2009 System z Expo

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Session Title:
Performance Experience with Databases on Linux for IBM System z

Session ID: zLP02

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Agenda

- **Objectives**
- **Avoid unnecessary disk I/O!**
  - Buffer Pool
  - Read Ahead
- **If you can't avoid it - make it fast!**
  - Disk Setup
  - Log Files
  - I/O Schedulers
  - Direct I/O and Asynchronous I/O
  - Hyperpav
  - Storage Pool Striping
- **z9/z10 comparison**
- **A little tuning story**
- **Summary**

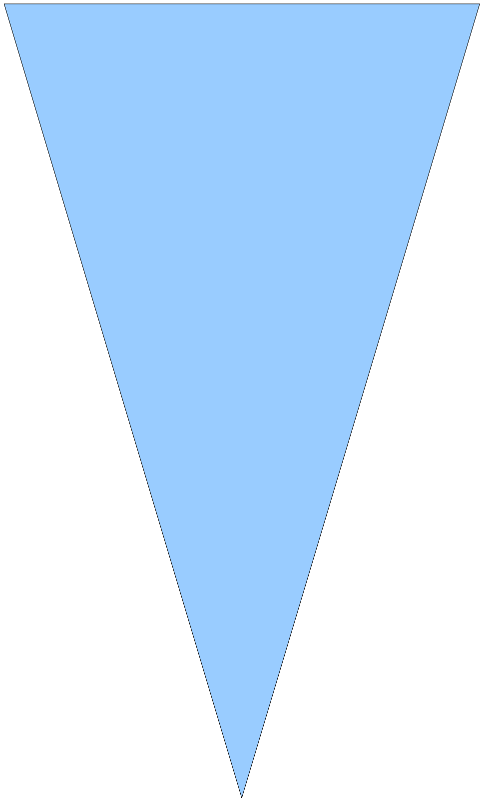
Objectives

- **Demonstrate how database application performance can benefit from the advantages provided by IBM System z**
  - What needs to be done to get the best performance
  - How to improve the disk I/O performance
  - How databases on Linux on System z scale
- **We did no high end benchmarking!**
  - Customer-like environments are used.
- **Most results are not limited to one database product. Tests have been made with**
  - Oracle 9i and 10g
  - DB2 8.1, 8.2 and 9
  - Informix 9.4.0

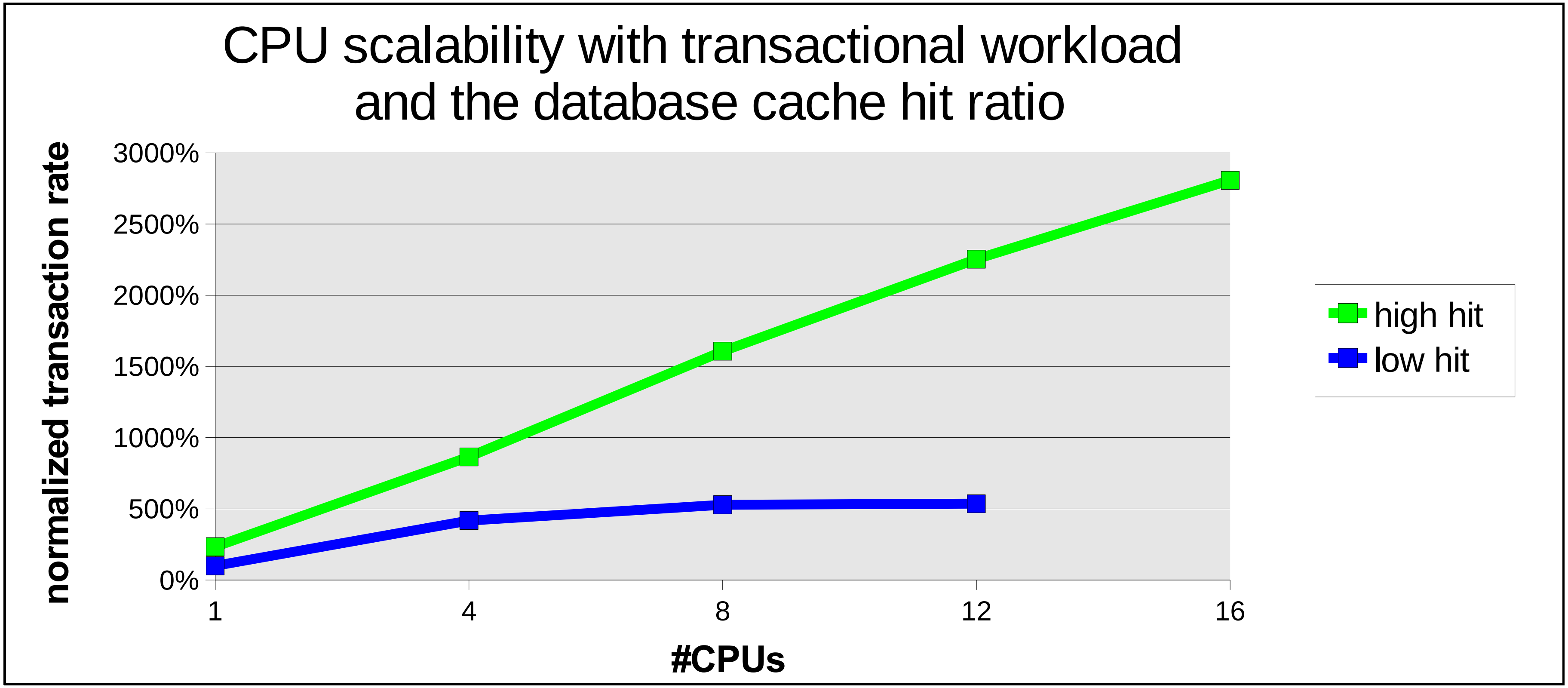
Performance tuning at all layers

- **Optimize your stack from the TOP to the BOTTOM**
  - Application design
  - Application implementation
  - Database
  - Operating system
  - Virtualization system
  - Hardware

Covered in this presentation



CPU Scalability with transactional workloads



- **The best disk I/O is the one which does not need to be done!**
  - High database cache hit ratios are a successful implementation for avoiding disk I/O
  - throughput rate scales from 1 to 16 CPUs very well
- **Low cache hit scenario depends on the possible throughput bandwidth.**
  - make the I/O fast!
- **The real world is mostly somewhere in between.**

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Optimize Caching – adjust the buffer pool size

- **Reducing the amount of I/Os is heavily related to**
  - Application design, don't ask for data not needed
  - Application implementation, for example having the right indexes

- **The key component on database level are correctly sized buffer pools**
  - Which pools are needed depends on the application
  - The larger the better
  - Critical point: avoid that the system starts swapping (monitor with vmstat/sar)

- **Recommendations:**
  - Rule of thumb for database buffer pool size (start value)
    when using
    - page cache for file I/O: 60% of the memory size
    - direct I/O for file I/O: 70% of the memory size
  - you might increase the database buffer pool size, but stop before swapping starts
  - it is recommended to leave at least 5% free memory (free command)

Read ahead setup

- **On Linux block device layer level**
  Set the read ahead value to 0 using the blockdev command!
  – for example: blockdev --setra 0 /dev/sda

- **On Logical Volume Manager (LVM) level (same for ASM)**
  Disable it by setting the read ahead with the commands lvcreate or lvchange
  – LVM2: -r, --readahead none   (instead of auto)

- **On database level**
  The database is the only instance which can do a meaningful read ahead!
  – For OLTP workloads we recommend to disable the read ahead, compare results w/ and w/o read ahead
  – Oracle: set profile parameter DB_FILE_MULTIBLOCK_READ_COUNT to 0
  – DB2: set the tablespace parameter PREFETCHSIZE to 0
  – Informix: set the onconfig parameters RA_PAGES and RA_THRESHOLD to 0

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What is the characteristics of the OLTP workload?

- **Cache "unfriendly"**
  - Small packets size (typically 4 or 8 KB) and randomly distributed over the disk space
  - Relief: larger caches
    avoid cache pollution with unnecessary data

- **Disk I/O intensive**
  - Disk utilization is typically at 80% or higher
  - Physical disk access times are limiting the throughput
  - Relief: use as many physical disks as possible
    make the buffer pools as large as possible

- **High write I/O portion**
  - Exceeds the non-volatile storage cache (NVS) from the storage server frequently
  - Interrupts the data flow to flush the cache
  - Relief: make sure to use as much of the NVS as possible

What can we do to get the best disk I/O performance?

- **Don't treat a storage server as a black box, understand its internal structure!**

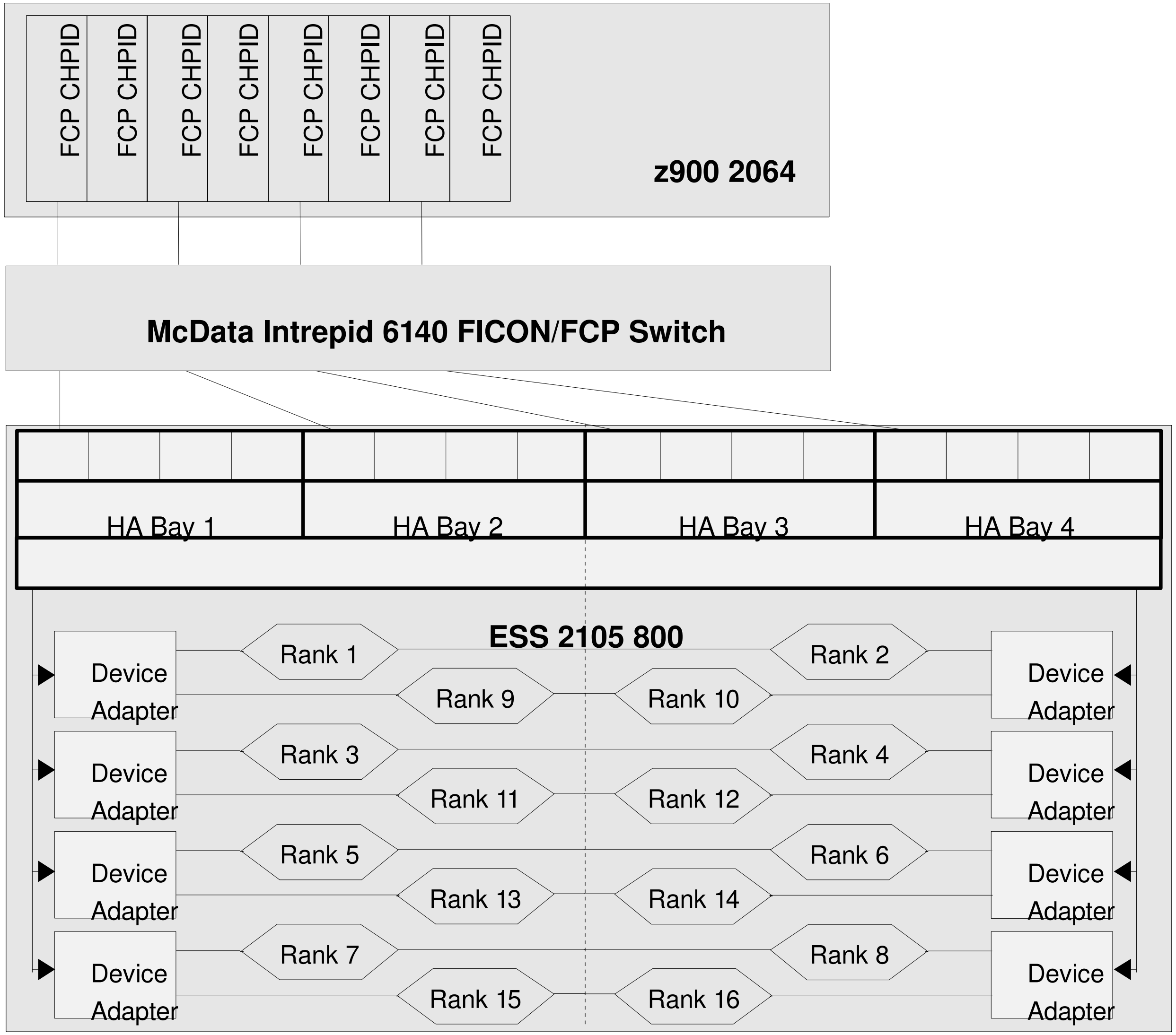
- A typical task:
  - You ask for 16 disks and
  - your system administrator gives you disks with addresses like 5100-510F...

- This will bring you close to the worst case in terms of disk performance...

➢ **What's wrong with that?**

Storage Server Architecture (1)

– Let's have a closer look at the elements of the scenario:



- **CHPIDs**
  - the FICON Express card supports 2 ports, either FCP or FICON
- **Host Adapter (HA) supporting FCP (FCP port)**
  - -16 Host Adapters, organized in 4 bays, 4 ports each
- **the ESS is divided into two Clusters**
  - Caches are organized per cluster!
- **Device Adapter Pairs (DA)**
  - each one supports two loops
- **Disks are organized in ranks**
  - each rank (8 physical disks) implements one RAID array (with logical disks)

Storage Server Architecture (2)

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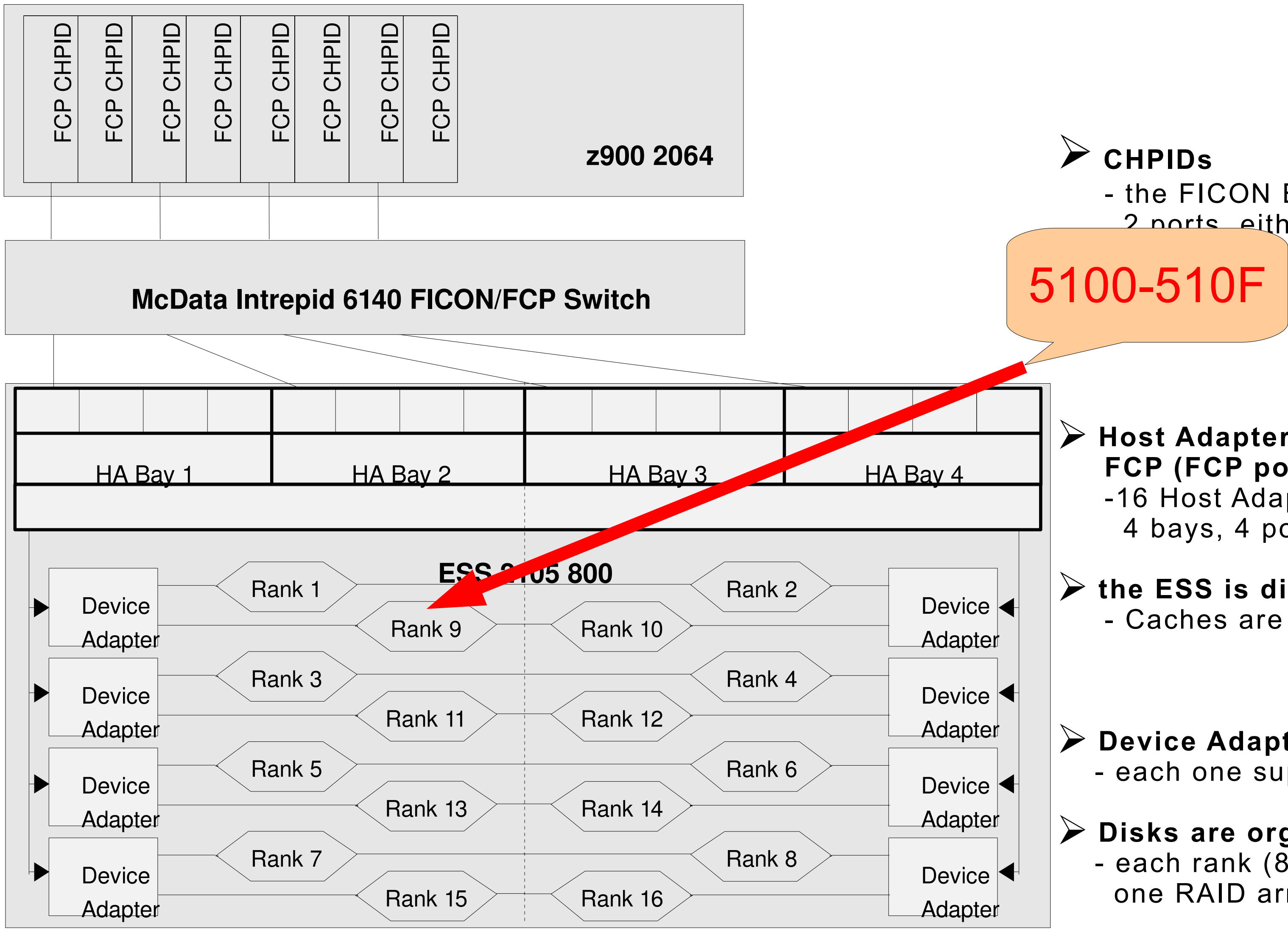

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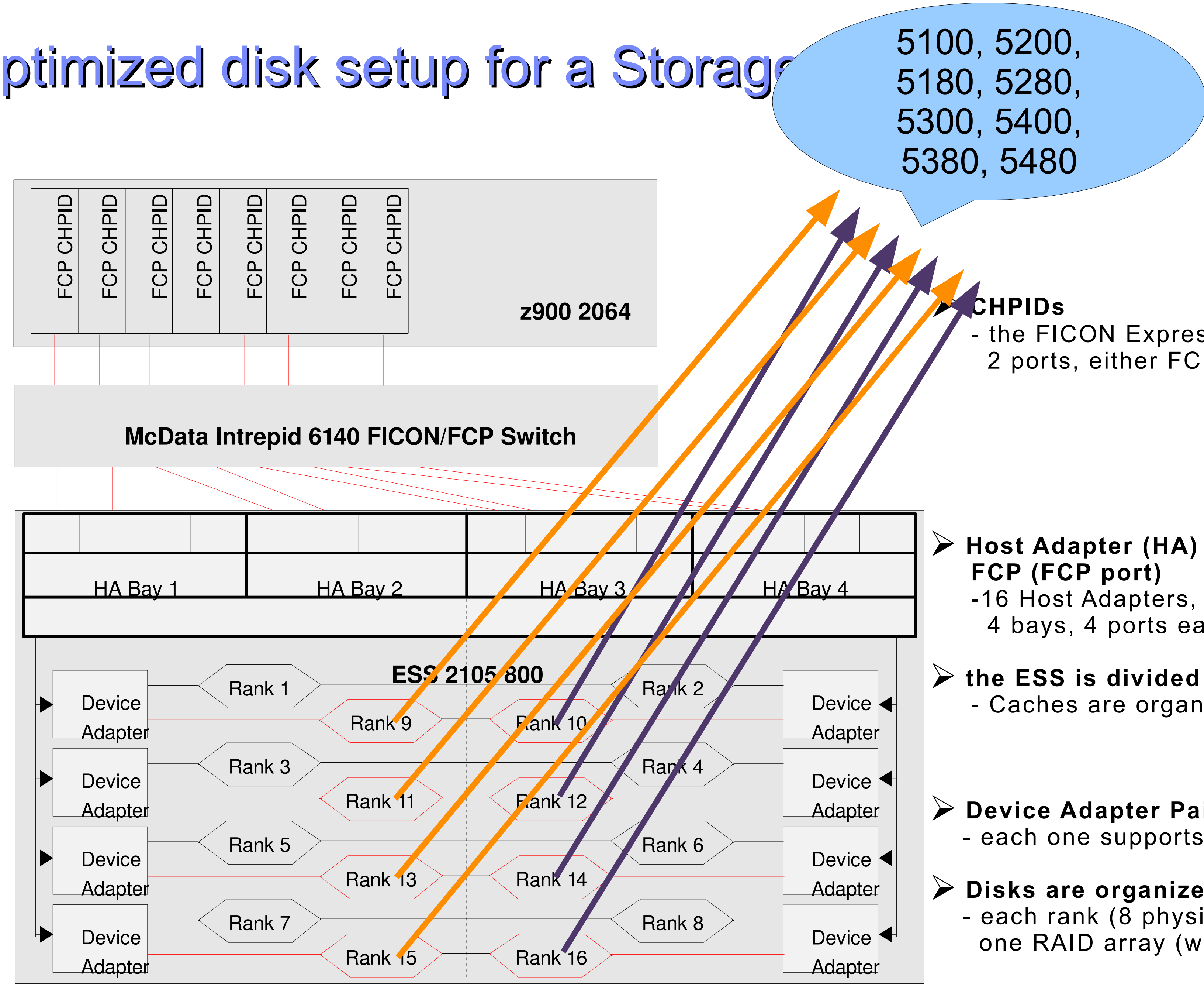
Optimized disk setup for a Storage



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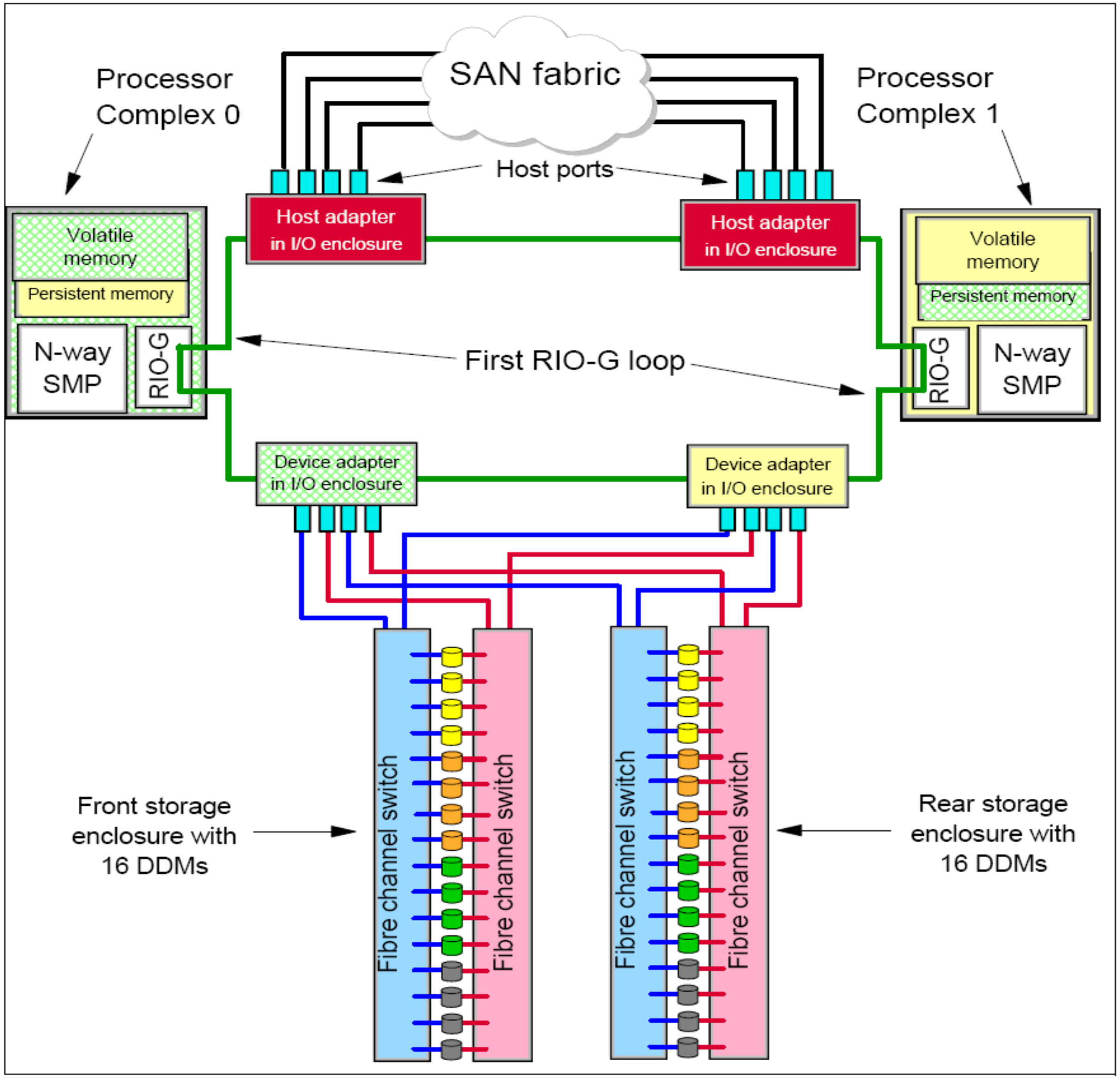
DS8000 Architecure

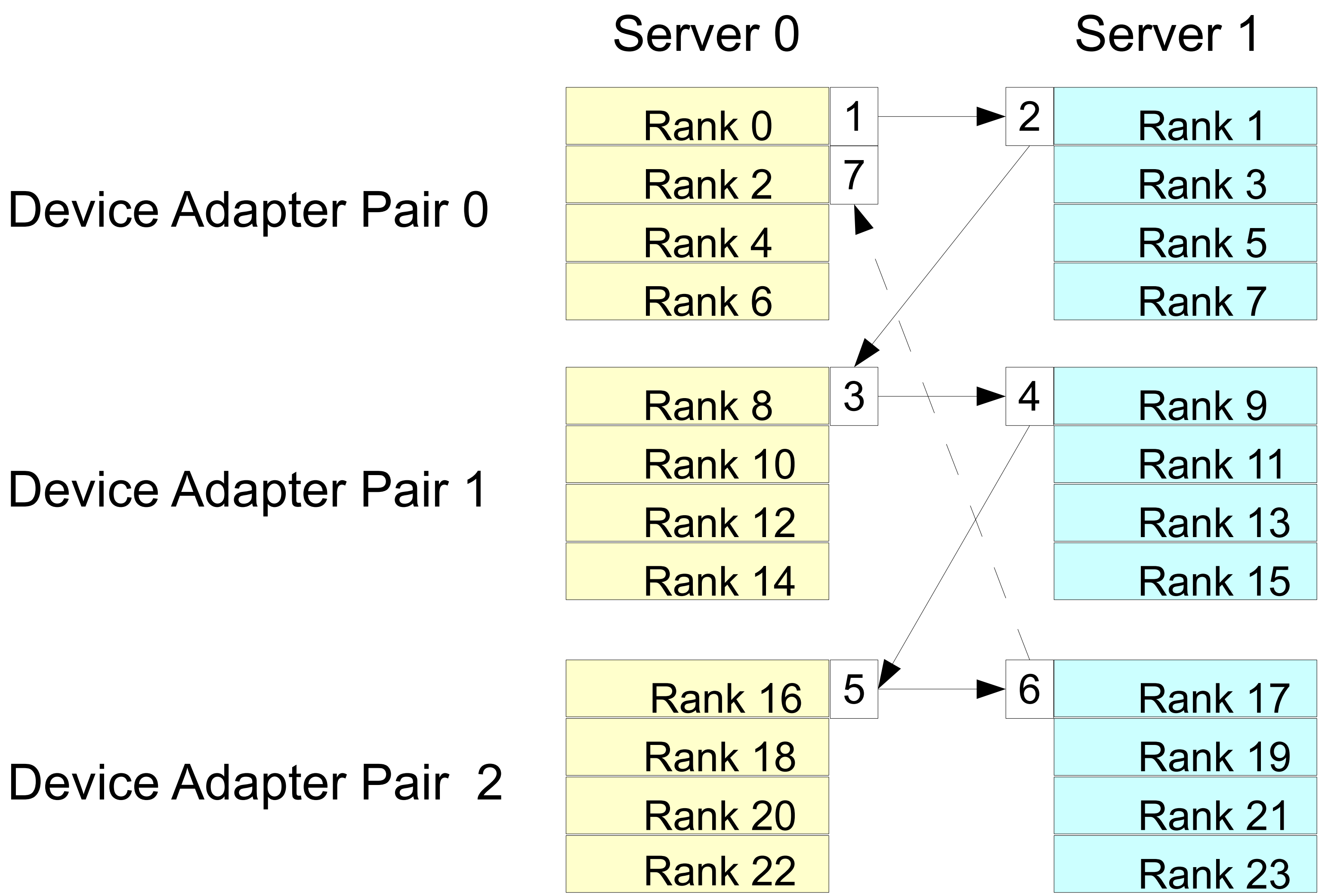


- **structure** is much more complex
  - disks are now connected via two internal FCP switches for higher bandwidth
- the DS8000 is still divided into two parts named **processor complex** or just **server**
  - caches are organized per server
- one **device adapter pair** addresses now 4 array sites
- one **array site** is built from 8 disks
  - disks are distributed over the front and rear storage enclosures
  - have the same color in the chart
- one **RAID array** is defined using one array site
- one **rank** is built using one RAID array
- ranks are assigned to an **extent pool**
- extent pools are assigned to **one of the servers**
  - this assigns also the caches
- **the rules are the same**
  - one disk range resides in one extent pool

Rules for selecting disks

- **Target is to get a balanced load on all paths and physical disks**
  - use as many paths as possible (CHPID -> host adapter)
  - for ECKD switching the paths is done automatically
  - FCP needs a fixed relation between disk and path
    - we establish a fix mapping between path and rank in our environment
    - taking a disk from another rank will then use another path
  - switch the rank for each new disk
  - switch the ranks used between servers and device adapters
  - select disks from as many ranks as possible!
  - avoid reusing the same resource (path, server, device adapter, and disk) as long as possible

Sample for optimal disk selection



- **assign the disks to the system in the order from 0 to 7, etc.**

How to make the disks available for the database

- **use a striped Logical Volume (LV)**
  - add the volumes appropriate to Volume Group (VG)
  - we recommend a stripe size of 32KB for OLTP workloads
  - number of stripes equal to the number of disks in VG

- **let the database do the striping:**
  - e.g. for Oracle: use ASM managed storage
  - for DB2: use multiple containers
    - ```
      CREATE TABLESPACE dms1 MANAGED BY DATABASE
        USING (FILE '/TSTEST_cont0/file' 1000,
               FILE '/TSTEST_cont1/file' 1000,
               …
      ```
    - ```
      CREATE TABLESPACE dms2 MANAGED BY DATABASE
        USING (DEVICE '/dev/sda2' 1170736,
               DEVICE '/dev/sda3' 1170736,
               …
      ```
    - Select the disks in the right order from the ranks
    - The database will stripe over the containers automatically

What to do with database LOG files?

- **I/O pattern:**
  - OLTP database access is random read/write I/O
  - writing to a database log file is pure sequential write I/O (except for rollback)

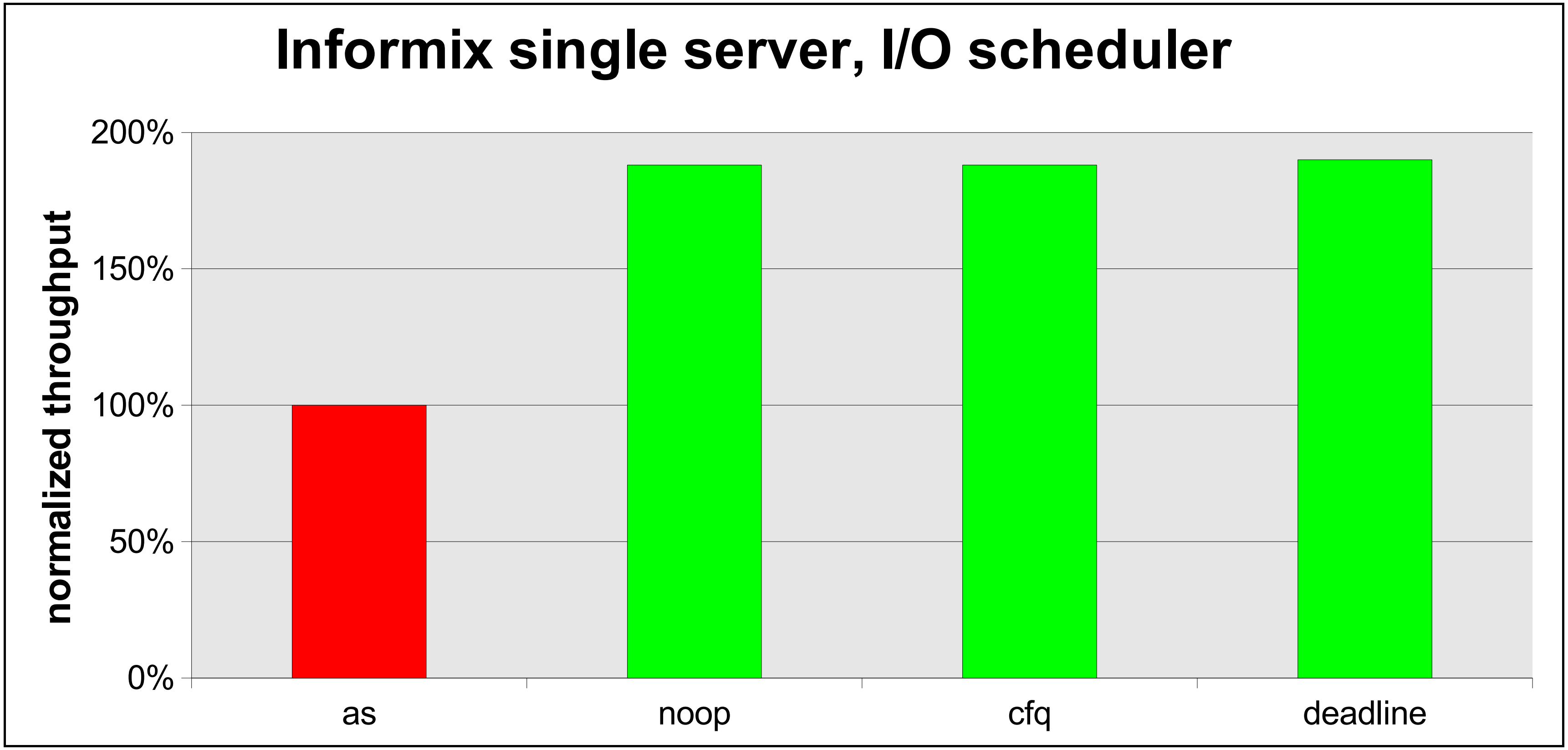
- **Mixing database log files and the database files on the same disks (either SCSI LUN, ECKD device or Logical Volume)**
  - the sequential characteristics of the log I/O gets lost
  - the I/O schedulers prefer read requests!
  - → degradation of the speed for writing log records to the disk
  - → degradation of the priority when writing logs
  - → overall a performance degradation of the application throughput rate

➢ **make separate log and data devices, use if possible**
  - different ranks on the same storage server
  - use different storage servers
  - → This ensures a contiguous log disk I/O and good transaction rates.

Linux kernel 2.6 I/O schedulers

- **four different I/O schedulers are available**
  - **noop** scheduler
    does only request merging
  - **deadline** scheduler
    avoids read request starvation, offers the possibility to give write requests the same priority like reads
  - 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 kernel 2.6 I/O schedulers - Results



- as scheduler is not a good choice for OLTP environments
- all other schedulers show similar results
- **deadline scheduler is used for further tests**

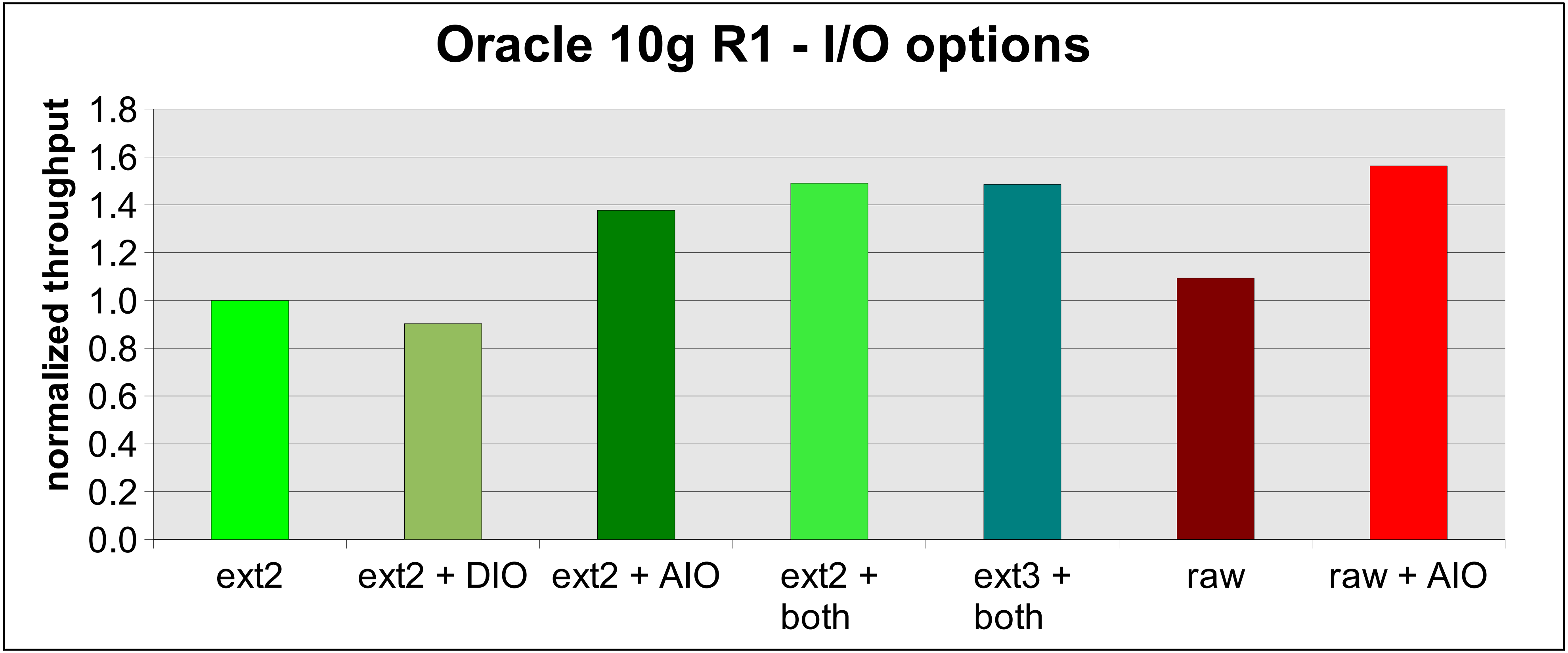
Disk I/O Options with Linux kernel 2.6

- **Direct I/O (DIO)**
  - transfer the data directly from the application buffers to the device driver
  - advantage
    - saves page cache memory
    - same data are not cached twice (no copying of the data to the Linux page cache)
    - use larger buffer pools instead
  - disadvantage
    - ensure that no utility is accessing the same data through the file system (page cache) --> danger of data corruption

- **Asynchronous I/O (AIO)**
  - I/O requests are issued asynchronously by the application
  - the application does not have to wait for I/O request completion
  - application can immediately continue processing
  - advantage
    - the number of parallel I/O processes can be reduced (this saves memory and CPU)

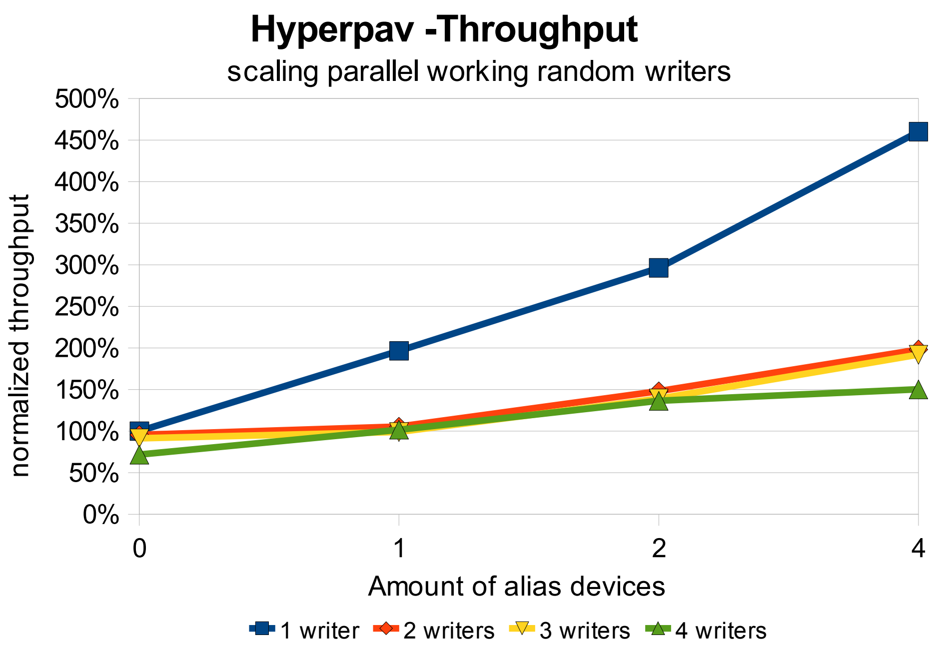
➢ **use both features together**

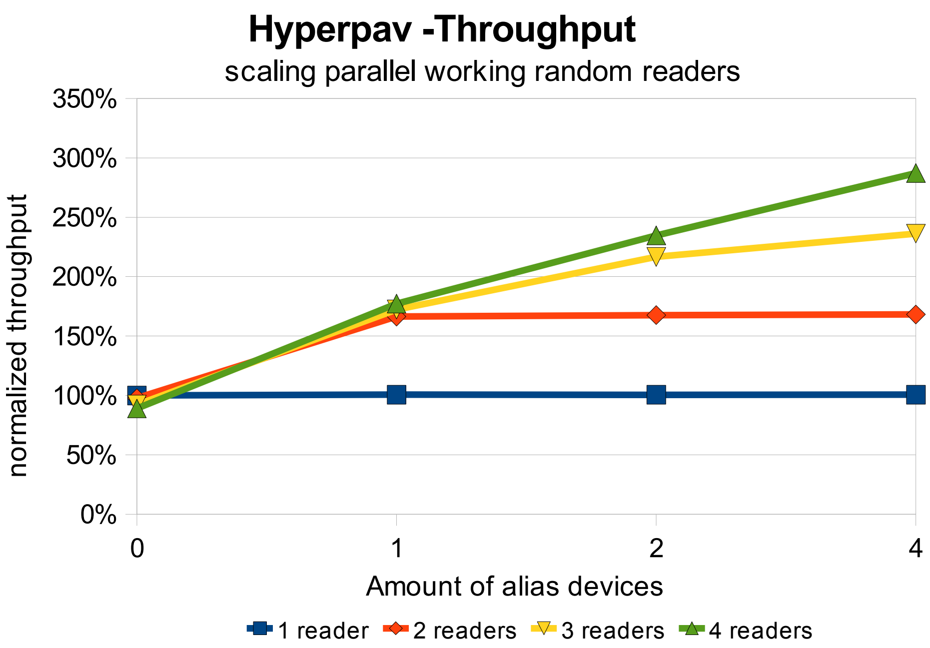
DIO and AIO – Results



- **The combination of DIO and AIO shows the best results for the Linux file system**
  - filesystemio_options=setall
- **The best throughput rate is provided by raw I/O + AIO**
  - raw I/O uses implicitly DIO

new feature with SLES 11 – Hyperpav





- **Access to ECKD DASD could become contented when used in parallel from multiple processes (subchannel busy)**
- **Solution: having multiple subchannels per device = alias device**
  - HYPERPAV: pool of aliases assigned temporarily to a device as needed
- **usage of Hyperpav can be highly recommended!**

DS8000 Storage Pool Striping

- **requires License Machine Code 5.30xx.xx**
- **Stripe the extents of a DS8000 Volume across multiple RAID arrays/ranks**
- **Pro**
  - Storage pool striped volumes are simple to set up and to administrate as a few large disks
  - Provides a similar performance advantage as the disk setup described earlier (striping over ranks)
  - Striping on the storage device lowers CPU consumption (LVM) on the Linux side
- **Con**
  - Stripe size is 1 GB (relatively large)
  - Losing control how the extents are selected from the ranks
  - Cannot span internal servers

- **ECKD disks**
  - Without HiperPAV only one I/O per DASD can be processed which limits the performance!
  - FICON path groups do the load balancing

➢ **Using storage pool striping makes administration easy and provides a very good overall performance**

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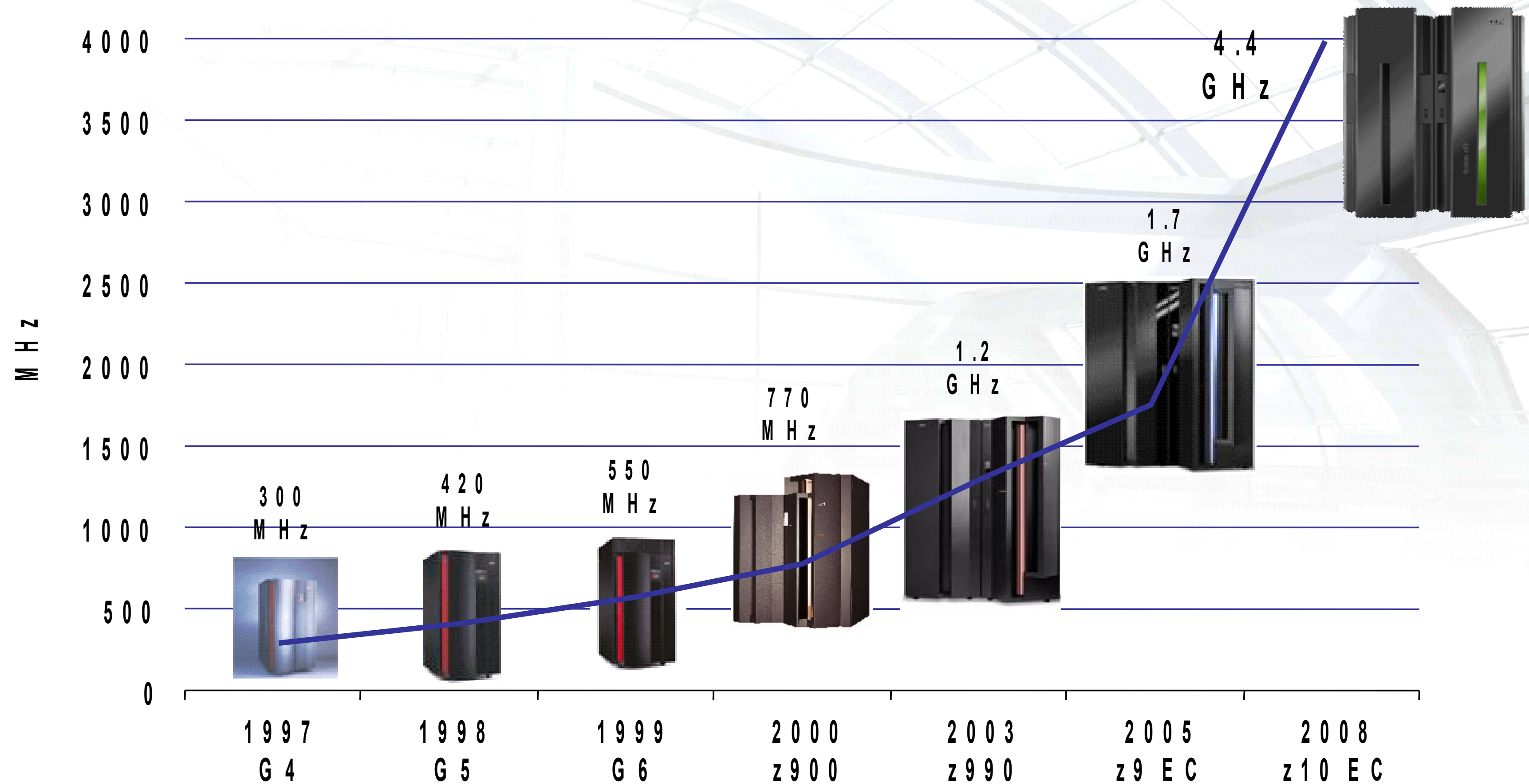
IBM z10 EC Continues the CMOS Mainframe Heritage

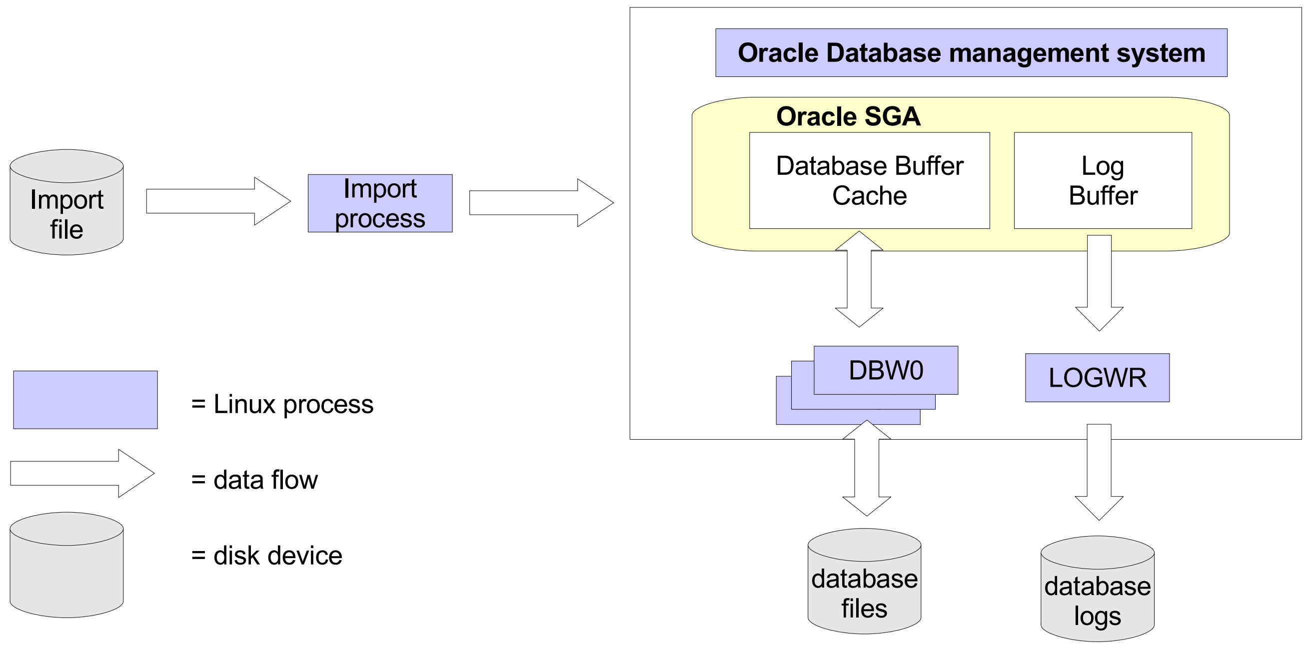


- G4 - 1st full-custom CMOS S/390®
- G5 - IEEE-standard BFP; branch target prediction
- G6 - Cu BEOL

- IBM eServer zSeries 900 (z900) - Full 64-bit z/Architecture®
- IBM eServer zSeries 990 (z990) - Superscalar CISC pipeline
- z9 EC - System level scaling

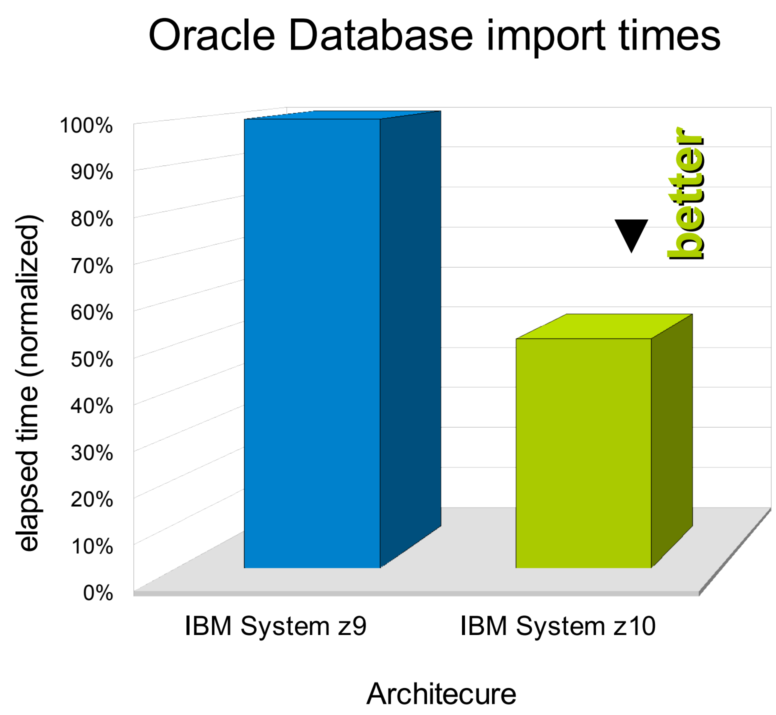
- z10 EC - Architectural extensions

Oracle Import – Environment



- Importing 20 GB data into the database from a single import file
- The whole performance depends on the speed of the single import process
  - A fast disk I/O subsystem is required, e.g. IBM DS8000

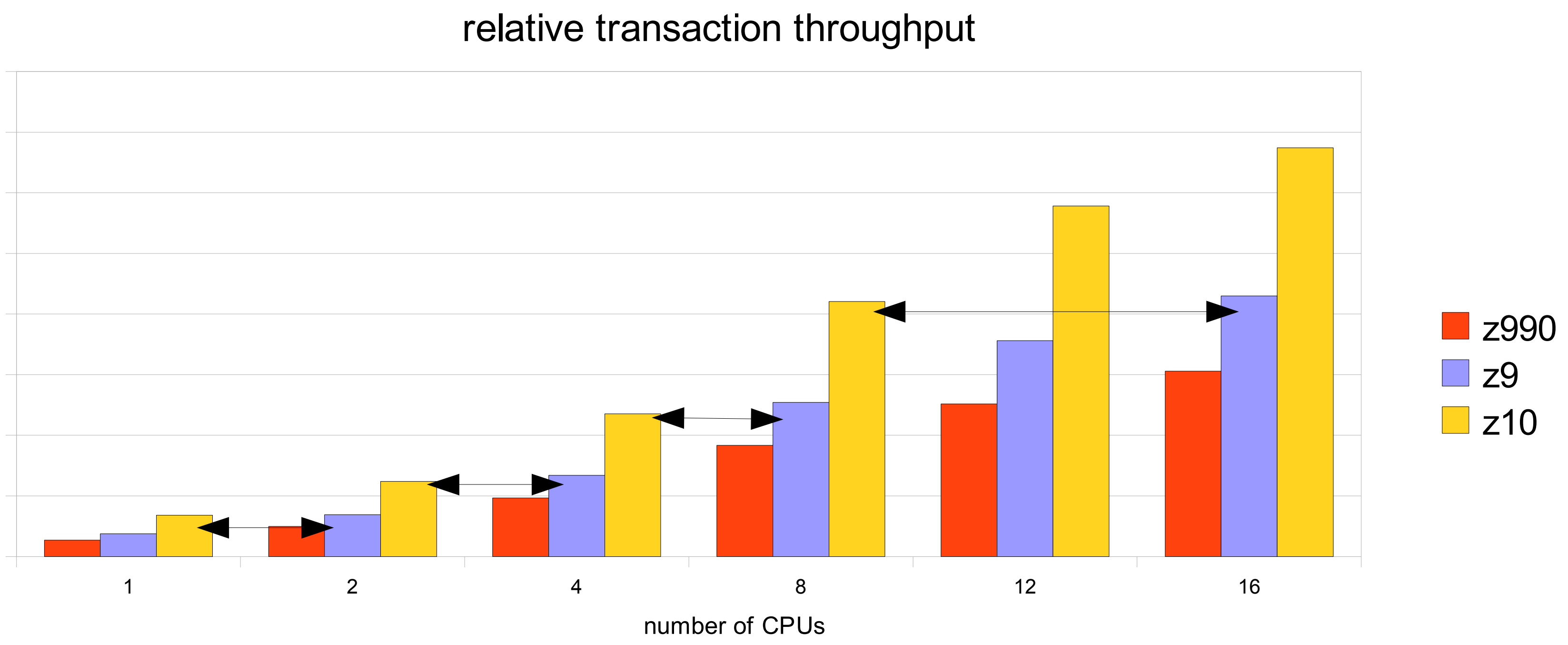
Oracle Import – Results



- IBM System z10 provides a reduction of the runtime by 50%

➢ **The import of the data runs twice as fast!**

z10 with Informix IDS 11 OLTP workload



- **Throughput improvements**
  - z9 to z10: 65% - 82%
  - *n* numbers of z10 CPUs can do the same work as 2*n* z9 CPUs

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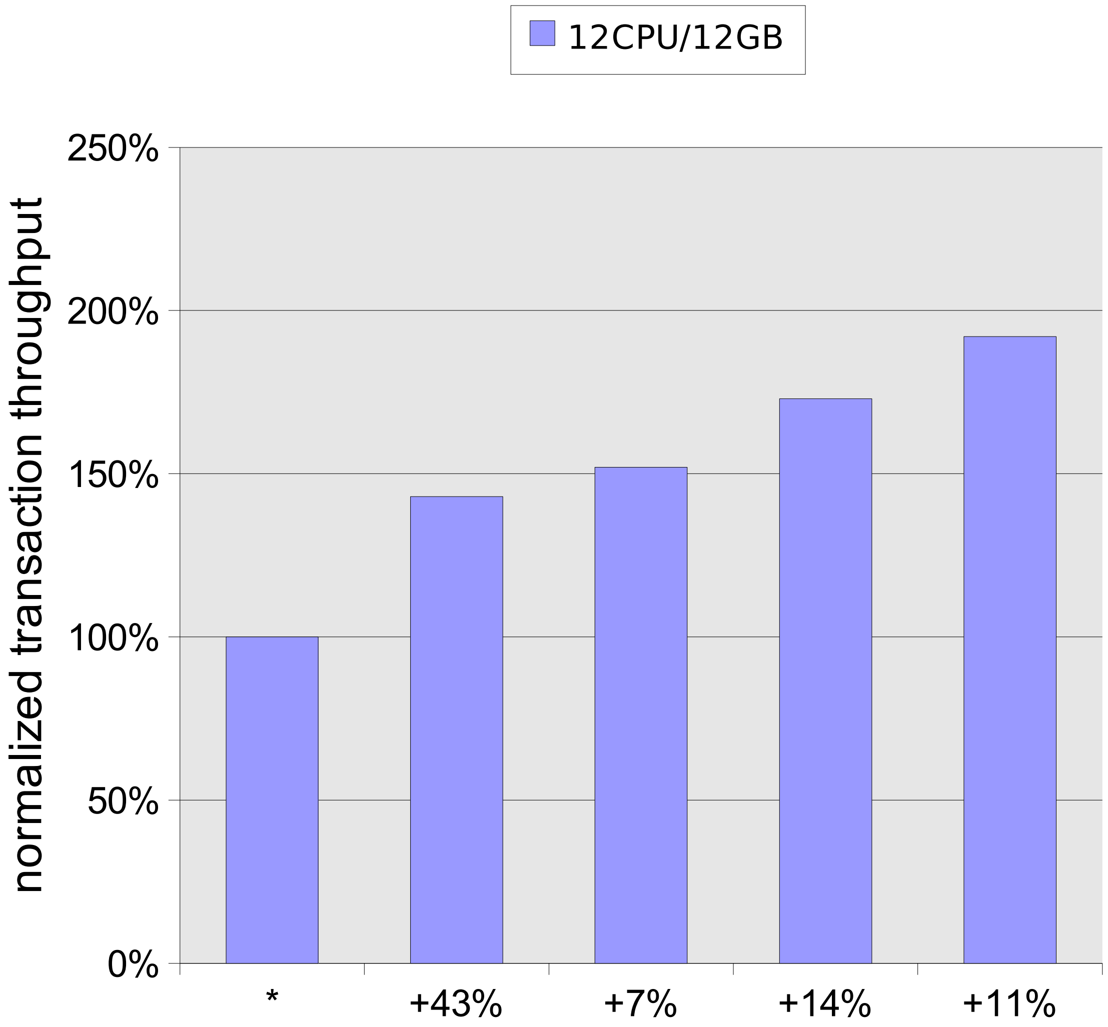
A little DB2 Tuning Story



* started tuning here

tablespace prefetch 0
LVM readahead 0
→ **+43%**

Changed CHNGPGS_THRESH from 30 to 60
→ **+7%**

separate data and index bufferpools

for tablespaces with very large rows

→ **+14%**

8K pagesize for the index from the tablespaces with very large rows
→ **+11%**

Overall Tuning Result:
The throughput rate is nearly doubled compared to the starting point.

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Summary (1)

- **Avoid physical disk I/O**
  - **<u>Database:</u>**
    - carefully choose the right buffer pool sizes
    - if any instance is doing read ahead, this should be done by the database
  - **<u>Linux:</u>**
    - disable readaheads for OLTP workloads
    - choose the right kernel parameter settings (shared memory)
- **Monitor the database cache hit ratio**

➢ **high cache hit scenarios scale well with the number of CPUs on IBM System z**

Summary (2)

- **If you can't avoid a lot of disk I/O, make it fast...**
  - Storage server:
    - use disks out of all ranks
    - alternate between the device adapter pairs and servers on the storage server
    - use storage pool striping
  - Linux:
    - ensure that a suitable I/O scheduler is used (e.g. deadline scheduler)
    - use Hiperpav with ECKD devices
  - z/VM:
    - use version 5.2 or higher
  - Database:
    - use striped storage structures provided by ASM or LVM to access disks in parallel
    - use separate disks for Data and Log files
    - async and direct I/O save memory and improve database performance

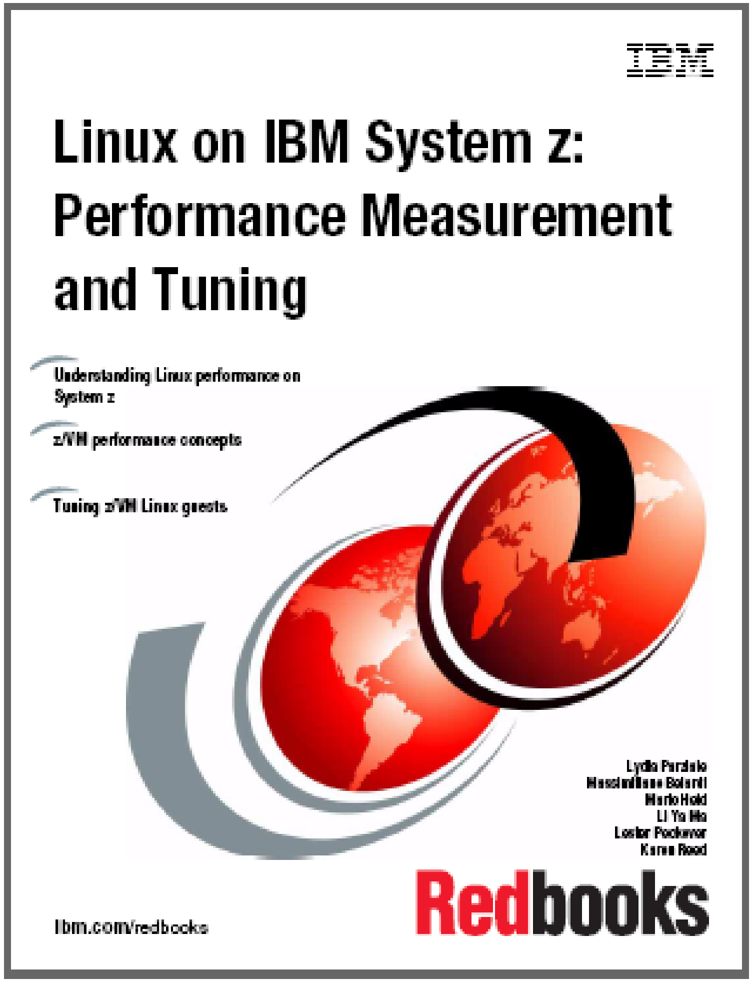
- **System z10 provides a performance improvement up to factor 2x**

Related Topics at 2009 System z Expo

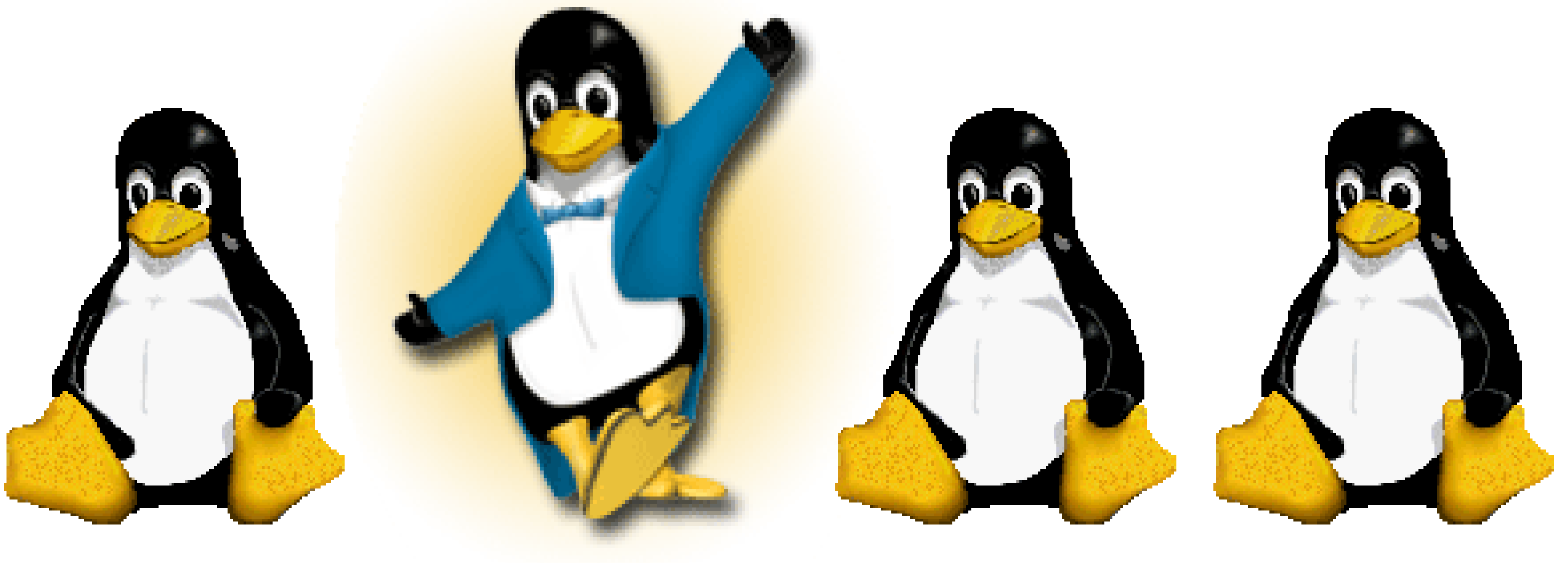
- **Performance Tuning and Monitoring: DB2 for Linux, Unix and Windows (LUW) for Linux**
  zLA08 Wednesday 4:10 PM

Visit us !

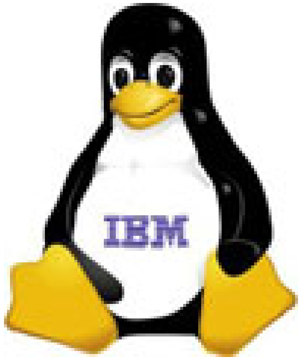
- **Linux on System z: Tuning Hints & Tips**
  - http://www.ibm.com/developerworks/linux/linux390/perf/
- **Linux-VM Performance Website:**
  - http://www.vm.ibm.com/perf/tips/linuxper.html
- **IBM Redbooks**
  - http://www.redbooks.ibm.com/



Questions



BACKUP



Workload description

- **OLTP workload, simulating an order entry system**
- **Five different transaction types, executed randomly within a defined mix**
  - new order
  - payment
  - order status
  - delivery
  - stock status
- **High and low database buffer read hit ratios simulate different production environment conditions**

Linux Kernel parameters (1)

- **Linux kernel parameters can limit the amount of shared memory!**
  Shared memory is needed for database buffer pools!
  - kernel.shmall available memory for shared memory in 4 K pages
  - kernel.shmmax maximum size of one shared memory segment in bytes
  - kernel.shmmni maximum number of shared memory segments

- **shm parameter recommendations:**
  - set shmall and shmmax equal to the current memory size, so that they're not a limiting factor.

Linux memory	shmall	shmmni	shmmax
8 GB	1971200	4096	8074035200

- **Kernel parameter changes were made in /etc/sysctl.conf**
  - Enable sysctl service with `chkconfig boot.sysctl on`
  - sysctl.conf is read during boot time by the sysctl command
  - Insert a line for each kernel parameter according to

```
kernel.parameter = value
```

Linux Kernel parameters (2)

- **Take care for the database specific recommendations for following kernel parameters:**

- **Kernel semaphores limits**
  - kernel.sem (Kernel semaphores limits)
    Max. semaphores per array / max. Semaphores system wide / max. ops per per semop call / max. number of arrays
  - e.g. kernel.sem = 250 32000 32 128

- **Kernel message limits**
  - kernel.msgmni maximum queues system wide
  - kernel.msgmax maximum size of message (bytes)
  - kernel.msgmnb default size of queue (bytes)