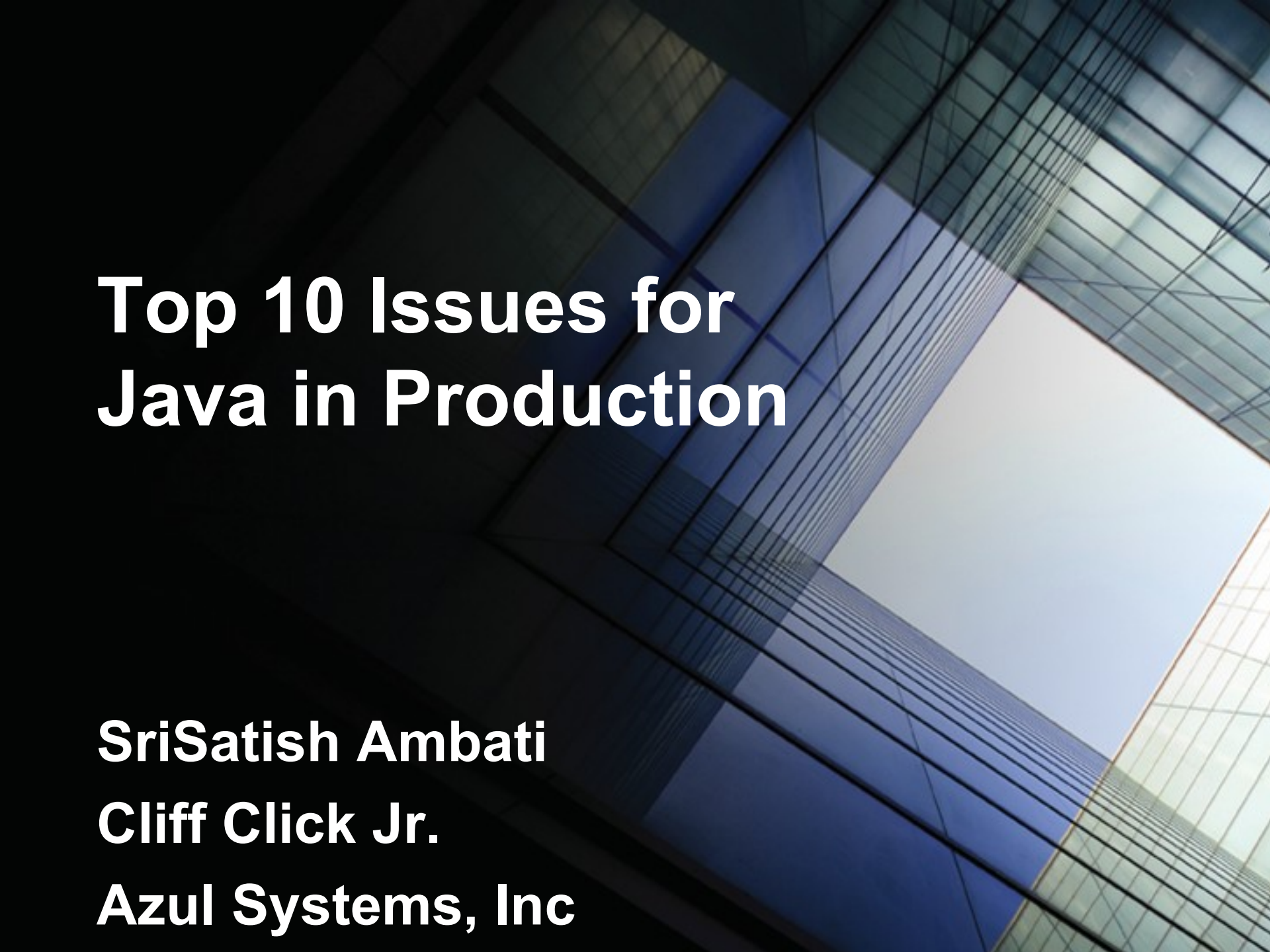


Top 10 Issues for Java in Production

SriSatish Ambati
Cliff Click Jr.
Azul Systems, Inc

A Decade of Java in Production

- A lot of hard-earned wisdom
- A lot of victories (quickly forgotten)
- A lot of endless pain points
- Usually the Pain Point is really

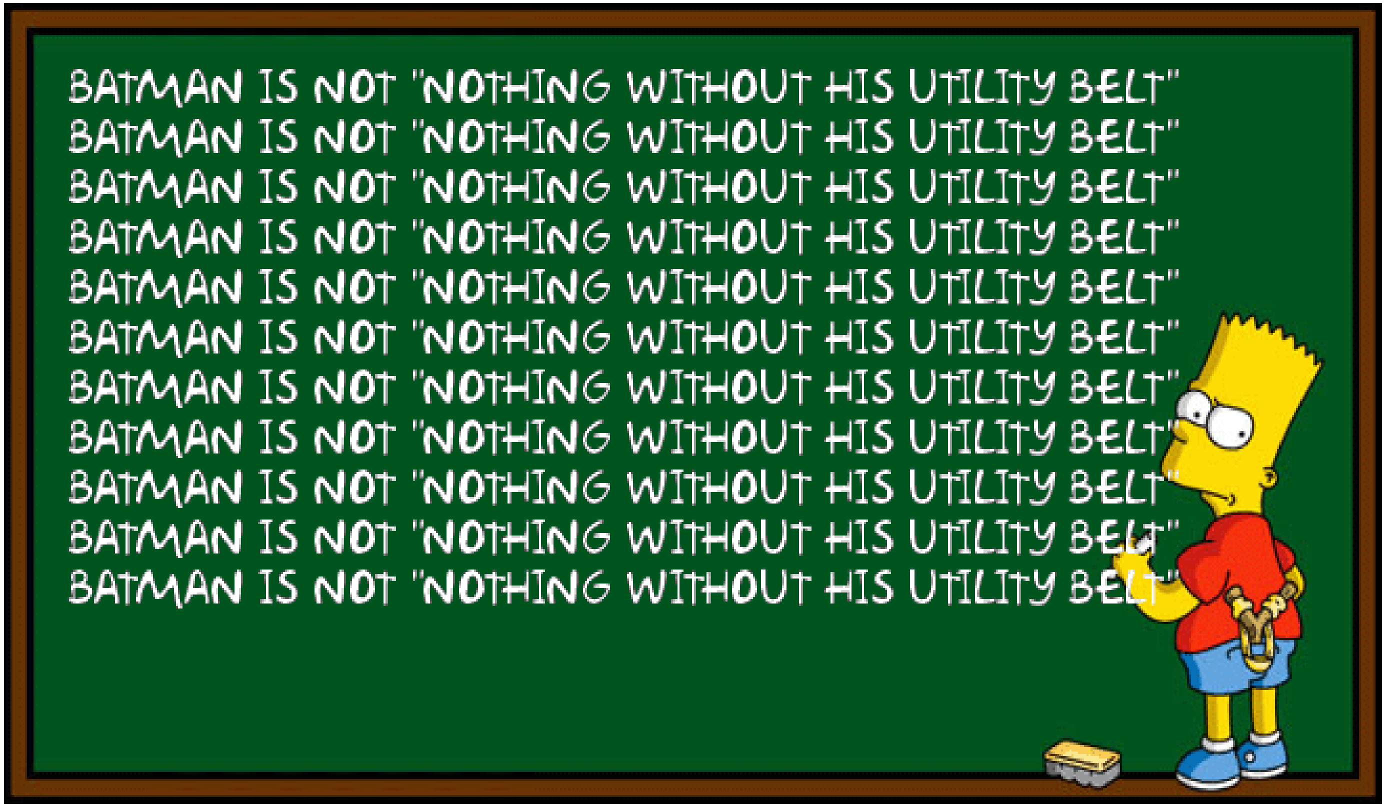
A Systems Issue

- It's Not Just the JVM (nor network, nor ...)

Tools of the Trade

- What the JVM is doing:
  - dtrace, hprof, introscope, jconsole, visualvm, yourkit, azul zvision
- Invasive JVM observation tools:
  - bci, jvmti, jvmdi/pi agents, logging
- What the OS is doing:
  - dtrace, oprofile, vtune
- What the network/disk is doing:
  - ganglia, iostat, lsof, nagios, netstat

Tools of the Trade



10 - Instrumentation is Not Cheap

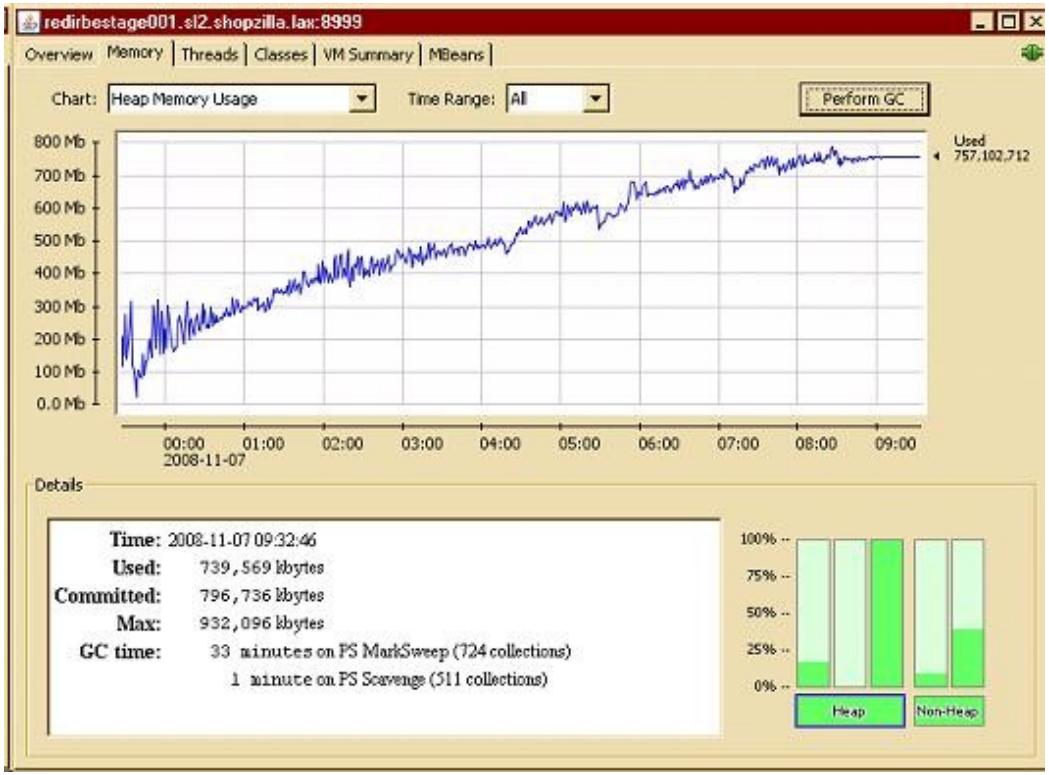
- Symptom
  - Production monitoring can be very expensive
    Staging environment does not repro issues
  - Instrumented code changes cache profile
  - MBeans are not cheap either!
- Solutions
  - Pick the right axe for the problem!
  - Avoid expensive heap walks
  - Finish task then increment perf counters
  - Asynchronous logging, jconsole, azul zvision

9 - Leaks

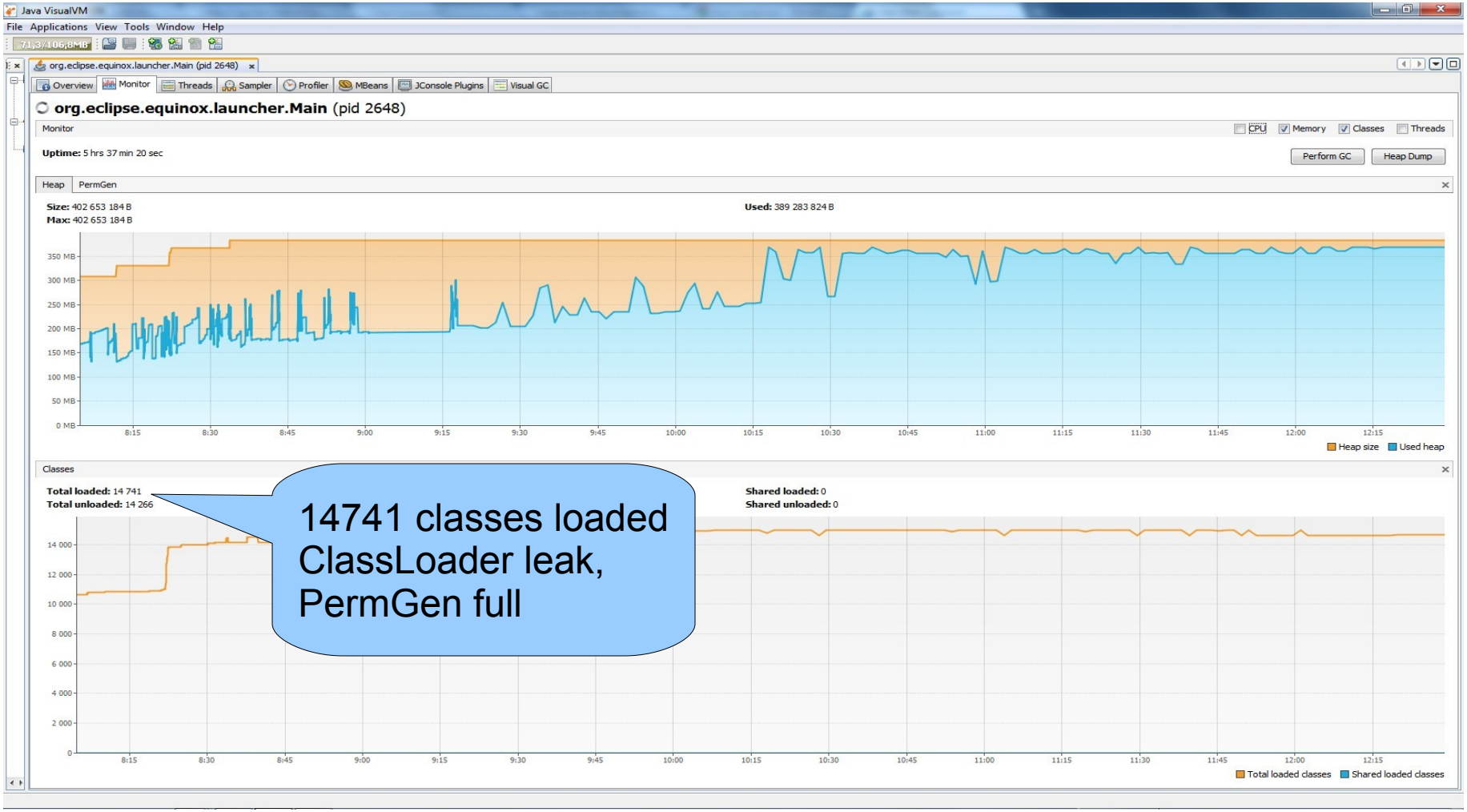
- Symptom
  - App consumes all the memory you got
  - Live Heap trend is a ramping sawtooth
  - Then slows, then throws OutOfMemory
- Tools
  - yourkit, hprof, eclipse mat, jconsole, jhat, jps, visualvm, azul zvision
- Theory
  - Allocated vs Live Objects, vm memory, Perm Gen
  - Finalizers, ClassLoaders, ThreadLocal

Leaks: jconsole

- Tomcat + ActiveMQ
  - 1 week in production
  - after 9hrs in test
  - Leaks 100MB/hr

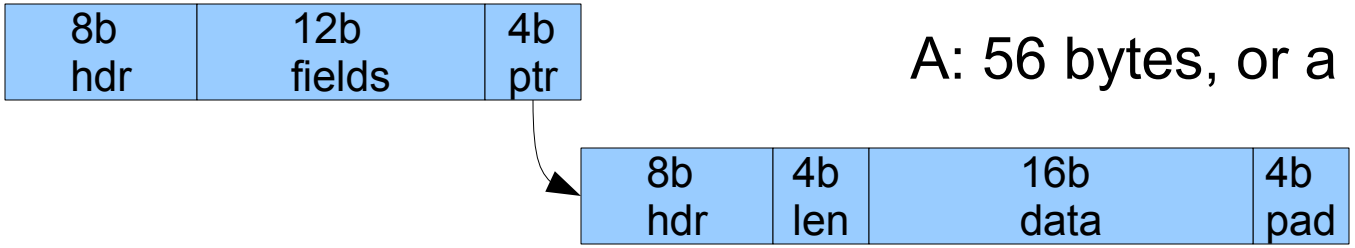


Leaks: Visual VM



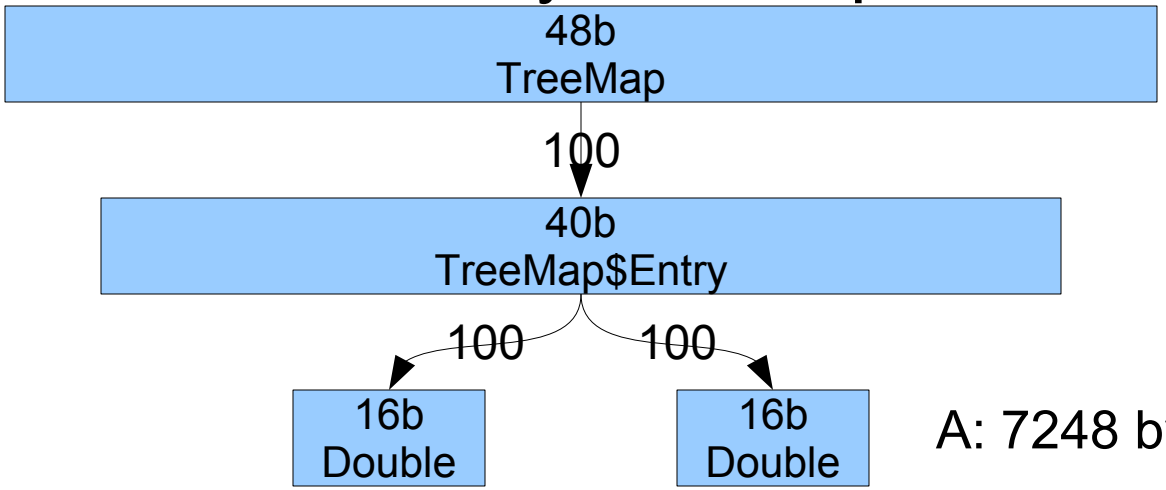
9 – Leaks: Bloat

- Cost of an 8-char String?



A: 56 bytes, or a 7x blowup

- Cost of 100-entry TreeMap<Double,Double> ?



A: 7248 bytes or a ~5x blowup

JEE is not cheap!

JBoss & Apache startup
- 20M objects *before* starting the app

JBoss 5.1	**20**	**4**
Apache Tomcat 6.0	**0.25**	**0.1**

JBoss 5.1
Allocated

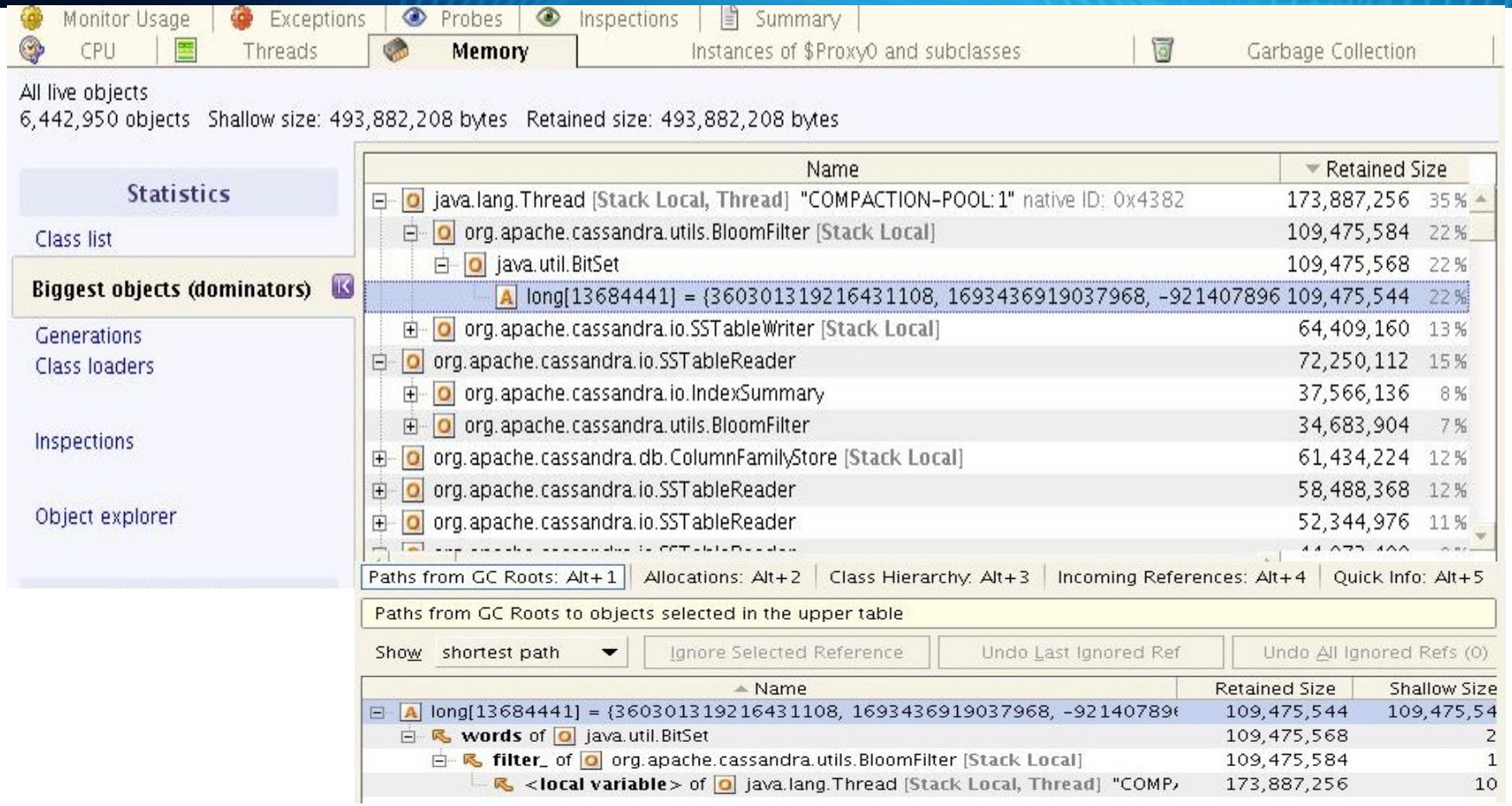
Class name	Size (B)	Count	Avg (B)
Total	1,410,764,512	19,830,135	71.1
char[]	423,372,528	4,770,424	88.7
byte[]	347,332,152	1,971,692	176.2
int[]	85,509,280	1,380,642	61.9
java.lang.String	73,623,024	3,067,626	24
java.lang.Object[]	64,788,840	565,693	114.5
java.util.regex.Matcher	51,448,320	643,104	80
java.lang.reflect.Method	43,374,528	301,212	144
java.util.HashMap$Entry[]	27,876,848	140,898	197.9
java.util.TreeMap$Entry	22,116,136	394,931	56
java.util.HashMap$Entry	19,806,440	495,161	40
java.nio.HeapByteBuffer	17,582,928	366,311	48
java.nio.HeapCharBuffer	17,575,296	366,152	48
java.lang.StringBuilder	15,322,128	638,422	24
java.util.TreeMap$EntryIterator	15,056,784	313,683	48
java.util.ArrayList	11,577,480	289,437	40
java.util.HashMap	7,829,056	122,329	64
java.util.TreeMap	7,754,688	107,704	72

Apache Tomcat 6.0
Allocated

Class name	Size (B)	Count	Avg (B)
Total	**21,580,592**	**228,805**	**94.3**
char[]	4,215,784	48,574	86.8
byte[]	3,683,984	5,024	733.3
Built-in VM methodKlass	2,493,064	16,355	152.4
Built-in VM constMethodKlass	1,955,696	16,355	119.6
Built-in VM constantPoolKlass	1,437,240	1,284	1,119.30
Built-in VM instanceKlass	1,078,664	1,284	840.1
java.lang.Class[]	922,808	45,354	20.3
Built-in VM constantPoolCacheI	903,360	1,132	798
java.lang.String	753,936	31,414	24
java.lang.Object[]	702,264	8,118	86.5
java.lang.reflect.Method	310,752	2,158	144
short[]	261,112	3,507	74.5
java.lang.Class	255,904	1,454	176
int[][]	184,680	2,032	90.9
java.lang.String[]	173,176	1,746	99.2
java.util.zip.ZipEntry	172,080	2,390	72

Live

example: yourkit memory profiling



Know footprint: use memory profiling!

(snapshots are still expensive)

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Got Leaks?

8 – I/O: Serialization

- Symptom
  - Multi-node scale-out does not scale linearly
  - Time in both CPU and I/O (serialization costs)
- Tools
  - Cpu profiling, I/O profiling
- Solution
  - All serialization libraries are not equal!
  - Pick a high performance serialization library or roll-your-own
  - Avro, kryo, protocol-buffers, thrift

8 – I/O: Limits, Tuning

- Symptom
  - Application hangs or remote call fails after awhile
  - “Too many open File Descriptors”, “Cursors”
  - Inconsistent response times
- Tools
  - nagios, pkg, rpm info, ulimit, yum
- Solutions
  - Check for “new” OS patches, user & process limits, network & semaphore configurations
  - Close all I/O streams
  - Maybe you are I/O bound!

8 – I/O: Sockets, Files, DB

- Symptoms
  - Socket.create/close takes too long
  - JRMP timeouts, long JDBC calls
  - Running out of file descriptors, cursors, disk
- Tools
  - dbms tools, du, iostat, gmon, lsof, netstat
- Workaround
  - Check all O/S patches, sysctl flags, run ping/telnet test
  - Check & set SO_LINGER, TCP_LINGER2

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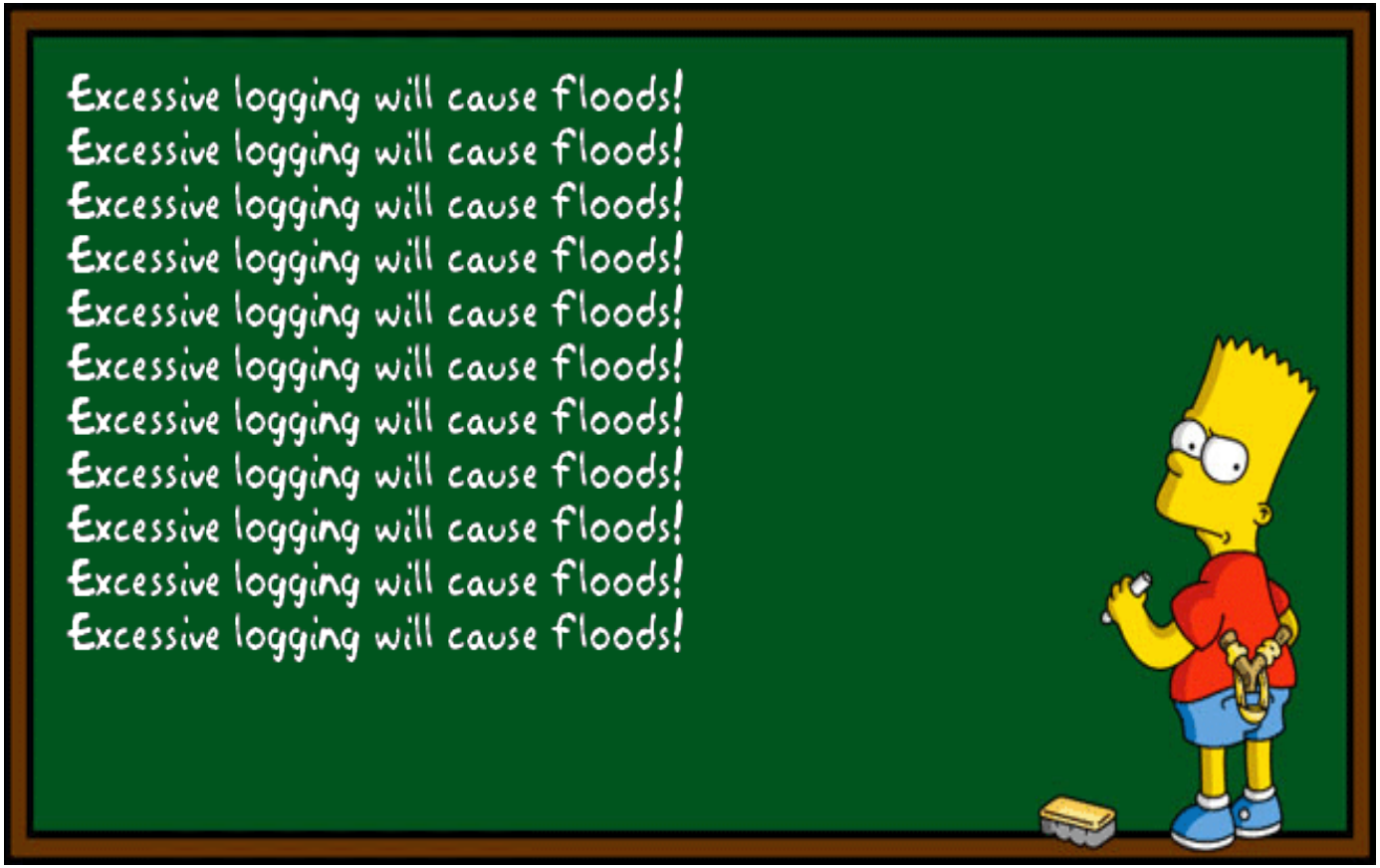
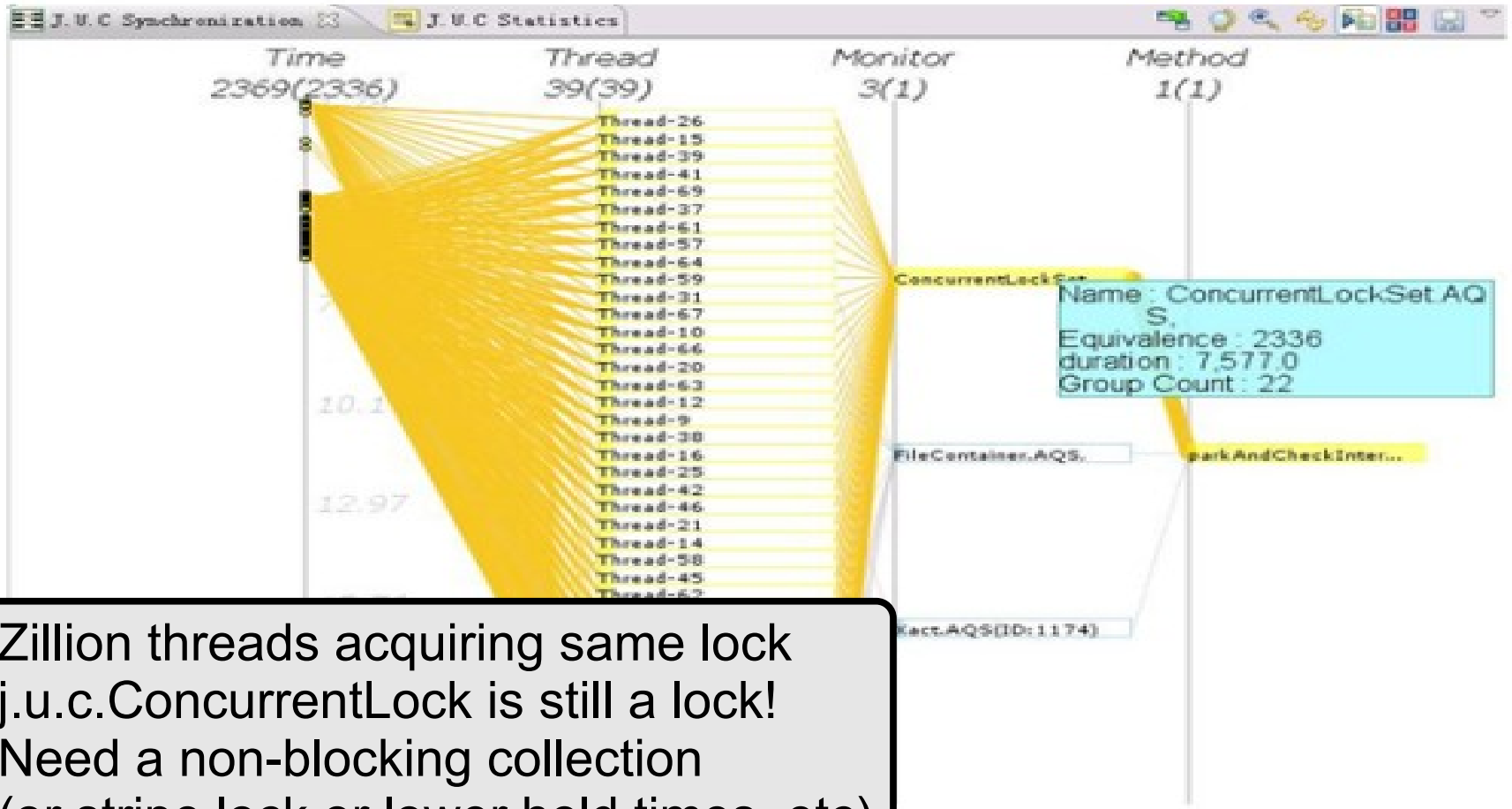
8 - I/O



7 – Locks & `synchronized`

- Symptoms
  - Adding users / threads / CPUs causes app slow down (less throughput, worse response)
  - High lock acquire times & contention
  - Race conditions, deadlock, I/O under lock
- Tools
  - d-trace, lockstat, azul zvision
- Solution
  - Use non-blocking Collections
  - Striping locks, reducing hold times, no I/O

Example: IBM Visual Analyzer (j.u.c view in eclipse)



Zillion threads acquiring same lock
j.u.c.ConcurrentLock is still a lock!
Need a non-blocking collection
(or stripe lock or lower hold times, etc)

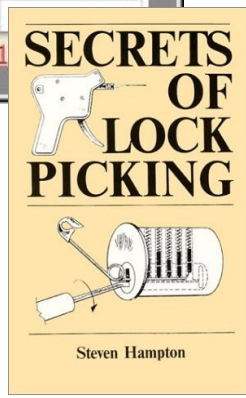
Example: zvision

Monitors - Contention

Name	Acquire time (ms) Total [1]	Acquire time (ms) Max [1]	Blocking acquires Count	Waits Count	Waits Max (ms)	Waits Total (ms)
java.util.HashMap	5,412,770	118	2,120,373	0	0	0
org.apache.catalina.session.StandardManager	4,539,163	4,053	36,286	0	0	0
CodeCacheOopTable_lock	1,442,962	1,028	14,904	0	0	0
CodeCache_lock	1,408,999	881	29,508	0	0	0
CompileTask_lock	834,393	2,349	47,247	48,151	3,729	10,114,752
CompiledIC2_lock	393,090	310	5,831	0	0	0
Compile_lock	328,325	1,938	16,936	0	0	0
org.apache.jasper.servlet.JspServletWrapper	314,008	1,931	627	0	0	0
CompiledIC3_lock	249,978	290	5,301	0	0	0
CompiledIC1_lock	227,530	313	5,428	0	0	0
CompiledIC0_lock	124,506	236	4,809	0	0	0
java.lang.reflect.Method	80,805	1,563	2,342	0	0	0
AdapterHandlerLibrary_lock	70,063	730	182	0	0	0

Done 0.771s 10.10.1

Hot lock is usually 10x to 100x
more acquire time than next lock..
Look for rapidly growing acquire times!



Example: zvision

Lock Statistics of org.apache.catalina.session.StandardManager

Contention Tree

1. 94.46% 4,601,974ms 30,347 org.apache.catalina.session.ManagerBase.generateSessionId (ManagerBase.java:959, bci=-1)
    2. 100.00% 4,601,974ms 30,347 org.apache.catalina.session.ManagerBase.createSession (ManagerBase.java:801, bci=43)
        3. 100.00% 4,601,974ms 30,347 org.apache.catalina.session.StandardManager.createSession (StandardManager.java:291, bci=49)
            4. 100.00% 4,601,974ms 30,347 org.apache.catalina.connector.Request.doGetSession (Request.java:2232, bci=245)
                5. 100.00% 4,601,974ms 30,347 org.apache.catalina.connector.Request.getSession (Request.java:2031, bci=2)
1. 5.54% 269,912ms 7,167 org.apache.catalina.session.ManagerBase.generateSessionId (ManagerBase.java:959, bci=-3)
    2. 100.00% 269,912ms 7,167 org.apache.catalina.session.ManagerBase.createSession (ManagerBase.java:801, bci=43)
        3. 100.00% 269,912ms 7,167 org.apache.catalina.session.StandardManager.createSession (StandardManager.java:291, bci=49)
            4. 100.00% 269,912ms 7,167 org.apache.catalina.connector.Request.doGetSession (Request.java:2232, bci=245)
                5. 100.00% 269,912ms 7,167 org.apache.catalina.connector.Request.getSession (Request.java:2031, bci=2)

Hot Lock Backtrace

6 – Endless Compilation

- Symptom
  - Time “compiling”
  - Time in the Interpreter
- Tools
  - -XX:+PrintCompilation, cpu profiler
  - Find endlessly-recompiling method
- Workaround
  - Exclude using .hotspot_compiler file
- Root cause: It's a JVM Bug! File a bug report!

5 – Endless Exceptions

- Symptom
  - Application spends time in j.l.T.fillInStackTrace()
- Tools
  - Cpu profiler, azul zvision
  - Thread dumps (repeated kill -3, zvision)
  - Track caller/callee to find throw'r
    - Not all exceptions appear in log files
- Solution
  - Don't Throw, alternate return value (e.g. null)

5 – Endless Exceptions

- Related
  - Exception paths are typically failure paths
  - JVMs do not to optimize them much
  - Often found when a server collapses

4 - Fragmentation

- Symptom
  - Performance degrades over time
  - Inducing a “Full GC” makes problem go away
  - Lots of free memory but in tiny fragments
- Tools
  - GC logging flags, e.g. for CMS

```
-XX:PrintFLSStatistics=2
-XX:+PrintCMSInitiationStatistics
```

4 - Fragmentation

- Tools
  - “Fragger” www.azulsystems.com/resources
    - Tiny cpu cost, low memory cost
    - Frag's heap in 60sec like an hour in production
    - Get FullGC cycles at dev's desk
- Solution
  - Upgrade to latest CMS (CR:6631166)
  - Azul Zing & Gen Pauseless GC
  - Pooling similar sized/aged objects
    - (really hard to get right!)

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3 – GC Tuning

- Symptom
  - Entropy(gc) == number_of_gc_flags
    - Too many free parameters
    - 64-bit/large heap size is not a solution
  - Constant 40-60% CPU utilization by GC
  - Scheduled reboot before full-GC
  - Full time Engineer working GC flags;
- Workarounds
  - Ask JVM Vendor to give 1 flag solution
  - G1 GC, Azul's Zing GPGC

3 – GC Tuning
Oracle Weblogic GC Flags

```
-server -Xloggc:gc.log -XX:+PrintGCDetails
-XX:+PrintGCTimeStamps -XX:MaxPermSize=128m
-XX:+UseParNewGC -XX:+UseConcMarkSweepGC
-XX:MaxNewSize=64m -XX:NewSize=64m
-Xms1536m -Xmx1536m -XX:SurvivorRatio=128
-XX:MaxTenuringThreshold=0
-XX:CMSInitiatingOccupancyFraction=60
-Dsun.rmi.dgc.server.gcInterval=0x7FFFFFFFFF
FFFFFE
-Dsun.rmi.dgc.client.gcInterval=0x7FFFFFFFFF
FFFFFE
```

2 - Spikes

- Symptoms
  - Rush hour traffic, tax day, Black Friday
  - Outages under spikes, power law of networks
- Solution
  - **Measure**.
  - Test with realistic load & realistic multi-node setup
  - Build redundancy & elasticity into infrastructure
  - Don’t ignore Exceptions & retries under load

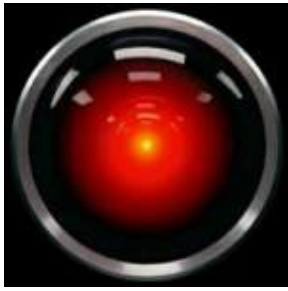
Busiest online day is...

1 – Versionitis

When ears wage class wars with jars

- Symptom
  - Different nodes have different configurations, different stack components, versions
  - classpath has dist/*, -verbose:class
  - subtle hard to reproduce issues
- Solution
  - Method. Version Control.
  - Good ol' fashioned rigor

"It can only be attributable to human error" - HAL



0 – Collapse Under Load (pick any 3 above!)

- Runs fine as load Ramps Up
  - At peak load, system is unstable
  - Slightly above peak: Collapse!
- Heavy load triggers exception (e.g. timeout)
- Exception path is slow already (e.g. logging)
- Transaction retried (so more work yet again)
- So NEXT transaction times-out
- Soon all time spent throwing & logging exceptions
- No forward progress

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example: Driving into San Francisco

SFC / David Paul Morris

Q & A
(& Refs 1 of 2)

References:

Java.util.concurrent lock profiling

http://infoq.com/jucprofiler

Java serialization benchmarks

http://code.google.com/p/thrift-protobuf-compare/wiki/BenchmarkingV2

Memory profiling with yourkit

http://yourkit.com

Tuning gc

http://www.oracle.com/technetwork/java/gc-tuning-5-138395.html

http://blog.codecentric.de/en/2010/01/java-outofmemoryerror-a-tragedy-in-seven-acts/

Cliff Click's High Scale lib, Non-Blocking HashMap

http://sourceforge.net/projects/high-scale-lib/

Q & A
(& Refs 2 of 2)

References:

Memory Leak

http://deusch.org/blog/?p=9

Handy list of jvm options

http://blogs.sun.com/watt/resource/jvm-options-list.html

Fragger (with source code)

http://www.azulsystems.com/resources

Garbage Collection: Algorithms for Automatic Dynamic Memory Management, Richard Jones, Rafael D Lins

Backup slide– Fragmentation

- Works well for hours at 300-400MB
  - Same workload
- Suddenly haywire
  - Promotion
    - Too frequently
  - Back to back FullGCs
  - May not all be completing.