Enabling Starcat Performance Scaling

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Agenda

- Overview
- Hardware factors
- Solaris factors
- Practices and “big knob” tuning
- Recent Solaris enhancements
- Application tuning – no, that's another session!
- Q&A

- NOTE: Bias here is towards large Oracle apps

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Overview

What challenges scaling?

- Strategic
  - "Throwing iron at the problem"
  - “Bad Practices” - “The way we've always done it”
  - Managing expectations & sizing methodologies
  - Non-optimal solution architectures
- Technical
  - Ever-larger domains
  - Fewer/faster processors
  - Locks and synchronization objects
  - Sharing anything (CPU, I/O, memory ...)
  - Hardware and software revision levels
  - Design limits of algorithms in kernel and libraries

Some Low-Level Scalability Factors

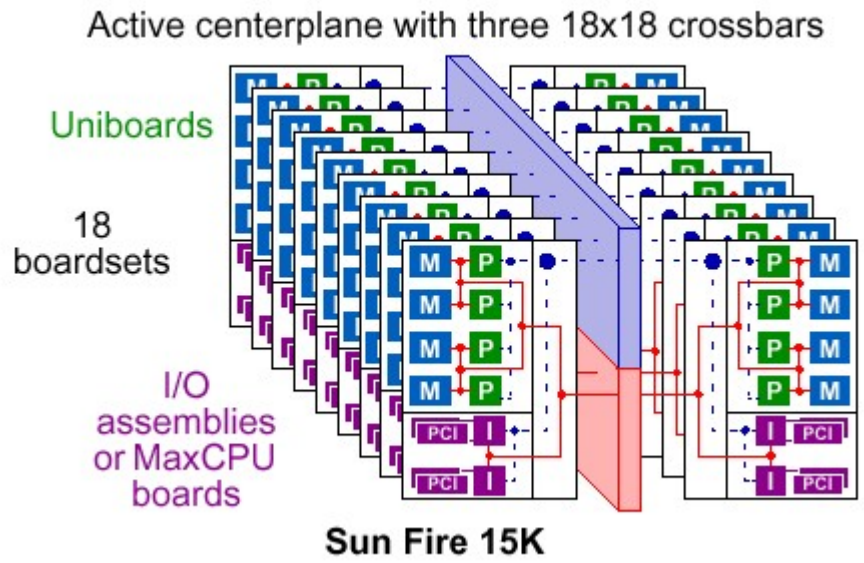
- The kernel cage and Dynamic Reconfiguration (DR)
  - kernel memory focused on a single board
  - sometimes limiting for large domains, but often issues are only provoked due to configuration practices
- Solaris segmap mechanism
  - Filesystem buffering involves global lock activity
- Global cache coherency
  - Global locks require global cache coherency
  - StarCat systems have a 3rd-level coherency mechanism on the expander boards, which contain an “AXQ” chip
- Cache-to-cache copies
  - When the CPU ownership of the most recent change occurs, data must be copied
- Local versus remote memory

Common Customer Perspectives

- Recent experiences
  - Cannot reproduce production load in Q-A/Test/Stress environment; too costly, complex, and time-consuming
  - High-end upgrades sometimes lead to alarming statistics or disappointing capacity forecast
  - Typical “performance cases” involve multiple root causes; best to fix proactively versus reactively
- Default expectations
  - Bigger is better
  - Applications will scale near-linearly
  - Existing capacity planning techniques are OK
  - Existing practices “like we've always done it” are OK

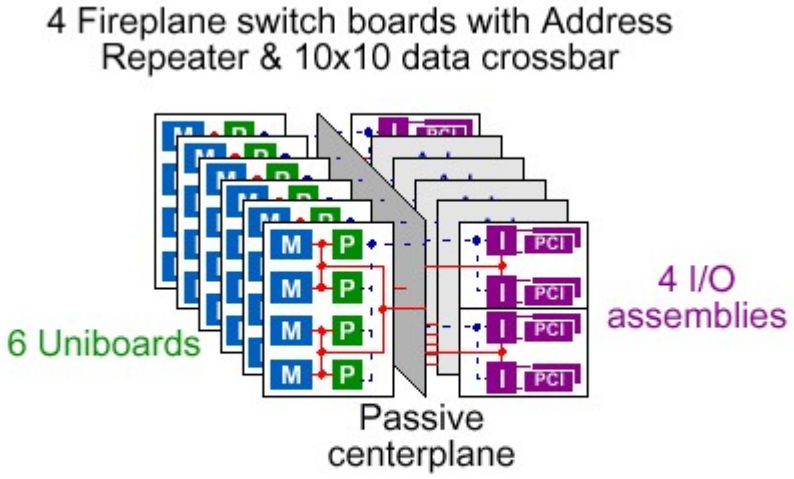
Hardware Factors

StarCat Architecture



Sun Fire 15K

Excerpted from: "Solaris Memory Placement Optimization and SunFire Servers", by Alan Charlesworth, March 2003 (Easily found on www.sun.com using Google)



Sun Fire 6800

Hardware Factors

- Performance-impacting components upgraded since first StarCat release
  - Expander Boards
    - AXQ >= 6.2 needed to support LPA+MPO to deliver full S9 benefit
  - hsPCI+
    - Some older cartridges did not do 66 Mhz correctly
    - I/O multiplexor chip (PCI bridge) improved in newer gear (older chip had issue requiring pcisch driver to use an extra DMA sync operation, which can diminish the odds of data streaming)
    - New bridge chip has deeper data buffer that improves data streaming
  - CPUs
    - US-III - “Cheetah”
    - US-IV - “Jaguar” – dual-core US-III+
    - Soon: US-IV+ - “Panther” - dual-(improved)-core, enhanced cache architecture

Hardware Factors

- New components shipped as standard in new systems - of course!
- Be aware of what you have
- Consult Sun for upgrade pricing

Solaris Factors

Solaris for StarCat Systems

- Solaris 8 - Design point: E4500
  - Now entering the EOL process
  - IP scalability permanently limited
  - Reduced price/performance; no MPO, no MPSS
- Solaris 9 - Design point: F12K
  - Prevailing “Best Practice” on all systems
  - Improved CPU, IP, and memory scaling
  - Improved instrumentation and controls
- Solaris 10 - Design point: CMP/CMT
  - Best technically - but ...
    - Data centers are not usually “early adopters”
    - Some key ISV certifications still in process
    - Training required for Fault Management Architecture (FMA) - at least

Solaris 9 - The Recommended "Minimum" OS Release

- Solaris 9 - high-order bits ...
  - A "Best Practice" on high-end gear
  - Delivers generally improved performance
  - Required minimum for best StarCat performance
  - Better support scenario than Solaris 8 (less to fix)
  - Extreme and seamless Solaris 8 compatibility
  - No re-training required
- Countdown the "Top 8" reasons ...

Solaris 9 - Reason #8

- In general, improved performance
  - “M-Value” uplift (Sun's “horsepower” metric)
  - Numerous smaller fixes
  - Enhanced UFS and NFS performance
  - Some things, for example fsync() performance, are abysmal in Solaris 8 – an will never be improved there
  - Other performance improvements more likely to flow down to Solaris 9 than Solaris 8 (many have Solaris 9 foundation prerequisites)

Solaris 9 - Reason #7

- IP scaling enhancements
  - Multi-threaded (MT) STREAMS scheduling
  - IP syncq fixes
  - Overall more robust “out of the box” networking
  - A major category of where high-end users “hit the wall” with Solaris 8 design limits

Solaris 9 - Reason #6

- Memory Placement Optimization (MPO)
  - Required to get best price/performance from StarCat
  - 8-12% OLTP uplift often cited
  - Some compute-bound tasks benefit as much as 300%
  - Benefits are immediate and automatic (on properly-configured StarCat of recent vintage)
  - Quick check (as root)
    - echo “nlgrps/D” | mdb -k
    - multi-board domains should show greater than 1
  - NOTE: Requires modern AXQ hardware

Solaris 9 - Reason #5

- Multiple Page Size Support (MPSS)
  - Decreases overhead of managing Very Large Memory (VLM)
  - Offers tuning opportunities for applications with large memory footprint
  - Directly exploited by Oracle 9i

Solaris 9 - Reason #4

- Improved instrumentation
  - 'trapstat' - facilitates MPSS benefit analysis
  - %sys more accurately counted
  - improved 'ipcs' and 'pmap' commands

Solaris 9 - Reason #3

- Improved Resource Management facilities
  - FSS - Fair Share Scheduler (previously Solaris Resource Manager (SRM)) - now bundled for free
  - FX - Fixed priority scheduling class added - useful for improving efficiency in complex workloads
  - Persistent processor sets (psrsets) - processor sets can be made to survive reboots
- These can help a lot when pushing the system scaling performance envelope

Solaris 9 - Reason #2

- Maturity - Stable and market-proven
  - Solaris 8 - “old” - about to EOL, known limitations
  - Solaris 9 - “mature” - reduces life cycle maintenance costs, driving down Total Cost of Ownership (TCO)
  - Solaris 10 - “wonderful” - but requires some training and integration investments

Solaris 9 - Reason #1

- "None of the above"!
  - Once again, many S9 improvements will never be in S8
  - Having S9 as a baseline avoids re-evaluating S8 issues and limitations if there are operational issues
  - Diagnosing new issues in S10 is much easier with DTrace ... but S9 can give huge serviceability gains without a big adoption delay

OS Version – Not a panacea!

- Sometimes, tangible difference will be zero
  - "Nominal" operations may be imperceptibly different
  - The shape of the scaling curve changes at the high end
  - Perceived difference may be partly due to improved instrumentation in newer releases
- Many issues are not addressed by the OS version
  - ISV certification gaps
  - Bad application configuration and tuning
  - 3rd-party factors (Storage, system software)
  - Interrupt management pathologies
  - Pathological locking / non-scalable code
  - … but there is continuous progress in all of these areas

Solaris 9 – Apparent Barriers

- ISV Certifications
  - Generally, a “paper tiger”
- Q-A/Test and promote-to-production costs
  - Another “paper tiger” - patching S8 is higher-risk
- Customer staff training
  - None required, really
- “Skip 9, go straight to 10”
  - OK, if it will happen quickly
- “If it isn't broken, don't fix it!”
  - It's all a matter of TCO
- Unforeseen compatibility issues
  - We just haven't seen any!
  - Occasionally, a script will gratuitously check OS version

Practices & “Big Knob” Tuning

Recurring Issues

- "Worst-of-all worlds" I/O tuning
  - disk_asynch_io=false
  - db_writer_processes=10
  - self-imposed filesystem constraints (single-writer lock and/or memory management underlying filesystem caching)
- Fear of large SGA sizes
  - 64-bit Oracle is all about using large memory efficiently
- Incorrect evaluation of filesystem options
  - When the OS page cache is removed, the Oracle SGA typically needs to be increased to exploit memory
  - When AIO is used (the default) the motivation for multiple DB writers is radically reduced

Buffered Filesystems Limit Scaling

- Application scaling can be limited by multiple "invisible" factors that are not in sizing models
  - segmap scalability
  - AXQ bandwidth
  - kernel cage bandwidth
  - cache-to-cache copies
  - cost of database block checksum re-validation
- Not all "unbuffered" solutions perform the same; VxFS "direct I/O" enforces a single-writer lock where UFS "direct I/O" does not
- The "extra copy" of I/O buffering can begin to hurt at high I/O rates, but the first things to bite are locking and serialization effects

Filesystem Scalability Factors

- Memory management (segmap) scalability
  - underlying mechanism involves global locking
  - huge cross-call generator
  - tunable, but tuning rarely satisfies (segmap_percent)
  - much improved in Solaris 10
- POSIX single-writer lock throttle
  - impacts reads as well as writes (!)
- Filesystem logging mechanisms
  - impact varies with workload
  - impact varies with I/O modes
  - good news: most Oracle files are static-sized
  - good news: tweaks like “noatime” mount option are sometimes worthwhile

AIO Clarifications

- Solaris supports Asynchronous I/O to all file targets
  - API contained in libaio.so
  - For RAW, QFS samaio & VxFS Quick I/O, uses kaio(2)
    - This is a Sun private, non-public API
  - For ordinary files, uses LWP-based threads
    - LWP payload is a pwrite() or pread()
- Implementation inside libaio.so has evolved ...
  - Used to see kaio() -> ENOTSUP as normal for filesystem targets
  - Now used pre-spawned LWPs and remembers target attributes

Filesystem & Feature Selection

	Cost	Logging	Write		Kernel IO	Administrative	Performance
RAW	FREE[1]	N/A	YES	NO	YES	HIGH	BASELINE
			NO	YES			
UFS direct I/O	FREE	YES [2]	YES	NO	NO	LOW	NEARLY EQUAL
			NO	YES			
QFS Q-Writes	-	N/A	YES	YES	NO	LOW	
QFS samaio	-	N/A	YES	NO	YES	LOW	NEARLY EQUAL
			NO	YES			
			NO				
VxFS Quick I/O (QIO)	$++	YES	YES	NO	YES	HIGH	NEARLY EQUAL
VxFS Cached Quick I/O (CQIO)	$++	YES	YES	YES	YES	HIGH	
VxFS Oracle Disk Manager (ODM)	$++	YES	YES	?	YES	VERY LOW	NEARLY EQUAL

Network Scaling Issues

- **“IP syncq” - system “hangs”, high %sys**
  - Better fixes in Solaris 9, still better in S10
  - Incremental improvements in Solaris 8
- Gigabit Ethernet slow relative to non-StarCat
  - PCI latency limiting
  - hsPCI+ may benefit
  - Application-specific tuning may help
- Possible CPU saturation from interrupt handling
  - Can cascade into degraded RT performance
- Possible degradation from interrupt competition
  - NICs can compete with each other or HBAs
- “localhost” performance being improved
  - Critical to messaging apps and much more

Network Scaling Remedies

- Tune application
  - Fewer, larger packets better
  - Fewer packets always a win
- Prefer Solaris 9 or 10
  - S9 IP sync patches - better than Solaris 8
  - S9 -> MT STREAMS scheduler; S10 -> “Fire Engine”
- NIC selection; Prefer Cassini (ce), generally
  - Many tunables! (Too many - see Sun Online Blueprints)
  - “Jumbo Frames” - useful in some settings

Network Scaling Remedies

- Other possibilities
  - Consider possible benefit of hsPCI+
  - Tweak sq_max_size: default of 2 is too small, “20” is a “good number”; tuning is controversial!
  - Use Ethernet flow control
  - Using more “less-loaded” NICS
  - Card placement in I/O boats; bus sharing
  - Interrupt Fencing; processor sets
  - Using trunking & IPMP across NICs

Network Scaling Remedies

- In summary ...
  - Expert guidance may be needed
  - Gigabit Ethernet should always be purposefully tuned on high-end systems
  - A simple means is needed for specifying an appropriate NIC population early in a project
  - Expect the products to become self-tuning over time

Recent Solaris Enhancements

Recent Solaris Enhancements

- Some context ...
  - Recent patches have aggressively addressed issues with high-end application scaling
  - This is not just a routine “install the latest patches” pitch!
  - Some enhancements are still trickling into Solaris 8, but it will forever have some inherent limitations

Recent Enhancements

- “Idle loop” issues
  - Solaris idle loop degrades throughput on largely-idle systems - and not-so-idle systems, too
  - Explains most of “my system runs better when it's busier” and “adding CPUs hurt my performance”
  - Increased %sys
  - Increased migrations
  - Poor CPU cache utilization
  - Impacts network throughput indirectly
  - Fix is generally beneficial; but critical for larger domains
- “Idle loop” answers
  - Addressed in Solaris 8, 9 (KU-17), and of course S10

Recent Enhancements

- Semaphore scaling issue
  - poor scaling with high contention on high CPU counts
  - key to scaling major applications like Oracle
- Semaphore scaling answer
  - “exponential back-off” algorithm reduces contention
  - Delivered in recent patches of S8, S9, and of course S10
  - (More refinements in-process: use of “undo” has scaling limitations … but Oracle does not use this)

Recent Enhancements

- fsflush issues
  - Multiple issues cascaded from fsflushd hogging a CPU (at SYS priority)
  - On large-memory systems, “Best Practice” has been “set autoup=<4*N_GB_RAM>”
- fsflush answers
  - Addressed in S8, S9 (KU-17, or just prior), and of course S10: CPU usage by fsflushd greatly reduced
  - “set tune_t_fsflushr=1” - new default setting; probably a Universally Good Idea (so don't override)
  - Need for autoup tuning reduced or maybe eliminated - but not yet fully characterized

Recent Enhancements

- fsync(3) and fdsync(2) issue
  - Tragically poor performance in S8
- fsync(3) and fdsync(2) answer
  - S9, U5 minimum.

- MPO issue
  - No memory placement and related scheduling improvements without it
- MPO answer
  - S9 is the required minimum. (recent patch advised)

Recent Enhancements

- Thread starvation issue (not so recent, actually)
  - Low-priority sleeping threads never got higher priority
  - A major cause of Oracle crashes from AIO timeouts on filesystem-based asynchronous I/O (AIO)
- Thread starvation answer
  - “set TS:ts_sleep_promote=1” in /etc/system as Best Practice on Solaris 8 only (it's default in Solaris 9)
  - This tunable completely removed in Solaris 10

Memory Management Issues

- Using Dynamic Intimate Shared Memory (DISM)with an inadequate OS patch level
  - Triggered by setting sga_max_size to anything
  - DISM uses small pages only on Solaris 8; not generally recommended where performance is critical
  - Solaris 9 adds large-page DISM; improves performance
  - Be certain that oradism is correctly configured
- System page fragmentation leading to slow instance start and stop operations
  - Fixes (and related tuning) in recent Solaris patches
- Overuse of filesystem cache, such as with VxFS “Cached Quick I/O (CQIO)”
  - If it hurts when you do that - don't do that

Wrapup

Rx for Scalability

- Modern system hardware components
- Modern OS release - Solaris 9 or later
  - Recent Solaris patch levels
    - especially for high CPU-count systems!
    - especially where recent enhancements are high-payoff!
- Oracle's “big knobs” settings
  - SGA size
  - I/O concurrency controls
- Purposeful filesystem and feature usage
  - avoid segmap and single-writer locks as needed
- Purposeful network configuration and tuning
- And ... don't forget ... fix that application code!

References

- "Avoiding Common Performance Issues Scaling Oracle on Sun Servers"
  - http://www.sun.com/blueprints/0303/817-1781.pdf by Glenn Fawcett
  - http://www.sun.com/blueprints/0303/817-2196.pdf (Appendix to paper)
- “Sun/Oracle Best Practices"
  - (Aging) http://www.sun.com/blueprints/0101/SunOracle.pdf by Bob Sneed
- “Performance Forensics”
  - http://www.sun.com/blueprints/1203/817-4444.pdf by Bob Sneed
- "Oracle I/O: Supply and Demand"
  - Sun User's Performance Group (SUPerG) whitepaper by Bob Sneed
- "To 100% - and Beyond!"
  - Sun User's Performance Group (SUPerG) whitepaper by Bob Sneed

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Q&A

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