Optimize Java for Cloud

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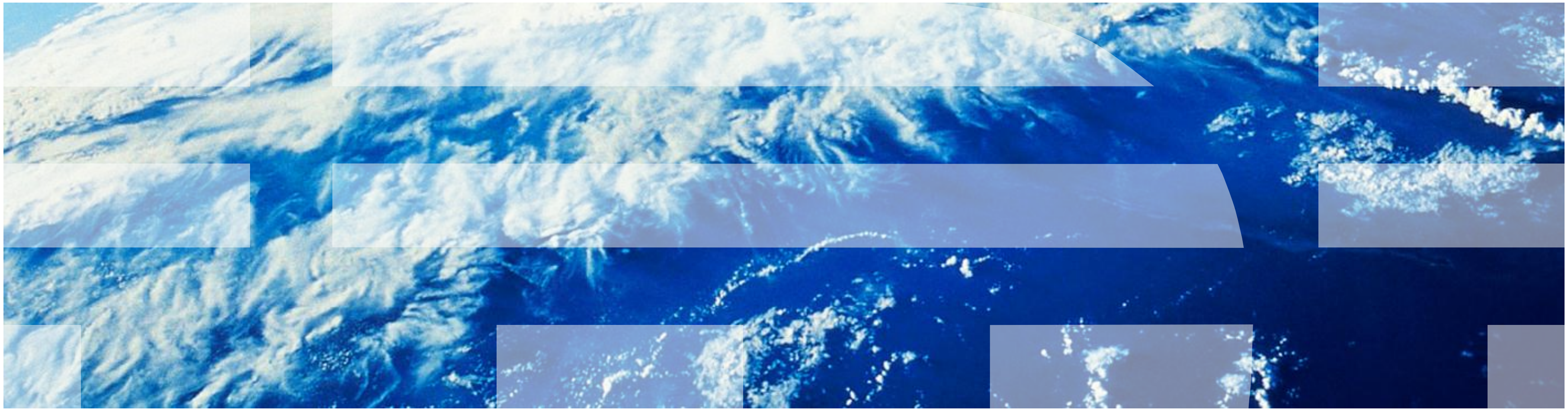
Technical lead of Java for multi-tenancy



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Introduction to the speaker

- Started from improving runtime security on Expeditor(OSGi-based and Eclipse-based platform) and progressed to working on the development of IBM's Java Virtual Machine in 2010.
- Recent work focus:
  - Java Virtual Machine improvements for ‘cloud’
    - Multi-tenancy technology
    - Footprint and performance
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Agenda

- Cloud computing
  - Basics & Definition
  - Use cases & Challenges
- IBM JDK support for virtualization
  - Cross-guest class sharing
  - Softmx
  - JMXBean for virtualization
- IBM JDK support for multi-tenancy

Cloud Computing Is…

- A style of computing in which dynamically scalable and often virtualized resources are provided as a service over the Internet. Users need not have knowledge of, expertise in, or control over the technology infrastructure in the “cloud” that supports them.

- Wikipedia

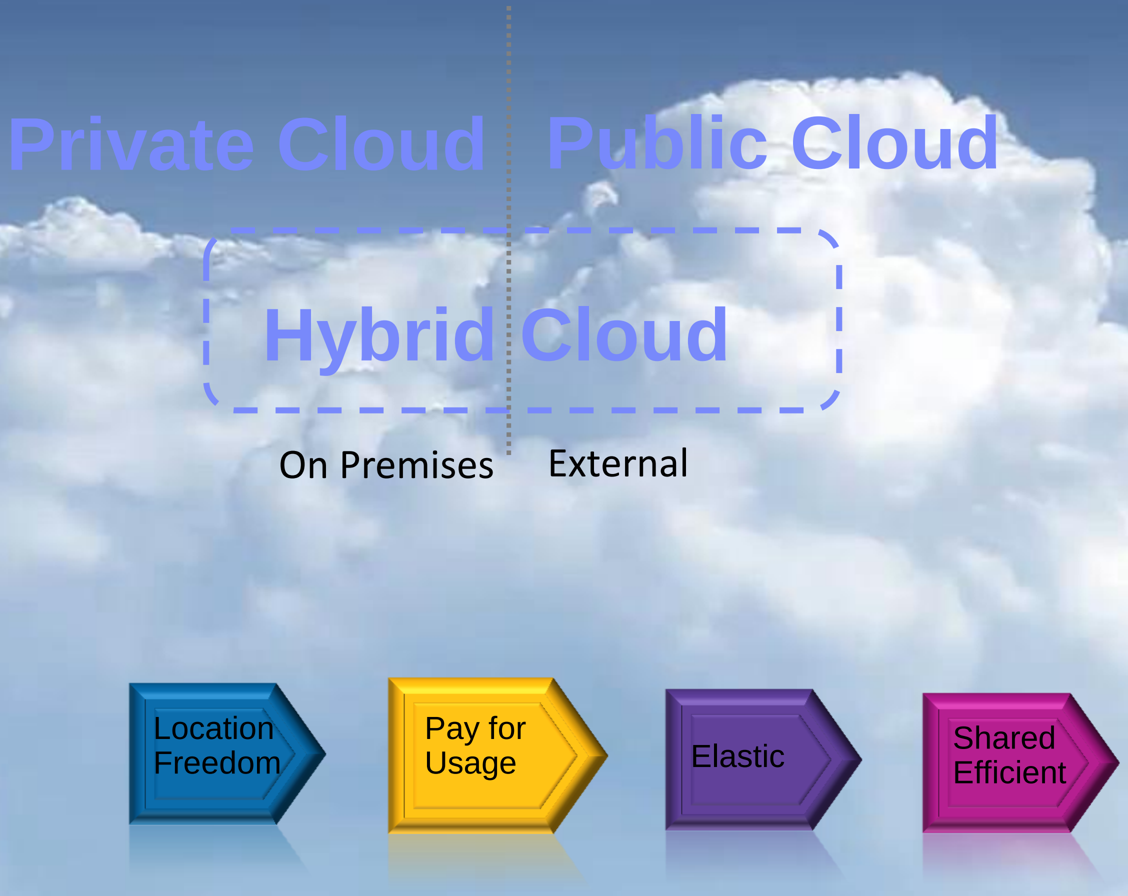
Cloud Computing Is…

- Computing resources are provided as a service
  - Infrastructure as a Service – IaaS
  - Platform as a Service – PaaS
  - Software as a Service – SaaS
- Computing Resources

Infrastructure	***Platform***	***Software***
Processor	LAMP Stack	Email
Memory	**JVM**	CRM System
Storage	Python VM	ERP System
Network	MapReduce	SCM System
amazon web services slicehost	MOSSO the rackspace cloud	salesforce.com Success On Demand. Gmail by Google BETA SAP

- As a Service
  - Pay-as-you-go or Subscription

Cloud Types



Private Cloud

Public Cloud

Hybrid Cloud

On Premises

External

Location Freedom

Pay for Usage

Elastic

Shared Efficient

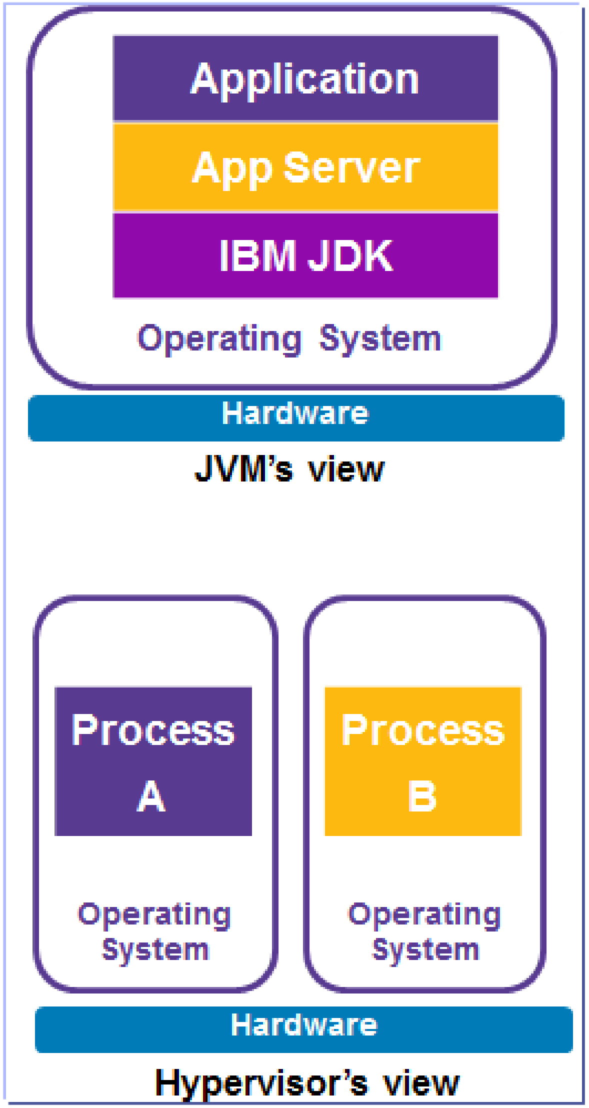
Enables innovative business models by providing IT services from a dynamic infrastructure faster, simpler, and cheaper

Scenarios where ‘Cloud’ works well

- **Server Consolidation**
  - Cost savings, merging low resource utilization systems
- **Evaluation**
  - Easy demonstration & test platform
- **Isolation**
  - Protect sensitive processes in their own OS
- **Shared Systems**
  - Development environments with varied workloads
- **Legacy Support**
  - Replace obsolete hardware via emulation

JVM vs. Hypervisor

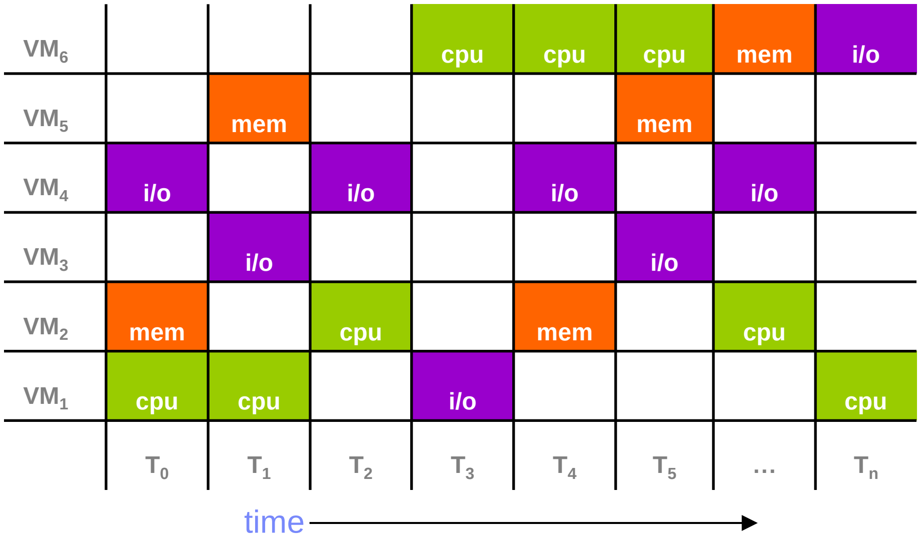
- JVM is managing resources (primarily memory) on behalf of the user
- JVM built assuming it has full control over resources for the duration of the process
- Hypervisor managing resources used by each Guest
- Hypervisor assumes it has full control over resources provided to each Guest
- Both are attempting to manage resources (without consulting each other)



Exploiting Idleness can yield better utilization

- **Baseline**: Today's JVM makes static decisions about the environment & never changes
  - Example: Heap sizes are a percentage of installed RAM
  - Example: Helper thread counts are a percentage of installed cores
- **Impact**: Static decisions hurt Java elasticity, makes it hard to shift resources toward need.
- **Example**: Consider dynamic workload spread across 6 VMs on a machine that has 1 unit of each resource to share:

cpu mem i/o



	T_0	T_1	T_2	T_3	T_4	T_5	…	T_n
VM_6				cpu	cpu	cpu	mem	i/o
VM_5		mem				mem		
VM_4	i/o		i/o		i/o		i/o	
VM_3		i/o				i/o		
VM_2	mem		cpu		mem		cpu	
VM_1	cpu	cpu		i/o				cpu

Challenge: make workload 'fit' (it should)

- Be able to measure reliably
- Make the JVM elastic enough to respond
- Make middleware elastic too
- Avoid JVM startup requirement for elasticity

Cloud Challenges

- **Hypervisor will attempt to shift resources toward need**
  - **Memory**: force action in guest via ballooning
  - **CPUs**: either by doling out a smaller slice, or ‘hotplug’ changes
  - Naïve JVM behaviour based on static decisions can foil the hypervisor’s efforts
- **Lesson: ‘Dynamic decisions are the new normal’**
  - # of installed CPUs or memory can change mid-run
  - Static decisions made at start-up are no longer good enough
- **Lesson: ‘Conserve. Every byte of memory or CPU cycle we waste could have been used to help others’**
  - Idle behaviour is critical (you can help here)

IBM JDK: Innovate Java for Cloud

- **Reduce** the Java appetite for resources
- **Reuse** artifacts between Java invocations
- **React** to changes in hypervisor, O/S, and other Java VMs

IBM JDK: Innovate Java for Cloud

Multitenancy JDK(XiHu)
- Sharing JVM process between multiple applications using isolates

Cross-Guest Class Sharing
- Share classes cache cross-guest

Hypervisor & Guest MxBean
- Identify & query the underlying hypervisor
- Provide enhanced O/S performance info

Automatic ‘softmx’
- Reduce heap size under memory pressure

Delivering on the Cloud Promise

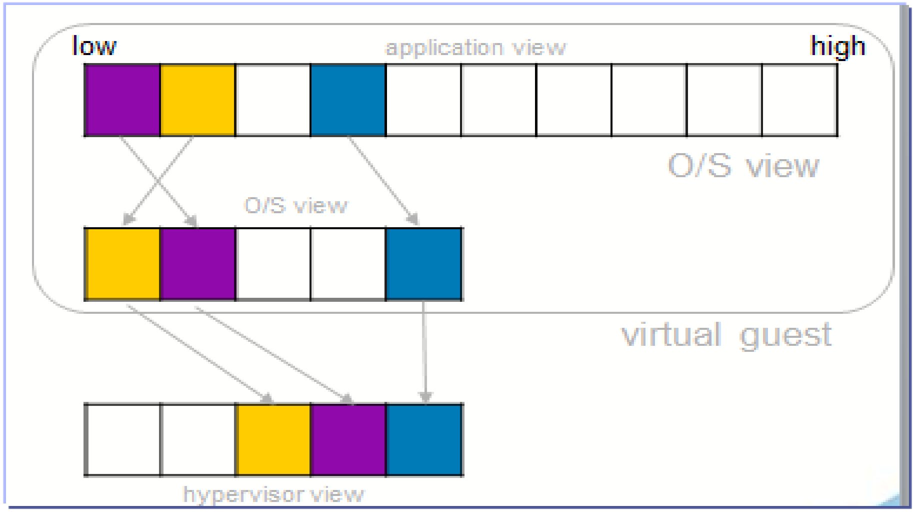
- **Over-commit is the golden solution**
  - –2:1 or better over-commit ratios possible with careful tuning

- **Memory Over-commit**
  - –**Swapping** – increase memory by using disk
  - –**Ballooning** – trick Guest into choosing what to swap
  - –**Page Sharing** – find identical pages and share

- **Exploiting idleness**
  - –Collocating workloads with different periods of demand

Memory Basics

- **Applications** work at the level of pages in a virtual address space
- **Operating system** maps the virtual address space onto pages (vRAM)
- **Hypervisor** adds another layer of mapping from vRAM to physical RAM (pRAM)
- Each layer adds:
  - –some overhead
  - –challenges for passing intent
  - –different views of state

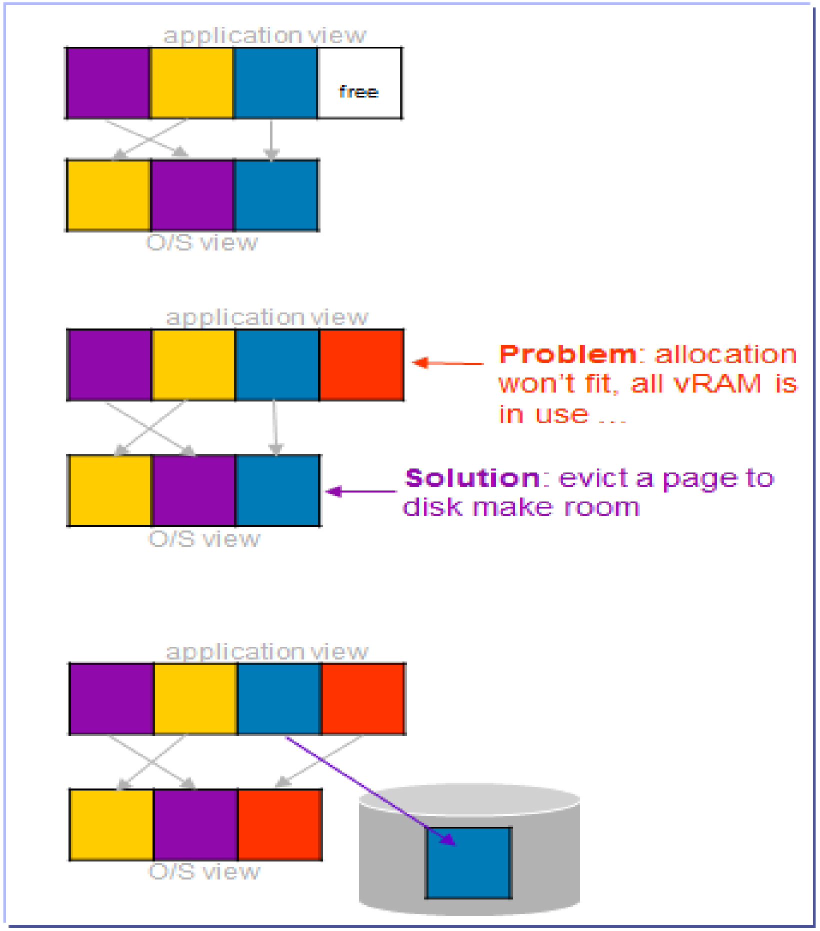


Swapping Trades CPU & I/O for Memory

- **Before**: vRAM is full, let's try to allocate another page (in red)

- **Decision**: vRAM is full, we'll need to evict a page to satisfy the request

- **After**: Allocation satisfied, one page (blue) moved to disk
  - Virtualized I/O can be slow
  - Paging is real work

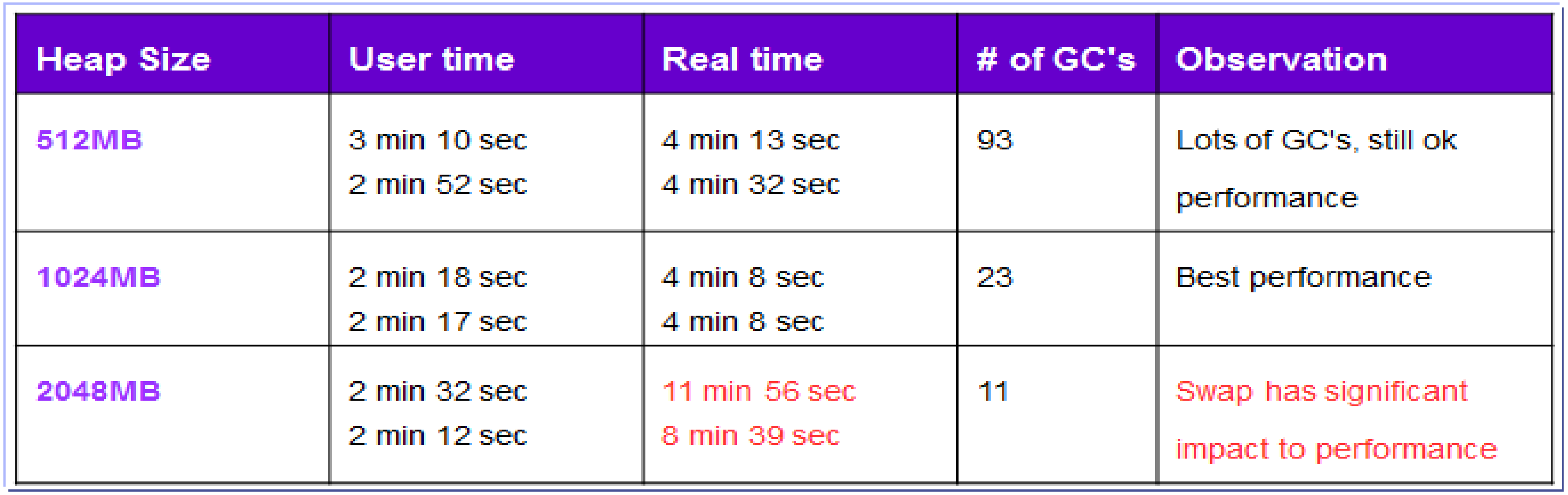


Problem: allocation won't fit, all vRAM is in use …

Solution: evict a page to disk make room

Swapping Can Severely Impact Java Performance

- **Experiment: How badly does swapping hurt?**
  - –Benchmark: Heap dump analysis – memory, I/O and processor intensive
  - –Lower times are better, two concurrent runs
  - –Hardware: Thinkpad W500 2.53GHz w/ **4GB** RAM

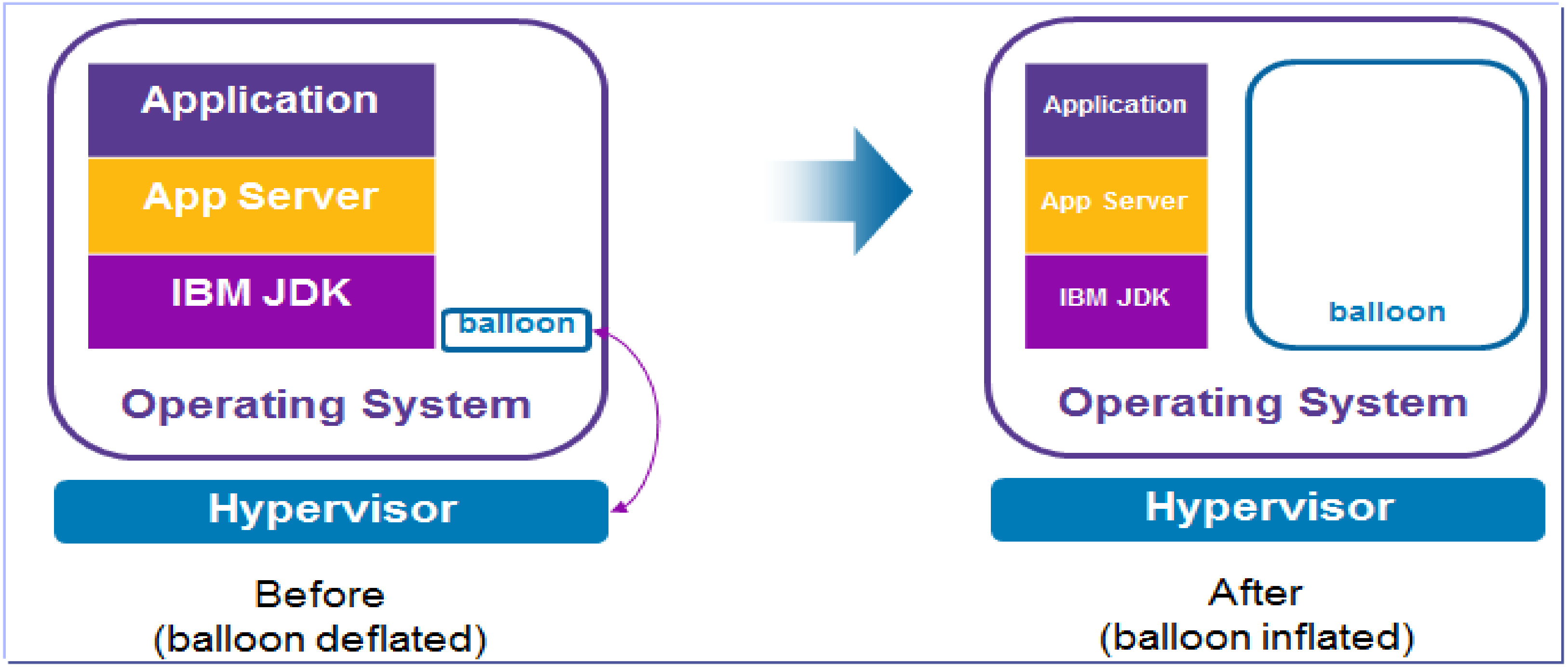


Heap Size	User time	Real time	# of GC's	Observation
512MB	3 min 10 sec 2 min 52 sec	4 min 13 sec 4 min 32 sec	93	Lots of GC's, still ok performance
1024MB	2 min 18 sec 2 min 17 sec	4 min 8 sec 4 min 8 sec	23	Best performance
2048MB	2 min 32 sec 2 min 12 sec	11 min 56 sec 8 min 39 sec	11	Swap has significant impact to performance

More on Java performance tuning
@Room 403 : Wed 10:15 - my JavaOne session

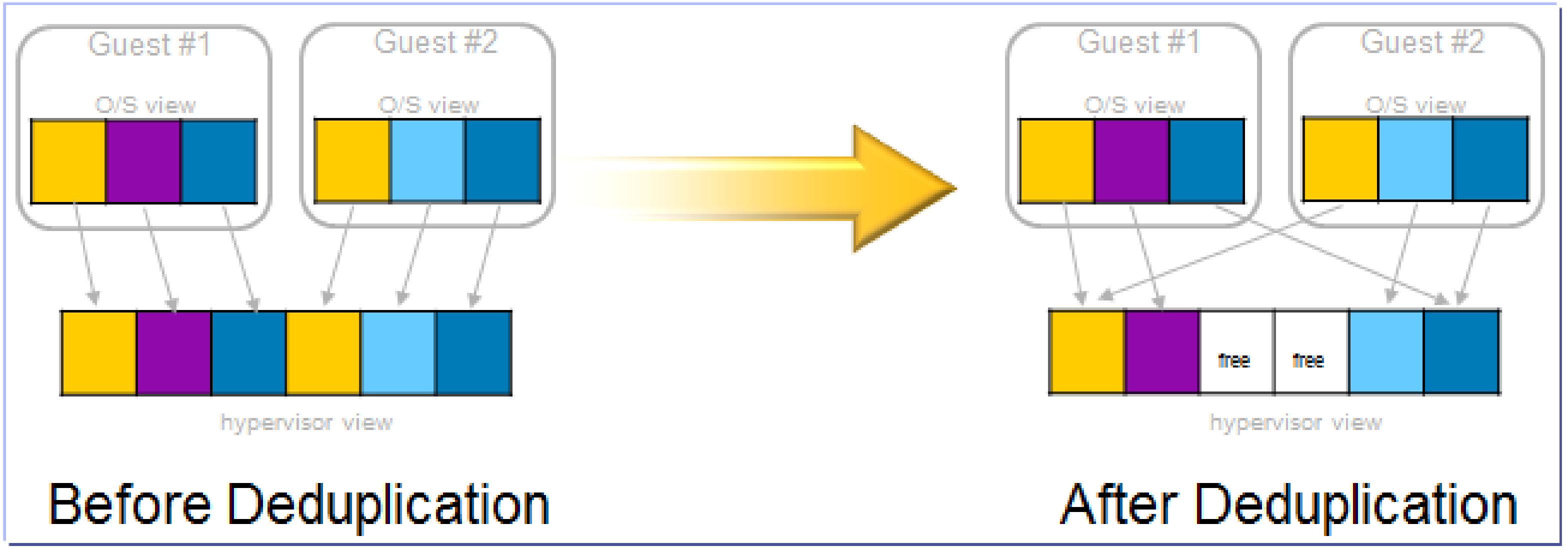
Hypervisor Trick : Ballooning

- **Encourage the operating system to move pages to disk**
- **Size of balloon controlled by the hypervisor**
  - No need to back the balloon with physical RAM
  - May result in paging to disk (swap), or dropping of buffers



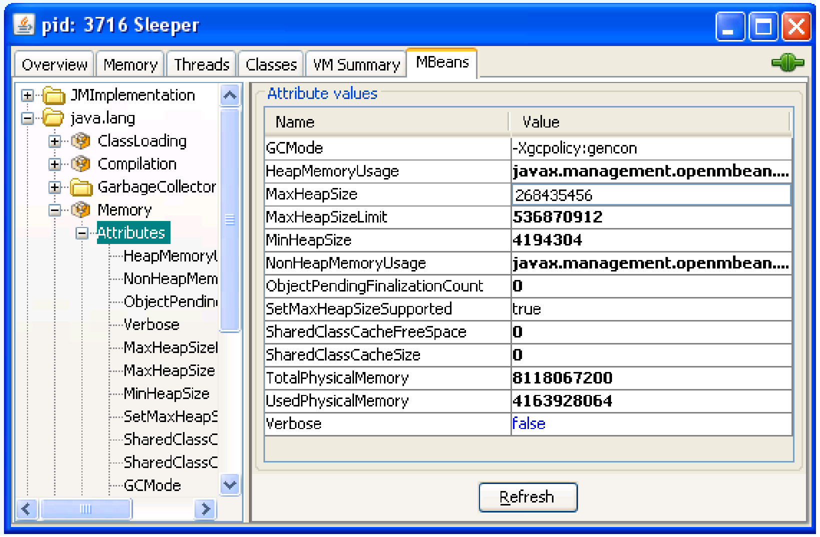
Saving Memory via Page Sharing

- **Share memory pages with identical content across guests**
  - –Use copy-on-write behavior if pages change
  - –Sharing Opportunities: shared libs, some JVM artifacts
  - –“Rebate” model – pay up front, refund some time later

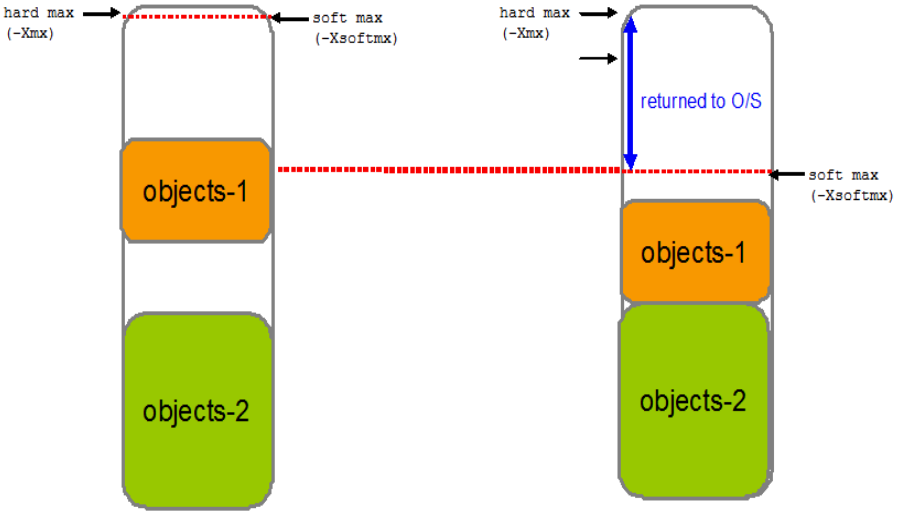


Dynamic Heap Adjustment (softmx) : Core function

- **-Xmx**
  - fixed at startup
- **-Xsoftmx**
  - can be set dynamically through JMX
  - <= -Xmx
  - Garbage collector tries to shrink to softmx over time
  - Once at target will not expand beyond it
- **OS Interaction**
  - JVM advises OS when memory freed
  - Effectiveness depends on OS support
- **Use cases**
  - Cap early, grow later
  - Shrink to free unused memory



Name	Value
GCMode	-Xgcpolicy:gencon
HeapMemoryUsage	javax.management.openmbean....
MaxHeapSize	268435456
MaxHeapSizeLimit	536870912
MinHeapSize	4194304
NonHeapMemoryUsage	javax.management.openmbean....
ObjectPendingFinalizationCount	0
SetMaxHeapSizeSupported	true
SharedClassCacheFreeSpace	0
SharedClassCacheSize	0
TotalPhysicalMemory	8118067200
UsedPhysicalMemory	4163928064
Verbose	false



Am I Real or Virtual ?!

Q. Do Java applications need to know if they are running inside a Guest OS ?

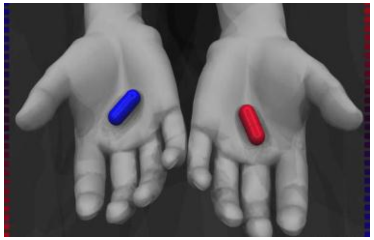
A. Mostly No. Only a small class of applications benefit

- Load Balancers
- Monitoring tools
- Debuggers and RAS Tools

Q. Does the JVM need to know if it is running inside a Guest OS ?

A. Absolutely Yes !

Virtualization Aware JVM: Benefits



- Make the most ***efficient*** use of resources in a virtualized environment
- Propagate the knowledge up the stack to enable load balancers to take appropriate decisions
- Remove necessity for multiple middleware products to understand intricacies of hypervisors.
- Provide unified interface to be able to deal with a multitude of hypervisors

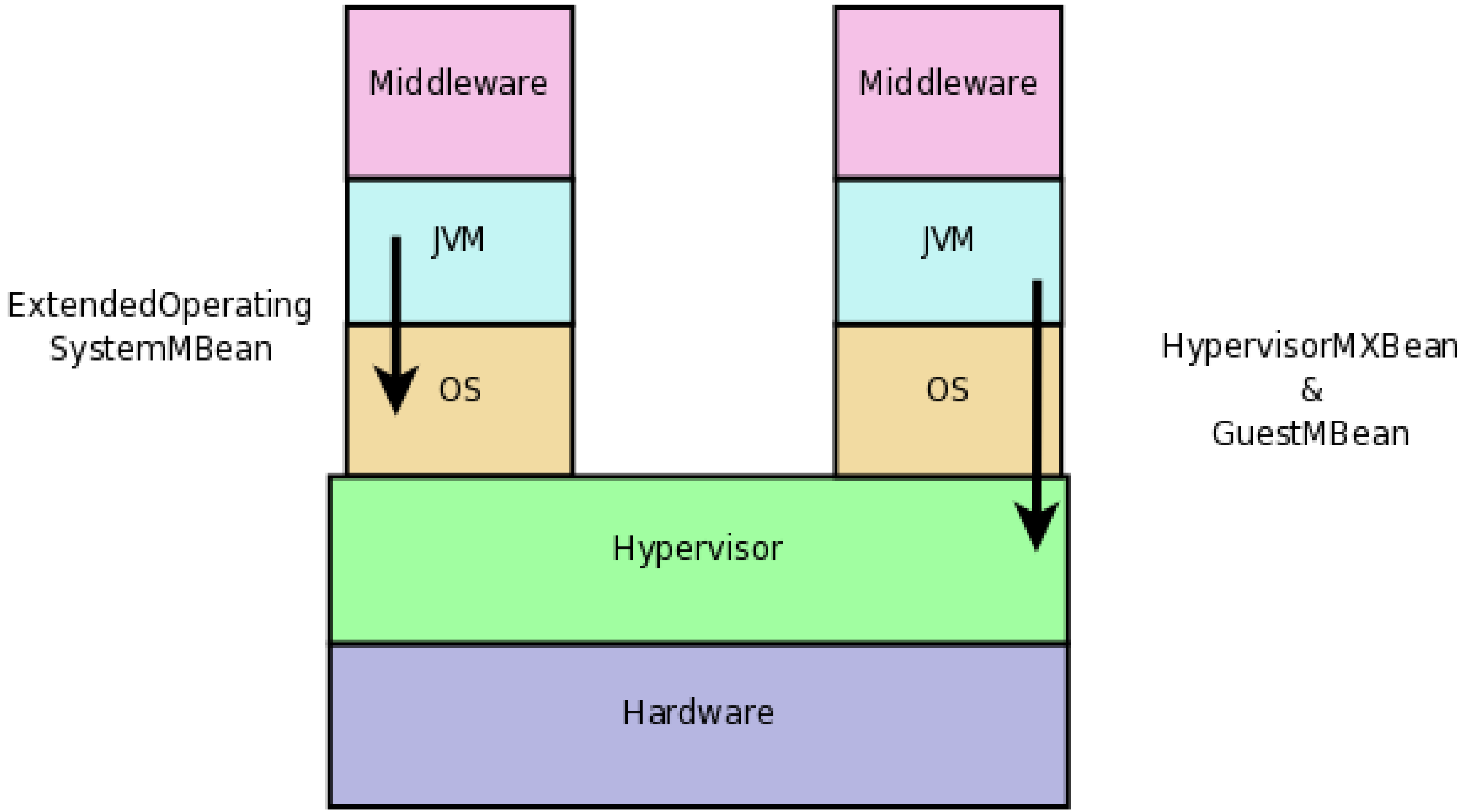
JMX Beans for Virtualization

- **ExtendedOperatingSystemMBean**
  - Extended OS usage statistics
    - Processor
    - Memory
  - OS Support: Aix, Linux, Windows and z/OS

- **HypervisorMXBean**
  - Detect if we are running on a hypervisor
  - Hypervisors Supported: z/VM, PowerVM, VMWare, KVM (x86 only), Hyper-V and OracleVM

- **GuestMBean**
  - Guest OS Statistics as seen from the hypervisor
  - Usage Statistics
    - Processor
    - Memory
  - Aix & Linux on PowerVM, Linux and Windows on VMWare, KVM, Hyper-V and OracleVM, z/OS & zLinux on z/VM

JMX Beans for Virtualization



What is Multitenancy?

Wikipedia
The Free Encyclopedia

Multitenancy refers to a principle in software architecture where a single instance of the software runs on a software-as-a-service (SaaS) vendor's servers, serving multiple client organizations (tenants).

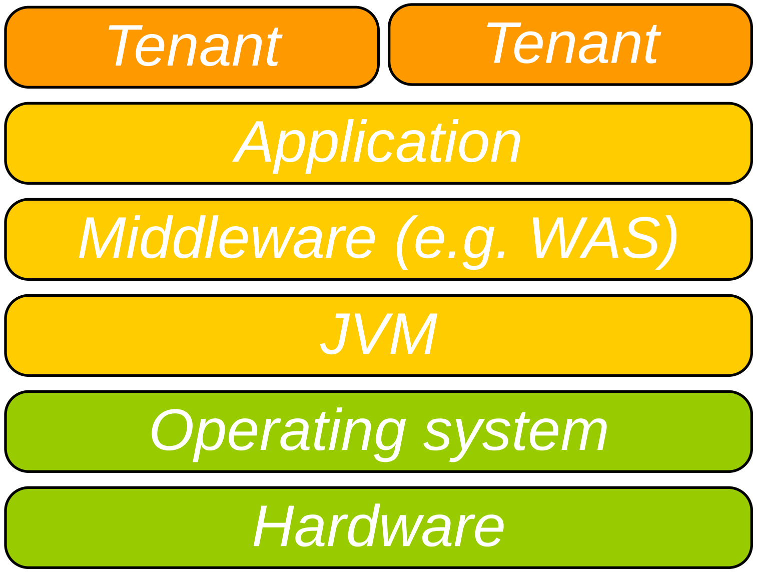
With a multi-tenant architecture, a software application is designed to virtually partition its data and configuration so that each client organization works with a customized virtual application instance.

Examples: ebay salesforce Google App Engine

- **Why you should care about multitenant applications:**
  - Cheaper to run: enables consolidation of IT resources
  - Data Aggregation: all the data is one place and easier to mine
  - Complexity: easier to manage upgrades and deployment of new tenants

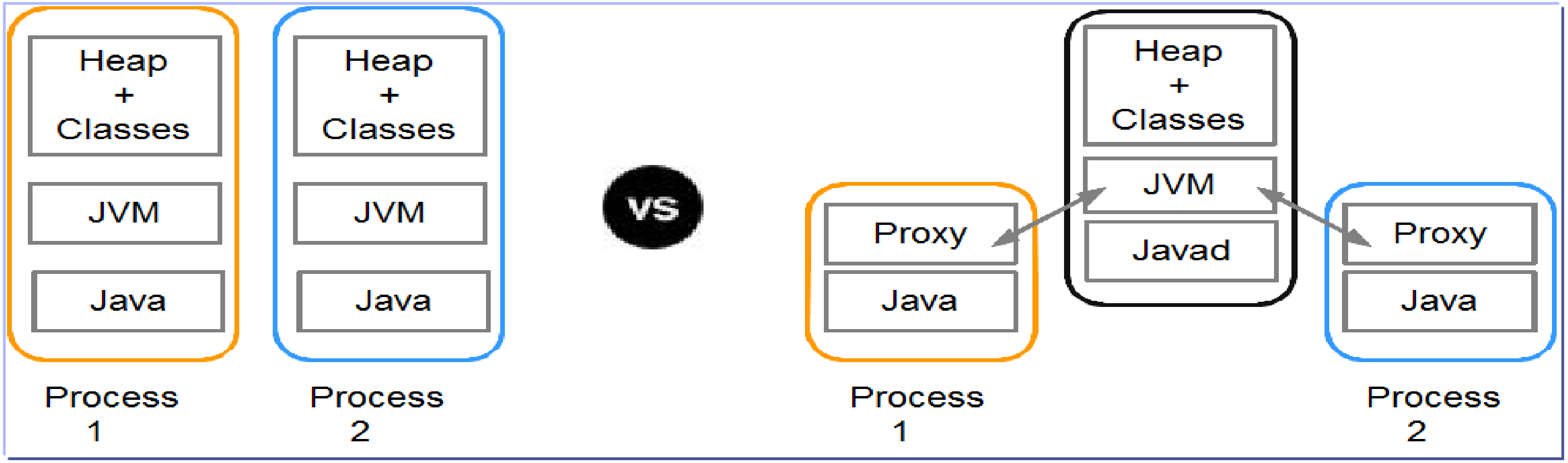
Multi-tenancy defined at different level

- Can make the MT at different stack level, from low HW level to high application level.
- Different levels of MT means the different deployment density
- Depending on the business scenarios, one may select different MT strategies



Multi-tenancy in jvm

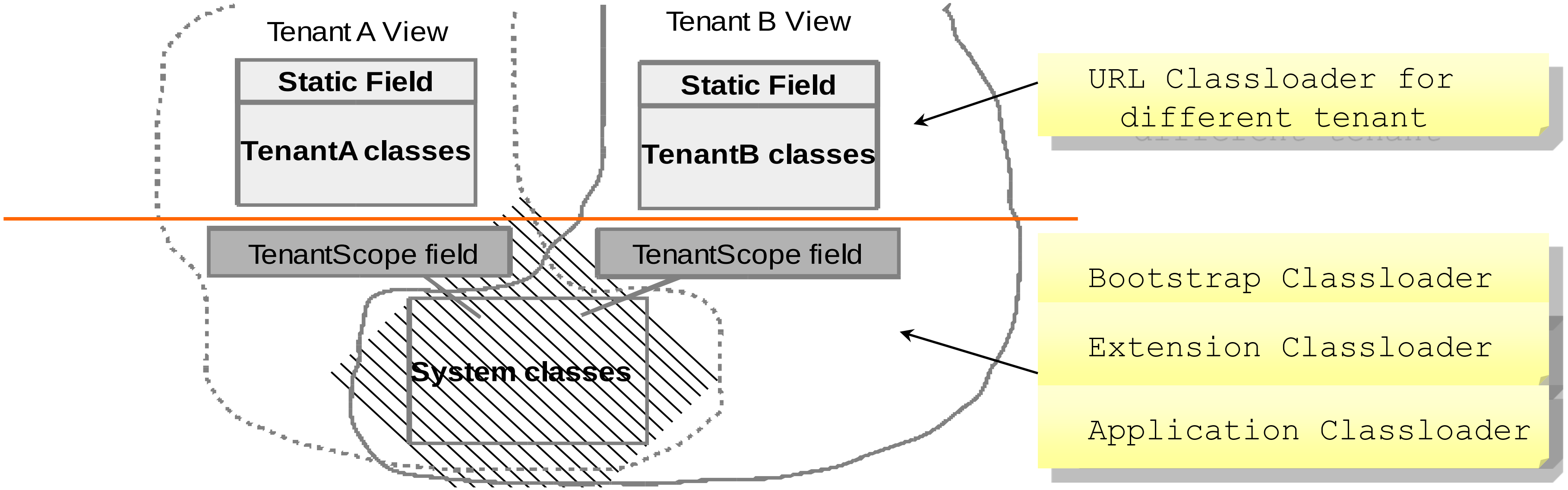
- **Allow for collocation of multiple Java applications in a single instance of JVM**
  - *Isolate application from one another and each "thinks" it has the whole VM all to itself.*
  - *Share metadata aggressively and transparently, such as:*
    - *bytecodes of methods*
    - *GC*
    - *JIT*



More on Multi-tenant JVM
@Room 430 : Wed 9:00 - my JavaOne session

Anatomy of multi-tenant JRE

- Making all static fields in the classes loaded by the bootstrap, extension and app classloaders as “@TenantScope”
- Loading each application with a separate classloader
- Changing the class library to be tenant aware, such like
  - System properties
  - Standard in/out/err
  - System.exit



Thanks!

Your questions?