Linux on zSeries Performance Update

Linux Performance Team

Boeblingen, Germany

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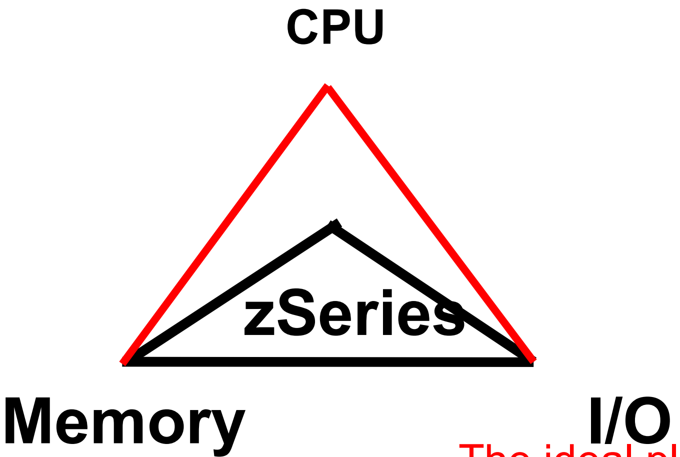
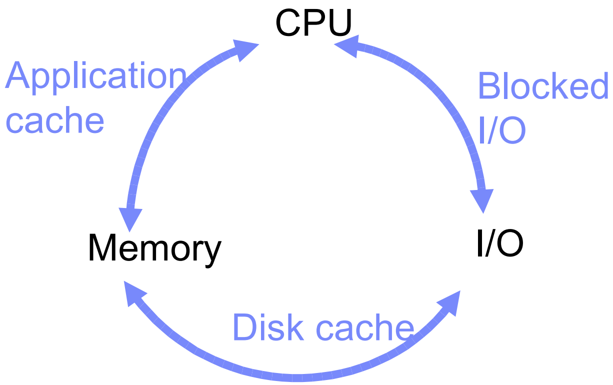
Agenda

- **System Capacity and zSeries hardware**
- **Kernel 2.6 based distros**
  - scalability
  - networking
  - compiler
  - Java
  - NPTL
  - I/O schedulers
  - sequential I/O scalability
  - direct I/O / async I/O
  - fixed I/O buffers

Relative System Capacity

- **A system provides different types of resources**
- **Capacity for each resource type may be different**
- **The ideal machine provides enough capacity of each type**
- **Don't forget additional Resources (Network, Skilled staff, Money, availability of software, reliability, time ...)**

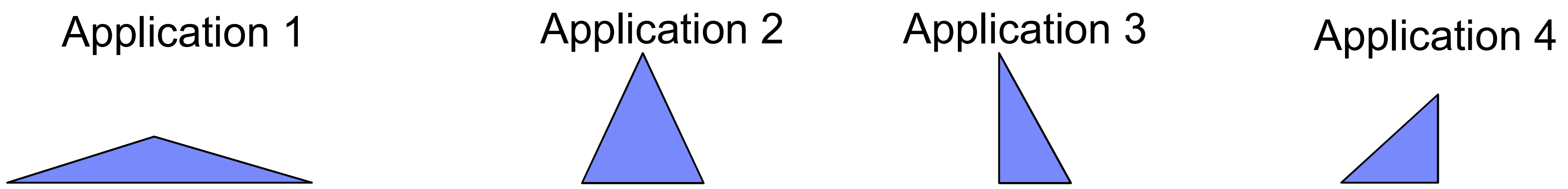




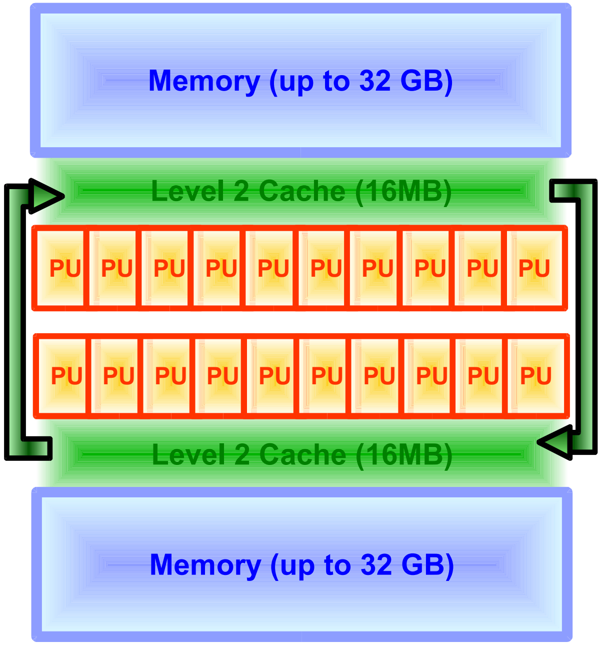
The ideal platform requires a mix of resources in right quantity

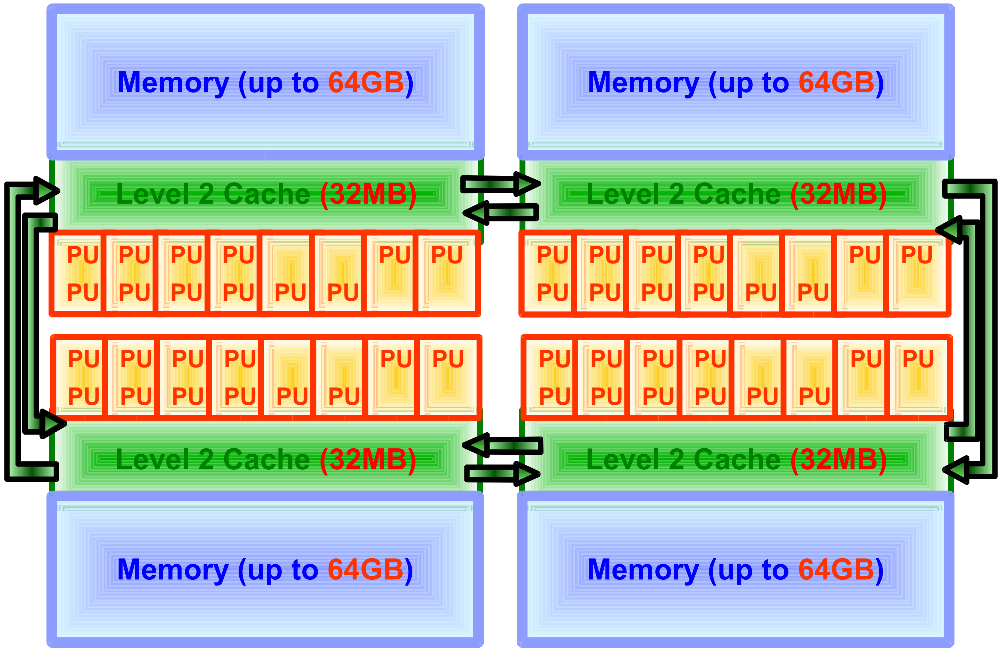
Resource Profiles

- Each application has its specific requirements
  - CPU intensive
  - I/O intensive
  - Memory intensive
- Applications can often be tuned to change the resource profile
  - Exchange one resource for the other
  - Requires knowledge about available resources
- Some platforms can be extended better than others
  - Not every platform runs every application well
  - It's not easy to determine the resource profile of an application

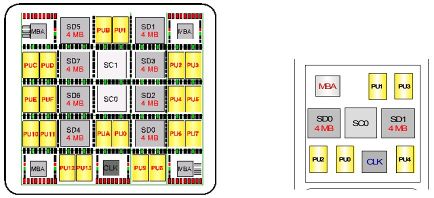


zSeries extended multi book structure



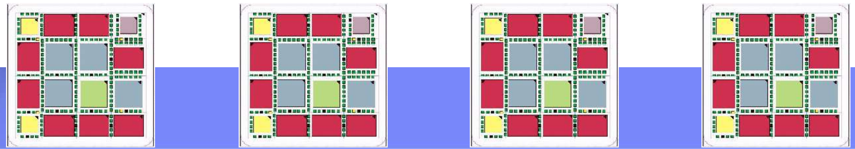


From z900/z800 ...

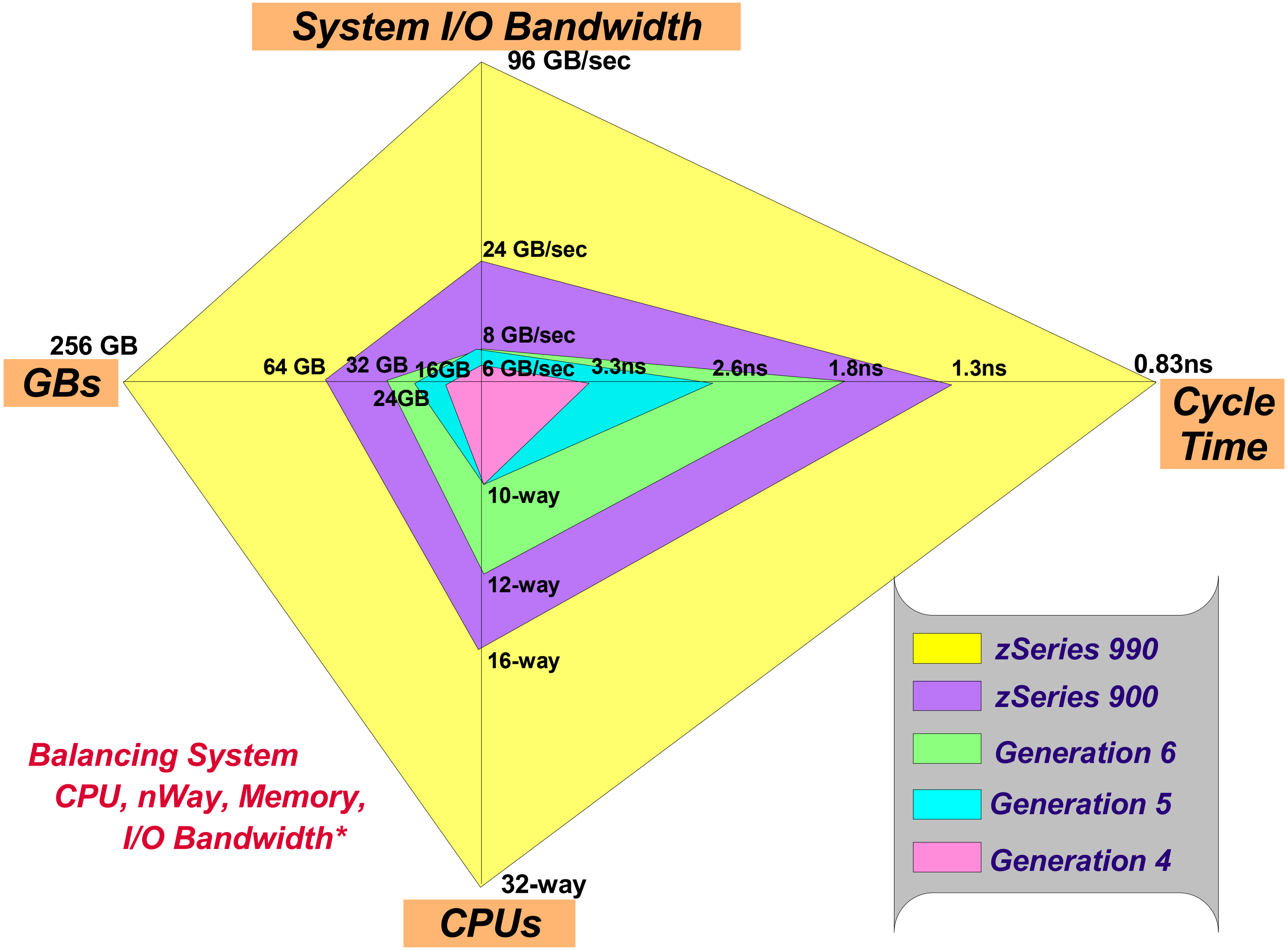


... to modular z990 systems with up to 3-fold capacity

- **0.83 nsec CPU-Cycle (1.2 GHz)**
- **Superscalar design**
- **50 - 60% more UP-Performance z900**



IBM S390 and zSeries Servers - Balanced Scaling



Balancing System
CPU, nWay, Memory,
*I/O Bandwidth**

* External I/O or STI bandwidth only (Internal Coupling Channels and HiperSockets not included) zSeries MCM internal bandwidth is 500 GB/s. Memory bandwidth not included (not a system constraint)

Our Hardware for Measurements

2064-216 (z900)

1.09ns (917MHz)
2 * 16 MB L2 Cache (shared)
64 GB
FICON Express
HiperSockets
OSA Express GbE

2105-F20 (Shark)

16 GB Cache
384 MB NVS
128 * 36 GB disks
10.000 RPM
FCP (1 Gbps)
FICON (1 Gbps)

2105-800 (Shark)

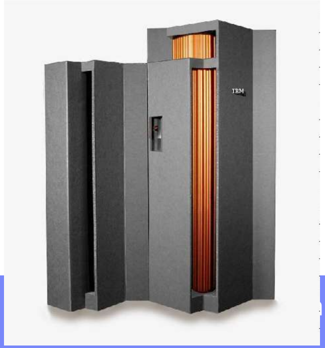
32 GB Cache
1 GB NVS
128 * 72 GB disks
15.000 RPM
FCP (2 Gbps)
FICON (2 Gbps)

2084-B16 (z990)

0.83ns (1.2 GHz)
2 Books each with 8 CPUs
2 * 32 MB L2 Cache
96 GB
FICON Express
HiperSockets
OSA Express GbE

8687-3RX (8-way x440)

8-way Intel Pentium III Xeon
1.6 GHz
8*512K L2 Cache (private)
hyper threading
summit chip set



Kernel 2.6 – Support for Large Configurations

- **255 CPUs**
- **64 GB Memory**
- **16 TB File Size**
- **4095 major / 1 million minor numbers**
- **4 billion UIDs / GIDs**
- **16 TB Large block device size**
- **1 billion PID size**

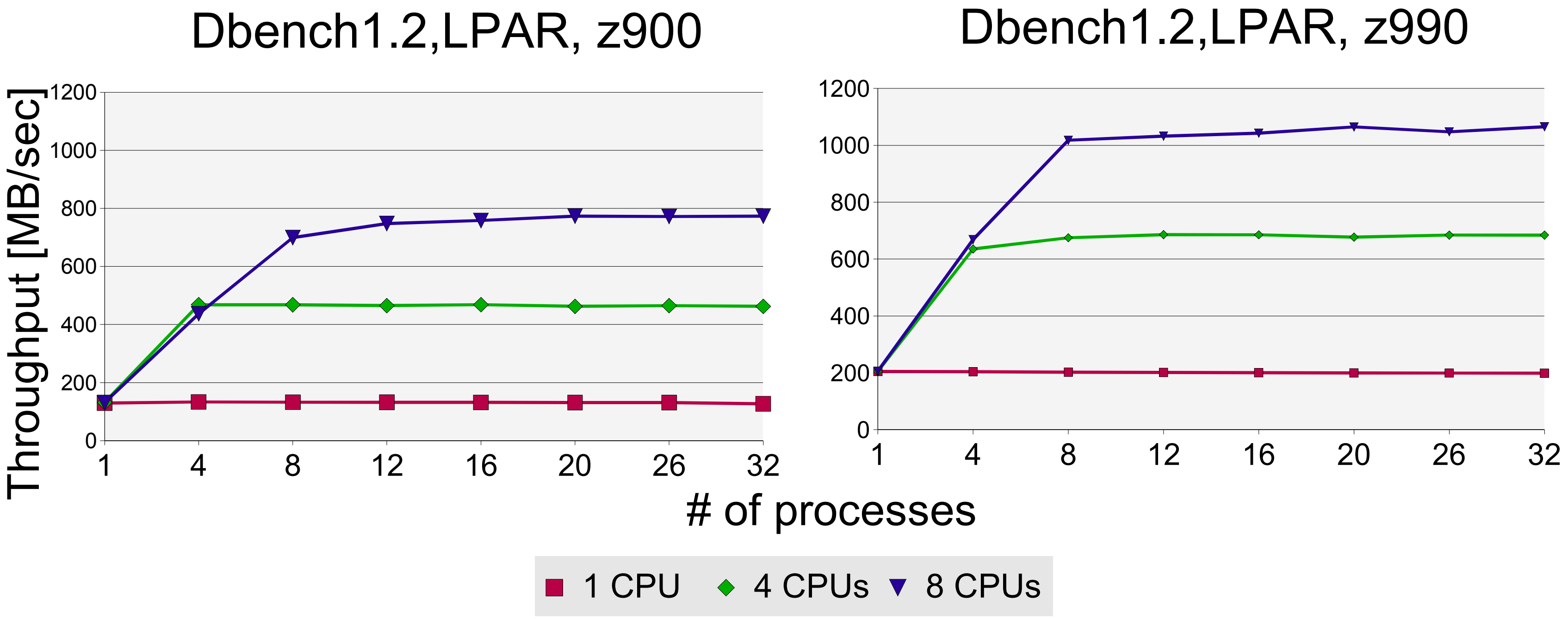
Linux on zSeries – Kernel 2.6 Technology

- **O(1) Scheduler**
  - Allows faster and more processess
  - Response time improvements: linear complexity in 2.6 vs square complexity with 2.4
- **Block I/O**
  - Allows customizable I/O priorities
  - Asynchronous I/O layer improvements
  - Big improvement for Web servers and DB
- **Memory Management enhancements**
  - Provides more capacity for swapping systems
- **SMP scalability enhancements and Per-CPU optimizations**
  - Performance improvement by lock contention reduction
  - Improved memory consumption
- **New POSIX compliant threading model**
  - Kernel assisted threading
  - Speedup for e.g. Java multi-threaded appls
- **IPv6 and IPsec additional features**
  - Allows for cryptographic security at network protocol level
  - Enables stage I for z990 crypto exploitation
- **New file system and volume manager features**
  - XA (extended attributes)
  - Mgmt and security improvements for Samba servers
  - ext3 with ACL support
- **Constraint relief**
  - Support for disks larger than 2 TB
  - Support for > 32 CPUs

Scalability Benchmark

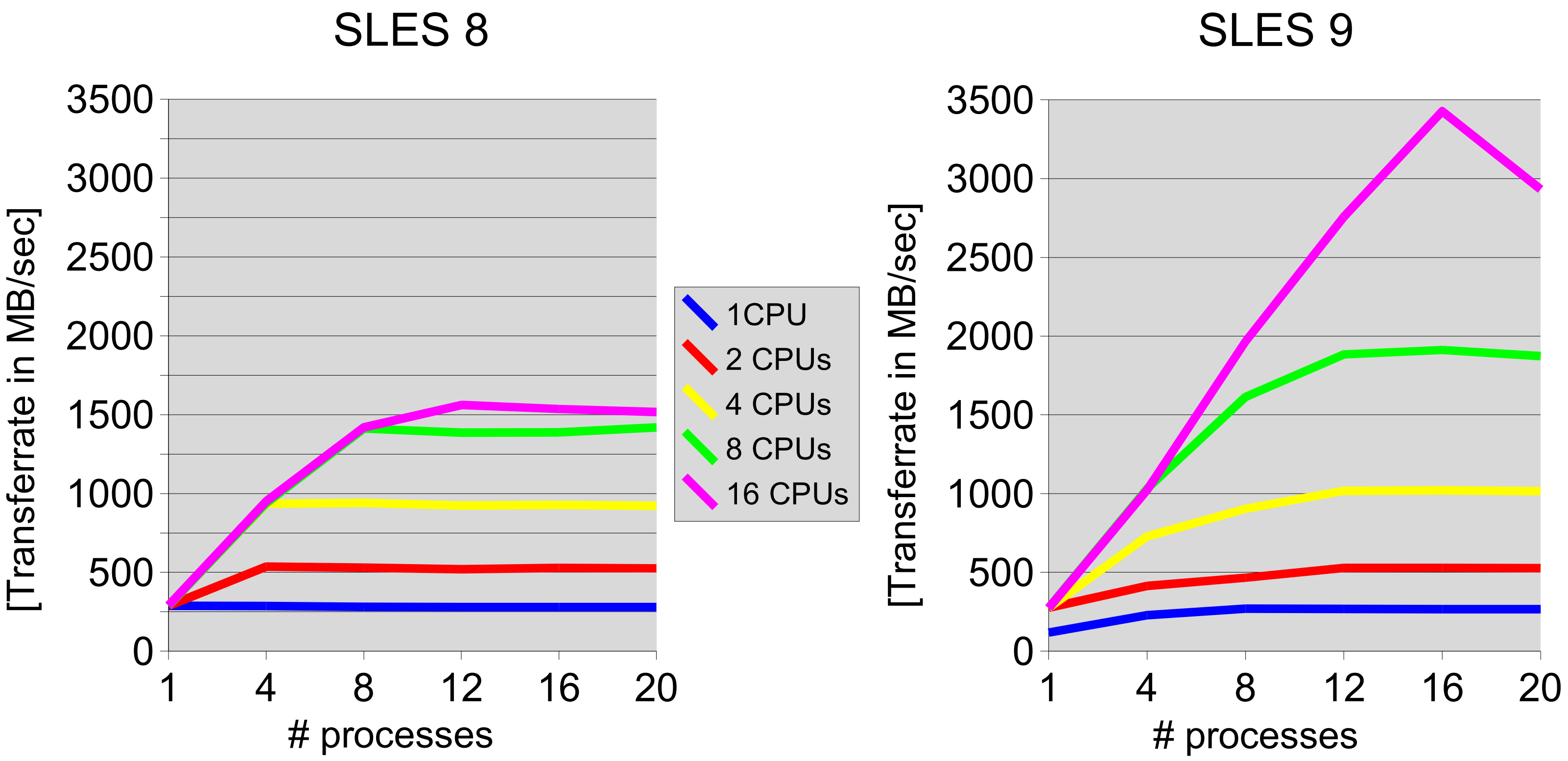
- **Dbench**
  - Emulation of Netbench benchmark, rates windows file servers
  - Mixed file operations workload for each process: create,write,read,append, delete
  - Scaling with 1,2,4,8,16 CPUs and 1,4,8,12,16,20,26,32 and 40 processes
  - 2 GB main memory

Scalability - z900 vs z990



- z990 takes advantage of higher memory bandwidth
- Test is with large amount of memory and few disk I/O

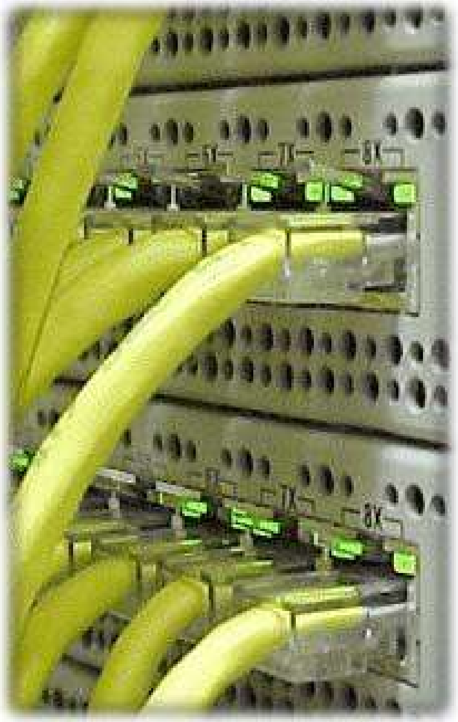
Scalability – kernel 2.4 vs kernel 2.6



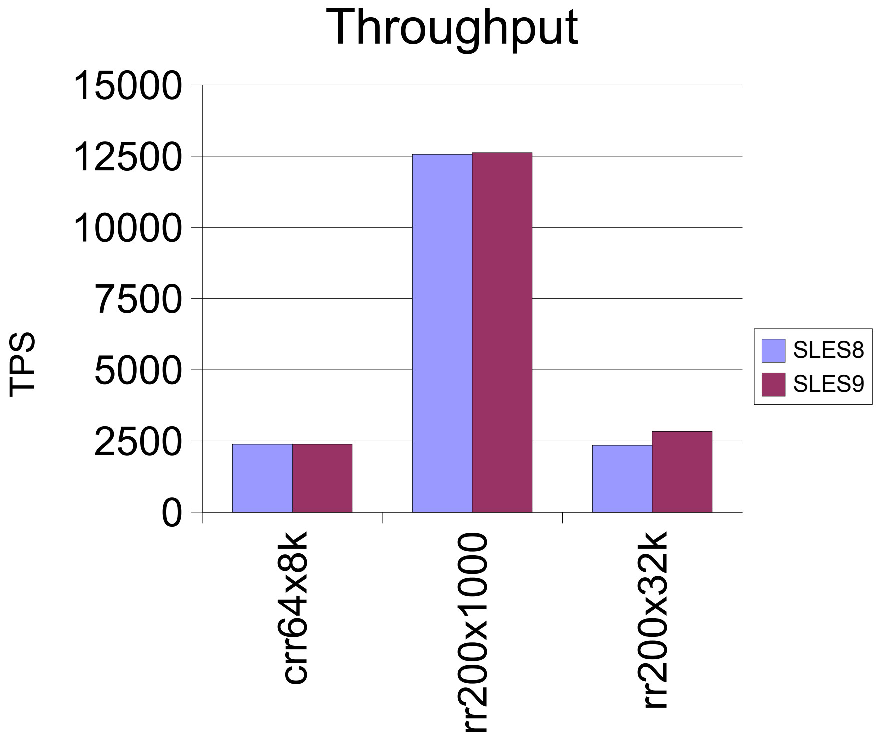
- SLES9 scales better with 8 and 16 CPUs (max 2x)
- Dbench V2.1

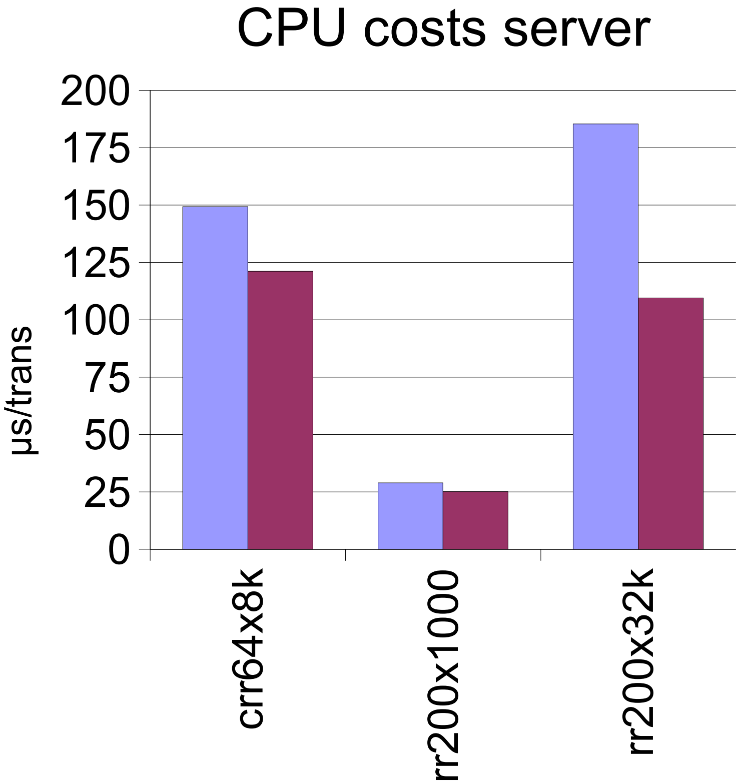
Networking Benchmark

- **AWM**
  - several workload models
    - transactional workload
    - streaming workload
    - mixed workload
  - measured with GbE (QDIO, LCS), Hipersockets, and virtual connections in z/VM
  - throughput and cost (CPU) measurements



Networking Gigabit Ethernet, MTU 1500





- **rr200x32k improved by 20%**
- **reduced CPU costs**

crr64x8k – website request

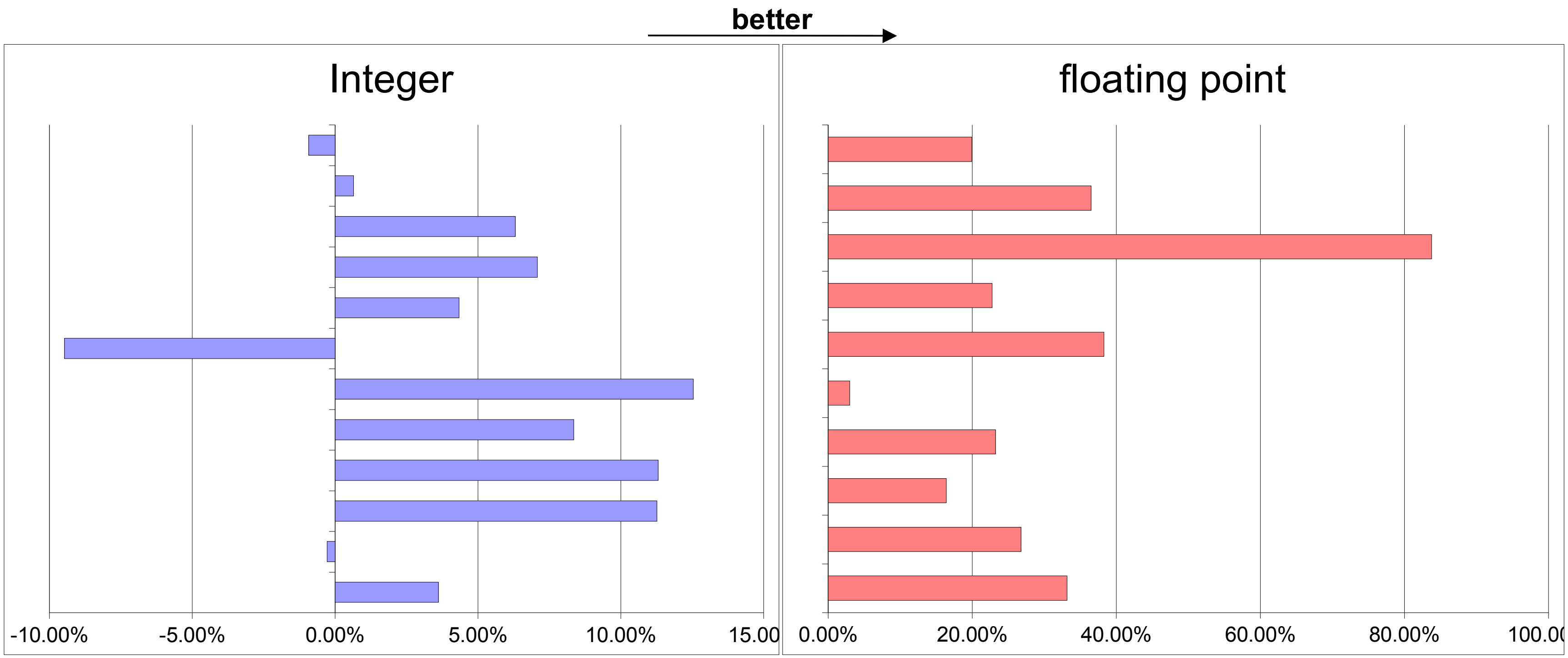
rr200x1000 – online transaction

rr200x32k – database query

The GNU gcc Compiler

- **Compiler supports various architectures**
  - s390 (31-bit) and s390x (64-bit) are integrated in GNU development cycles
- **Recommended compile options**
  - '-O3' to enable many performance optimization options
  - SLES8 and RHEL3 based on gcc-3.2.2
  - Parameter 'march=' and 'mtune=' values <G5,z900,z990>
    - with SLES8 SP3 comes optional experimental gcc-3.3
    - SLES9 includes gcc-3.3
    - RHEL4 AS includes gcc-3.4.3 as default

gcc 64bit compiler

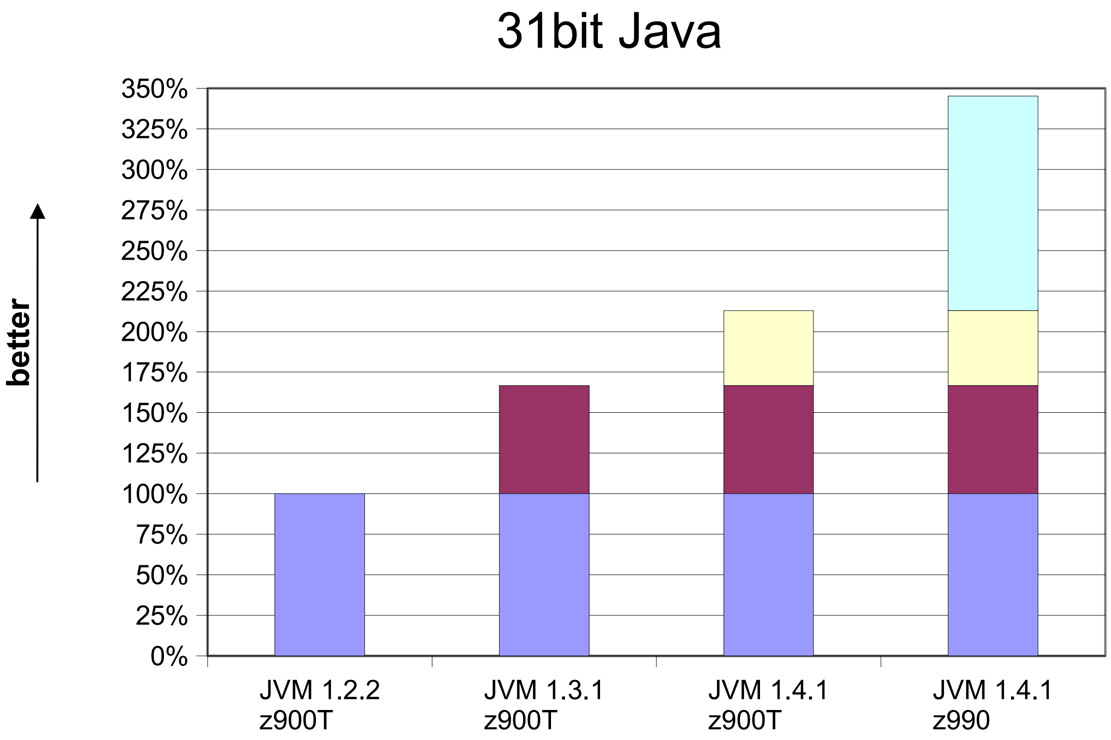


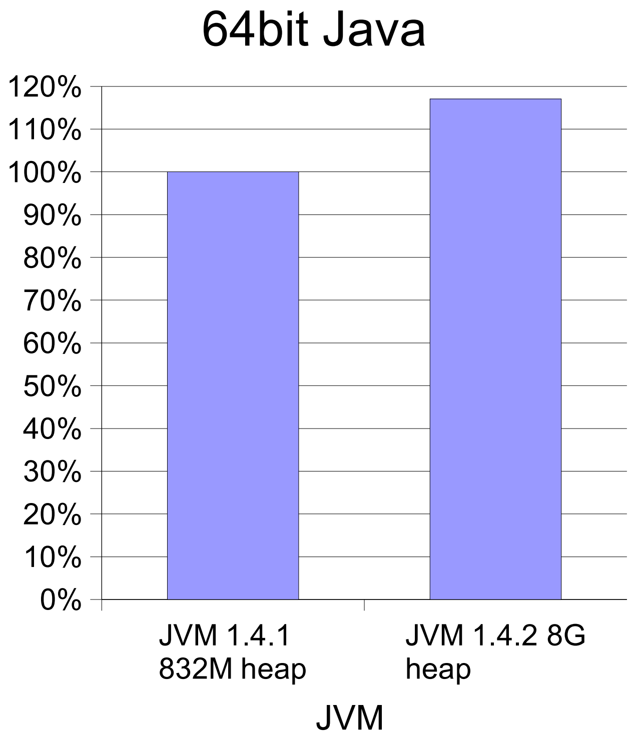
- new compiler SLES9 / RHEL4 is worth a try
- optimize for your architecture e.g. -march=z990

Java

- Java Virtual Machine improved
- zSeries Just in Time Compiler improved
- 2001: JVM 1.2.2, Websphere 3.x
- 2002: JVM 1.3.1, Websphere 4.x, 5.0
- 2003: JVM 1.4.1, Websphere 5.0.x
  - JVM 1.4.1 available in 31-bit | 64-bit
- 2004: JVM 1.4.2, Websphere 5.1, 6.0

Java





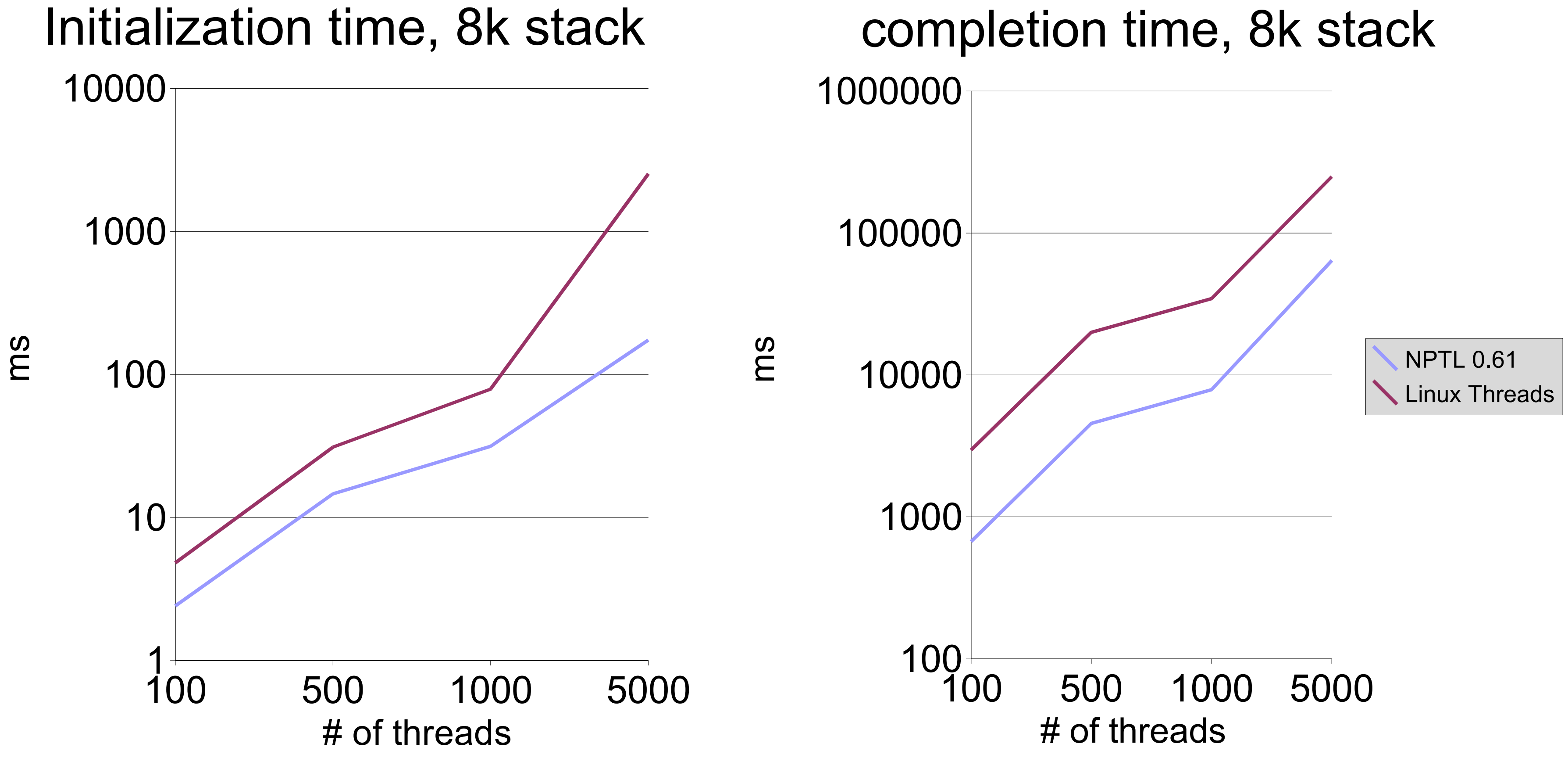
- improvements in HW, Linux, JVM and JIT
- 64 bit Java is now production ready

Linux threading models

- **Linux threads**
  - not fully POSIX compliant
  - per process manager thread to create and coordinate between the threads
  - lack per thread synchronization for inter – thread communication and resource sharing
  - scalability problems
- 2.6 based distributions have both
- switch with `export LD_ASSUME_KERNEL=2.4.21`

- **New Posix Thread Library**
  - fully POSIX compliant
  - no per process manager but new system calls, ..., TLS
  - high performance threading support
  - exploitation requires minor modifications in most threaded applications
  - NPTL is the strategic direction for Linux threading

NPTL results, 8 CPUs



Linux 2.6 I/O Schedulers

- Four different I/O scheduler are now available
  - noop scheduler
    - only request merging
  - deadline scheduler
    - avoids request starvation
  - anticipatory scheduler (as scheduler)
    - designed for the usage with physical disks, not intended for storage subsystems
  - complete fair queuing scheduler (cfq scheduler)
    - all users of a particular drive would be able to execute about the same number of I/O requests over a given time.

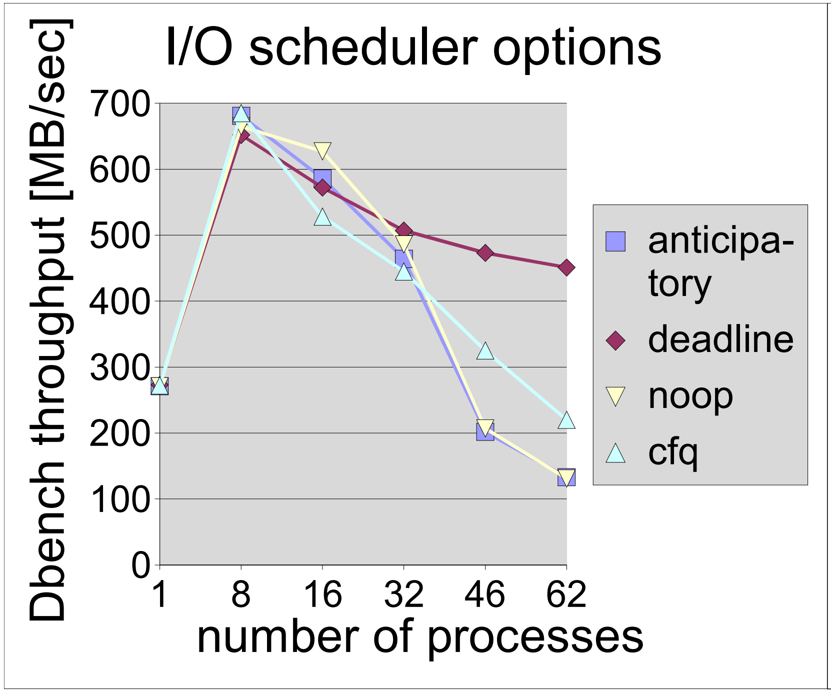
Linux 2.6 I/O Scheduler

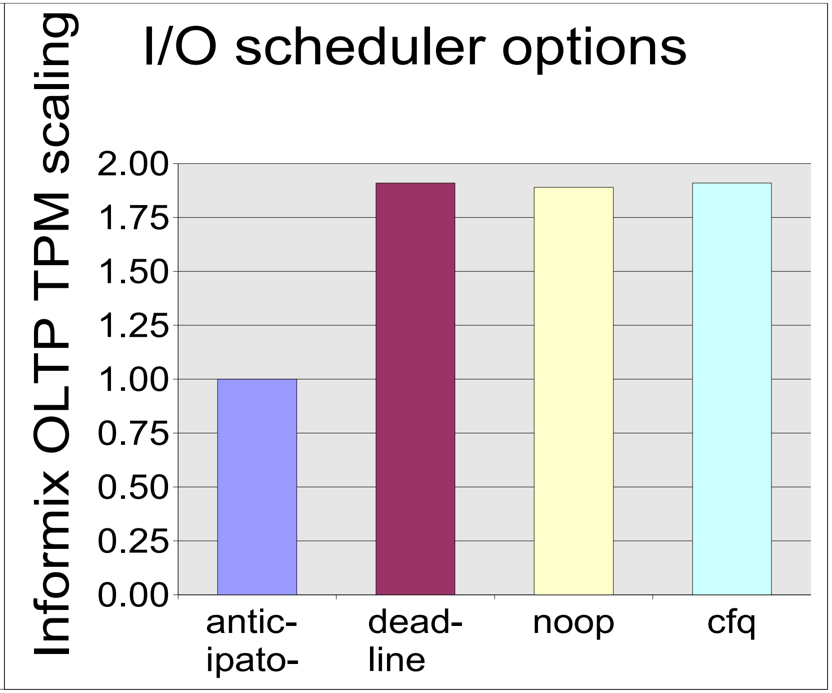
- **Defaults**
  - Kernel 2.6 anticipatory scheduler
  - SUSE SLES 9 (s390, s390x), RHEL4 (s390, s390x): cfq scheduler
- **How to identify which I/O scheduler is used**
  - `Red Hat RHEL4: cat /var/log/dmesg | grep scheduler`
  - `SuSE SLES9:   cat /var/log/boot.msg | grep scheduler`

    `->  Using cfq io scheduler`
- **How to select the scheduler**
  Set boot parameter elevator in zipl.conf, e.g.

  -
    ```
    [ipl2GB8CPUdeadl]
    target = /boot/zipl
    image = /boot/image
    ramdisk = /boot/initrd
    parameters = "maxcpus=8 dasd=5849 root=/dev/dasda1
    elevator=deadline"
    ```
- **possible values: as | deadline | cfq | noop**

I/O scheduler





- Test characteristics: random disk I/O, many processes
- Significant difference between best and worst case

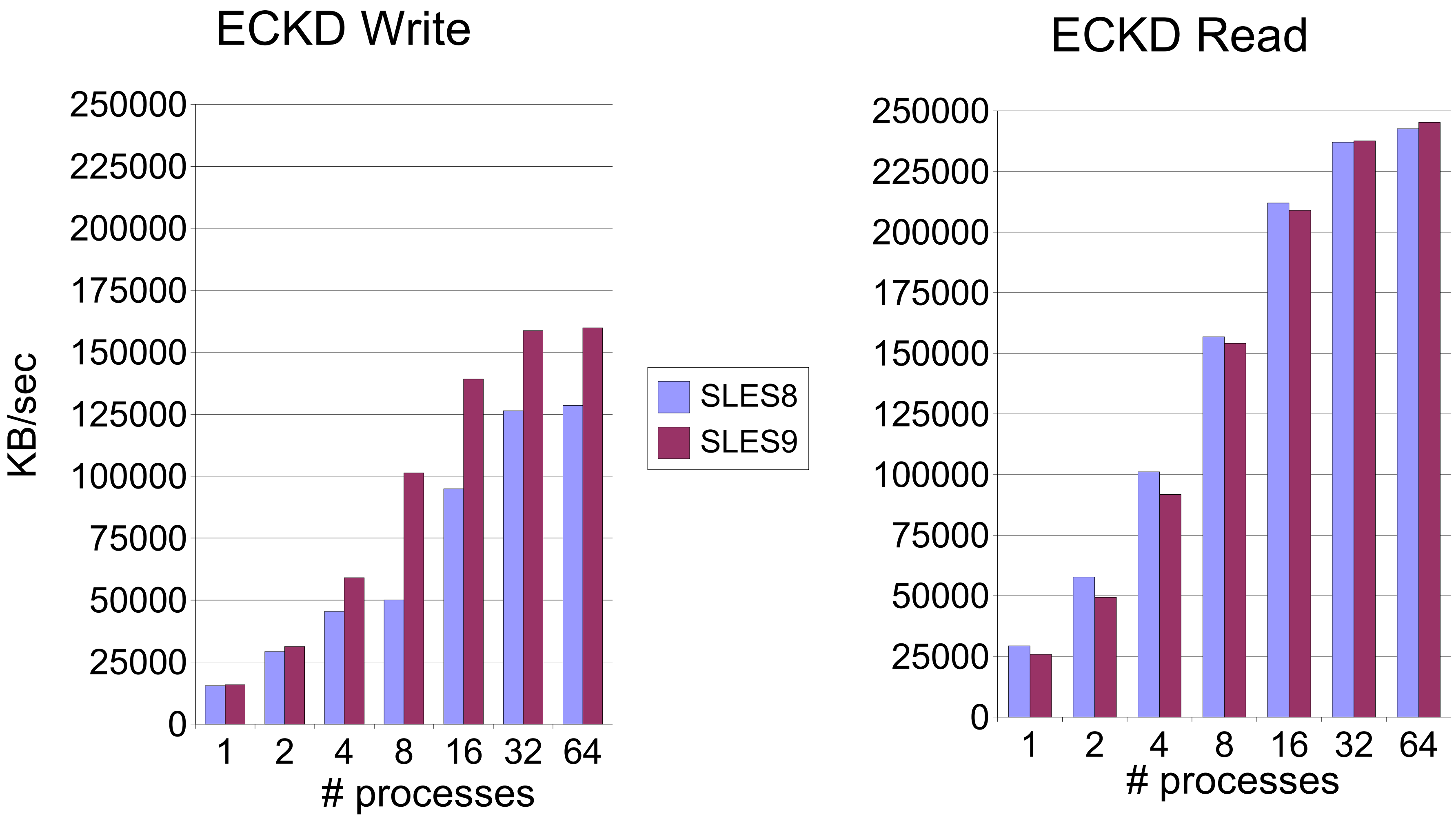
Random I/O - Summary

- Choice of the I/O scheduler is workload dependent
  - Deadline option performs best in our experiments with Dbench and Informix OLTP
  - Anticipatory I/O scheduler is not recommended for zSeries
- Sorting of requests (elevator) is not be an advantage on storage subsystems
- I/O scheduler influence not seen for sequential I/O, but experiments are ongoing

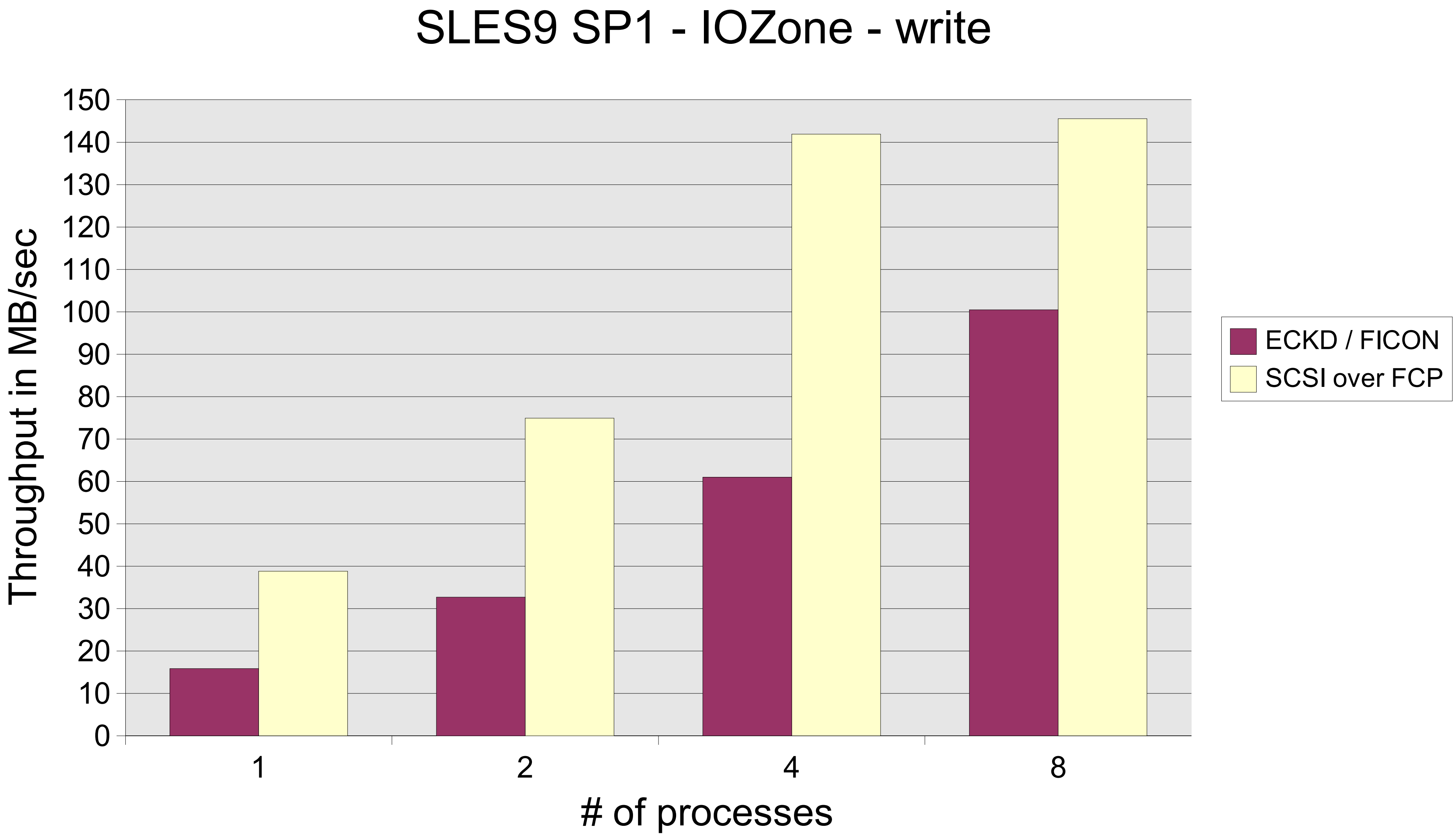
I/O Sequential Benchmark

- **Iozone**
  - Threaded file system benchmark used to measure synchronous I/O
  - write, rewrite, read of a 700MB file
  - 1,2,4,8,16,32,64 threads write on the same number of disks
  - Used on FICON and SCSI disks
  - Main memory was restricted to 256MB

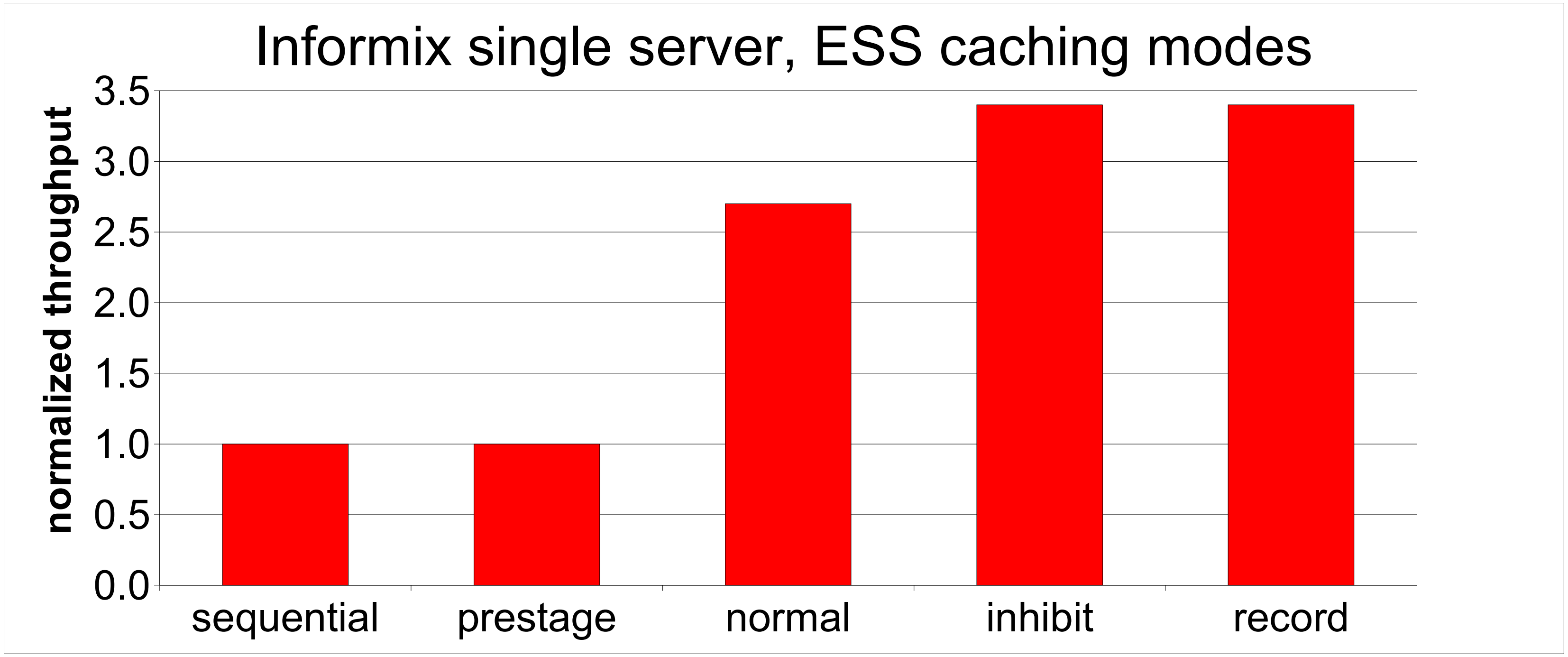
Kernel 2.6 Sequential I/O



Sequential I/O



ESS Caching Modes

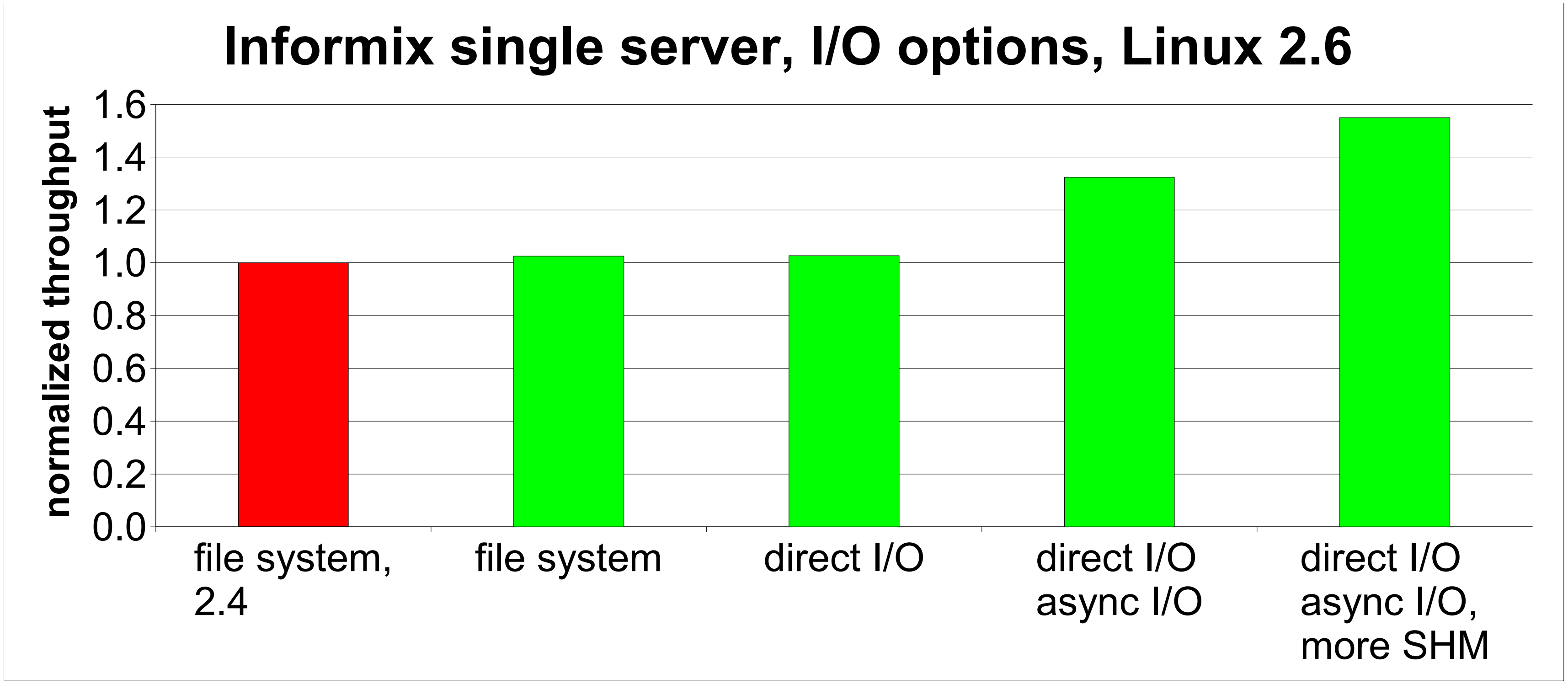


- The caching mode “record” returns the best result.
- ESS caching modes are described in
  - Command Reference 2105 Models SC26-7298-xx
- On 2.6 based distros the caching mode can be changed with the tool "tunedasd"

Linux 2.6 Disk I/O Options

- **new I/O options now available with Informix:**
  - direct I/O on block device
    similar to the raw devices from 2.4,
    now a block device, like /dev/sda1, is used directly
  - async I/O on a block device
    the issuer of a read/write operation is no longer waiting until the request finishes.

Linux 2.6 Disk I/O Options - Results



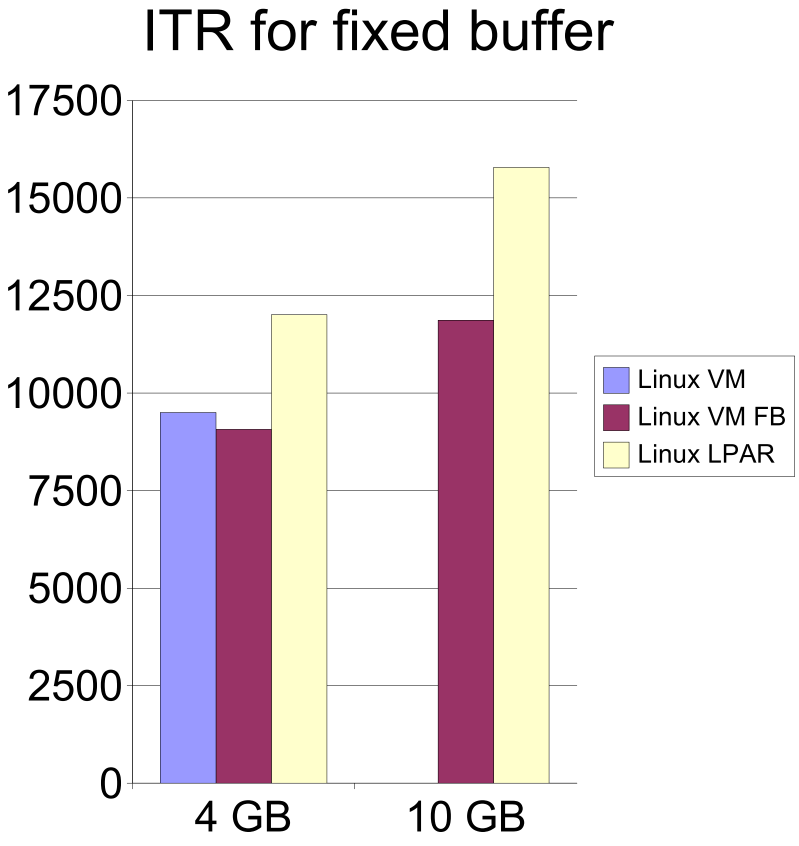
- the combination of direct I/O and async I/O is a very good improvement
- Further enhancements:
  the dedicated I/O processes of the database are not longer needed, the additional free memory can be used to increase the database buffer in shared memory
- see: http://www.ibm.com/developerworks/db2/library/techarticle/dm-0503szabo/

Fixed IO buffers

- **problem with large z/VM guests doing heavy disk IO**
  - – 2 GB for CP can become a bottleneck
  - – see http://www.vm.ibm.com/perf/tips/2gstorag.html
- **mitigation for ECKD disks:**
  - – fixed io buffers in SLES9 SP1 and RHEL4
    - extra copy for all disk I/O
  - – enable using dasd driver kernel parameter “fixedbuffers” e.g.
    - dasd=0.0.7000-0.0.7002,fixedbuffers
- **more details at:**
  - – http://www.ibm.com/developerworks/oss/linux390/perf/tuning_how_fixed_io_buffers.shtml

Informix – Fixed IO buffer results - ITR

- **large guest can now be run under z/VM**
- **price to pay:**
  - for smaller guest 4% additional ITR loss
- **LPAR well suited for high utilized Linux**
- **more results:**
  - http://oss.software.ibm.com/linux390/perf/tuning_res_fixed_io_buffers.shtml



Visit us !

- **Linux on zSeries Tuning Hints and Tips**
  - http://oss.software.ibm.com/linux390/perf/
- **Linux-VM Performance Website:**
  - http://www.vm.ibm.com/perf/tips/linuxper.html

Questions