
intel
Leap ahead
How to Get the Most Performance from Sun* JVM* on Intel® Multi-Core Servers
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FORUM

Agenda

- Intel, Sun and Java – really?
- Hardware Features on Hardware Features on Intel® Xeon® Processor-based servers
- Optimizing Java SE for Multi-Core Systems
- Performance Tuning
- Case Studies
- Summary

Intel, Sun and Java – Really?

Absolutely!

- Modern processors require carefully matched code to perform at their best.

- Tuning of the Java Virtual Machine to the processor provides:
  - Best possible performance on the platform
  - Robustness and quality across many applications

- Today's presentation covers what we've done together
  - and how you can take advantage of our work

Motivation

- Performance of your Java application depends on:
  - Your code
  - **Your choice of JVM and JVM parameters**
  - Your choice of operating system (Solaris, Linux, Windows, etc)
  - Your choice of hardware

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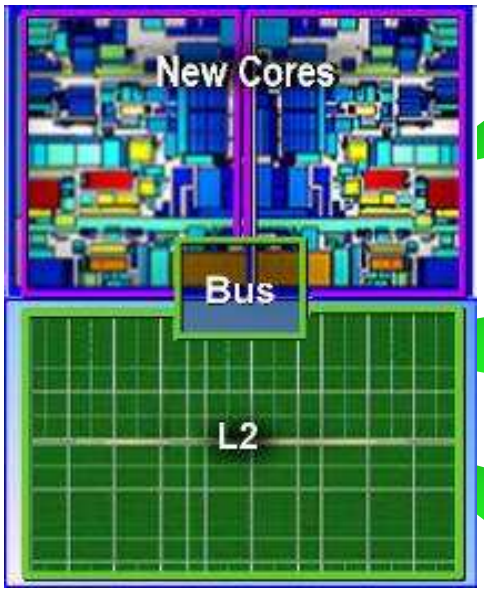
New Intel® Core™ Microarchitecture

Delivering a Performance and Power Advantage for IT



FASTER

Intel® Wide Dynamic Execution Engine

4 instructions per cycle

EFFICIENT

Intel® Intelligent Power Capability

Ultra fine grained power control

SMARTER

Intel® Advanced Smart Cache
Intel® Smart Memory Access

2x cache size, shared Advanced pre-fetching

[1] compared to previous generation Dual-Core Intel® Xeon® Processor based servers

Performance tests and ratings are measured using specific computer systems and/or components and reflect the approximate performance of Intel products as measured by those tests. Any difference in system hardware or software design or configuration may affect actual performance.

Intel's® Quad-Core™ Implementation

Energy Efficient Performance

Breakthrough Performance

Large L2 caches

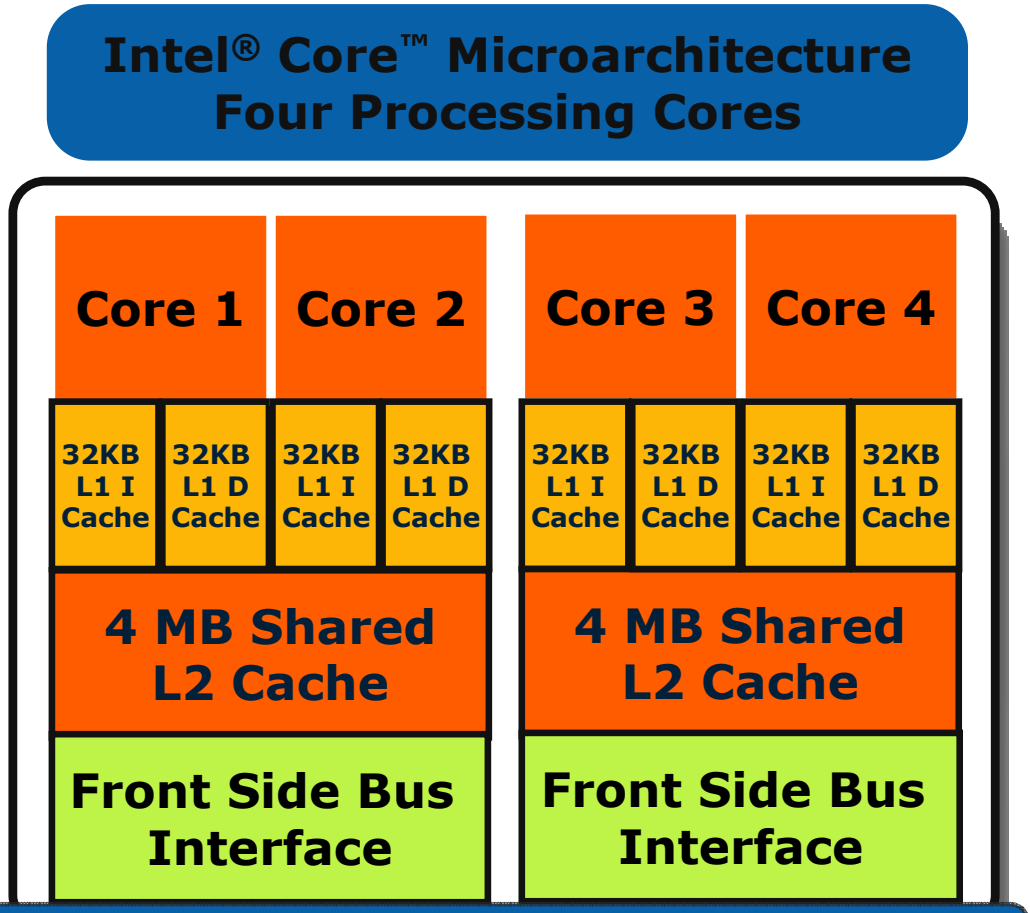
High bandwidth

Quick access to data

IT Investment protection

Socket compatible
to 45nm quad-core

Up to 1333MHz bus



Latest Intel processors = great performance potential

Looking into the JVM…

Processor Features

- J — Instruction Selection, Instruction Ordering, Dynamic Recompilation, Prefetch
- G — Cache Management, Memory Layout, Page Management
- Clas — Threading, Performance Tuning
- Inter — Instruction Selection

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Optimization for Intel® Xeon® processors

- Plentiful Hardware Threads
  - Increase Throughput
    - Java (and JVMs) are inherently multi-threaded
    - Threading in Java is Easy!
    - java.util.concurrent
    - Parallel Garbage Collection
  - Improve Determinism
    - Concurrent Garbage Collection
    - RTSJ – Real-time System for Java
  - Both
    - Concurrent / Parallel Garbage Collection
    - Concurrent / Parallel Dynamic Compilation
    - Concurrent / Parallel Classloading

Optimization for Intel® Xeon® processors

- All those hardware threads pound memory, so must optimize memory system use
- Overcome latency (time to fetch data from memory) and bandwidth (amount of data transferred between memory and processor in a given time) limitations
- Processor / memory affinity
  - Always run a given software thread on the same hardware thread
  - Keeps data "close" to processor (caches warm)
  - OS does its best (with your help: binding, processor sets)

Optimization for Intel® Xeon® processors

- Number of simultaneously active software threads should be >= number of hardware threads
  - But may be less due to memory system limitations
  - Plan to use all the hardware threads
  - Include non-Java threads in the count: concurrent GC, native threads
- Minimize writes to shared data
  - Processor must acquire data ownership, which usually means a write to plus a read from long-latency memory
  - Synchronization requires write to shared lock word
  - Reads of shared data are ok

Optimization for Intel® Xeon® processors

- How important are memory system optimizations for your hardware?
- Optimization effectiveness depends on latency / bandwidth ratios in the memory hierarchy
  - Shared cache(s), local and remote memory
- Likely effectiveness, most to least
  - Intel Core2 L1, L2, memory

JVM Optimizations: Affinity

- Thread-Local Allocation Buffers (TLABs)
  - Java threads allocate objects in thread-private memory
  - Otherwise app serializes on shared heap access
- Parallel Thread-Local Allocation Buffers (PLABs)
  - GC threads copy live objects to thread-private memory

JVM Optimizations: Affinity / Bandwidth

- Copying garbage collectors can scatter objects around memory that were originally allocated next to each other in TLABs
- Objects allocated together are usually accessed together, so scattering causes extra memory traffic
- Object copying order can be
  - Breadth-first: copy all children, then all children's children
  - Depth-first: copy first child, then first-child's first child, ..., then second child, ...
  - Some combination of the two
- Which is better is app-dependent, but for most applications depth-first is better

JVM Optimizations: Latency (1)

- Allocation prefetch
  - Prefetch instructions can acquire cache line ownership for a processor in time for later writes
  - Allocate space in cache for the acquired line
  - When allocating objects linearly in TLABs, prefetch a platform-dependent distance ahead of address of the object being allocated
  - Subsequent allocations should find line already cached
  - Sometimes it's a good idea to prefetch multiple cache lines ahead

JVM Optimizations: Latency (2)

- Processors cache virtual-to-physical address translations in Translation Lookaside Buffers (TLBs)
- TLB size is limited, typically 8 to 64 entries
- TLB miss is expensive
  - Requires walking page table in memory
- Intel Xeon processors support large pages
  - 2 to 4 mb rather than 4 to 8 kb
  - Can map memory with many fewer TLB entries
- JVM can map Java heap and generated code cache with large pages
- Far fewer TLB misses

JVM Optimizations: Bandwidth

- Object field reordering
  - Group frequently accessed fields together so they end up in minimum number of cache lines
  - Often with object header
  - Experience shows that scalar fields should be grouped together separately from object reference fields
- Vectorization
  - Load, operate on and store multiple array elements at once with single machine instructions
  - E.g., use 8- or 16-byte loads and stores to access 4 or 8 char array elements at a time
  - Compiler-generated or tailored assembly code: e.g., System.arraycopy
  - Detect and parallelize execution in JVM
    - detect sequential data access
    - transform sequential execution code into code that takes advantage of SIMD architecture parallelism

JVM Optimizations: Latency/Bandwidth

- 64-bit JVMs enable heaps larger than 4 gb, but are ~20% slower than 32-bit JVMs
- Essentially all of the difference is due to extra memory system pressure caused by moving 64-bit pointers around
- Solution: use 32-bit offsets from a Java heap base address instead of 64-bit pointers
- If objects are highly aligned, can use > 4 gb heaps
  - If objects are 8-byte aligned, a 32-bit object offset can represent a 35-bit byte offset => 32 gb Java heap
- On Intel® Xeon® platforms, resulting 64-bit JVM can be faster than 32-bit equivalent!

JVM Optimizations: Instruction Selection

- Tune JIT code generation to match architecture:
- Take advantage of new architectural features
  - Example: Use efficient SSE instructions to move data
- Improve decode/allocation efficiency
  - Avoid length-changing prefixes to improve decode efficiency
  - Branch target alignment
- Eliminate inherent stalls in generated code
- Tune register allocation to reduce memory traffic:
  - Better register allocation can reduce stack operations
  - Use additional registers afforded by SSE or Intel64®

Sun JVM + Intel arch. = further increase performance

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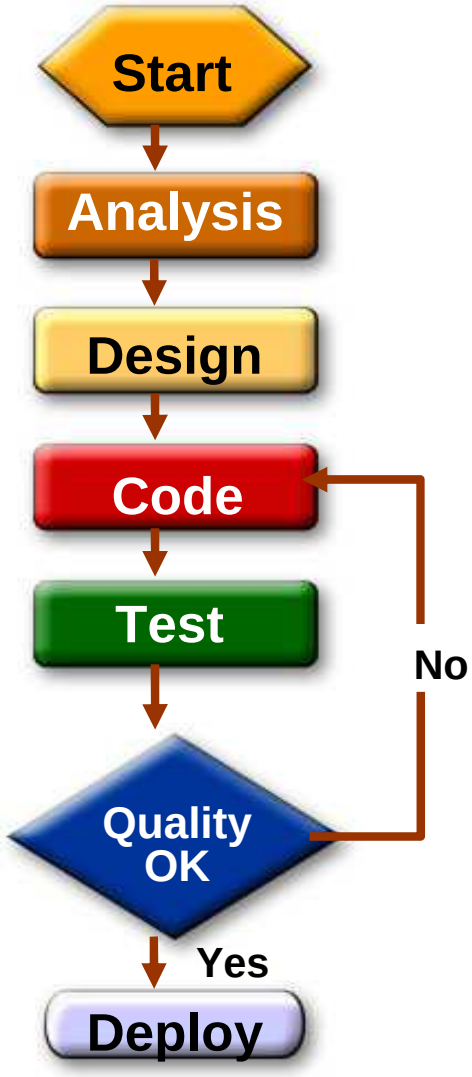
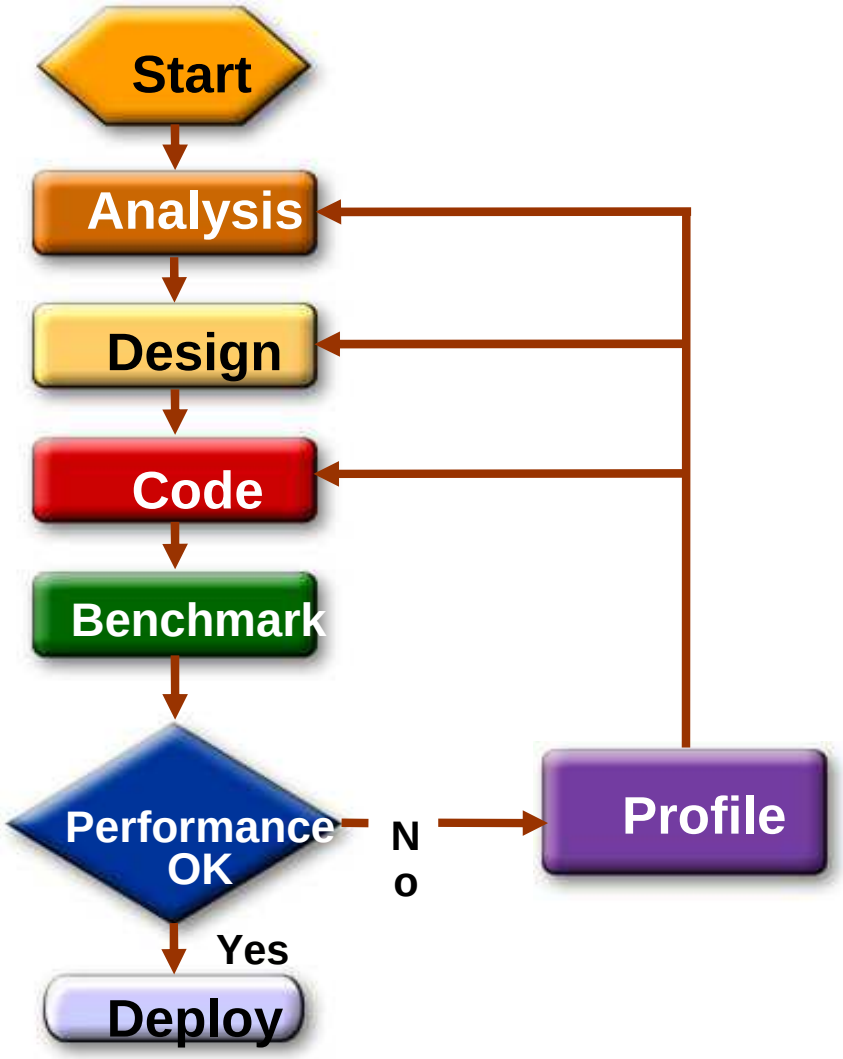
What's Tuning?

- The process of making an app run well on a particular platform
- Use the JVM to help
- Trust the JVM (but verify)
  - Don't warp your source code to compensate for perceived JVM problems
  - JVMs constantly improve
  - They optimize for the common case
  - Warped source code eventually becomes a performance liability
- http://java.sun.com/performance/reference/whitepapers/tuning.html

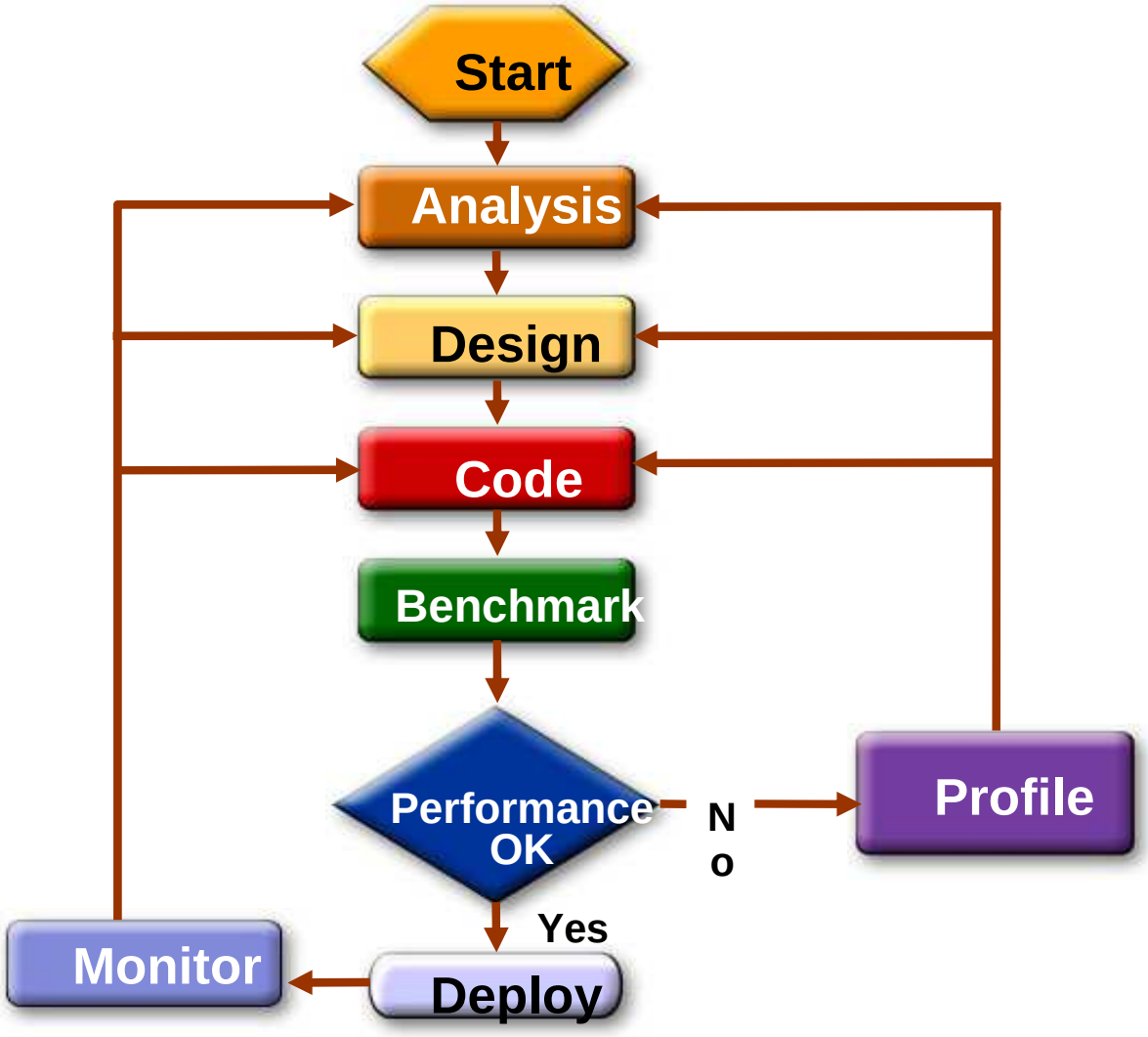
Typical Development Process



Application Performance Process



Application Performance Process



Common Bottlenecks

- Three General Categories
  - Excessive Allocation
    - Increased pressure on GC and memory systems
  - Synchronization
    - Serialization in your application will limit scalability
  - Untuned Java heap configuration, including collector selection

Reduce Object Allocation Rate

- Steps to Identify Hot Allocation Sites
  - Profile
    - Sun Studio Performance Analyzers
    - VTune
    - Netbeans Profiler
    - HPROF
  - Identify alternate strategies
    - Thread-local variables?
  - If unable to reduce allocation rate, then Tune

JVM Tuning for High Allocation Rates

- Steps to Tune the JVM
  - Observe GC behavior using VisualGC or jconsole
  - Tune Java heap and generation sizes
    - Increase overall heap and young generation sizes
    - Large heaps need a parallel collector
  - Tune TLABs
    - Not necessary with Sun's HotSpot JVM
  - Tune allocation prefetch
    - Again, not necessary with Sun's HotSpot JVM

Identify Synchronization Bottlenecks

- Steps to Identify Hot Locks
- Profile
  - Sun Studio Performance Analyzers
  - VTune
  - Netbeans Profiler
  - HPROF
- OS CPU statistics
  - High mutex spin count
  - High context switch rates
  - Unable to utilize 100% of CPU
- Identify alternate strategies
  - Maintain thread affinity
  - Use java.util.concurrent

Basic Java Heap Tuning

- First Steps to Tuning GC
- Observe GC behavior
  - -verbose:gc -XX:+PrintGCDetails -XX:+PrintGCTimeStamps
  - jvmstat, VisualGC, jconsole
- Identify proper heap size
  - -Xms -Xmx
- Identify proper young generation size
  - -Xmn -XX:NewSize= -XX:MaxNewSize=

JVM Throughput Tuning

- Tuning parameters and why we use them
- -XX:+UseParallelOldGC
  - Minimize garbage collection impact on throughput
  - Does not target low pause times (use CMS for that)
- -XX:ParallelGCThreads=<n>
  - Large-scale deployment running multiple JVMs
  - By default, = #hardware threads
  - total GC threads on the system should not exceed 20: you might have expected 32
  - Experiment needed, mileage will vary

JVM Throughput Tuning

- Tuning parameters and why we use them
- -XX:+UseBiasedLocking(5-10%)
  - On by default in Java SE 6
  - Bias synchronized object to the thread that created it
  - If the synchronized block is never accessed by another thread, uses cmp+branch, not atomics, to lock/unlock
  - +3%; CAS is cheap
- -XX:+AggressiveOpts (+5-10%)
  - New wrapper flag for performance optimizations.
  - Features will be enabled by default in upcoming releases.
  - Code quality optimizations, not GC

JVM Low Pause Time Tuning

- Key Parameters for CMS
- -XX:NewRatio=N -Xmn -XX:[Max]NewSize
- -XX:SurvivorRatio=
- -XX:MaxTenuringThreshold=
  - Smaller young generation can put more pressure on CMS old generation
  - Larger young generation can increase young generation pause times
  - Experiment

JVM Low Pause Time Tuning

- Key Parameters for CMS
- -XX:ParallelCMSThreads=<n>
  - Dynamically set based on ParallelGCThreads
- -XX:ParallelGCThreads=<n>
  - Default: number of hardware threads (ncpus)
  - Try ncpus = ncpus <= 8 ? ncpus : ncpus * 5 / 8;
- -XX:CMSInitiatingOccupancyFraction=<n>
  - Old gen occupancy at which CMS starts collecting
    - Larger values improve throughput and Full GC risk
    - Lower values reduce throughput and Full GC risk

Using Large Pages on Solaris

- Enabled by default: it just works
- Default page size 4k on x64
- X86 supports 4mb pages
- X64 supports 2mb pages

Using Large Pages on Windows

- Use the local security settings console to "lock pages in memory" for the user running the application
- -XX:+UseLargePages
- For more detailed information:
  - http://java.sun.com/docs/hotspot/VMOptions.html#largepages

Using Large Pages on Linux

- Create huge page folder
  - mkdir /mnt/hugepages
- Mount the huge page file system
  - mount -t hugetlbfs nodev /mnt/hugepages
- Set permissions for read and write on the folder for the user/users that will use huge pages. By default only root will have access after mounting. In this example, all users will be allowed
  - chmod 755 /mnt/hugepages
  - chmod 777 /mnt/hugepages
- Specify how many pages you want to allocate as large pages:
  - echo 1500 > /proc/sys/vm/nr_hugepages
- Verify result:
  - cat /proc/meminfo | grep -E "(HugePage|Hugepage|Mem)"
- -XX:+UseLargePages
- For more detailed information:
  - http://java.sun.com/javase/technologies/hotspot/largememory.jsp

Tuning = squeeze the last bit of performance

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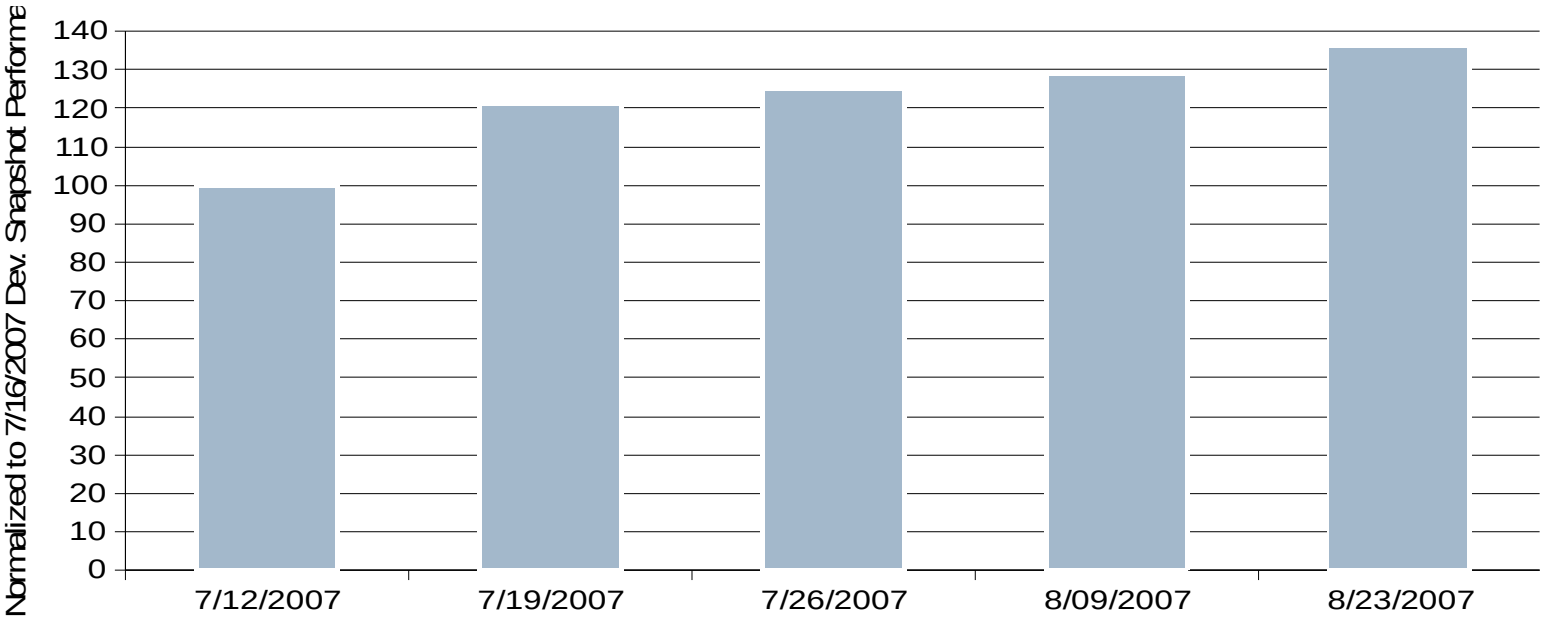
Case Study 1 – SPECjbb2005

- Sun and Intel engineers improved performance by 20% in just 3 months (announced in JavaOne).
- Performance continued to get better after JavaOne (Chart).



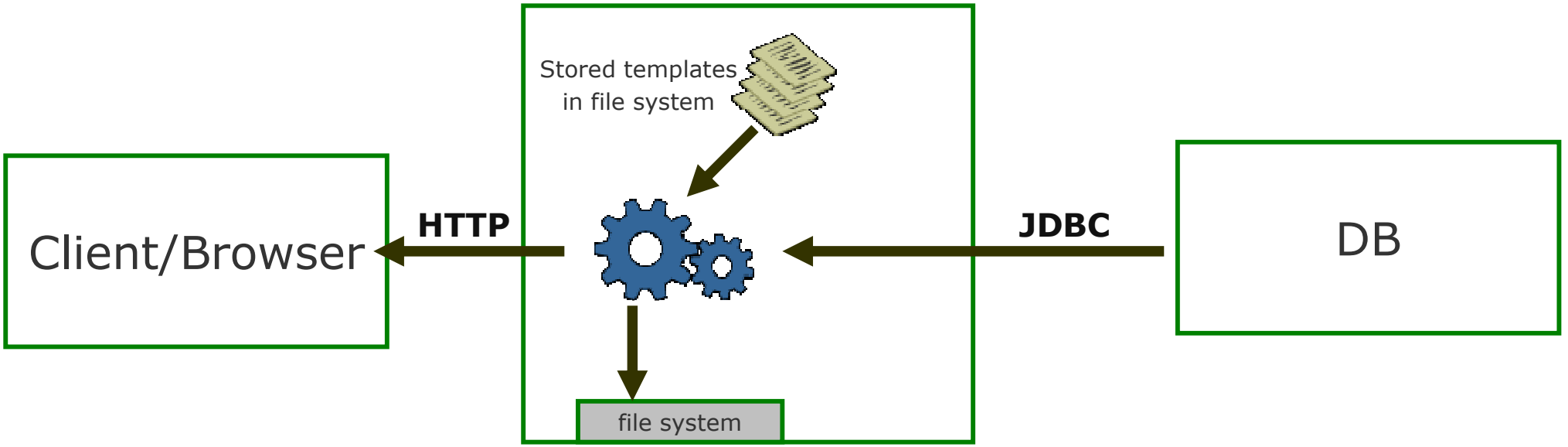
Source: Sun Microsystems, Inc.
SPECjbb2005 run on 2 x 2.66Ghz Intel Xeon processors X5355, 8GB RAM
SPECjbb2005 are trademarks of the Standard Performance Evaluation Corporation. For the latest SPECjbb2005 benchmark results, visit http://www.spec.org/osg/jbb2005.

Case Study 2 – SPECjAppServer2004

- SPECjAppServer2004 (Java Application Server) is a multi-tier benchmark for measuring the performance of Java 2 Enterprise Edition (J2EE) technology-based application servers.
  - Ref: www.spec.org
- Tuning multiple tiers (both SUT and non SUT boxes)
  - OS & network tuning
  - Java & non-Java components on the app server
- Additional tunings required on OS
- http://www.spec.org/jAppServer2004/results/res2007q3/jAppServer2004-20070619-00068.html
- Performance gain: ~1.3x (Best performance with 64-bit JVM)

Case Study 3 – Customer Workload

- A pure J2EE application
- Running on top of a J2EE Container
- Basically a XSLT transformation engine
- ~2.5x performance gain using the same default JVM parameters (response time reduction)



Case Study 4 – Customer Workload

- Data is gathered on Clovertown (2.66 GHz, 16GB memory), Linux32 RH AS4.0, and
- **defaultjdom-parsing:** jaxp_default (dom parsing): ~1.3x performance boost
- **defaultjdom:** jaxp_default (dom parsing + tree traversal): ~1.3x performance boost

Case Studies Summary

- Latest Sun JVM + Latest Intel® Xeon® processors

1.3x ~ 2.5x with Sun JDK6 for Intel Xeon processors

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Summary

- Latest Intel processors = great performance potential
- Sun JVM + Intel architecture = further increase performance
  - Using a VM targeted for Intel architecture may increase your application performance without changing a line of code
- Tuning = squeeze the last bit of performance
- 1.1x ~ 2.5x with Sun JDK6 for Intel® Xeon® processors

Sun JVM + Intel = High Performance for You

Additional sources of information on this topic:

- Other Sessions / Chalk Talks / Labs -
  - SSGS011– Event-Based Techniques for Software Tuning and Performance Analysis (Speaker: David A. Levinthal, Senior Software Engineer, Intel Corporation)
- More web based info:
  - http://blogs.sun.com/dagastine/
  - http://www.spec.org/

This Session presentation (PDF) is available from www.intel.com/idf. Some sessions will also provide Audio-enabled presentations after the event.

Call to Action!

- Run your Java applications with Sun JDK optimized for Intel® Xeon® processors
  - Performance gain out of the box, as Sun JDK is optimized for Intel® Xeon® processors
  - JVM and OS tunings to squeeze the last drop of performance

Risk Factors

This presentation contains forward-looking statements. All statements made that are not historical facts are subject to a number of risks and uncertainties, and actual results may differ materially. Please refer to our most recent Earnings Release and our most recent Form 10-Q or 10-K filing available on our website for more information on the risk factors that could cause actual results to differ.

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