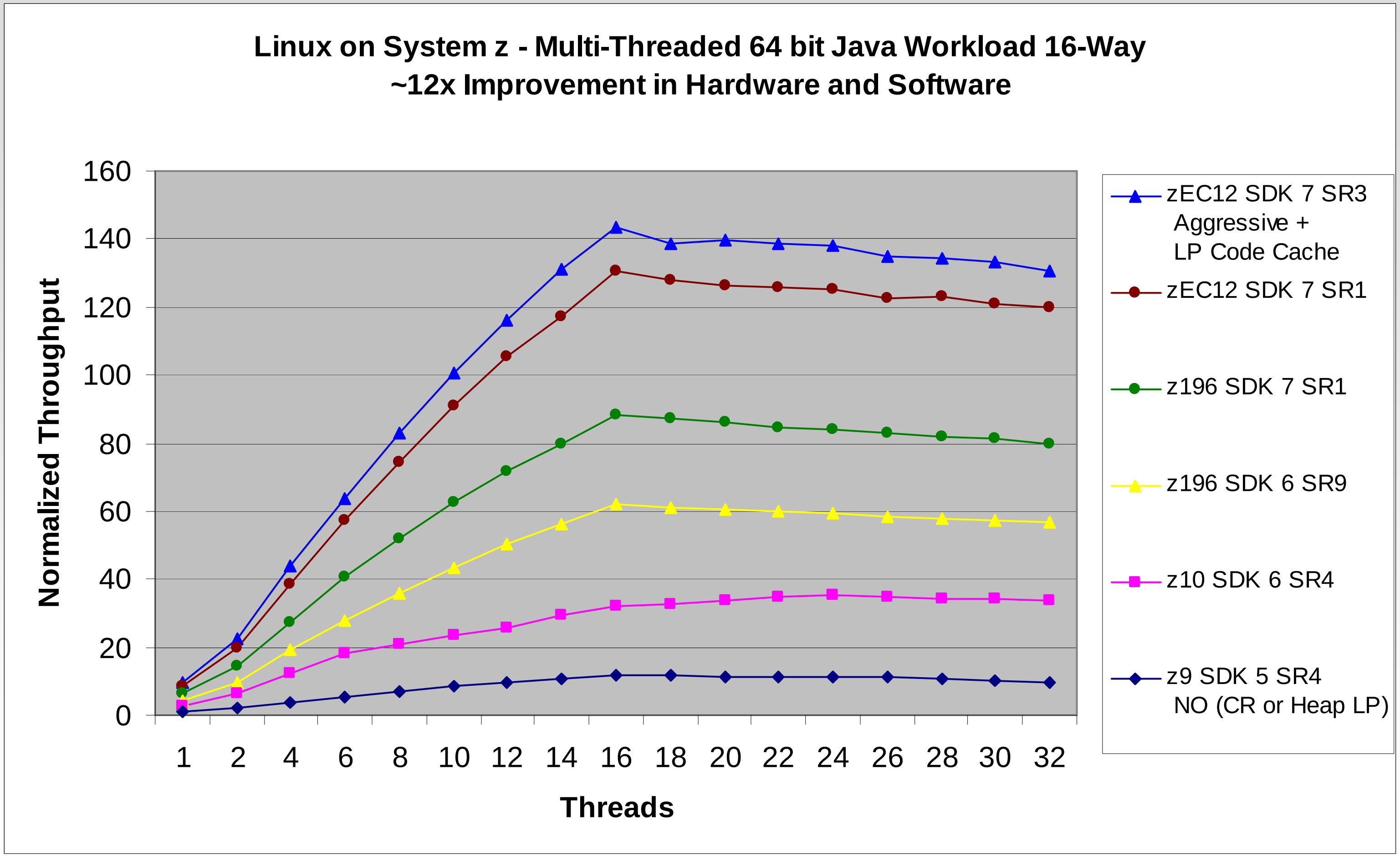
Aggregate 60% improvement from zEC12 and Java7SR3

- **zEC12 offers a ~45% improvement over z196 running the Java Multi-Threaded Benchmark**
- **Java7SR3 offers an additional ~10% improvement (-Xaggressive)**

(Controlled measurement environment, results may vary)

Linux on System z and Java7SR3 on zEC12:

64-Bit Java Multi-threaded Benchmark on 16-Way



~12x aggregate hardware and software improvement comparing Java5SR4 on z9 to Java7SR3 on zEC12

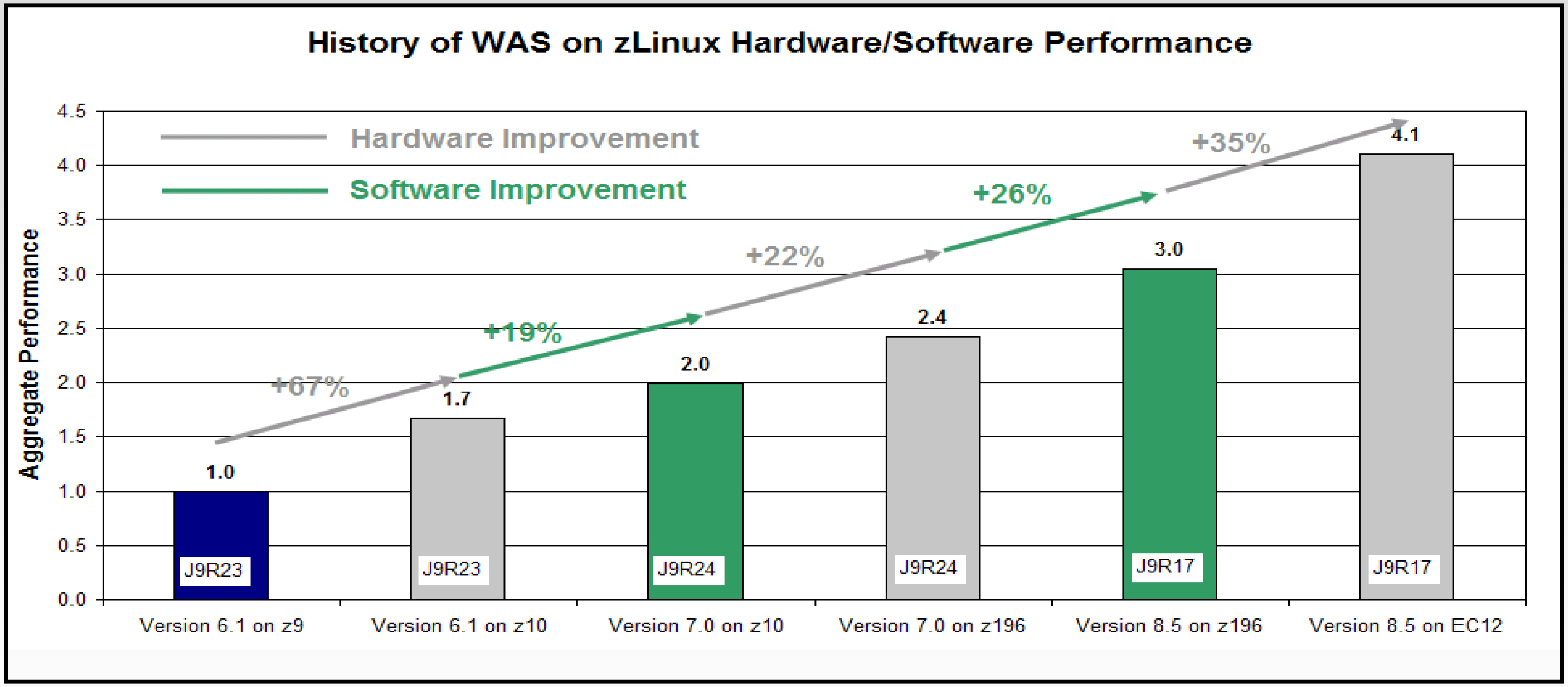
LP=Large Pages for Java heap CR= Java compressed references

Java7SR3 using -Xaggressive + 1Meg large pages

(Controlled measurement environment, results may vary)

WAS on zLinux –

Aggregate HW, SDK and WAS Improvement: WAS 6.1 (Java 5) on z9 to WAS 8.5 (Java 7) on zEC12



~4x aggregate hardware and software improvement comparing WAS 6.1 Java5 on z9 to WAS 8.5 Java7 on zEC12

(Controlled measurement environment, results may vary)

Marcel Mitran
mmitran@ca.ibm.com

Thank
You

Summary of Links

- Documentation
  - http://www.ibm.com/developerworks/java/jdk/docs.html
- zOS SDK
  - http://www.ibm.com/servers/eserver/zseries/software/java
- System z Linux SDK
  - http://www.ibm.com/developerworks/java/jdk/linux/download.html
- GC Tuning documentation
  - http://www.ibm.com/developerworks/views/java/libraryview.jsp?search_by=java+technology+ibm+style
- IBM Support Assistant
  - http://www.ibm.com/software/support/isa/