



Advanced Technical Skills

AIX Performance: Configuration & Tuning for Oracle

Vijay Adik
vadik@us.ibm.com
ATS - Oracle Solutions Team

Legal information

The information in this presentation is provided by IBM on an "AS IS" basis without any warranty, guarantee or assurance of any kind. IBM also does not provide any warranty, guarantee or assurance that the information in this paper is free from errors or omissions. Information is believed to be accurate as of the date of publication. You should check with the appropriate vendor to obtain current product information.

Any proposed use of claims in this presentation outside of the United States must be reviewed by local IBM country counsel prior to such use.

IBM, ^, , RS6000, System p, AIX, AIX 5L, GPFS, and Enterprise Storage Server (ESS) are trademarks or registered trademarks of the International Business Machines Corporation.

Oracle, Oracle9i and Oracle10g are trademarks or registered trademarks of Oracle Corporation.

All other products or company names are used for identification purposes only, and may be trademarks of their respective owners.

Agenda

- **AIX Configuration Best Practices for Oracle**
 - **Memory**
 - **CPU**
 - **I/O**
 - **Network**
 - **Miscellaneous**

AIX Configuration Best Practices for Oracle

- **The suggestions presented here are considered to be basic configuration “starting points” for general Oracle workloads**
- **Your workloads may vary**
- **Ongoing performance **monitoring and tuning** is recommended to ensure that the configuration is optimal for the particular workload characteristics**

Agenda

- **AIX Configuration Best Practices for Oracle**
 - **Memory**
 - CPU
 - I/O
 - Network
 - Miscellaneous

Virtual Memory Manager (VMM) Tuning

- **The AIX “vmo” command provides for the display and/or update of several parameters which influence the way AIX manages physical memory**
 - The “-a” option displays current parameter settings
 - `vmo -a`
 - The “-o” option is used to change parameter values
 - `vmo -o minfree=1440`
 - The “-p” option is used to make changes persist across a reboot
 - `vmo -p -o minfree=1440`

On AIX 5.3, number of the default “vmo” settings are not optimized for database workloads and should be modified for Oracle environments

Kernel Parameter Tuning – AIX 6.1/7.1

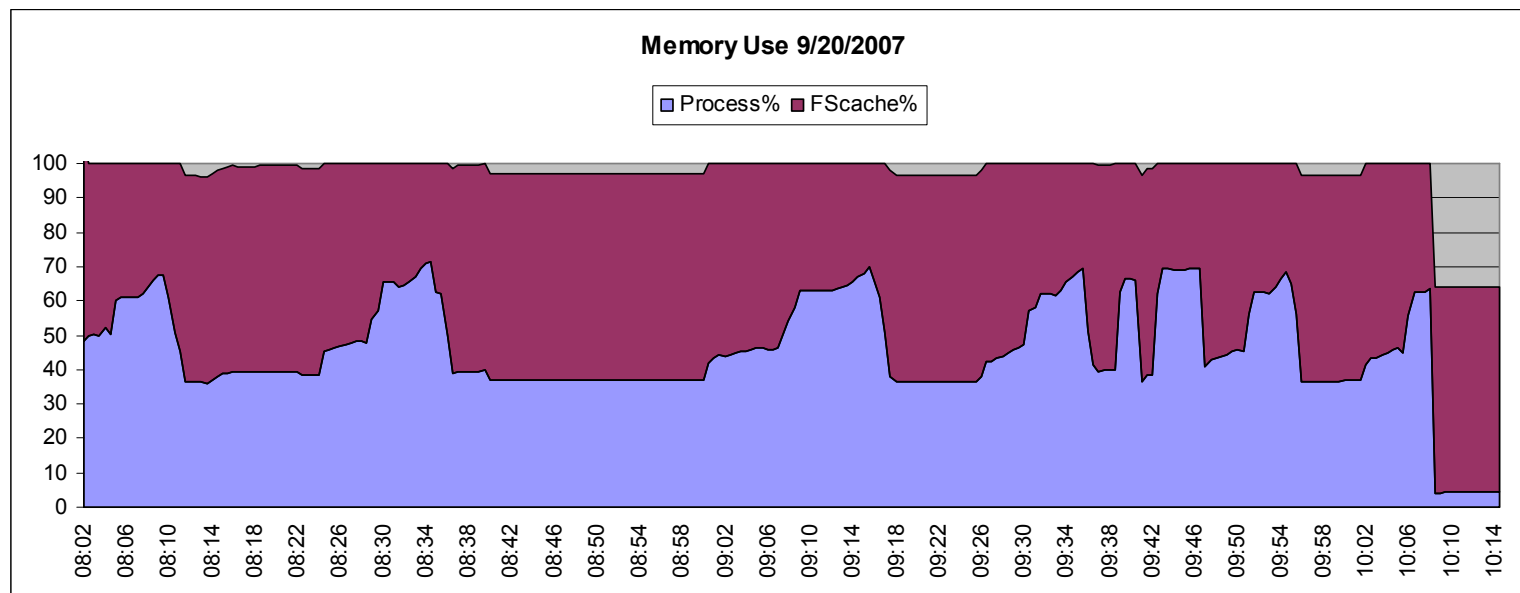
- **AIX 6.1/7.1** configured by default to be ‘correct’ for most workloads.

- **Many tunable are classified as ‘Restricted’:**
 - Only change if AIX Support says so
 - Parameters will not be displayed unless the ‘-F’ option is used for commands like vmo, no, ioo, etc.

- **When migrating from AIX 5.3 to 6.1/7.1, parameter override settings in AIX 5.3 will be transferred to AIX 6.1/7.1 environment**

General Memory Tuning

- **Two primary categories of memory pages: Computational and File System**
- **AIX will always try to utilize all of the physical memory available (subject to vmo parameter settings)**
 - What is not required to support current computational page demand will tend to be used for filesystem cache
 - Raw Devices and filesystems mounted (or individual files opened) in DIO/CIO mode do not use filesystem cache



AIX System Paging Concepts & Requirements

- **By default, AIX uses a “demand paging” policy**
 - For Oracle DB, the goal is **ZERO** system paging activity
 - Filesystem pages written back to filesystem disk (if dirty); never to system paging space
 - Unless otherwise specified, computational pages are not written to paging space unless/until they are stolen by lru. (*1)
- **Once written to paging space, pages are not removed from paging space until the process associated with those pages terminates**
 - For long running processes (e.g. Oracle DB), even low levels of system paging can result in significant growth in paging space usage over time
 - Paging space should be considered a fail-safe mechanism for providing sufficient time to identify and correct paging issues, not a license to allow ongoing system paging activity
- **Paging space allocation Rule-of-Thumb:**
 - $\frac{1}{2}$ the physical memory + 4 GB, with the following cap:

Physical Memory lower or equal to	Paging Space Max
128GB	60GB
256GB	100GB
512GB	150GB
1TB	200GB

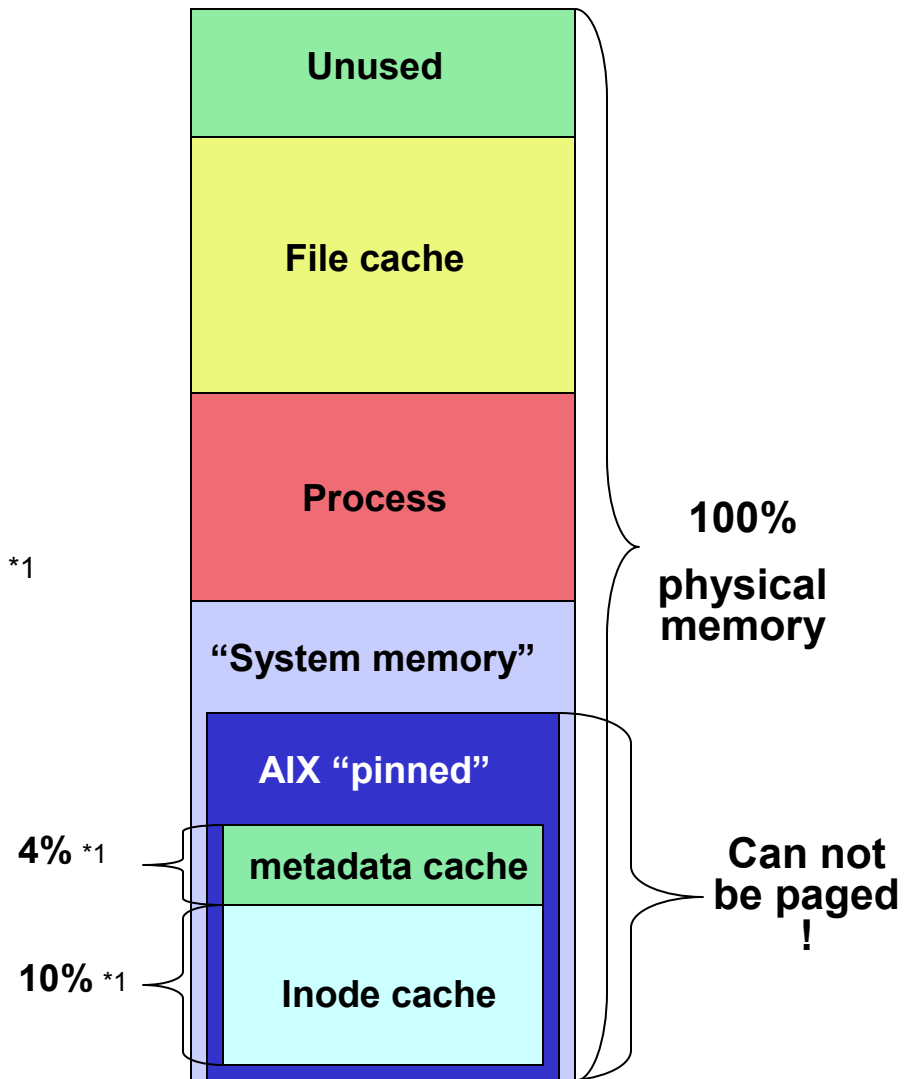
Resolve paging issues quickly:

- Reduce effective minimum file system cache size (minperm)
- Reduce Oracle SGA or PGA size
- Add physical memory

JFS2 inode / metadata caches

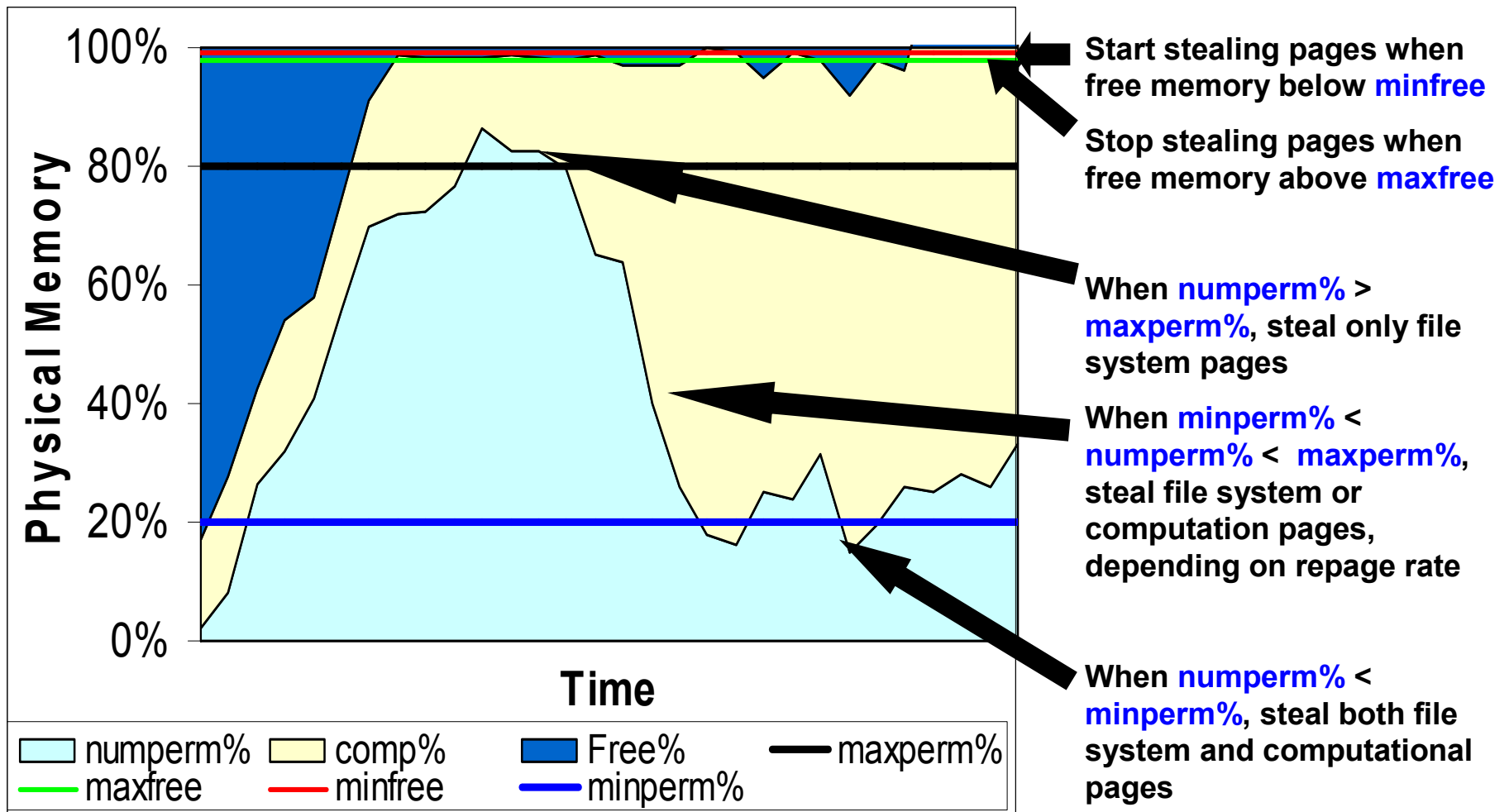
- JFS2 utilizes two caches - one for inodes and one for metadata
- Caches grow in size until maximum size is reached before cache slots are reused
- Default values are tuned for a file server!
- Each entry in the inode cache requires about 1KB of physical memory
 - ➔ 1MB of memory can cache about 1000 files
- Configured via ioo parameters:
 - j2_inodeCacheSize (Default: 400 = 10%) *1
 - j2_metadataCacheSize (Default: 400 = 4%) *1
- The current memory use can be verified via:


```
cat /proc/sys/fs/jfs2/memory_usage
metadata cache: 31186944
inode cache: 34209792
total: 65396736
```



*1 Note: Default values in AIX 7.1 are 200 (5%) , 200 (2%)

Virtual Memory Management (VMM) Thresholds



Page Steal Method

- **Historically, AIX maintained a single LRU list which contains both computational and filesystem pages.**
 - In environments with lots of computational pages that you want to keep in memory, LRUD may have to spend a lot of time scanning the LRU list to find an eligible filesystem page to steal

- **AIX 6.1 introduced the ability to maintain separate LRU lists for computational vs. filesystem pages.**
 - Also backported to AIX 5.3

- **New `page_steal_method` parameter**
 - Enabled (1) by default in 6.1/7.1, disabled (0) by default in 5.3
 - Requires a reboot to change
 - Recommended for Oracle DB environments

Large Segment Aliasing (AIX 6.1 TL06, AIX 7.1)

- **Feature allows user applications to “automagically” use 1TB segments.**
 - 1 SLB entry in POWER7 can now address 1TB of memory.
 - Segment Lookaside Buffer (SLB) fault issue no longer relevant
 - Immediate performance boost for applications, new and legacy

- **Significant changes under the covers**
 - New address space allocation policy
 - Attempts to group address space requests together to facilitate 1TB aliasing.
 - Once certain allocation size thresholds have been reached, OS automatically aliases memory with 1TB aliases.
 - 256MB segments still exist for handling IO

- **Aliasing only available for shared memory regions at this point.**
- `vmo -p -o esid_allocator = 1` and `shm_1tb_unsh_enable = 0`

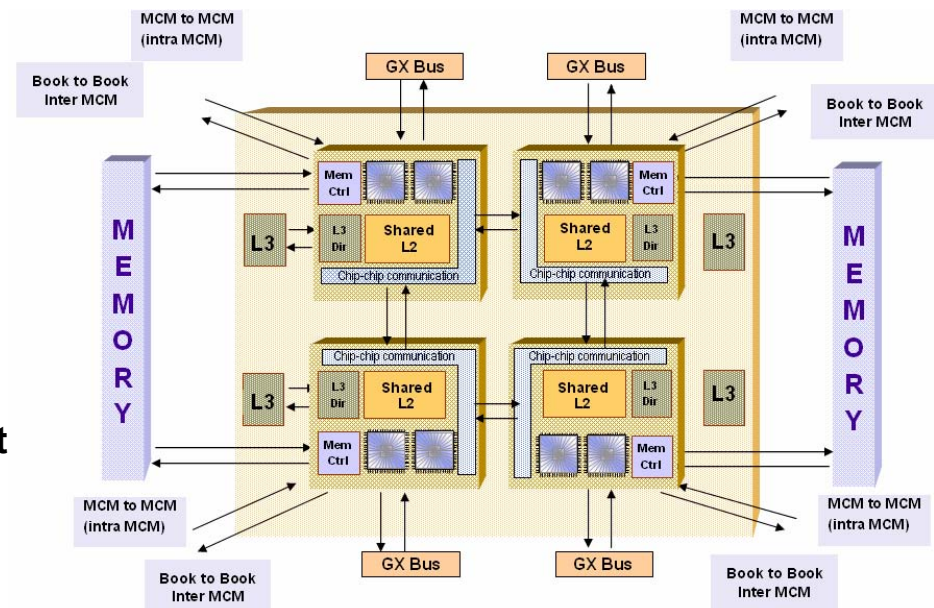
Recommended vmo “Starting Points” - Review

Parameter	Recommend Value	AIX 7.1 Default	AIX 7.1 Restricted	AIX 6.1 Default	AIX 6.1 Restricted	AIX 5.3 Default
minperm%	3	3	No	3	No	20
maxperm%	90	90	Yes	90	Yes	80
maxclient%	90	90	Yes	90	Yes	80
strict_maxclient	1	1	Yes	1	Yes	1
strict_maxperm	0	0	Yes	0	Yes	0
lru_file_repage	0	N/A	N/A	0	Yes	1 or 0(*1)
lru_poll_interval	10	10	Yes	10	Yes	10
minfree	960	960	No	960	No	960
maxfree	1088(*2)	1088	No	1088	No	1088
page_steal_method	1	1	Yes	1	Yes	0
memory_affinity	1	1	Yes	1	Yes	1
v_pinshm	0	0	No	0	No	0
lgpg_regions	0	0	No	0	No	0
lgpg_size	0	0	No	0	No	0
maxpin%	Leave at Default	90(*3)	No	80(*3)	No	80

*1 Depending on AIX 5.3 TL level *2 Do not reduce below default *3 Depends on LSA use – LSA active → 90, otherwise 80

Understanding Memory Pools

- **Memory cards are associated with every Multi Chip Module (MCM), Dual Core Module (DCM) or Quad Core Module (QCM) in the server**
 - The Hypervisor assigns physical CPUs to a dedicated CPU LPAR (or shared processor pool) from one or more MCMs, DCMs or DCMs
 - For a given LPAR, there will normally be at least 1 memory pool for each MCM, DCM or QCM that has contributed processors to that LPAR or shared processor pool
- **By default, memory for a process is allocated from memory associated with the processor that caused the page fault.**
- **Memory pool configuration is influenced by the VMO parameter “memory_affinity”**
 - Memory_affinity=1 means configure memory pools based on physical hardware configuration (DEFAULT)
 - Memory_affinity=0 means configure roughly uniform memory pools from any physical location
- **Number can be seen with ‘vmstat -v |grep pools’**
- **Size can only be seen using KDB**
- **LRUD operates per memory pool**



AIX Multiple Page Size Support

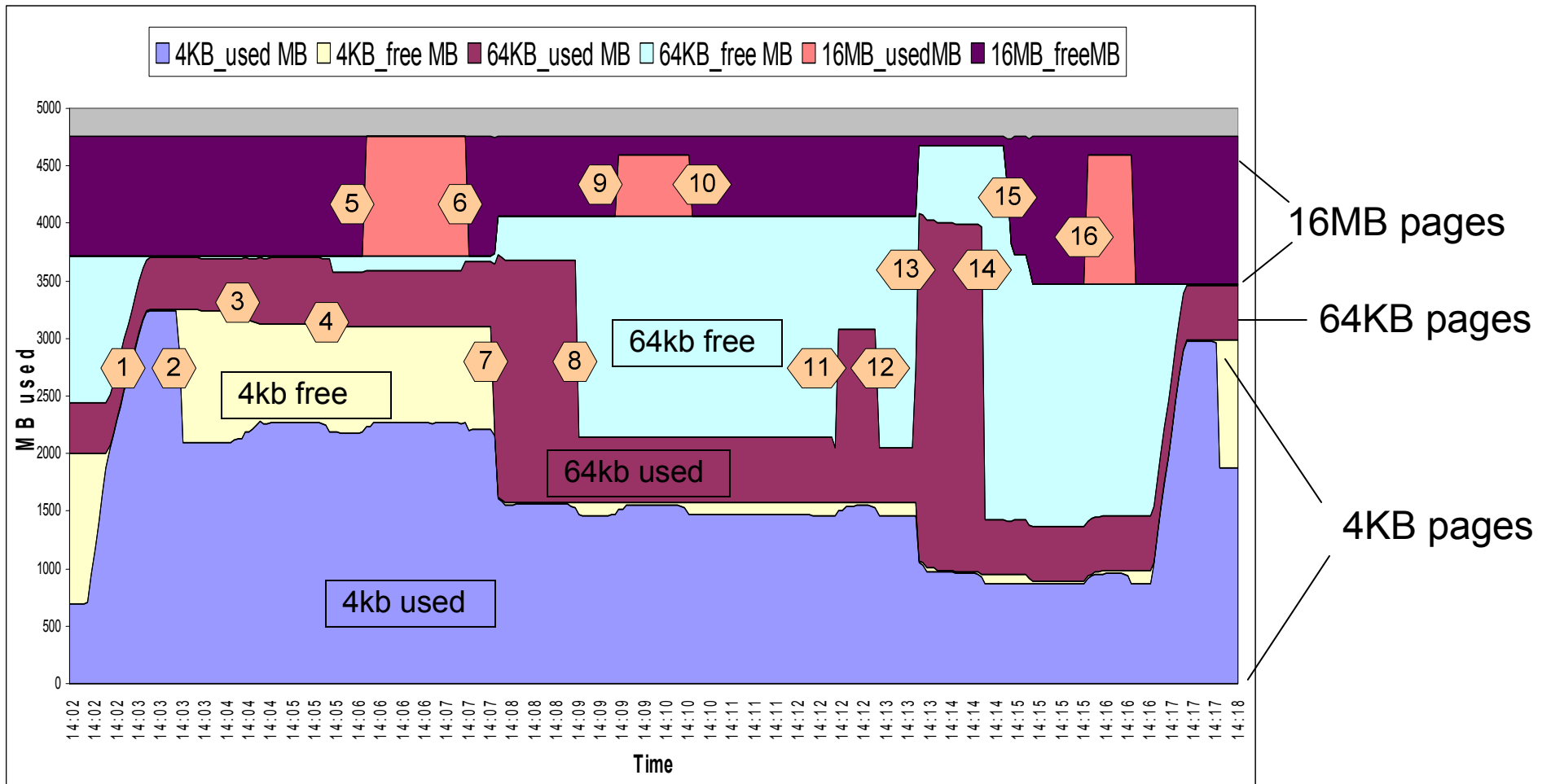
- **4K (Default)**
 - All memory pages in the filesystem cache are 4K in size!
 - Can be paged to paging space
 - 4K pages can be combined to a 64K page if not enough 64K pages are available

- **64K, available with POWER5+ and later & AIX 5.3 TL4+**
 - Can be paged to paging space
 - Can be converted to 4K pages if not enough 4K pages are available
 - Kernel page size used in AIX 5.3 TL4+ and above (can be configured)
 - Can be utilized for application code, data and stack as well, but requires specific configuration

- **16M available with POWER4 hardware (or later) (also referred to as Large Pages)**
 - Requires pinned memory and explicit configuration
 - Can not be paged to paging space

- **16G available with POWER5+ & AIX 5.3 TL4+**
 - **Cannot be used with Oracle**
 - Can not be paged to paging space

4K - 64K - 16MB Page Dynamics



AIX Multiple Page Size Support

- **User/Application must request preferred page size**
 - 64K page size is very promising, since they do not need to be configured/reserved in advance or pinned
 - export
LDR_CNTRL=DATAPSIZE=64K@TEXTFSIZE=64K@STACKP
SIZE=64K@SHMPSIZE=64K to use the 64K pagesize for
stack, data & text
 - Will require Oracle to explicitly request the page
size (10.2.0.4 & up plus Oracle patch# 7226548)
 - If preferred size not available, the largest available
smaller size will be used
 - Current Oracle versions will end up using 64KB pages even if
SGA is not pinned
- **Refer: http://www-03.ibm.com/systems/resources/systems_p_os_aix_whitepapers_multiple_page.pdf**

Large Page Support 16mb (optional)

Pinning shared memory

- AIX Parameters
 - `vmo -p -o v_pinshm = 1`
 - Leave `maxpin%` at the default of 80% unless the SGA exceeds 77% of real memory
 - `Vmo -p -o maxpin%=[(total mem-SGA size)*100/total mem] + 3`
- Oracle Parameters
 - `LOCK_SGA = TRUE`

Enabling Large Page Support

- `vmo -p -o lgpg_size = 16777216 -o lgpg_regions=(SGA size / 16 MB)`

Allowing user oracle to use Large Pages

- `chuser capabilities=CAP_NUMA_ATTACH,CAP_BYPASS_RAC_VMM,CAP_PROPAGATE oracle`

Using Monitoring Tools

- `svmon -G`
- `svmon -P`

Oracle metalink note# 372157.1

Note: It is recommended not to pin SGA, as long as you had configured the VMM, SGA & PGA properly.

Determining SGA size

SGA Memory Summary for DB: test01 Instance: test01 Snaps: 1046 -1047

SGA regions	Size in Bytes
-----	-----
Database Buffers	16,928,210,944
Fixed Size	768,448
Redo Buffers	2,371,584
Variable Size	1,241,513,984

sum	18,172,864,960

$lgpg_regions = 18,172,864,960 / 16,777,216 = 1084$ (rounded up)

Oracle Memory Structures Allocation

■ 11g : Automatic Memory Management (AMM)

- `memory_target` (dynamic parameter) – specifies the total memory size to be used by the instance SGA and PGA. Exchanges between SGA and PGA are done according to workload requirements
- If `sga_target` and `pga_aggregate_target` are not set, the policy is to give 60% of `memory_target` to the SGA and 40% to the PGA.
- `memory_max_target` (static parameter) – specifies the maximum memory size for the database instance.
- *To use Automatic Memory Management, `memory_target` must be >0.*
- *Can not be used together with “`LOCK_SGA=TRUE`”*
- **See Metalink notes 443746.1 and 452512.1 explaining AMM and these new parameters.**

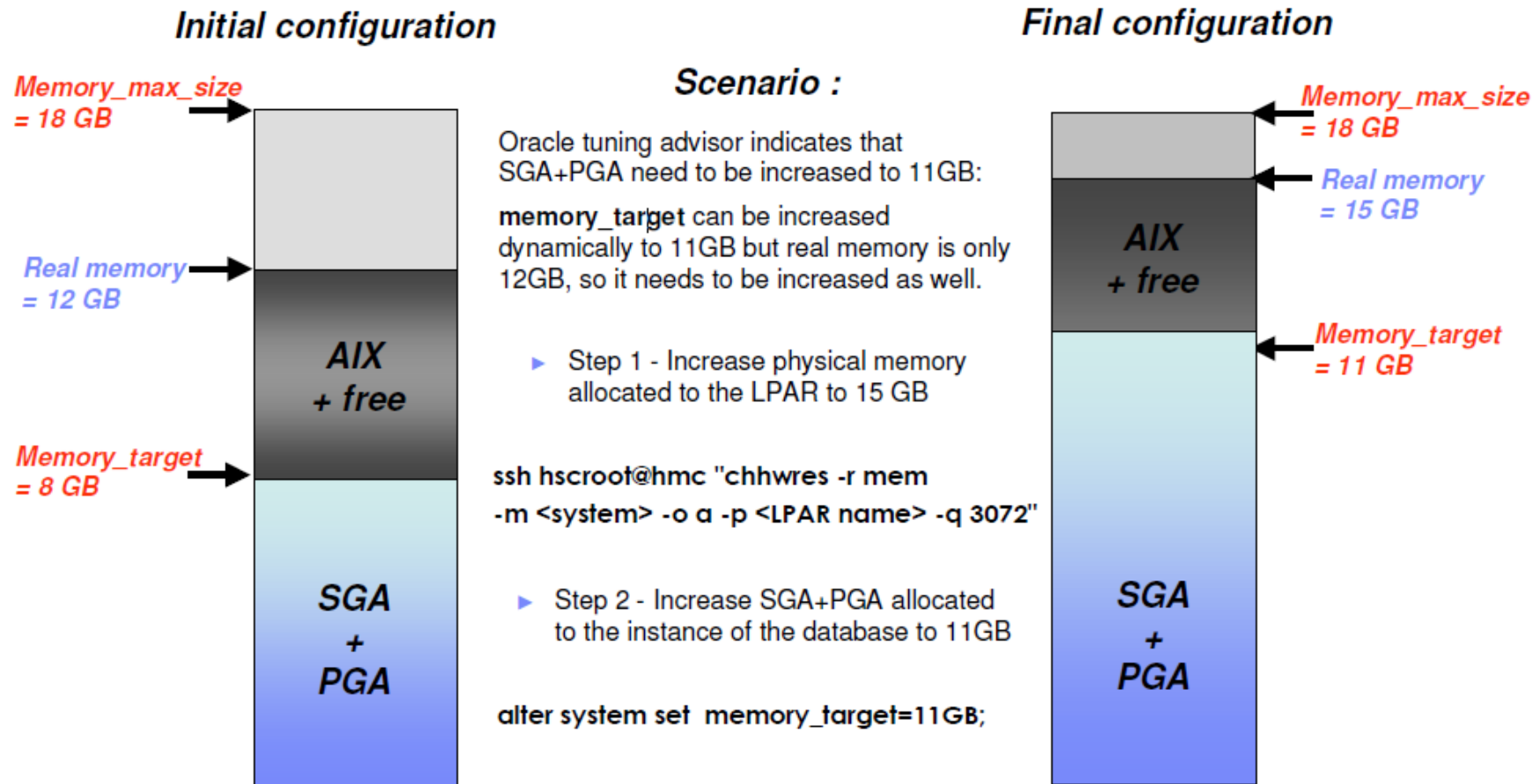
AMM dynamic resizing of the shared pool can cause a fair amount of “cursor: pin s” wait time. One strategy to minimize this is to set minimum sizes for memory areas you particularly care about.

In addition you can change the frequency how often AMM analyzes and adjusts the memory distribution. See: Metalink note: 742599.1 (`_memory_broker_stat_interval`)

SGA_MAX_SIZE and LOCK_SGA implications (11g, 10.2.4.0+)

- **LOCK_SGA=false Preferred**
 - Oracle dynamically **allocates memory for the SGA only as needed** up to the size specified by SGA_TARGET
 - **SGA_TARGET may be dynamically increased**, up to SGA_MAX_SIZE
 - **64K pages automatically used** for SGA if supported in the environment. If needed, 4K (or 16M) pages are converted to 64K pages.
- **LOCK_SGA=true Discouraged**
 - Oracle **Automatic Memory Management (AMM) cannot be used** (MEMORY_TARGET)
 - **Oracle pre-allocates all memory** as specified by SGA_MAX_SIZE and pins it in memory, even if it's not all used (i.e. SGA_TARGET < SGA_MAX_SIZE)
 - If sufficient 16M pages are available those will be used. Otherwise, **all** the SGA memory will be allocated from 64K (if supported) or 4K pages (if 64K pages are not supported). If needed, 4K (or 16M) pages will be converted to 64K pages, but **16M pages are never automatically created**.
 - If a value for sga_max_size is specified larger than the amount of available memory for computational pages, the **system can become unresponsive** due to system paging.
 - If the specified SGA_MAX_SIZE is much larger than the currently available pages on the combined 64K and 16M page free lists, the **database startup can fail with error: "IBM AIX RISC System/6000 Error: 12: Not enough space"**. In this case re-try to start the database.

AIX dynamic LPAR with Oracle AMM



- Memory allocated to the system has been increased dynamically, using AIX DLPAR
- Memory allocated to Oracle (SGA and PGA) has been increased on the fly

Memory Usage in an Oracle Environment

Computational

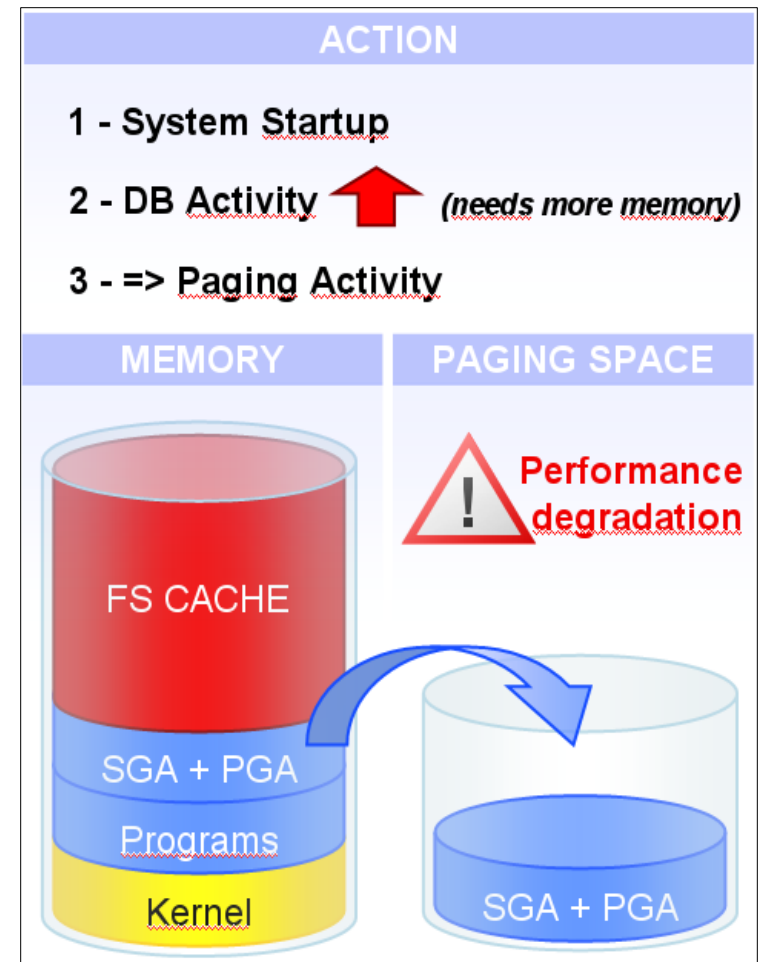
- Some used for AIX kernel processing
- Some used by Oracle/client executable programs
- Includes Oracle SGA and PGA memory

File System Cache

- May be used for caching or prefetching of Oracle .dbf files
 - Only for local filesystem based (non-RAC) environments where Direct I/O (or Concurrent I/O) is not used
- May be used for other Oracle related files
 - Archive logs, export/import files, backups, binaries, etc.
- May be used for non-Oracle related files
 - Application files, system files, etc.

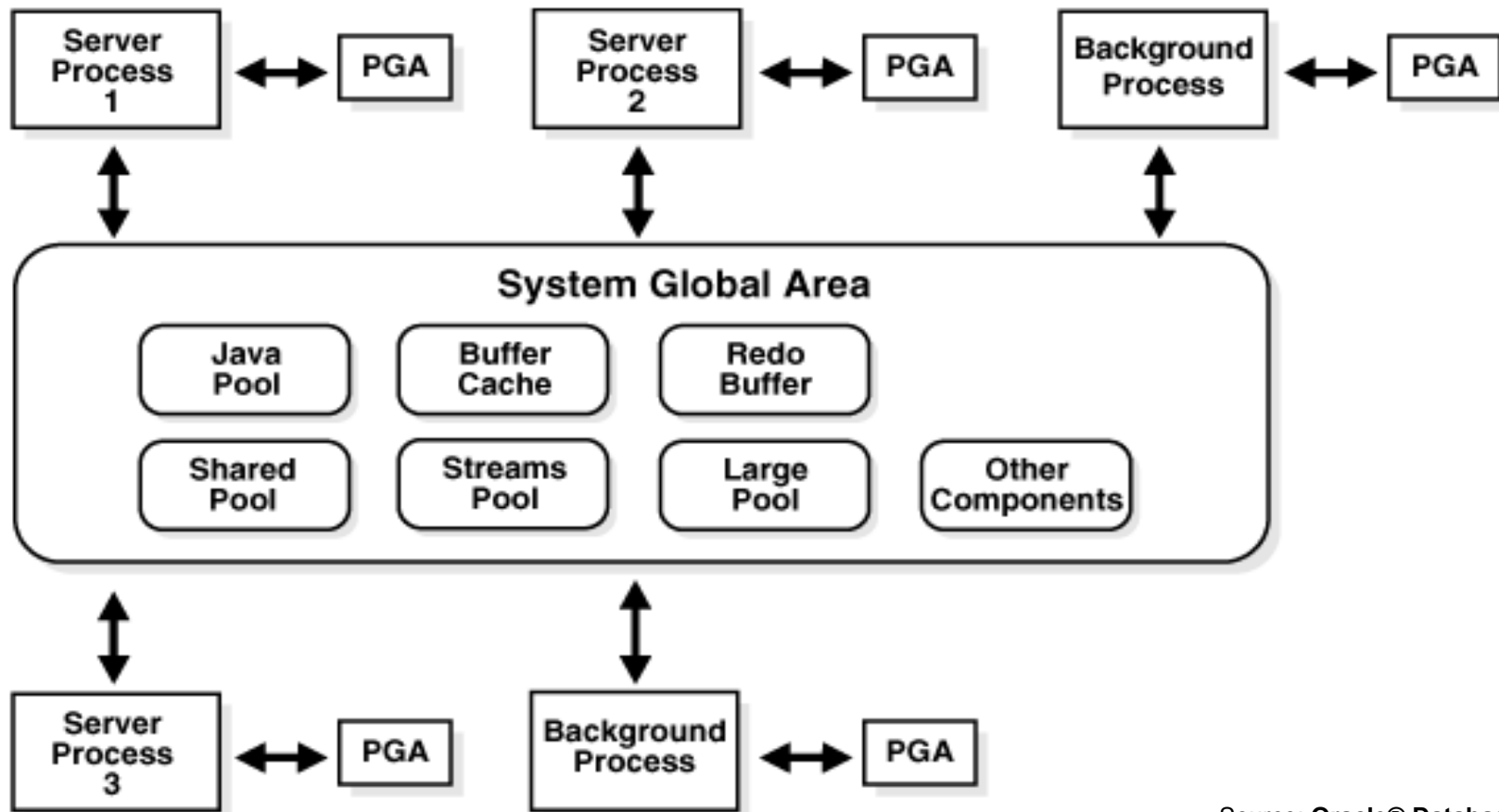
Virtual Memory Management Priorities

- Always want to keep computational pages in memory -- System paging/swapping may degrade Oracle/application performance
 - Allocate enough physical memory to support computational footprint requirement + small file cache
 - When necessary, steal filesystem pages, not computational



Oracle Server Architecture – Memory Structures

Figure 8-1 Oracle Database Memory Structures



Source: Oracle® Database Concepts
 11g Release 1 (11.1)
 Part Number B28318-05

Displaying Memory Usage Statistics

The 'vmstat' command provides information on current memory usage: (reported in 4K pages)

```
# vmstat -v
```

```
1048576 memory pages
1002006 lruable pages
812111 free pages
      1 memory pools
141103 pinned pages
      80.0 maxpin percentage
       3.0 minperm percentage
      90.0 maxperm percentage
       3.2 numperm percentage
32779 file pages
      0.0 compressed percentage
      0 compressed pages
      0.0 numclient percentage
      90.0 maxclient percentage
      0 client pages
      0 remote pageouts scheduled
      0 pending disk I/Os blocked with no pbuf
      0 paging space I/Os blocked with no psbuf
2484 filesystem I/Os blocked with no fsbuf
      0 client filesystem I/Os blocked with no fsbuf
      0 external pager filesystem I/Os blocked with no fsbuf
```

Displaying Memory Usage Statistics

The 'svmon -G' command provides information on current memory usage per page size: (general numbers are reported in 4K pages)

```
# svmon -G
```

	size	inuse	free	pin	virtual
memory	1179648	926225	290287	493246	262007
pg space	1572864	5215			
	work	pers	clnt	other	
pin	91390	0	0	74176	
in use	258573	4316	335656		
PageSize	PoolSize	inuse	pgsp	pin	virtual
s 4 KB	-	477713	5215	94606	141175
m 64 KB	-	7552	0	4435	7552
L 16 MB	80	0	0	80	0

AIX Paging Space

Allocate Paging Space:

- Configure Server/LPAR with enough physical memory to satisfy memory requirements
- With AIX demand paging, paging space does not have to be large
 - **Provides safety net to prevent system crashes when memory overcommitted.**
- Generally, keep within internal drive or high performing SAN storage

Monitor paging activity:

- `vmstat -s`
- `sar -r`
- `nmon`

Resolve paging issues:

- Reduce file system cache size (MAXPERM, MAXCLIENT)
- Reduce Oracle SGA or PGA (9i or later) size
- Add physical memory

Do not over commit real memory!

A few important notes

AIX 6.1 kernel pinning :

- `vmo -r -o vmm_klock_mode=2`
 - It is enabled by default in 7.1 and can be enabled on 6.1 TL6.
- There were cases of Oracle RAC node eviction due to higher memory allocation and/or bug/feature
- Make sure you are in this release : AIX 6.1 TL6 SP5+, plus APAR IZ95744

USLA heap issue:

- With the release of 11gR2, Oracle introduced a new feature called “on line patching” and is supported on AIX 6.1 TL02 and 7.1 TL0 onwards
- Upgrade to AIX 6.1 TL07 or AIX 7.1 TL01, and then apply the Oracle bug patch 13443029 for database 11.2.0.2 and 11.2.0.3
- If you cannot upgrade to AIX 6.1 TL07 or 7.1 TL01, then apply Oracle patch 10190759, which will have a reduced online-patch functionality
- It is recommended to use AIX 6.1 TL07 SP02 or AIX 7.1 TL01 SP02

P7 special patch:

- Patch 6784747 - Wasted memory in koh-kghu allocations. Free extents of memory might not get used.
- This bug impacts 10.2.0.4/5 and 11.1.0.x releases. This fix is not included in any of the PSU. This issue is fixed in Oracle 11.2.0.1 onwards

Agenda

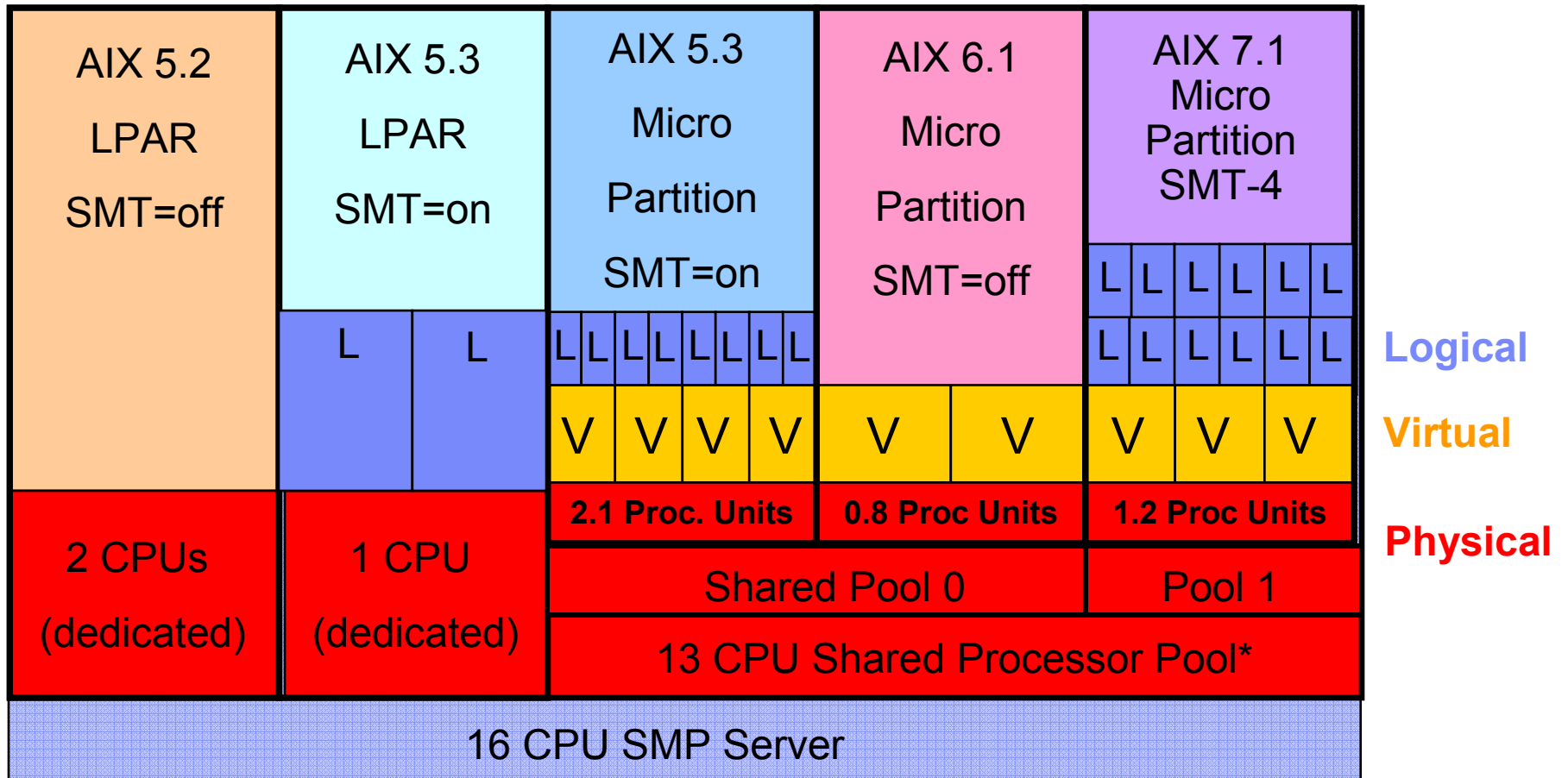
- **AIX Configuration Best Practices for Oracle**
 - Memory
 - **CPU**
 - I/O
 - Network
 - Miscellaneous

CPU Considerations

Oracle Parameters based on the # of CPUs

- DB_WRITER_PROCESSES
- Degree of Parallelism
 - user level
 - table level
 - query level
 - MAX_PARALLEL_SERVERS or
AUTOMATIC_PARALLEL_TUNING (CPU_COUNT *
PARALLEL_THREADS_PER_CPU)
- CPU_COUNT
- FAST_START_PARALLEL_ROLLBACK – should be using UNDO instead
- CBO – execution plan may be affected; check explain plan

Physical, Logical, Virtual Layers



Think “PVL “ P=Physical V=Virtual L=Logical (SMT)

* All activated, non-dedicated CPUs are automatically placed into the shared processor pool.
 Only 2.1+0.8+1.2 = 4.1 processor units of “desired capacity” has been allocated from the pool of 13 CPUs

Virtual Shared Processor Pools - Benefits

Server with 12 processor cores

POWER6/7 Multiple shared pools:

- Can reduce the number of software licenses by putting a limit on the amount of processors an uncapped partition can use
- Up to 64 shared pools

			Server with 12 processor cores														
			LPAR4			LPAR5			LPAR6			LPAR7			LPAR8		
			Uncapped AIX			Uncapped AIX			Uncapped AIX			Uncapped AIX			Uncapped AIX		
			Oracle DB			Oracle DB			OAS App 1			OAS App2			OAS App 3		
			VP = 5			VP = 4			VP = 4			VP = 6			VP = 3		
			Ent. = 2.5			Ent. = 1.70			Ent. = 2.00			Ent. = 2.00			Ent. = 1.00		
LPAR1 i5/OS	LPAR2 AIX Oracle DB	LPAR3 Linux	Virtual Shared pool #1 Max Cap: 5 processors						Virtual Shared pool #2 Max Cap: 6 processors								
Physical Shared Pool (9 processor cores)																	
1	1	1	1	2	3	4	5	6	7	8	9						

Oracle cores to license:

- 1 from dedicated partition LPAR2
 - 5 from pool 1
- = 6

OAS cores to license:

- 6 from pool 2
- = 6

Oracle DB core – license factors:

Power5 and earlier: 0.75
 Power6: 1.0
 Power7: 1.0

Virtual Processor - Folding

- **Dynamically adjusting active Virtual Processors (VPs)**
 - System consolidates loads onto a minimal number of VPs
 - Scheduler computes utilization of VPs every second
 - If VPs needed to host physical utilization is less than the current active VP count, a VP is put to sleep
 - If VPs needed are greater than the current active VPs, more are enabled
 - On by default in AIX 5.3 ML3 and later
 - **vpm_xvcpus tunable**
 - **vpm_fold_policy tunable**
- **Increases processor utilization and affinity**
 - Inactive VPs don't get dispatched and waste physical CPU cycles
 - Fewer VPs can be more accurately dispatched to physical resources by the Hypervisor with potential for improved processor cache efficiency
- **When to adjust – Check with IBM support before changing!**
 - Burst/Batch workloads with short response-time requirements may need sub-second dispatch latency
 - Disable processor folding or manually tune the number of VPs
 - # schedo -o vpm_xvcpus=[-1 | N]
 - Where N specifies the number of VPs to enable in addition to the number of VPs needed to consume physical CPU utilization
 - A value of "-1" disables CPU folding

		SMT	DLPAR	Micro-Partition	LPM	WPAR	AME
	AIX 5.2						
	AIX 5.3						
	AIX 6.1						
	AIX 7.1						
	Oracle 9i						
	Oracle 10g				*1	*3	
	Oracle 11g				*2	*4	*5

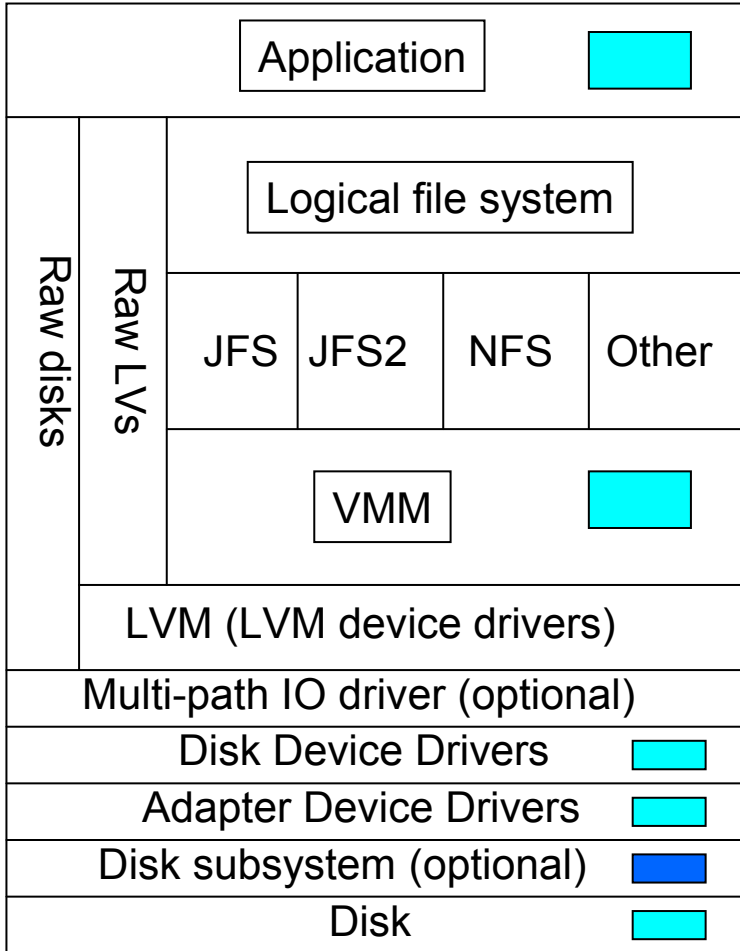
*1 - 10.2.0.4 with minimum of AIX 5.3 TL8 SP4 or AIX 6.1 TL2 SP3
 *2 - 11gR1 with AIX 6.1 TL3 SP1, 11gR2 with AIX 5.3 TL9 SP6, 11gR2 with AIX 6.1 TL4 SP1
 *3 - 10.2.0.4 with minimum AIX 6.1 TL2 SP2 (No AIX 7.1 support at this time)
 *4 - 11.2.0.2 with minimum AIX 6.1 TL2 SP2 (No AIX 7.1 support at this time)
 *5 - 11.2.0.2 and above with minimum AIX 6.1 TL6 SP5 and AIX 7.1

Note: Live partition mobility is certified for 10.2.0.4 and AIX 5.3 TL8 SP4 & 6.1 TL2 SP3.
 Oracle RAC 10.2.0.3 on VIOS 1.3.1.1 & AIX 5.3 TL07 and higher are certified.

Agenda

- **AIX Configuration Best Practices for Oracle**
 - Memory
 - CPU
 - **I/O**
 - Network
 - Miscellaneous

The AIX IO stack



Application memory area caches data to avoid IO

NFS caches file attributes
NFS has a cached filesystem for NFS clients

JFS and JFS2 cache use extra system RAM
JFS uses persistent pages for cache
JFS2 uses client pages for cache

Queues exist for both adapters and disks
Adapter device drivers use DMA for IO
Disk subsystems have read and write cache
Disks have memory to store commands/data

[Blue Cache] Write cache [Red Cache] Read cache or memory area used for IO

IOs can be coalesced (good) or split up (bad) as they go thru the IO stack

AIX Filesystems Mount options

- **Journalized File System (JFS)**

Better for lots of small file creates & deletes

- Buffer caching (default) provides Sequential Read-Ahead, cached writes, etc.
- Direct I/O (DIO) mount/open option → no caching on reads

- **Enhanced JFS (JFS2)**

Better for large files/filesystems

- Buffer caching (default) provides Sequential Read-Ahead, cached writes, etc.
- Direct I/O (DIO) mount/open option → no caching on reads
- Concurrent I/O (CIO) mount/open option → DIO, with write serialization disabled
 - **Use for Oracle .dbf, control files and online redo logs only!!!**

- **GPFS**

Clustered filesystem – the IBM filesystem for RAC

- Non-cached, non-blocking I/Os (similar to JFS2 CIO) for all Oracle files

GPFS and JFS2 with CIO offer similar performance as Raw Devices

AIX Filesystems Mount options (Cont'd)

➤ Direct IO (DIO) – introduced in AIX 4.3.

- Data is transferred directly from the disk to the application buffer, bypassing the file buffer cache hence avoiding double caching (filesystem cache + Oracle SGA).
- Emulates a raw-device implementation.

➤ To mount a filesystem in DIO

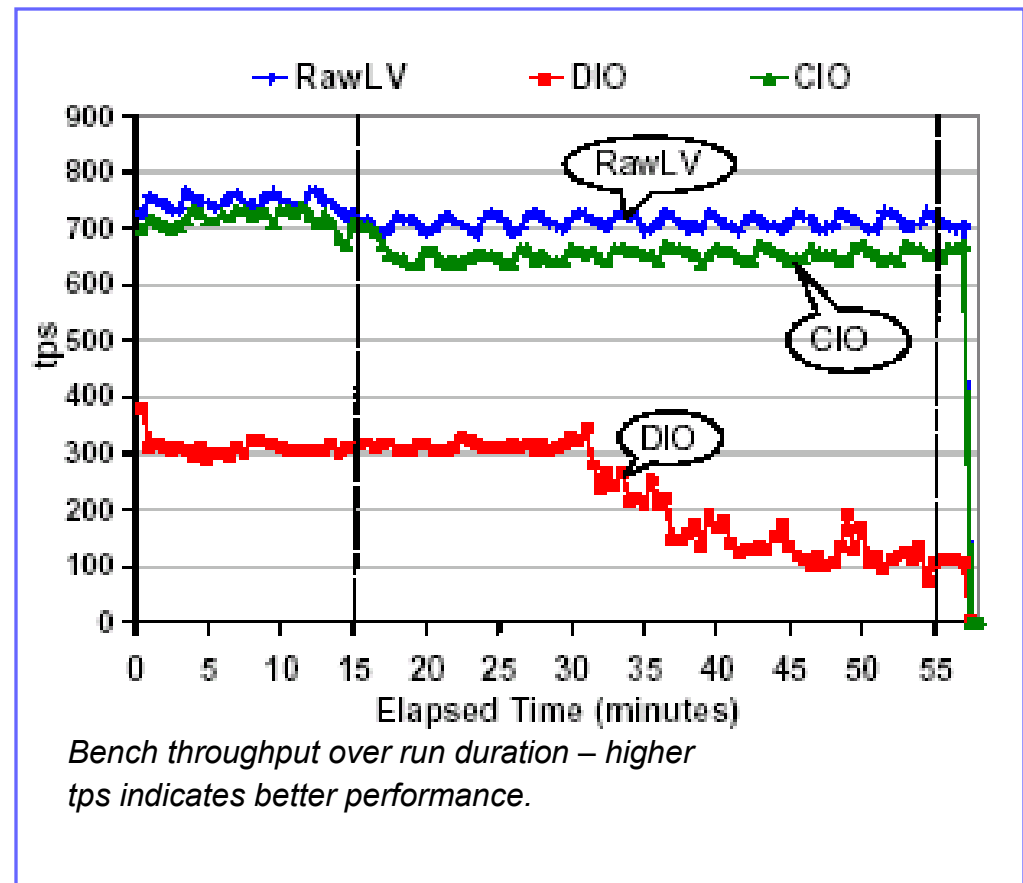
```
$ mount -o dio /data
```

➤ Concurrent IO (CIO) – introduced with JFS2 in AIX 5.2 ML1

- Implicit use of DIO.
- **No Inode locking** : Multiple threads can perform reads and writes on the same file at the same time.
- Performance achieved using CIO is comparable to raw-devices.

➤ To mount a filesystem in CIO:

```
$ mount -o cio /data
```



Cached vs. non-Cached (Direct) I/O

File System caching tends to benefit heavily sequential workloads with low write content. **To enable caching for JFS/JFS2:**

- **Use default filesystem mount options**
- **Set Oracle filesystemio_options=ASYNC**

DIO tends to benefit heavily random access workloads and CIO tends to benefit heavy update workloads. **To disable JFS, JFS2 caching, see the following table:**

	Oracle 9i	Oracle 10g/11g
JFS	Set filesystemio_options=SETALL -or- Use "dio" mount option	Set filesystemio_options=SETALL -or- Use "dio" mount option
JFS2	Use "cio" mount option	Set filesystemio_options=SETALL -or- Use "cio" mount option

Note: Refer Metalink Note #s 272520.1, 257338.1, 360287.1, 232935.1

CIO/DIO implementation Advices

	with Standard mount options	with optimized mount options
Oracle bin and shared lib.	mount -o rw Cached by AIX	mount -o rw Cached by AIX
Oracle Datafiles	mount -o rw Cached by Oracle Cached by AIX	mount -o cio ^{*(1)} Cached by Oracle
Oracle Redolog	mount -o rw Cached by Oracle Cached by AIX	mount -o cio (jfs2 + agblksize=512) Cached by Oracle
Oracle Archivelog	mount -o rw Cached by AIX	mount -o rbrw Use JFS2 write-behind ... but are not kept in AIX Cache.
Oracle Control files	mount -o rw Cached by AIX	mount -o rw Cached by AIX

Flash Recovery Area mount = rbrw

^{*(1)} : to avoid demoted IO : *jfs2 agblksize = Oracle DB block size / n*

CIO Demotion and Filesystem Block Size

Data Base Files (DBF)

- If `db_block_size = 2048` → set `agblksize=2048`
- If `db_block_size >= 4096` → set `agblksize=4096`

Online redolog files & control files

- Set `agblksize=512` and use CIO or DIO

Mount Filesystems with “noatime” option

- AIX/Linux records information about when files were created and last modified as well as last accessed. This may lead to significant I/O performance problems on often accessed files such as the contents of the `$ORACLE`, `/tmp`.

Data Layout for Optimal I/O Performance

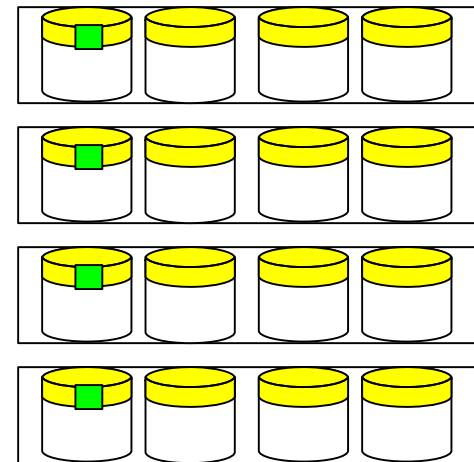
Stripe and mirror everything (SAME) approach:

- Goal is to balance I/O activity across all disks, loops, adapters, etc...
- Avoid/Eliminate I/O hotspots
- Manual file-by-file data placement is time consuming, resource intensive and iterative

Use RAID-5 or RAID-10 to create striped LUNs (hdisks)

Create AIX Volume Group(s) (VG) w/ LUNs from multiple arrays, striping on the front end as well for maximum distribution

- **Physical Partition Spreading (mklv -e x) –or–**
- **Large Grained LVM striping (\geq 1MB stripe size)**



<http://www-1.ibm.com/support/techdocs/atmastr.nsf/WebIndex/WP100319>

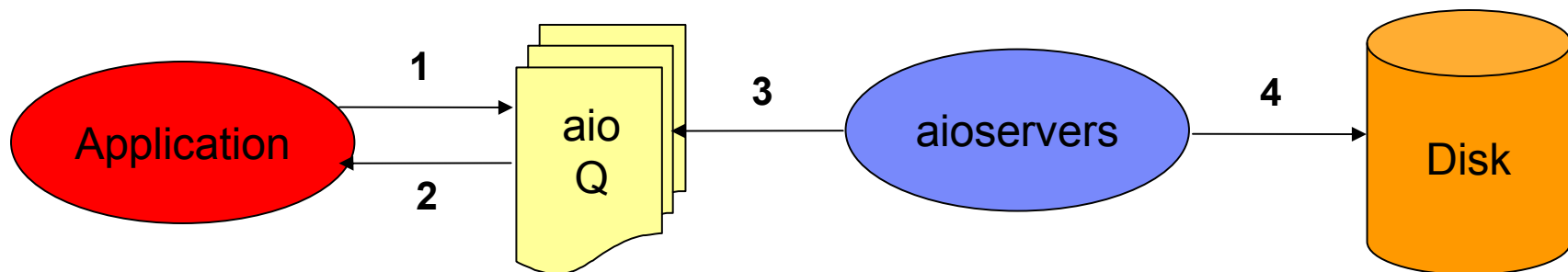
Other I/O Stack Tuning Options (Device Level)

lsattr/chdev:

- **num_cmd_elems** = maximum number of outstanding I/Os for an adapter.
- **queue_depth** = the maximum # of outstanding I/Os for an hdisk.
Recommended/supported maximum is storage subsystem dependent.
- **max_xfer_size** = the maximum allowable I/O transfer size (default is 0x40000 or 256k).
Maximum supported value is storage subsystem dependent. Increasing value (to at least 0x200000) will also increase DMA size from 16 MB to 256 MB.
- **dyntrk** = When set to yes (recommended), allows for immediate re-routing of I/O requests to an alternative path when a device ID (N_PORT_ID) change has been detected.
- **fc_err_recov** = When set to “fast_fail” (recommended), if the driver receives an RSCN notification from the switch, the driver will check to see if the device is still on the fabric and will flush back outstanding I/Os if the device is no longer found.

IO : Asynchronous IO (AIO)

- Allows multiple requests to be sent without to have to wait until the disk subsystem has completed the physical IO.
- Utilization of asynchronous IO is strongly advised whatever the type of file-system and mount option implemented (JFS, JFS2, CIO, DIO).



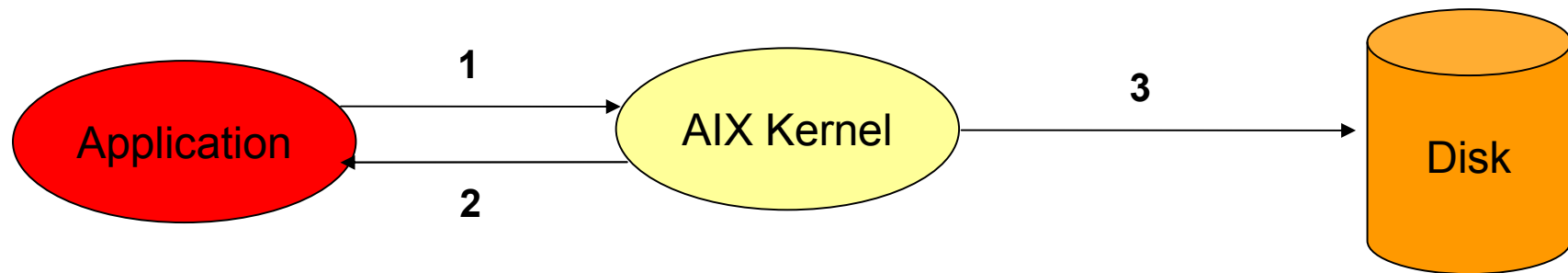
➤ Posix vs Legacy

Since AIX5L V5.3, two types of AIO are now available : Legacy and Posix. For the moment, the Oracle code is using the Legacy AIO servers.

IO : Asynchronous IO (AIO) fastpath

With `fast_path`, IO are queued directly from the application into the LVM layer without any “`aio servers kproc`” operation.

- Better performance compare to non-`fast_path`
- No need to tune the min and max `aio servers`
- No `io servers` proc. => “`ps -k | grep aio | wc -l`” is not relevant, use “`iostat -A`” instead



- **Raw Devices / ASM :**

- check AIO configuration with : `lsattr -El aio0`
enable asynchronous IO **`fast_path`** :

AIX 5L : `chdev -a fastpath=enable -l aio0` (*default since AIX 5.3*)

AIX 6.1/7.1 : `ioo -p -o aio_fastpath=1` (*default setting*)

- **FS with CIO/DIO and AIX 5.3 TL5+ :**

- Activate **`fsfast_path`** (comparable to `fast_path` but for FS + CIO/DIO)

AIX 5L : adding the following line in `/etc/inittab`: **`aioo:2:once:aioo -o fsfast_path=1`**

AIX 6.1/7.1 : `ioo -p -o aio_fsfastpath=1` (*default setting*)

Asynchronous I/O for filesystem environments...

Monitor Oracle usage:

- **Watch alert log and *.trc files in BDUMP directory for warning message:**

“Warning “lio_listio returned EAGAIN”

- If warning messages found, increase maxreqs and/or maxservers

Monitor from AIX:

- “pstat -a | grep aios”
- Use “-A” option for NMON
- iostat -Aq (new in AIX 5.3)

GPFS I/O Related Tunables

- Refer Metalink note 302806.1

Async I/O:

- Oracle parameter `filesystemio_options` is ignored
- Set Oracle parameter `disk_async_io=TRUE`
- `Prefetchthreads` = exactly what the name says
 - Usually set `prefetchthreads=64` (the default)
- `Worker1threads` = GPFS async I/O
 - Set `worker1threads=550-prefetchthreads`
- Set `aio_maxservers=(worker1threads/#cpus) + 10`

Other settings:

- GPFS block size is configurable; most will use 512KB-1MB
- `Pagepool` – GPFS fs buffer cache, not used for RAC but may be for binaries. Default=64M
`mmchconfig pagepool=100M`

I/O Pacing

- **I/O Pacing parameters can be used to prevent large I/O streams from monopolizing CPUs**
 - System backups (mksysb)
 - DB backups (RMAN, Netbackup)
 - Software patch updates

- **When Oracle ClusterWare is used, use AIX 6.1/7.1 Defaults:**
 - `chgsys -l sys0 -a maxpout=8193 -a minpout=4096` (AIX defaults)
 - `nfso -o nfs_iopace_pages=1024` (AIX defaults)
 - **On the Oracle clusterware set : `crsctl set css diagwait 13 -force`**
 - This will delay the OPROCD reboot time to 10secs from 0.5secs during node eviction/reboot, just enough to write the log/trace files for future diagnosis. Metalink note# 559365.1

ASM configurations

AIX parameters

- Async I/O needs to be enabled, but default values may be used

ASM instance parameters

- `ASM_POWER_LIMIT=1`
Makes ASM rebalancing a low-priority operation. May be changed dynamically. It is common to set this value to 0, then increase to a higher value during maintenance windows
- `PROCESSES=25+ 15n`, where `n=#` of instances using ASM

DB instance parameters

- `disk_asynch_io=TRUE`
- `filesystemio_options=ASYNCH`
- Increase Processes by 16
- Increase Large_Pool by 600k
- Increase Shared_Pool by [(1M per 100GB of usable space) + 2M]

Agenda

- **AIX Configuration Best Practices for Oracle**
 - Memory
 - CPU
 - I/O
 - **Network**
 - Miscellaneous

Network Options (no) Parameters

- Set `sb_max` \geq 1 MB (1048576)
- Set `tcp_sendspace` \geq 262144
- Set `tcp_recvspace` \geq 262144
- Set `rfc1323`=1

If `isno=1`, check to see if settings have been overridden at the network interface level:

```
$ no -a | grep use_isno=1
```

```
use_isno=1
```

```
$ lsattr -E -l en0 -H
```

attribute	value	description
<code>rfc1323</code>		N/A
<code>tcp_nodelay</code>	N/A	
<code>tcp_sendspace</code>	N/A	
<code>tcp_recvspace</code>	N/A	
<code>tcp_msdfilt</code>		N/A

Additional Network (no) Parameters for RAC:

- Set `udp_sendspace` = `db_block_size * db_file_multiblock_read_count`
(not less than 65536)
- Set `udp_recvspace` = `10 * udp_sendspace`
 - Must be `< sb_max`
- Increase if buffer overflows occur
- `ipqmaxlen=512` for GPFS environments
- Use Jumbo Frames if supported at the switch layer

Examples:

- `no -a |grep udp_sendspace`
- `no -o -p udp_sendspace=65536`
- `netstat -s |grep "socket buffer overflows"`

Agenda

- **AIX Configuration Best Practices for Oracle**
 - Memory
 - I/O
 - Network
 - **Miscellaneous**

Miscellaneous parameters

- **User Limits (smit chuser)**
 - Soft **FILE** size = -1 (Unlimited)
 - Soft **CPU** time = -1 (Unlimited)
 - Soft **DATA** segment = -1 (Unlimited)
 - Soft **STACK** size -1 (Unlimited)
 - **/etc/security/limits**

- **Maximum number of PROCESSES allowed per user (smit chgsys)**
 - **maxuproc** >= 2048

- **Environment variables:**
 - **AIXTHREAD_SCOPE=S**
 - **LDR_CNTRL=DATAPSIZE=64K@TEXTPSIZE=64K@STACKPSIZE=64K**

Decide based on facts



Marketplace Myths – Quotes from Customers

“I heard that.....”

- **“Oracle DB is only going to run on Sun in the future...”**
- **“Oracle will stop supporting Siebel on Power”**
- **“JD Edwards will stop releasing product on i OS on Power hardware”**
- **“Oracle DB and Oracle Apps will no longer run on Power hardware”**
- **“IBM’s Power is no longer relevant to Oracle”**
- **“POWER systems are losing support across the tech industry”**
- **“Oracle is dropping their System z strategy and support”**
- **“Oracle will move away from System z and it should be expected System z will not be supported in the future”**
- **“System z is the last platform to get an Oracle Patchset Update”**
- **“Oracle releases E-Business Suite fixes on Solaris first”**
- **“Oracle DB is only going to run on Sun in the future...”**
- **“Bugs take longer to get fixed on Power. OEL or RHEL are fixed first”**
- **“Oracle will move away from System z and it should be expected System z will not be supported in the future”**
- **“IBM Power is a Tier 4 port for Fusion Middleware”**

Oracle Certification Of Power Advanced Functionality

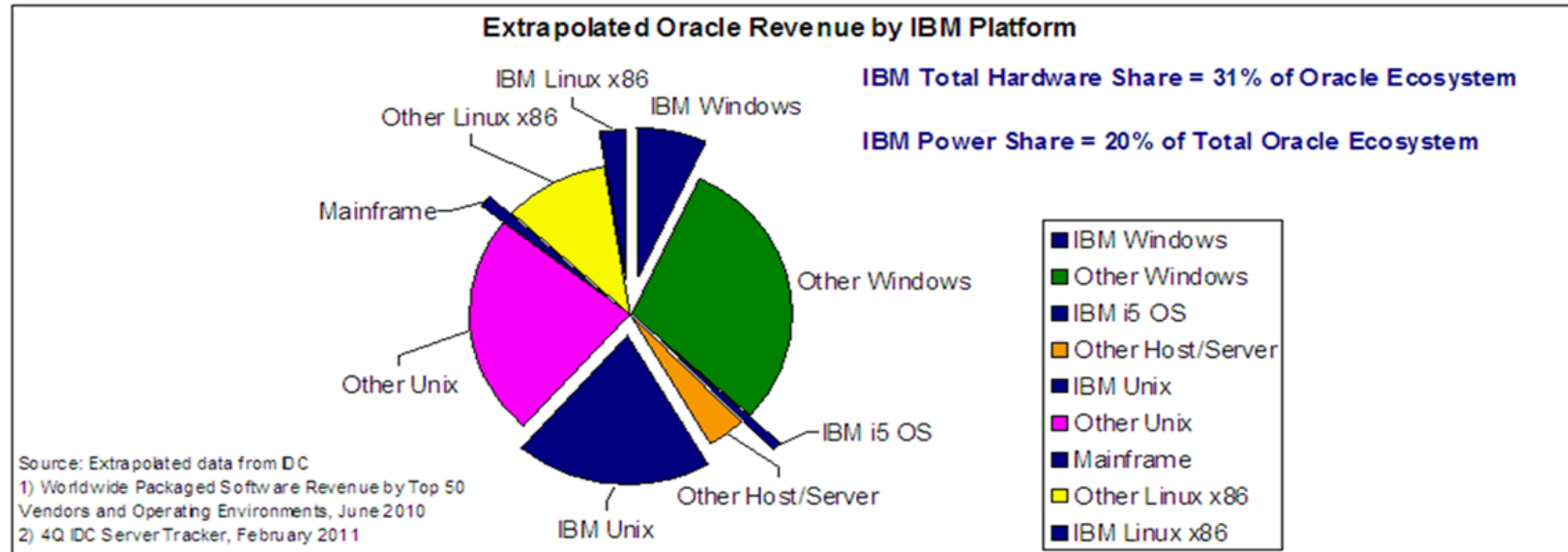
Shows partnership

- **Oracle continues to leverage IBM Power technology advantages**
 - **Micropartitioning**
 - **Sub capacity licensing support (exclusive)**
 - **Simultaneous Multi-Threading (SMT)**
 - **Use of VIOS for RAC and non RAC deployments**
 - **Support for Advanced Memory Expansion**
 - **Oracle DB 11gR2 support for Live Partition Mobility (LPM) on AIX 5.3, 6.1, 7.1**
 - **IBM Exclusive (No other hardware vendor, including Sun, supports LPM)**
 - **PowerHA Support**
 - **IBM GPFS**
 - **FMW 11gR1 released concurrently using IBM JDK 6**
 - **Oracle participated in IBM JDK 6 beta project**
 - **InfiniBand**



What Really Drives the Oracle – IBM Partnership

IBM Hardware Market Share of Oracle Ecosystem



- **IBM is the hardware market share leader in the Oracle ecosystem** driving approximately 31% of Oracle's SW License and maintenance revenue
- **IBM Power is Oracle's top selling hardware platform** from a single manufacturer at 20% share
- Oracle doubled Power's license factor to 1 and sales of Power increased – **Oracle Profited**
- Oracle's year long marketing attack on POWER has produced minimal results as POWER continues to grow market share
- DB2 is Oracle's primary competitor in the enterprise database market
 - **Easy to move Oracle workloads to DB2**
- SAP on DB2 is Oracle's primary competitor in packaged applications
- Websphere is Oracle's primary competitor in the application server market
- IBM is Oracle's primary competitor in middleware products

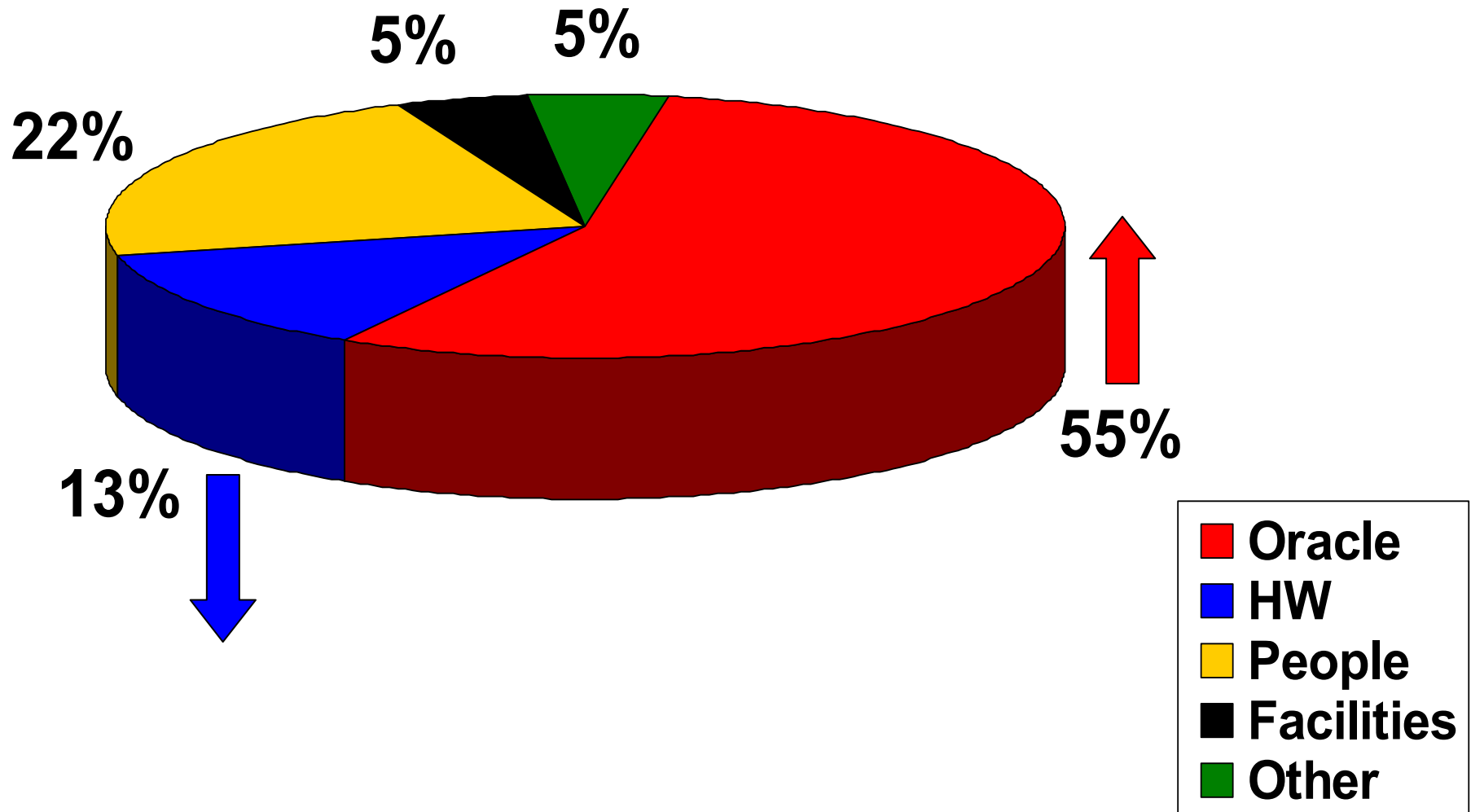
AIX Certification Is Better than OEL

- **Oracle Linux is the laggard**
 - On Sunday 6 February 2011, Oracle Linux 6 was released
 - Oracle Linux is Oracle's Development Platform for all Oracle Database, Middleware, and Application Products
 - As of January 12, 2012 (11 months later), zero Oracle products are certified on Oracle Linux 6

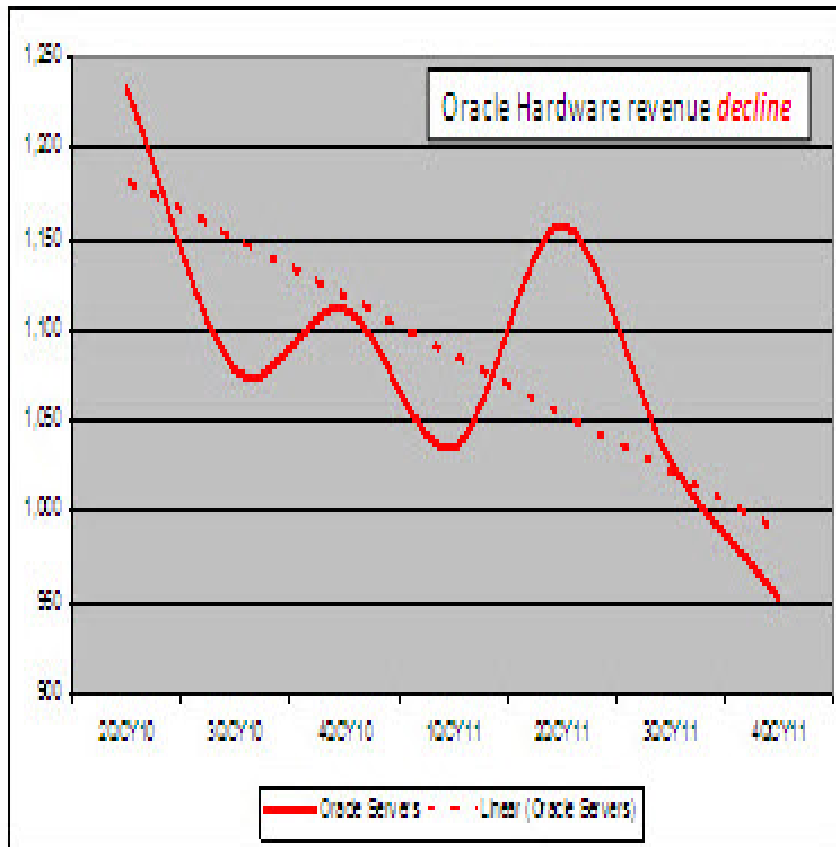
- **AIX is the leader**
 - AIX 7 GA date was in Sept. 2010
 - Oracle Certified DB 11gR2 on AIX 7 in Oct. 2010 (30 days later)
 - 1 year later, E-Business Suite, PeopleSoft, Oracle

Oracle sellers will tell customers that it takes a long time for products to become available on AIX, when in fact the exact opposite is the case. Products were delivered on the latest version of AIX (7.1) more than 11 months sooner than Oracle Linux 6 (6.x). They're still waiting and waiting and waiting for their first product on OL 6...

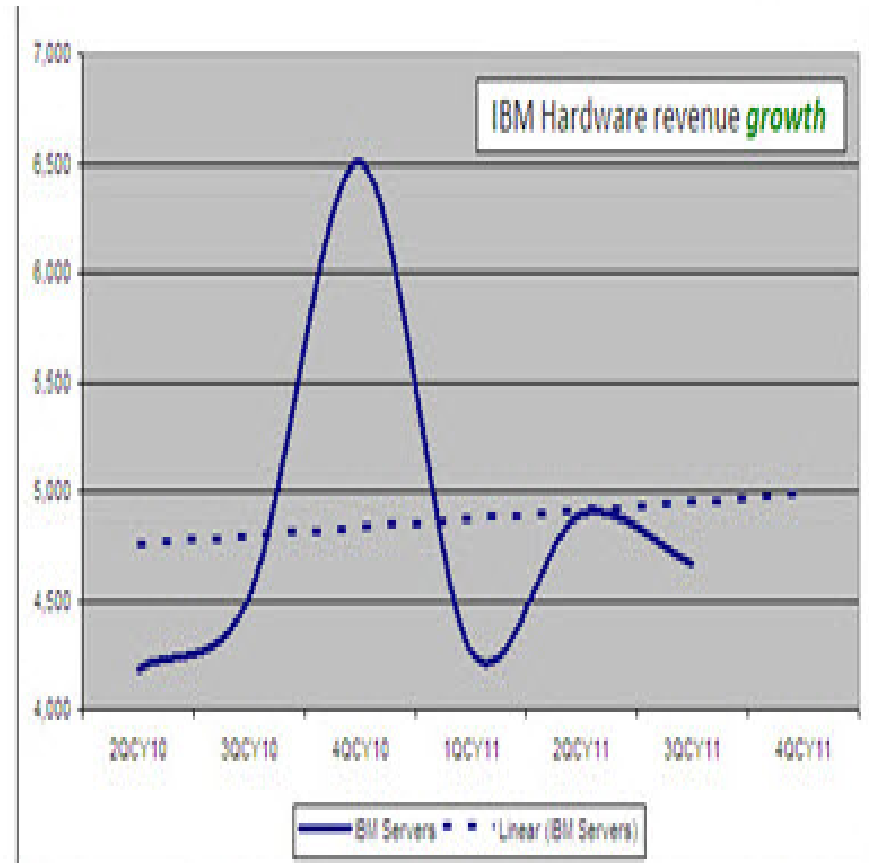
Average Estimated 2011 Oracle SW Solution Costs



Oracle's Hardware Business Continues to Hemorrhage



** Oracle H/W Products Rev 2QCY10 \$1233M thru 4QCY11 \$953 represents decline of 22%



** IBM STG Rev 2QCY10 \$4,187M thru 3QCY11 \$4,672M represents growth of 12%

Advantage Of What Or Whom?

Oracle's Price Increase History for Exadata

Oracle replaces HP with Sun Servers
Result: **2X HW cost increase V1 to V2**

Oracle begins to recommend triple mirroring vs "normal redundancy" in best practices documentation which could increase disk HW and SW up to 32% per usable TB for storage node

Pay separately for support
Result: effective price increase **22% over 3 years**

10% HW Increase

New version has more cores per rack resulting in software increases:
27% SW increase X2-2 over V2
64% SW increase X2-8 over V2

V 1.0
Sept
2008

Sept
2009

March
2010

Sept
2010

July
2011

Sept
2011

- Source: 1. <http://www.oracle.com/us/corporate/pricing/price-lists/index.html> (Price lists from 09/08 - 09/11)
2. Best Practices For Database Consolidation On Exadata Database Machine (Nov 2011)
3. Oracle Automatic Storage Management Administrator's Guide (11g Release 2 (11.2) E18951-02)
http://download.oracle.com/docs/cd/E11882_01/server.112/e18951.pdf

	IBM POWER7® Systems	Oracle Exadata
1. Open vs. Proprietary	Allows the utilization of “best of breed” solution components from IBM and non IBM solution providers. Build the best solution to meet workload requirements	Customer has little choice in solution design. Forced to buy components not relevant to workloads. One size fits all” requires total trust in Oracle as a single source provider.
2. Real Performance	Power 7 and optimized storage are better at: <ol style="list-style-type: none"> 1) Data with write requirements (OLTP) 2) DW with real time updates 3) Complex workloads (reads & writes) 4) Concurrent workloads sharing resources 	Exadata works best if data is read intensive, pre sorted, bulk loaded or can fit entirely into storage server cache. “Smart Scan” functionality not relevant for indexed tables or OLTP workloads
3. Flexible vs. Rigid	Power 7 has proven value in: <ol style="list-style-type: none"> 1) Consolidation of Oracle DB instances 2) Resource virtualization across instances 3) Virtualization of DB and non DB workloads 4) Granular resource upgrades and CoD 	Exadata has significant limitations in: <ol style="list-style-type: none"> 1) Consolidation of DB instances 2) Resource virtualization across instances 3) Running N-1 Oracle sw levels 4) Upgrading hw resources granularly
4. Storage	Intelligent Storage Management: Flash copy, Remote Mirror, San Volume Controller, RAID, Easy Tier, Concurrent Maintenance, No SPOF	Basic cheap disk – no data management. No internal disk RAID Parity –ASM mirroring only, No concurrent maintenance, Multiple SPOF
5. Integration Into Existing Environment	Easily integrated into existing production, test, backup – recovery, storage replication and DR environments	Requires redesign of operational architecture strategy and deployment and new, complex DBA skills in many customer environments
6. Complexity	Less systems to manage Less OS, DB and RAC and images to update RAC is an option, not a requirement	Significantly more systems, software images and RAC nodes to manage and update
7. Solution Cost	Initial acquisition costs are similar Consolidation favours Power (virtualization) Upgrades cost less on Power Cost of integration less (existing Power) Power price / performance costs declining	Initial acquisition costs similar Contractual terms can favour Oracle Upgrades cost more on Exadata Cost of integration more (existing Power) Price /performance costs increasing

Operating System on x86 vs. AIX on Power

AIX on Power Systems has demonstrated strengths and add significant real business value.

- The study correlated the technical components with their associated business metrics that in turn can be used to understand the advantages and key strategies that will help an organization to choose an optimal operating system
- When all of the data is examined, the different OS options were articulated using a graded scorecard approach¹

Category	Linux Score	Windows Score	AIX Score
User Complaints	B	C-	B+
Security Breaches	B+	C-	A+
Platform Resiliency	B-	C-	A
Staffing Requirements	B	C+	B+
Platform Integration	C	C	A
TCO	C+	C	B

Linux is the OS in Exadata !!

1. Graded on a normal college-level type of curve

Source: [Does Your OS Matter? Selecting a Strategic Operating System](#); Solitaire Interglobal Ltd (All rights reserved); October 2011.

- **Where to find the documentation/reference/wiki**



IBM TechDocs - Technical Sales Library

<http://www.ibm.com/support/techdocs>

- **Oracle Architecture and Tuning on AIX v2.20**

<http://www-03.ibm.com/support/techdocs/atmastr.nsf/WebIndex/WP100883>

- **Configuring IBM TotalStorage for Oracle OLTP Applications**

<http://www-03.ibm.com/support/techdocs/atmastr.nsf/WebIndex/WP100319>

- **Diagnosing Oracle® Database Performance on AIX® Using IBM® NMON and Oracle Statspack Reports**

<http://www-03.ibm.com/support/techdocs/atmastr.nsf/WebIndex/WP101720>

- **Breaking the Oracle I/O Performance Bottleneck**

<http://www-03.ibm.com/support/techdocs/atmastr.nsf/WebIndex/PRS3885>

- **Oracle Technology Essential White Papers**

Regularly Updated!

<http://www-03.ibm.com/support/techdocs/atmastr.nsf/WebIndex/WP101559>

There are many more Oracle related white papers – especially covering Oracle RAC with IBM servers and IBM storage.

Oracle Documentation



My Oracle Support: <http://support.oracle.com>

Regularly Updated!

- **282036.1 - Minimum Software Versions and Patches Required to Support Oracle Products on IBM Power Systems**

- **756671.1 - Oracle Recommended Patches -- Oracle Database**

- **Oracle Reference Manuals:**

<http://otn.oracle.com/documentation/index.html>

- **Oracle Certification Info (on MOS as well):**

<http://otn.oracle.com/support/metalink/index.html>

AIX

- AIX 5.3 Product Documentation.
 - <http://publib.boulder.ibm.com/infocenter/pseries/v5r3/index.jsp?topic=/com.ibm.pseries.doc/hardware.htm>
- AIX 6.1 Product Documentation
 - <http://publib.boulder.ibm.com/infocenter/aix/v6r1/index.jsp>
- AIX 7.1 Product Documentation
 - <http://publib.boulder.ibm.com/infocenter/aix/v7r1/index.jsp>
 - <http://www.redbooks.ibm.com/cgi-bin/searchsite.cgi?query=sg247910> (IBM AIX Version 7.1 Differences Guide)
- **IBM Wikis**
 - <https://www.ibm.com/developerworks/wikis/dashboard.action>
- AIX Wiki
 - <http://www.ibm.com/developerworks/wikis/display/WikiPtype/Home>
- AIX Performance Tools (nmon, nmon analyser/consolidator, etc)
 - <http://www.ibm.com/developerworks/wikis/display/WikiPtype/nmon>
- AIX DeveloperWorks
 - <http://www.ibm.com/developerworks/aix>
- AIX multiple page supprt
 - http://www-03.ibm.com/systems/resources/systems_p_os_aix_whitepapers_multiple_page.pdf
- Tuning IBM AIX 5L V5.3 and AIX 6.1 for Oracle Database on POWER systems
 - http://www-304.ibm.com/partnerworld/wps/servlet/ContentHandler/whitepaper/aix/oracle/performance_analysis
- PowerVM Wiki
 - <https://www.ibm.com/developerworks/wikis/display/virtualization/Home>

AIX / POWER

- **AIXpert Blog on Local, Near and Far Memory**

https://www.ibm.com/developerworks/mydeveloperworks/blogs/aixpert/entry/local_near_far_memory_part_1_large_power7_boxes_more_local_memory26?lang=en

- **Oracle Database and 1 TB Segment Aliasing (TD105761)**

<http://www.ibm.com/support/techdocs/atmastr.nsf/WebIndex/TD105761>

- **IBM EnergyScale for POWER7 Processor-Based Systems**

<ftp://public.dhe.ibm.com/common/ssi/ecm/en/pow03039usen/POW03039USEN.PDF>

- **Active Memory Expansion: Overview and Usage Guide**

<ftp://ftp.software.ibm.com/common/ssi/sa/wh/n/pow03037usen/POW03037USEN.PDF>

- **IBM PowerVM Virtualization Active Memory Sharing**

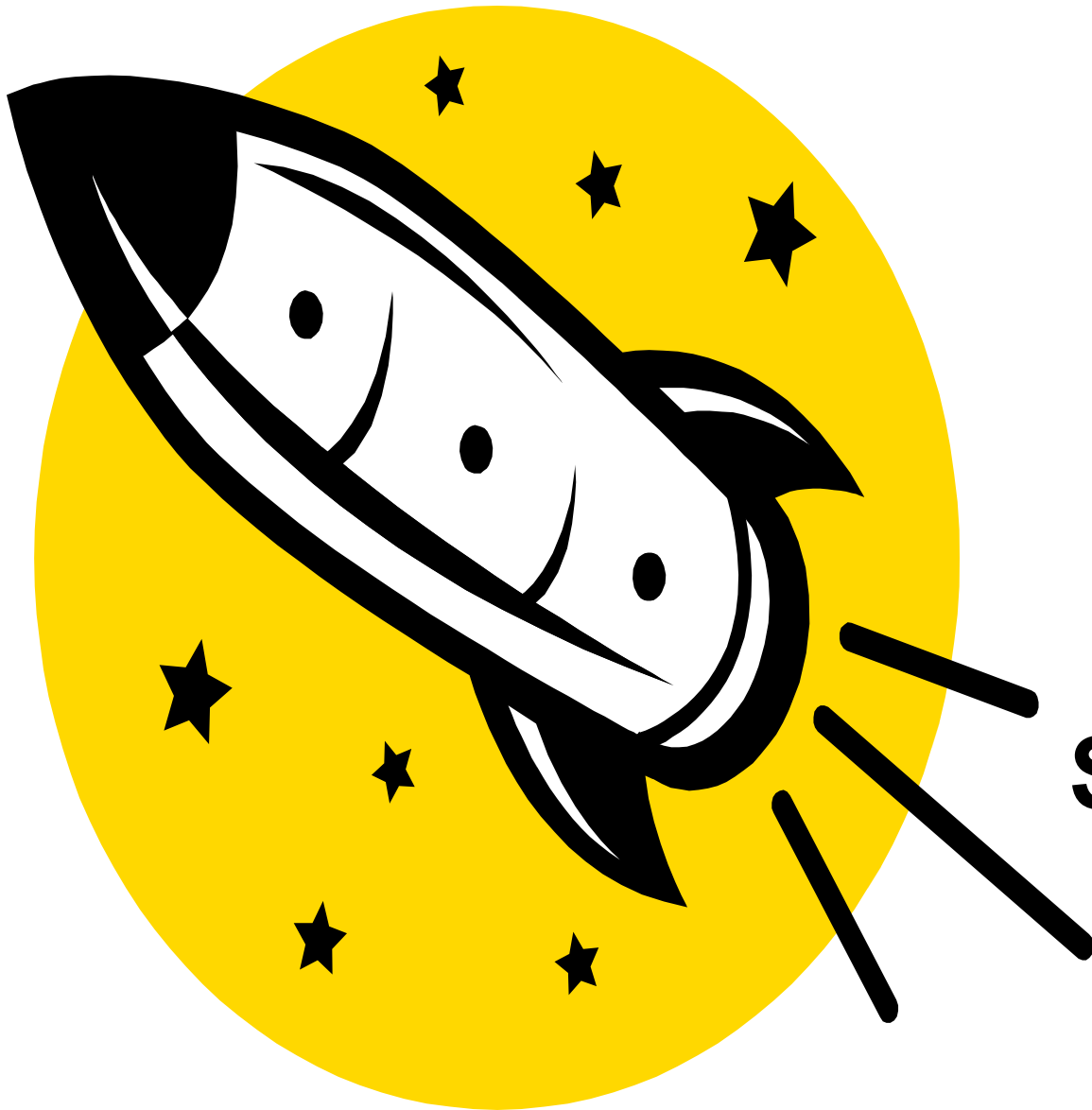
<http://www.redbooks.ibm.com/abstracts/redp4470.html?Open>

- **IBM System p Advanced POWER Virtualization (PowerVM) Best Practices**

<http://www.redbooks.ibm.com/abstracts/redp4194.html?Open>

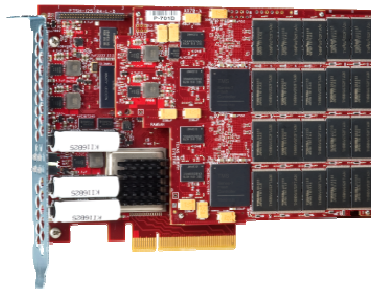
- **Power Systems Enterprise Servers with PowerVM Virtualization and RAS**

<http://www.redbooks.ibm.com/abstracts/sg247965.html?Open>



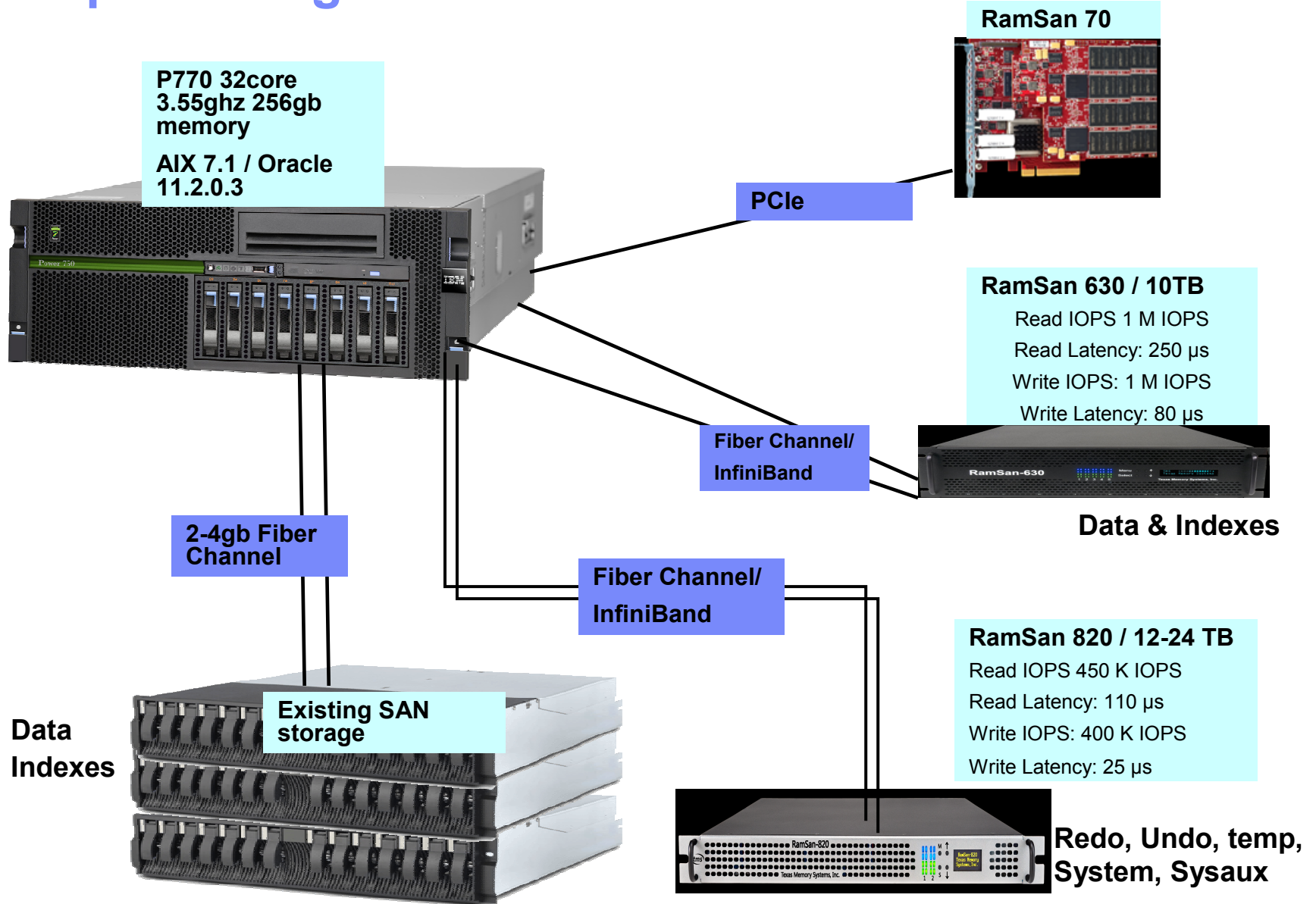
**Show me the
I/O Speed**

RamSan® Solid State Storage from Texas Memory System



RamSan-70	RamSan-710/720	RamSan-810/820	RamSan-630
SLC Flash	SLC Flash	eMLC Flash	SLC Flash
900 GB	5 TB/6-12TB	10 TB/12-24TB	10 TB
600K IOPS	400K IOPS	350K IOPS	1M IOPS
2 GB/s	5 GB/s	4 GB/s	10 GB/s
Full-height, half-length PCIe x8 2.0	1U rackmount, 4x IB or FC ports		3U rackmount, 10x IB or FC ports

Sample Configuration



**Thank
You**

Trademarks

The following are trademarks of the International Business Machines Corporation in the United States and/or other countries. For a complete list of IBM Trademarks, see www.ibm.com/legal/copytrade.shtml: AS/400, DBE, e-business logo, ESCO, eServer, FICON, IBM, IBM Logo, iSeries, MVS, OS/390, pSeries, RS/6000, S/30, VM/ESA, VSE/ESA, Websphere, xSeries, z/OS, zSeries, z/VM

The following are trademarks or registered trademarks of other companies

Lotus, Notes, and Domino are trademarks or registered trademarks of Lotus Development Corporation

Java and all Java-related trademarks and logos are trademarks of Sun Microsystems, Inc., in the United States and other countries

LINUX is a registered trademark of Linux Torvalds

UNIX is a registered trademark of The Open Group in the United States and other countries.

Microsoft, Windows and Windows NT are registered trademarks of Microsoft Corporation.

SET and Secure Electronic Transaction are trademarks owned by SET Secure Electronic Transaction LLC.

Intel is a registered trademark of Intel Corporation

* All other products may be trademarks or registered trademarks of their respective companies.

NOTES:

Performance is in Internal Throughput Rate (ITR) ratio based on measurements and projections using standard IBM benchmarks in a controlled environment. The actual throughput that any user will experience will vary depending upon considerations such as the amount of multiprogramming in the user's job stream, the I/O configuration, the storage configuration, and the workload processed. Therefore, no assurance can be given that an individual user will achieve throughput improvements equivalent to the performance ratios stated here.

IBM hardware products are manufactured from new parts, or new and serviceable used parts. Regardless, our warranty terms apply.

All customer examples cited or described in this presentation are presented as illustrations of the manner in which some customers have used IBM products and the results they may have achieved. Actual environmental costs and performance characteristics will vary depending on individual customer configurations and conditions.

This publication was produced in the United States. IBM may not offer the products, services or features discussed in this document in other countries, and the information may be subject to change without notice. Consult your local IBM business contact for information on the product or services available in your area.

All statements regarding IBM's future direction and intent are subject to change or withdrawal without notice, and represent goals and objectives only.

Information about non-IBM products is obtained from the manufacturers of those products or their published announcements. IBM has not tested those products and cannot confirm the performance, compatibility, or any other claims related to non-IBM products. Questions on the capabilities of non-IBM products should be addressed to the suppliers of those products.

Prices subject to change without notice. Contact your IBM representative or Business Partner for the most current pricing in your geography.

References in this document to IBM products or services do not imply that IBM intends to make them available in every country.

Any proposed use of claims in this presentation outside of the United States must be reviewed by local IBM country counsel prior to such use.

The information could include technical inaccuracies or typographical errors. Changes are periodically made to the information herein; these changes will be incorporated in new editions of the publication. IBM may make improvements and/or changes in the product(s) and/or the program(s) described in this publication at any time without notice.

Any references in this information to non-IBM Web sites are provided for convenience only and do not in any manner serve as an endorsement of those Web sites. The materials at those Web sites are not part of the materials for this IBM product and use of those Web sites is at your own risk.