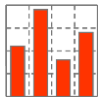
BENCHWARE

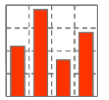


Flash Technology for Oracle Database Server

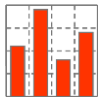
Technical Presentation

May 2014

Contents



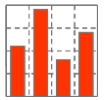
Introduction to Storage Performance Tests



Why measure Storage performance?

- Storage performance is essential not only for overall Oracle database performance, but also for system management tasks like backup, recovery and archiving
- Oracle uses all kinds of I/O patterns, but different o/s calls dependent upon the
  - operating system
  - system load (Oracle changes system call dependent on load)

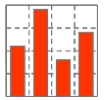
Introduction to Storage Performance Tests



Why measure Storage performance?

- Oracle sequential read
  - User processes: full table scan, full index scan
  - Temp segment
  - Backup, restore, recovery RMAN, Export, Data Pump
  - ARCH: reading online REDO logfile
- Oracle random read
  - User processes
- Oracle sequential write
  - Temp segment
  - Backup, restore RMAN, Export, Data Pump
  - LWGR process: small block size
  - ARCH processes:
    writing archived REDO logfile
  - RVWR process: flashback log file writer
  - CTWR process: block change tracking file
- Oracle random write
  - DBWR processes

Introduction to Storage Performance Tests

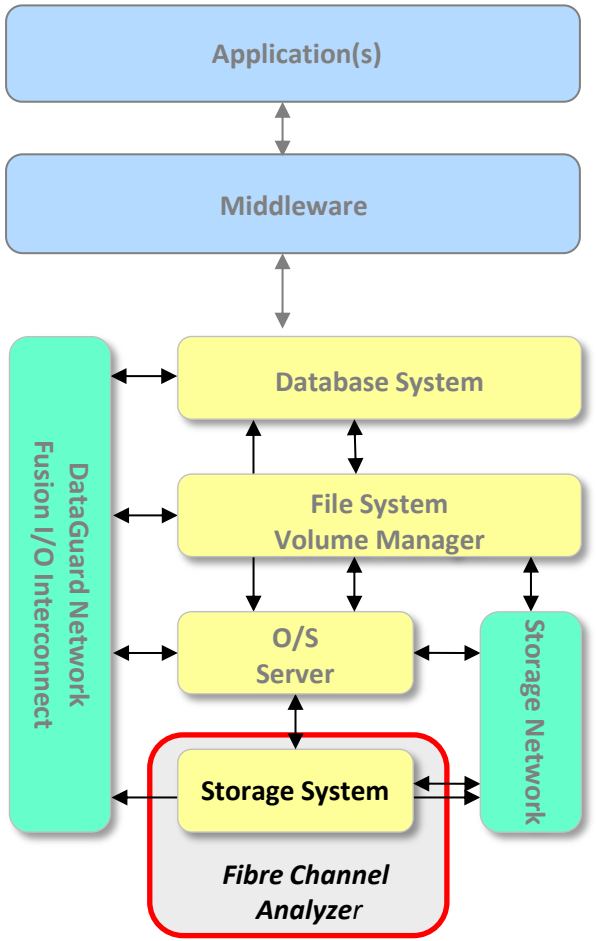


What is measured?

- Storage performance from the Oracle point of view
  - Using database block size
  - I/O service time measured within Oracle
- Throughput
  - Data transfer in mega byte per second [MBps]
  - Data transfer in database blocks per second [dbps]
  - I/O Operations in O/S system calls per second [IOPS]
- Service Time
  - For random I/O operation in [ms] or [µs]
- Efficiency of
  - Auto-Tiering
  - RAID-level
  - Striping
  - Remote mirroring
  - Virtualization

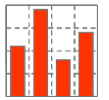
Introduction to Storage Performance Tests

Comparison of I/O Benchmarks

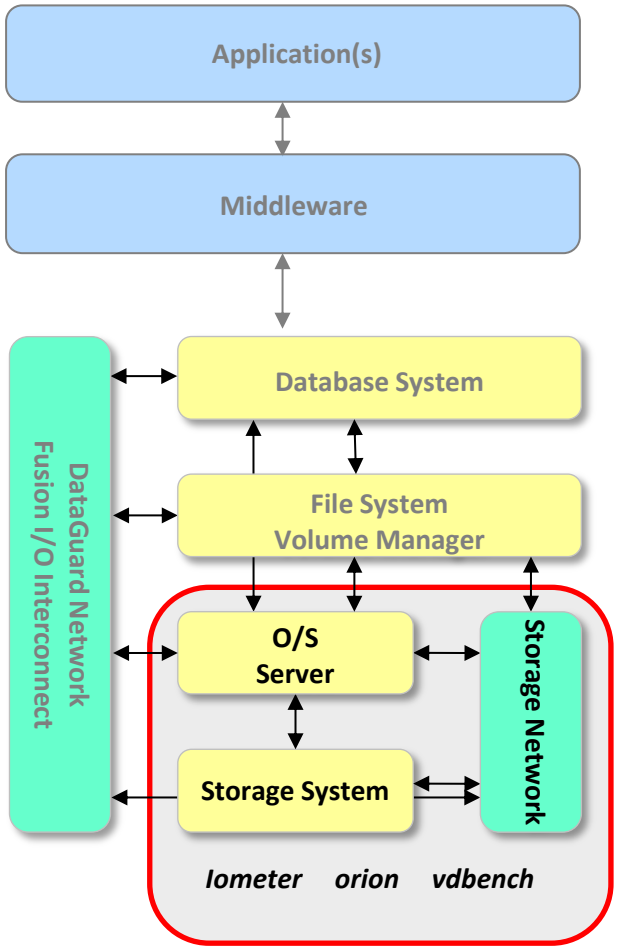


- Storage System I/O Performance
  - Useful to test storage system performance at port level
  - Vendors data sheet numbers

Introduction to Storage Performance Tests

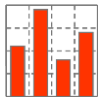


Comparison of I/O Benchmarks



- Server System I/O Performance
  - Tools like vdbench, Iometer, Orion, etc. just generate I/O system calls, but no further I/O processing
  - Useful to analyze transfer performance between storage system and server system
  - Unable to benchmark storage grids
  - Unable to benchmark Oracle ASM infrastructure

Introduction to Storage Performance Tests



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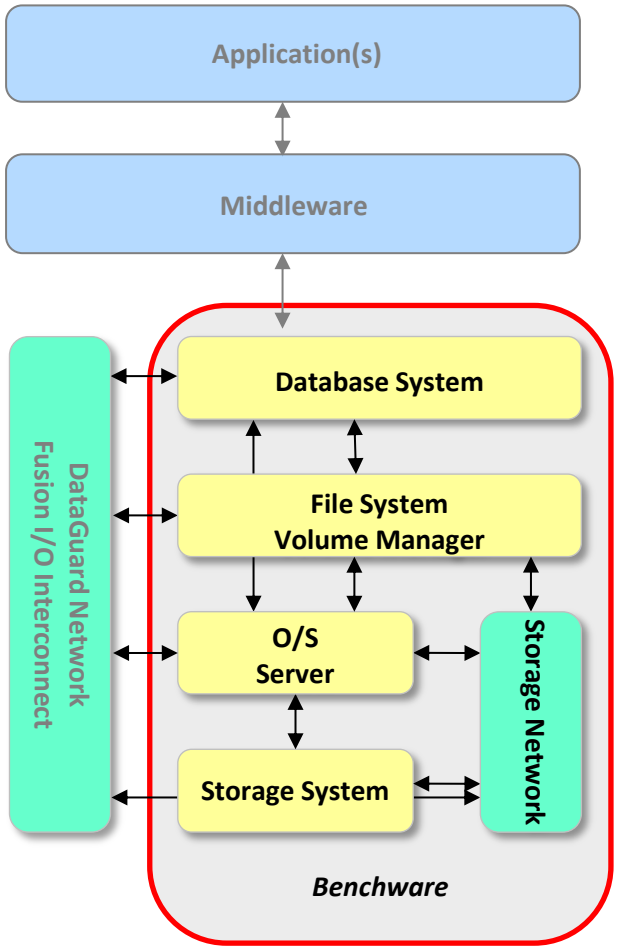
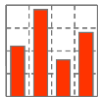
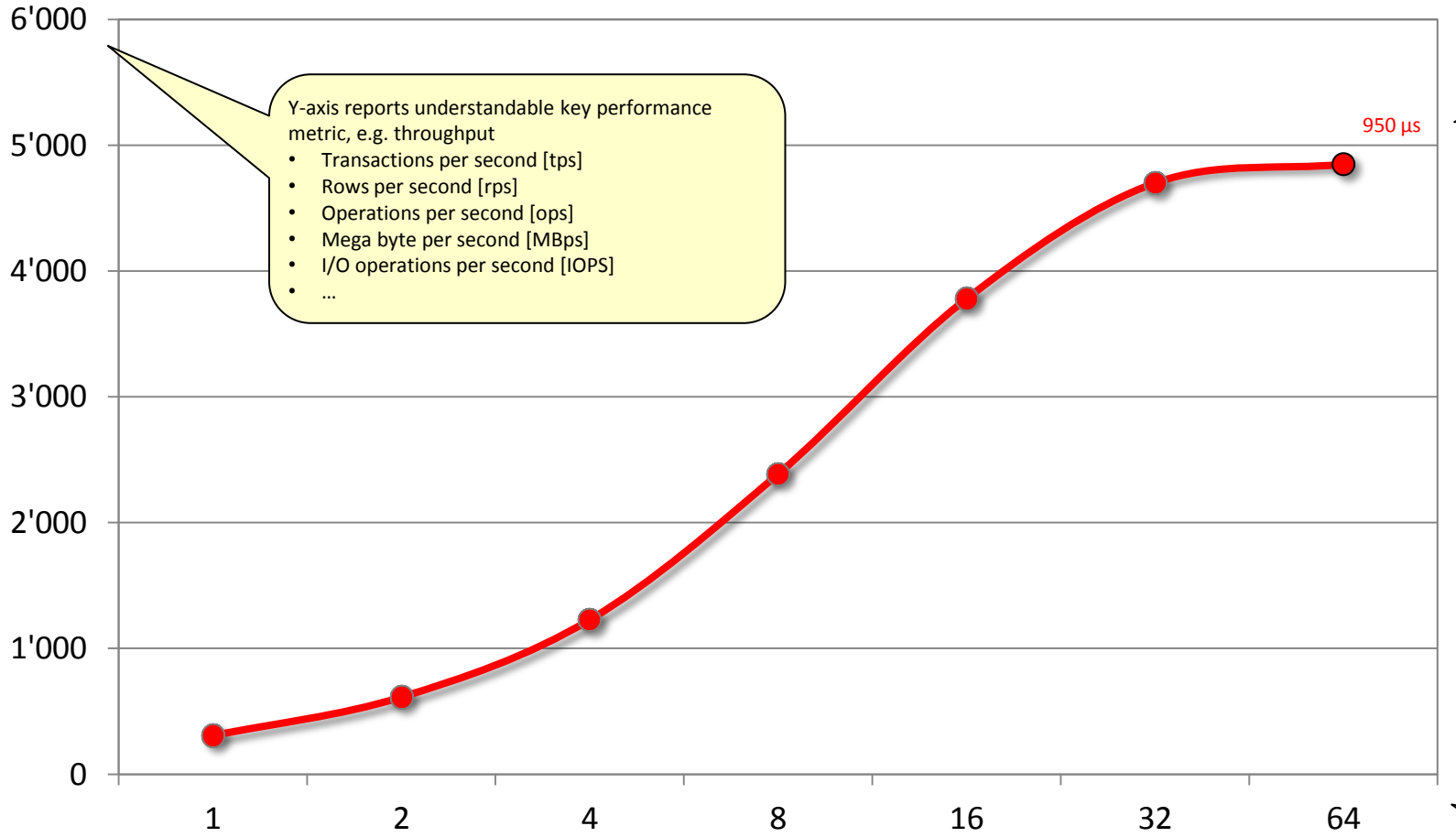


- Database System I/O Performance
  - Most complex I/O operation
  - Database buffer cache management
    - » find a free slot
    - » replace older blocks
    - » synchronize access to buffer cache
    - » database block consistency checks
  - Database I/O needs much more cpu resources than simple I/O generator
    - » Rule of thumb: 25'000 IOPS per x86 core
    - » Throughput does not scale linear
  - `dbms_resource_manager.calibrate_io` does not recognize hybrid storage systems and delivers wrong results

Introduction to Storage Performance Tests



All load profiles from single process to saturation

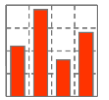


Y-axis reports understandable key performance metric, e.g. throughput
- Transactions per second [tps]
- Rows per second [rps]
- Operations per second [ops]
- Mega byte per second [MBps]
- I/O operations per second [IOPS]
- …

Optional additional information for each measuring point describes quality of performance, e.g.
- I/O service time in µsec
- Operations per core
- …

X-axis reports benchmark load, e.g. degree of parallelism
- Inter SQL or Intra SQL dependent on test
- Parallelism 1 shows best case: only one process
- Number of involved RAC nodes

Introduction to Storage Performance Tests



Monitoring

Speed:
- Best performance for one process
- No conflicts
- No contention

- I/O throughput in MBps and IOPS

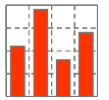
Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU sys [%]	Physical read [iops]	Physical read [dbps]	Physical read [MBps]	Physical write [iops]	Physical write [dbps]	Physical write [MBps]	REDO write [iops]	Hitrate db flash [%]	Hitrate exa flash [%]	Elap time [s]
2	20	STO-14	1	1	1	1	0	10082	1280024	10000	27	29	0	6	0	67	300
	21	STO-14	1	2	1	1	0	25605	3255841	25437	20	25	0	2	0	94	301
	22	STO-14	1	4	1	2	0	49250	6270027	48985	20	24	0	3	0	94	300
	23	STO-14	1	8	1	3	0	87799	11208636	87568	21	25	0	3	0	88	302
	24	STO-14	1	16	1	3	1	98534	12582808	98303	22	26	0	3	0	87	302
	25	STO-14	1	32	1	3	1	103230	13184237	103002	23	26	0	4	0	87	304
	26	STO-14	1	64	1	4	1	105525	13480546	105317	24	27	0	5	0	86	308

Legend:

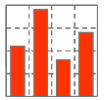
Run	benchmark run id	#N	number of RAC nodes	[rps]	rows per second	[iops]	i/o operations per second	[s]	time in seconds
Tst	benchmark test id	#J	number of load generators (jobs)	[tps]	transactions per second	[dbps]	database blocks per second	[ms]	time in milli seconds
Code	benchmark test code	#T	number of threads (PX)	[ops]	operations per second	[MBps]	mega byte per second	[µs]	time in micro seconds

Max throughput:
- Storage system saturated

Contents



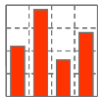
Architectures with Flash Technology



Capacity and access times

Server System	Capacity	Average Access Time	Throughput
CPU register	1 KByte	< 1 ns	
Level 1 Cache on-chip	128 KByte	1 ns	
Level 2 Cache	8 MByte	5 ns	
Level 3 Cache	32 MByte	15 ns	
Main memory	4 TByte	100 ns	Seq/Ran: > 10 GBps
PCI attached flash	n x 2.4 TByte	< 100'000 ns	Seq: > 1 GBps Ran: > 500'000 IOPS
Storage System			
Cache	<= 1 TByte	500'000 ns	
Solid state disks (SSD)	n x 1.4 TByte	1'000'000 ns	Seq: > 1 GBps Ran: > 200'000 IOPS
Hard drive disks (HDD)	n x 600 GByte, 15k rpm	8'000'000 ns	Ran: 250 IOPS
Hard drive disks (HDD)	n x 3.0 TByte, 7.2k rpm	15'000'000 ns	Ran: 120 IOPS
Tape drive	n x 2.5 TByte pro LTO Cartridge	50'000'000'000 ns	Seq: 160 MBps

Architectures with Flash Technology



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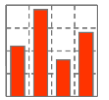
x 80'000

Architectures with Flash Technology



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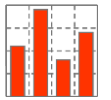
x 80

x 2'000

Architectures with Flash Technology



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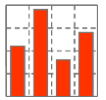
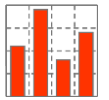
x 10'000

Architectures with Flash Technology



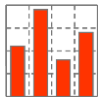
- Flash Technology currently changes architecture of computer systems dramatically
- Flash Technology may change application architecture and algorithms
- Example of a very new flash system: IBM Flash 840 (launched Q2 2014)
  - Rack space 2 units
  - Raw capacity 66 TByte
  - Usable capacity 48 TByte
  - Throughput ~ 500’000 IOPS - 8 kByte - 150 µs (estimation at port level)
  - Power 625 Watt
- Hardware vendors offer different architectures with flash technology for Oracle platforms

Architectures with Flash Technology



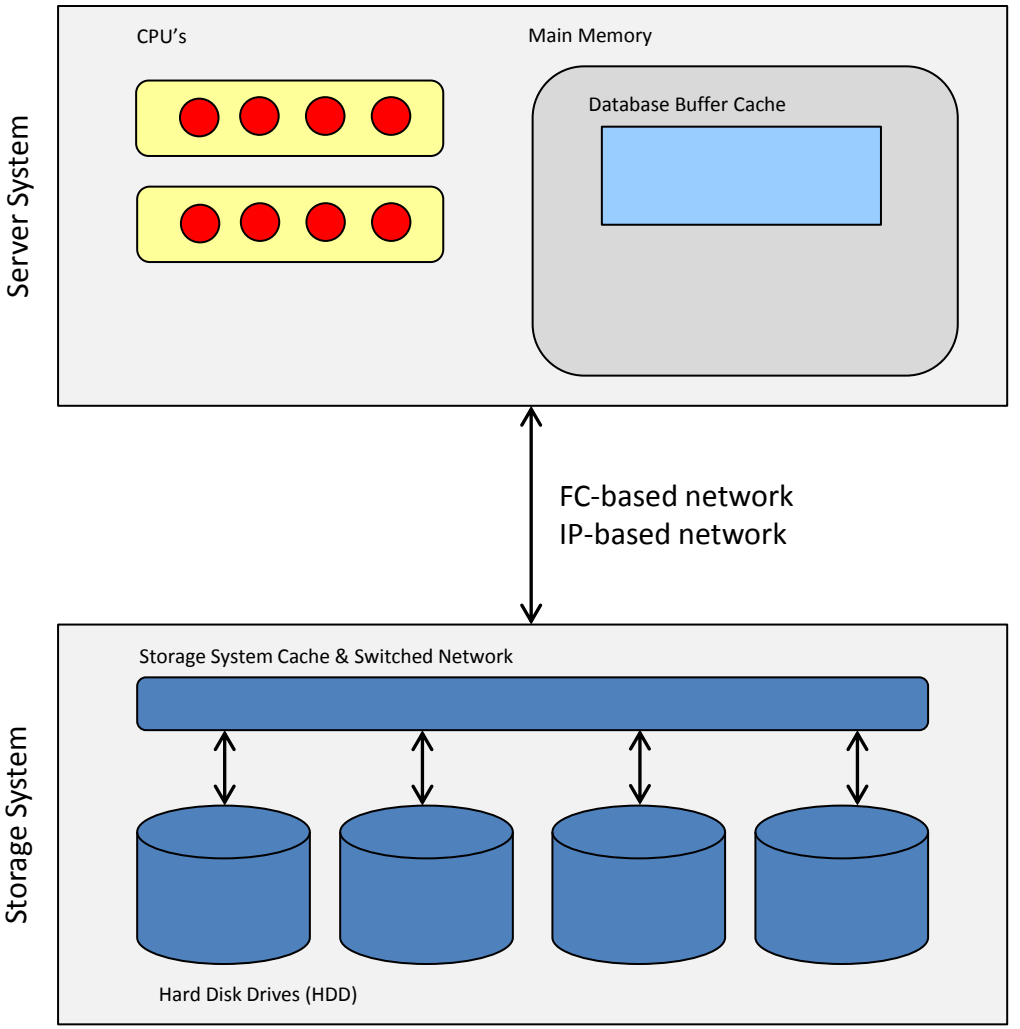
- The architectures provided by hardware vendors differ in
  - Volatility
  - Capacity
  - Throughput
  - Latency
  - Cost
  - Manageability
  - Shareability

Contents



Conventional System Architecture

Architecture without any Flash Technology



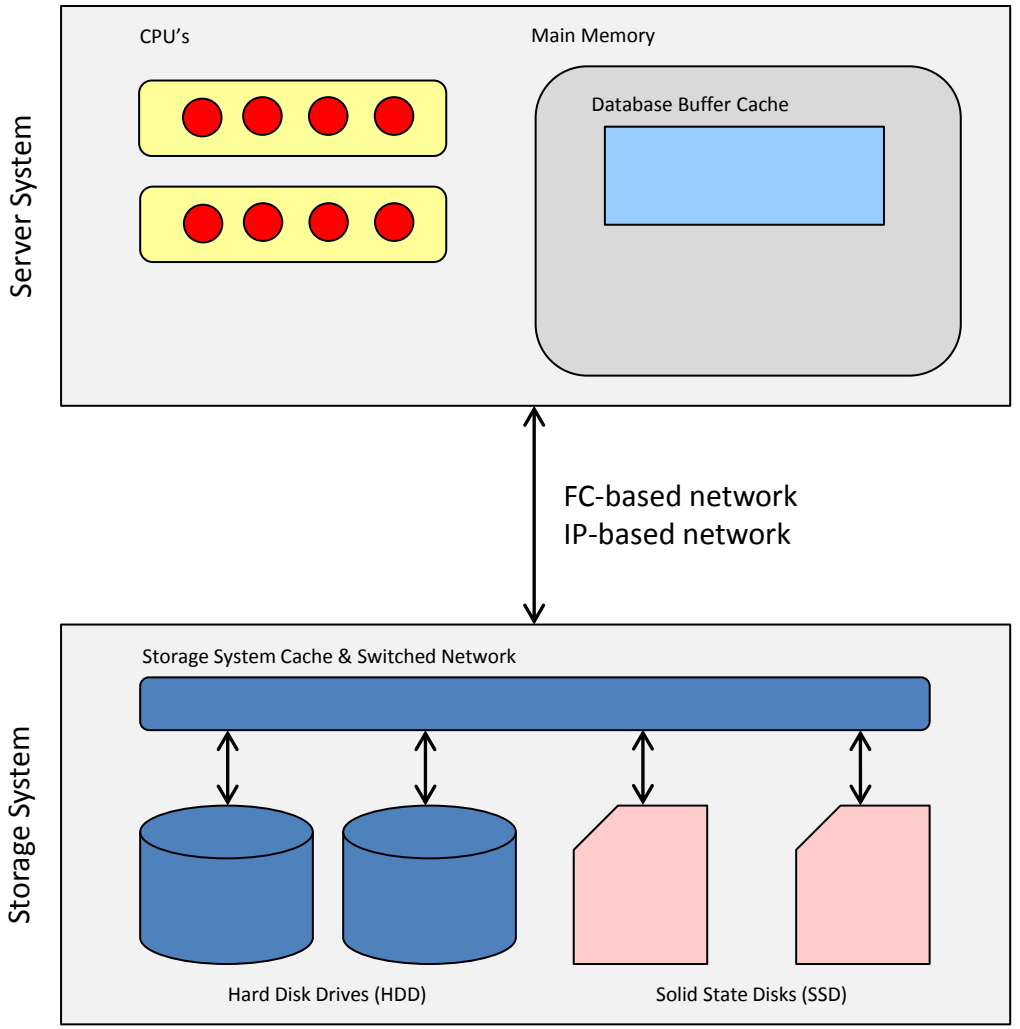
Access times (Sep 2011):

- CPU cache (SRAM) 1×10^{-9} s
- Database cache (DRAM) 100×10^{-9} s

- Storage system cache 500×10^{-6} s
- Storage system hdd 8×10^{-3} s

Storage System with mixed disks

Automatic tiering, e.g. EMC, HDS or IBM storage systems



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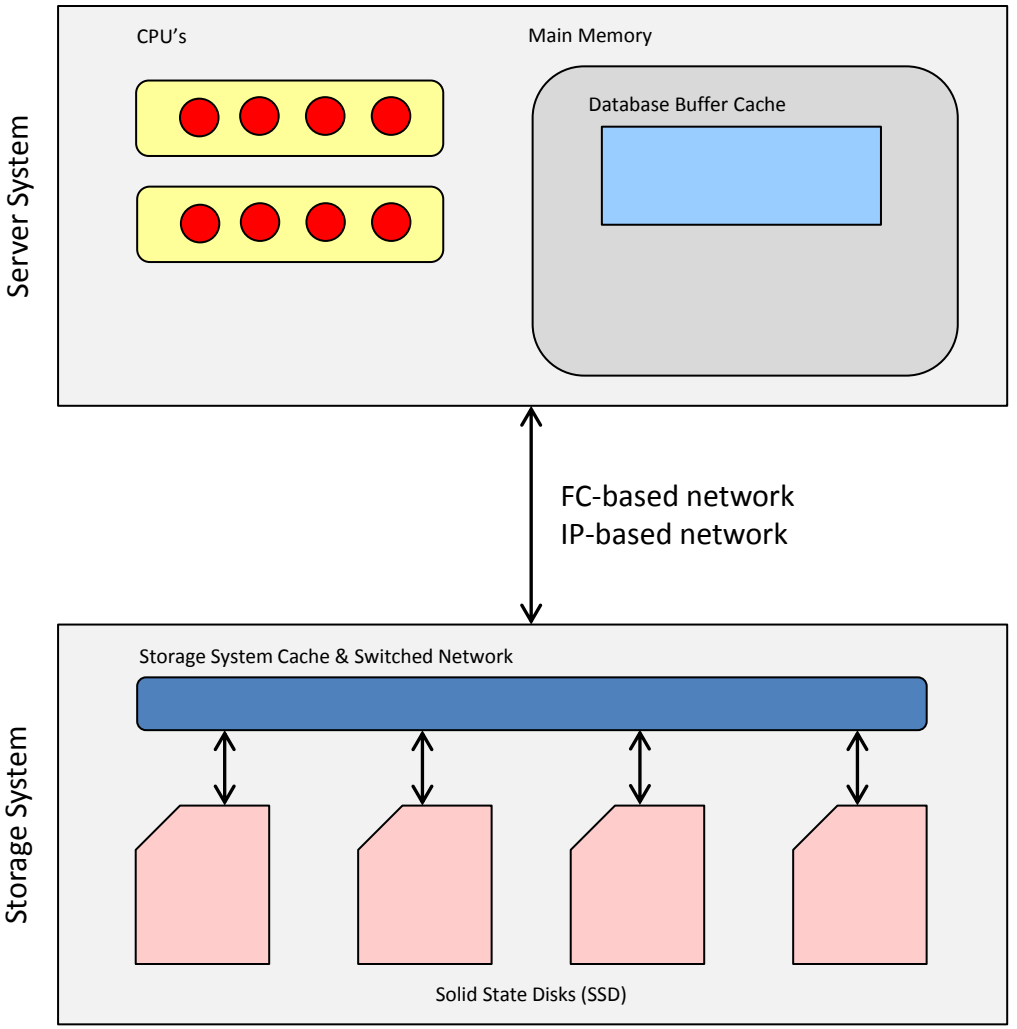
Storage System with solid state disks only

All Flash Array, e.g. HDS HUS VM AFA



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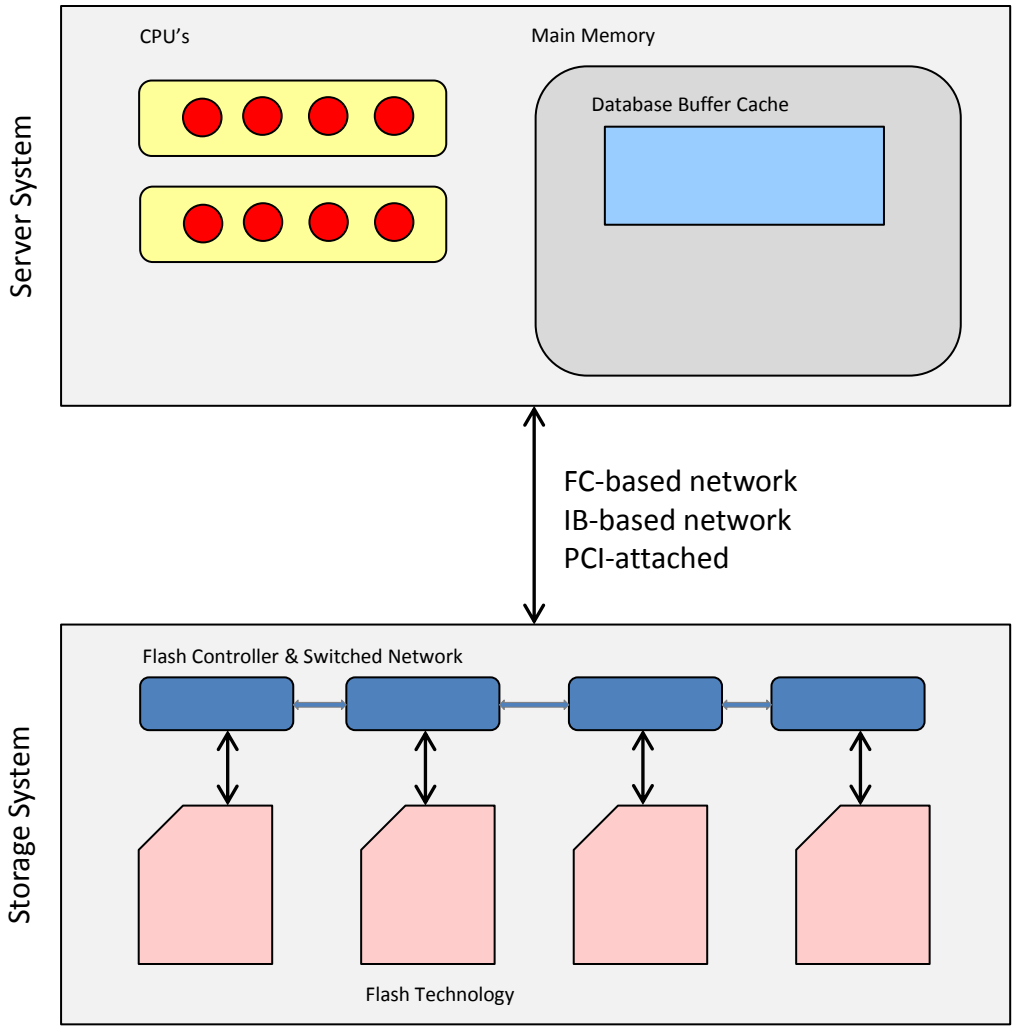
Storage System based on Flash Technology

Storage Systems completely build on flash technology, e.g. Violin, IBM Flash 840



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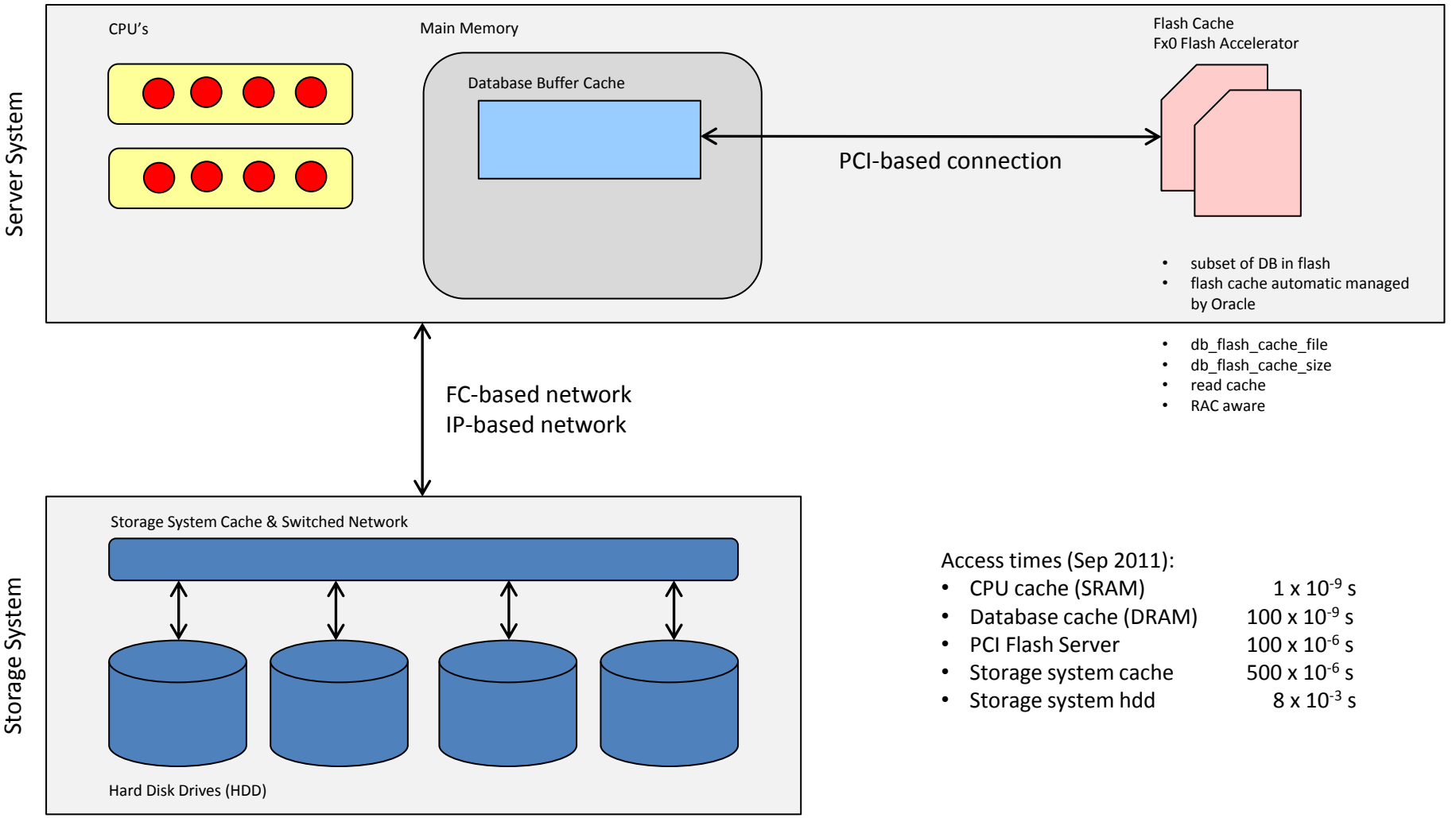
Oracle Database Smart Flash Cache Technology

Specific solution only for Solaris and OEL and Sun Fx0 Flash



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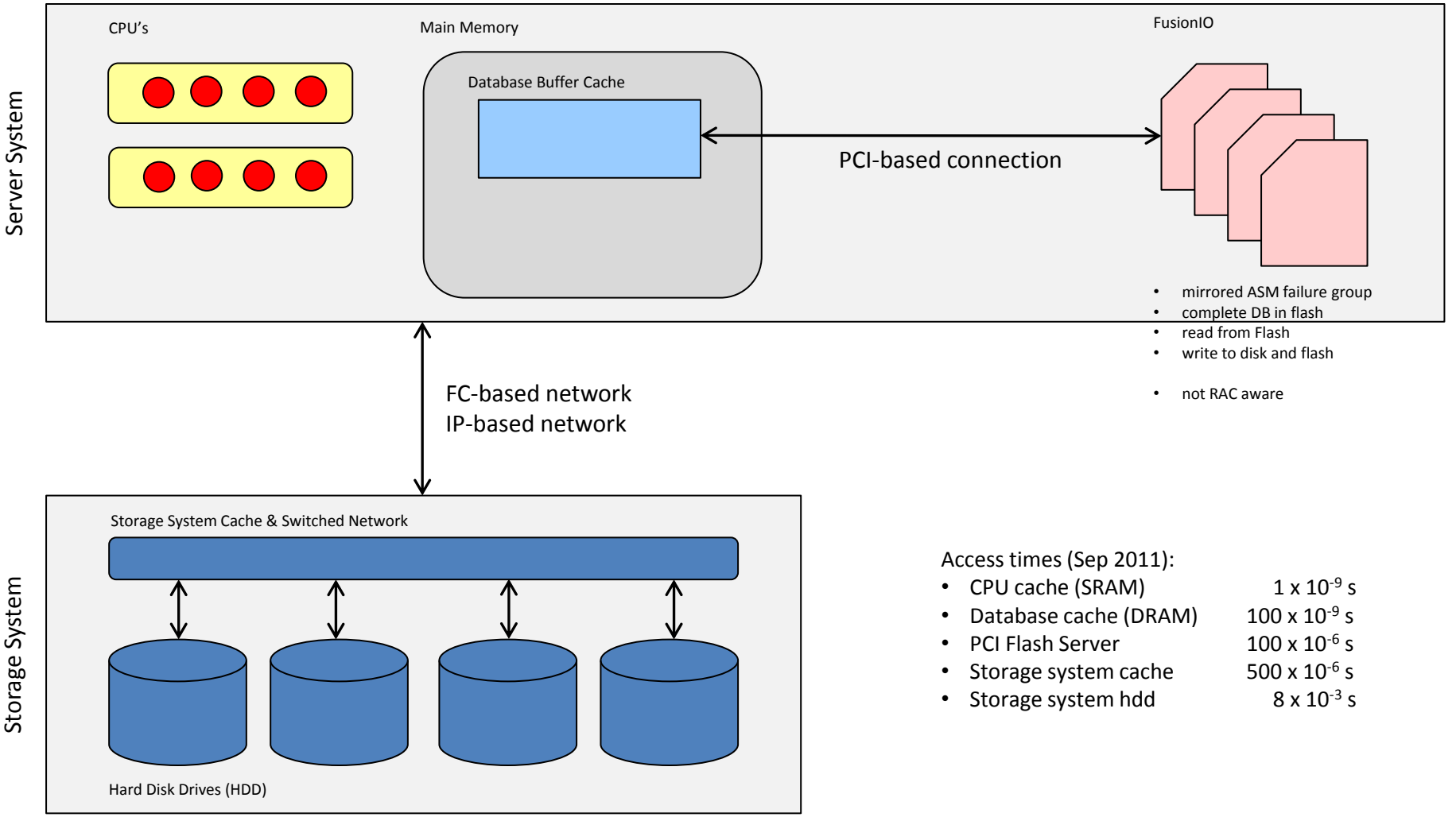
Mirrored Database in Server Fusion IO Cards

Mirrored ASM failure group, e.g. Hitachi UCP



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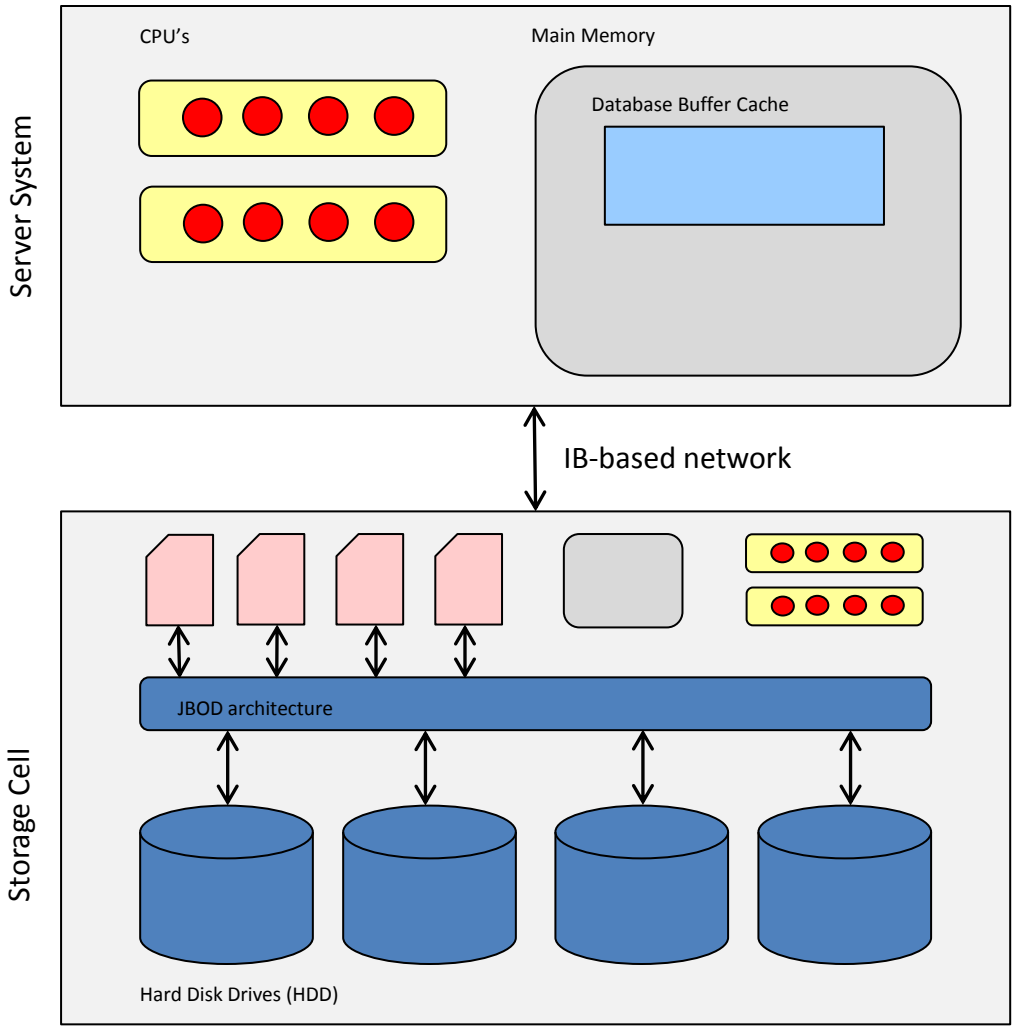
Intelligent Storage Grid

Offloaded database functions, e.g. Oracle Exadata



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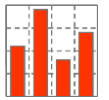
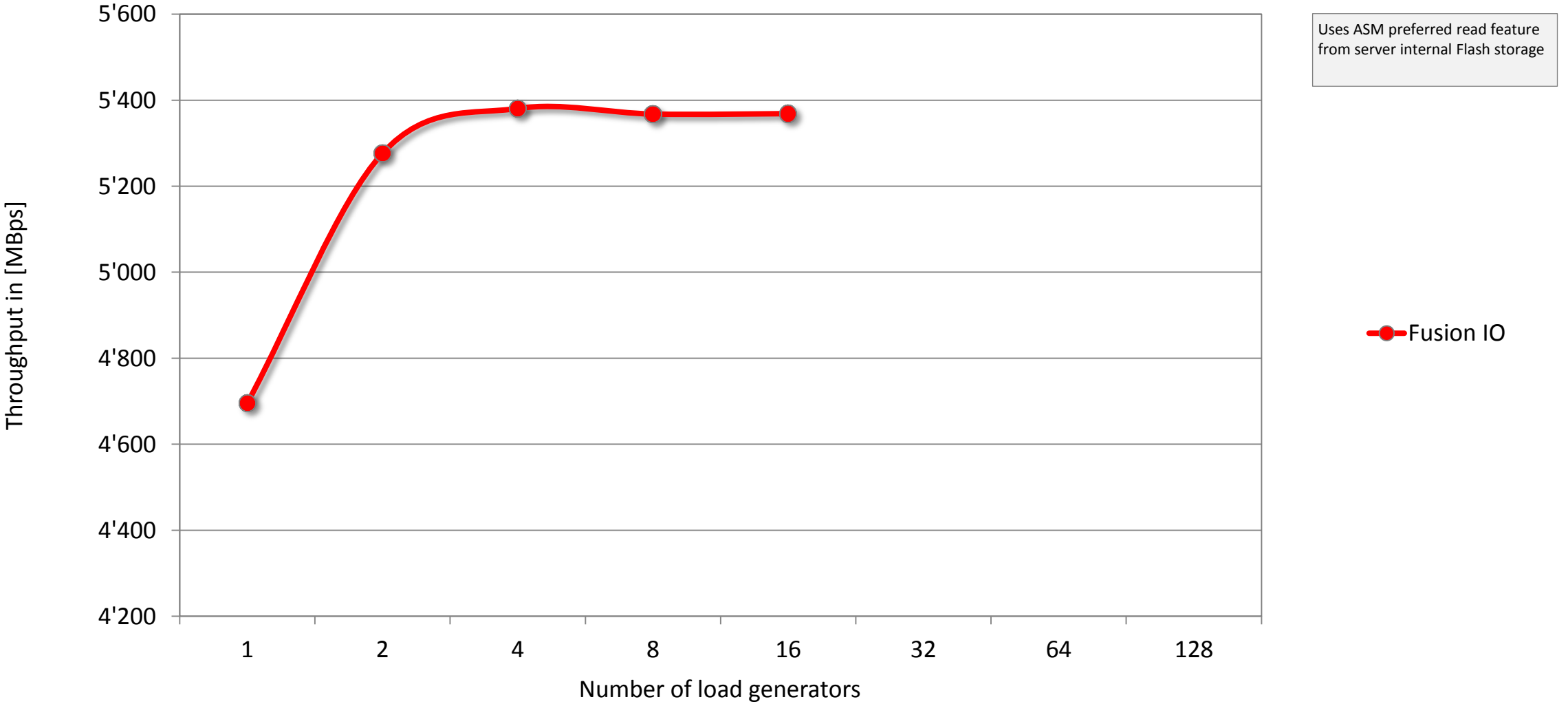


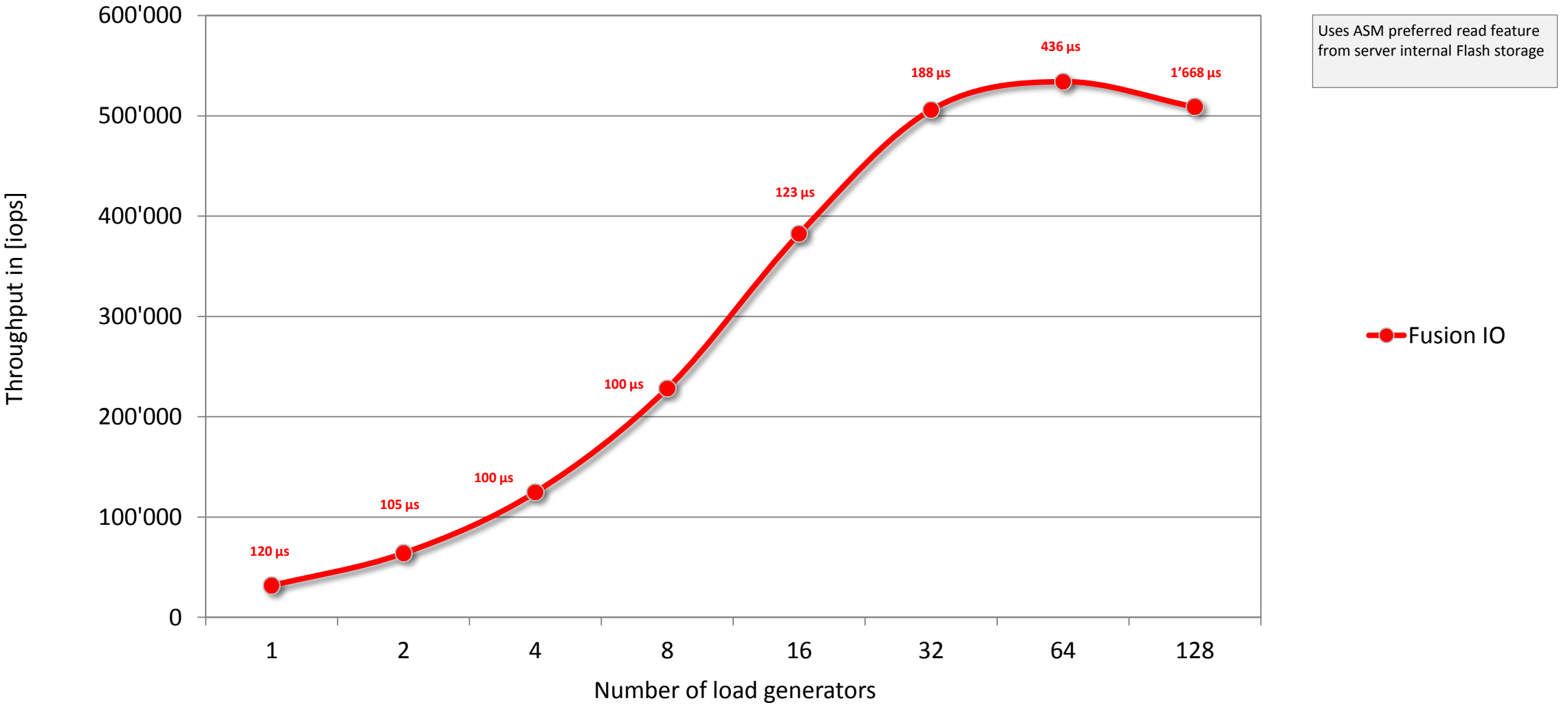
PCI attached Server Flash

Oracle storage performance: sequential read



PCI attached Server Flash

Oracle storage performance: random read



PCI attached Server Flash

Oracle storage performance: random read

Fusion IO

Run	Tst	Code	#N	#J	#T	CPU busy [%]	CPU sys [%]	Physical read [iops]	Physical read [dbps]	Physical read [MBps]	Physical write [iops]	Physical write [dbps]	Physical write [MBps]	REDO write [iops]	Hitrate db flash [%]	Hitrate exa flash [%]	Elap time [s]
15	10	STO-62	1	1	1	3	2	31747	31745	248	11	23	0	2	0	0	51
	11	STO-62	1	2	1	6	4	64039	64037	500	59	68	1	5	0	0	51
	12	STO-62	1	4	1	12	7	124897	124895	976	164	168	1	10	0	0	52
	13	STO-62	1	8	1	23	13	228361	228359	1784	356	351	3	19	0	0	57
	14	STO-62	1	16	1	45	27	382520	382518	2988	629	607	5	31	0	0	68
	15	STO-62	1	32	1	77	45	506050	506047	3954	854	812	6	41	0	0	103
	16	STO-62	1	64	1	95	51	534207	534206	4174	879	832	7	41	0	0	196
	17	STO-62	1	128	1	98	51	508957	508962	3976	810	764	6	40	0	0	305
	18	STO-62	1	256	1	98	48	508889	508888	3976	793	730	6	61	0	0	310

Top 5 Timed Foreground Events

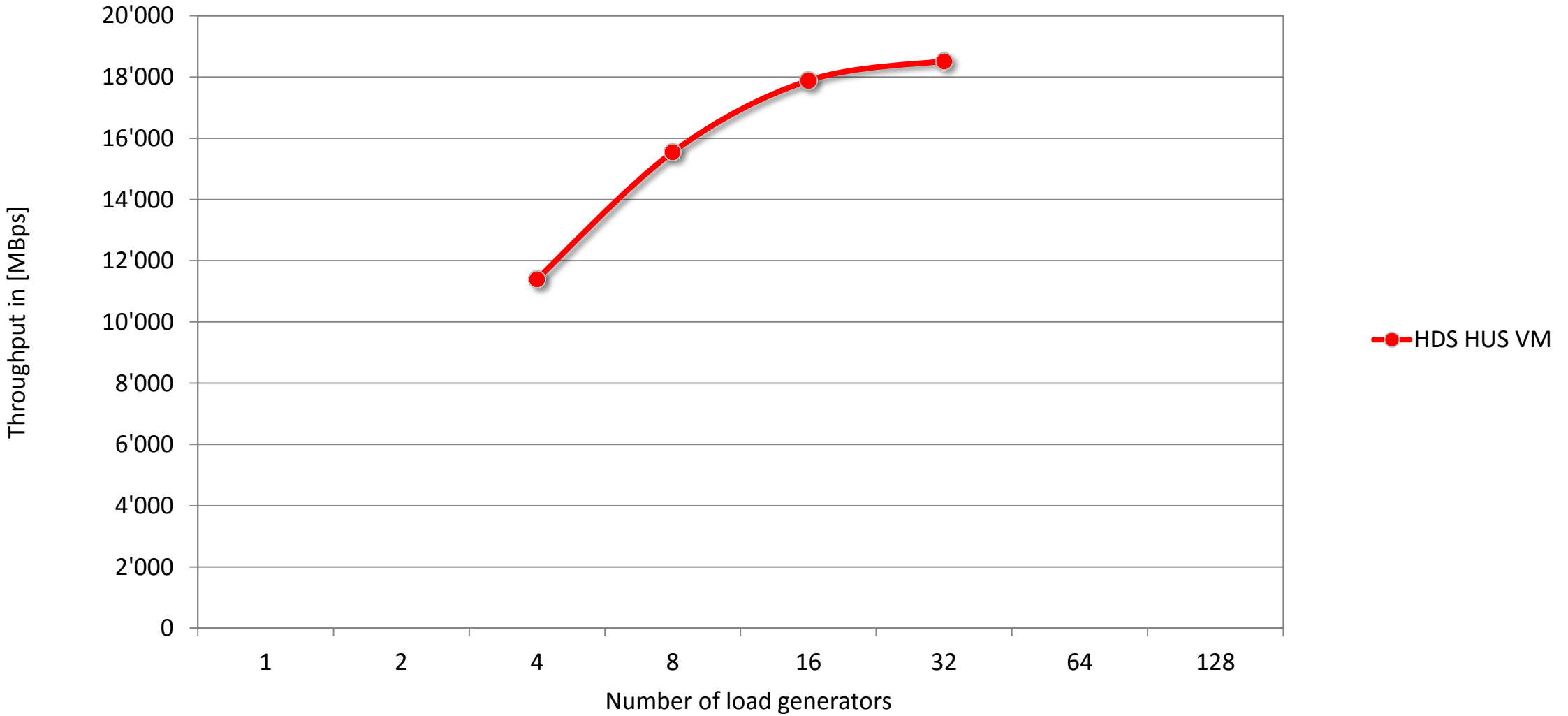
Event	Waits	Time(s)	Avg wait (ms)	% DB time	Wait Class
DB CPU		4,451		20.9	
db file parallel read	2,686,643	2,033	1	9.6	User I/O
db file sequential read	3,079,002	1,343	0	6.3	User I/O

Remarks:

- *In this test case, Oracle optimizes random I/O operations*
- *"db file sequential read" is a true single block read operation (one system call per database block read)*
- *"db file parallel read" is an optimized non-contiguous multi block random read operation (one system call for at least 2 or more database block read)*

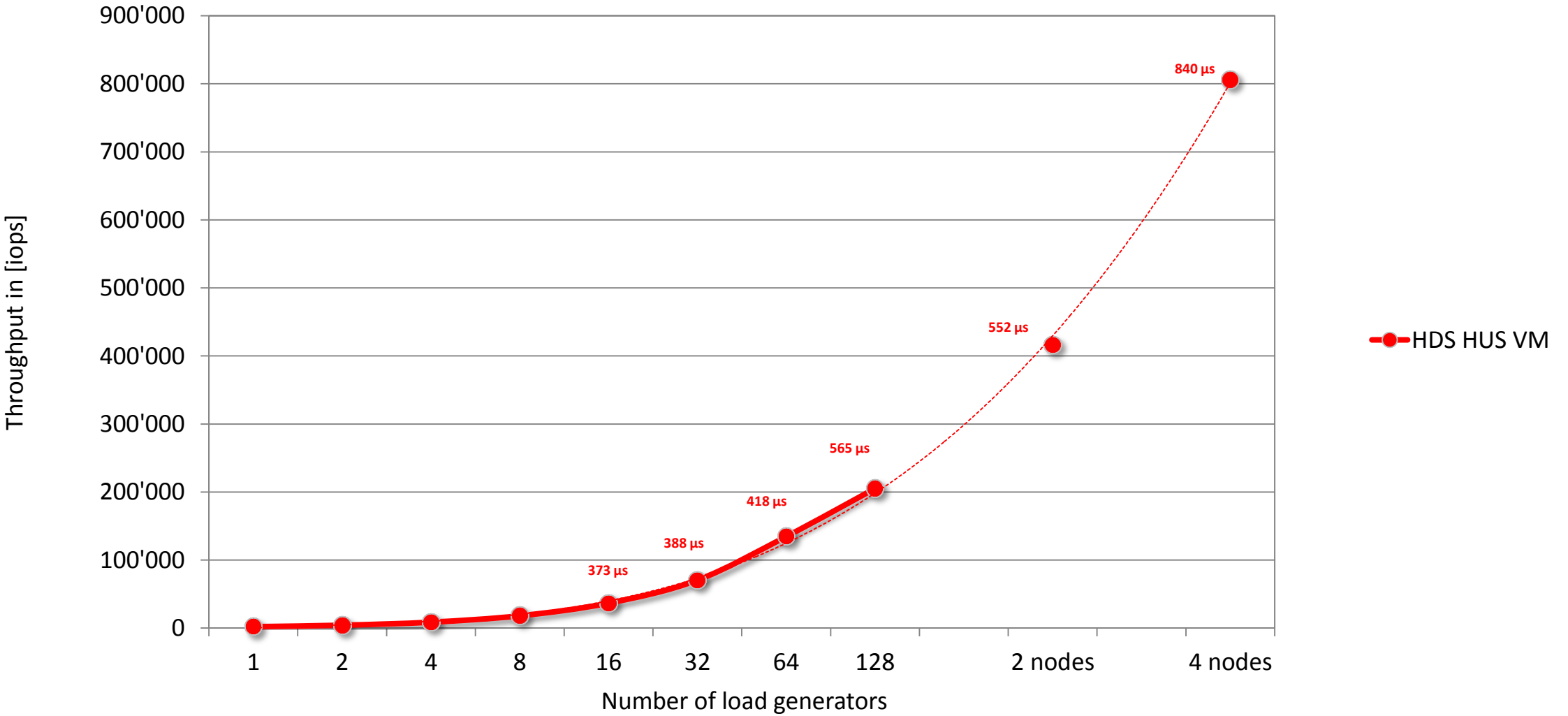
Conventional Storage Performance AFA

Oracle storage performance: sequential read



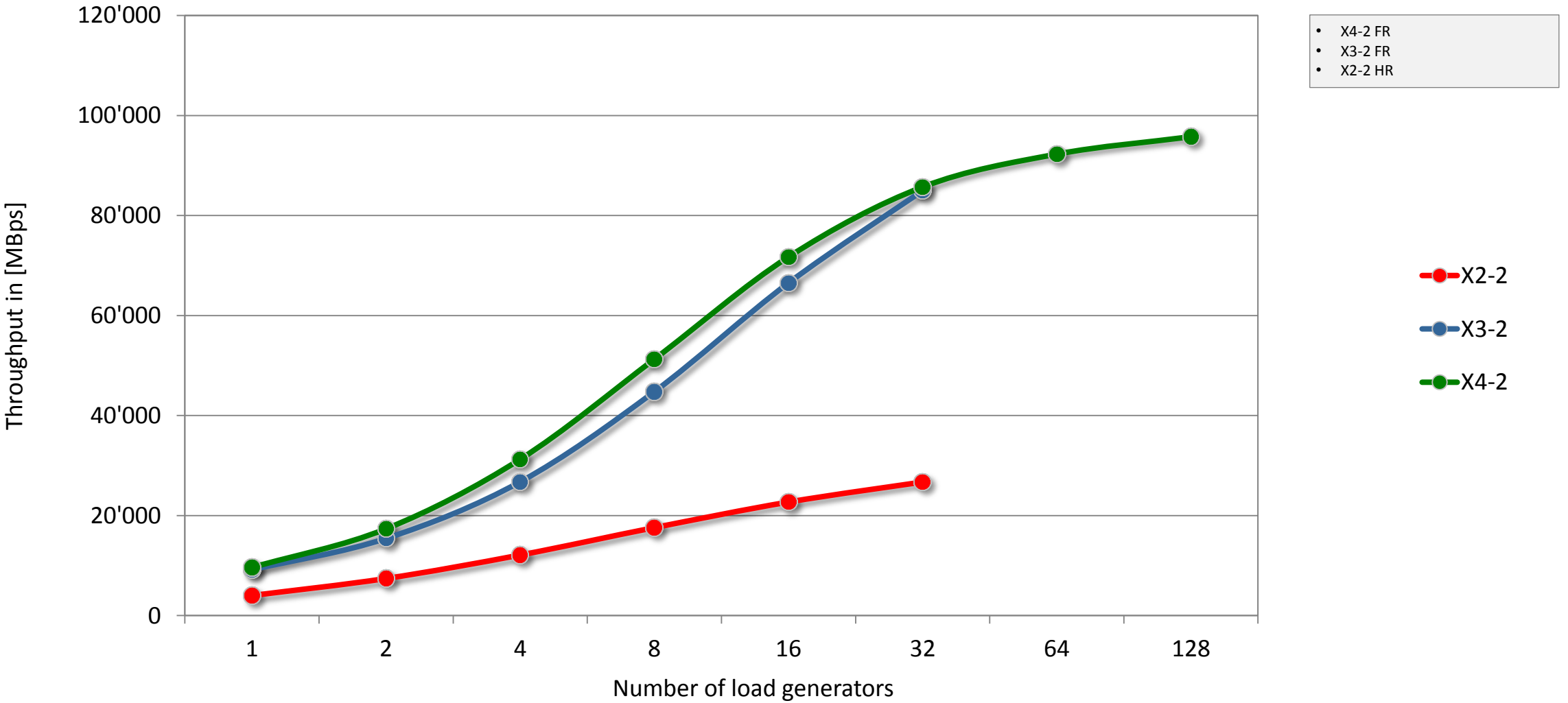
Conventional Storage Performance AFA

Oracle storage performance: random read



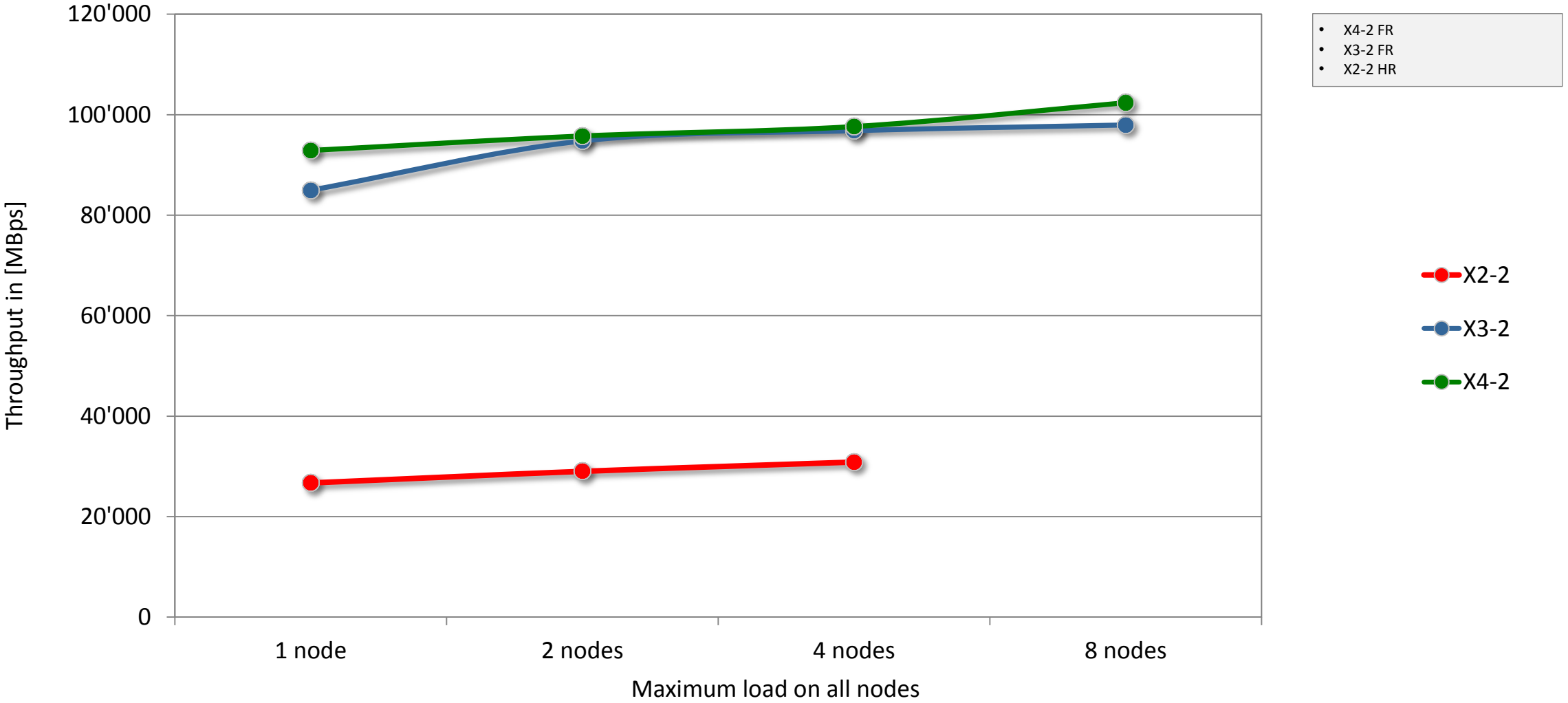
Exadata Storage Grid

Oracle storage performance: sequential read, 1 DB Server



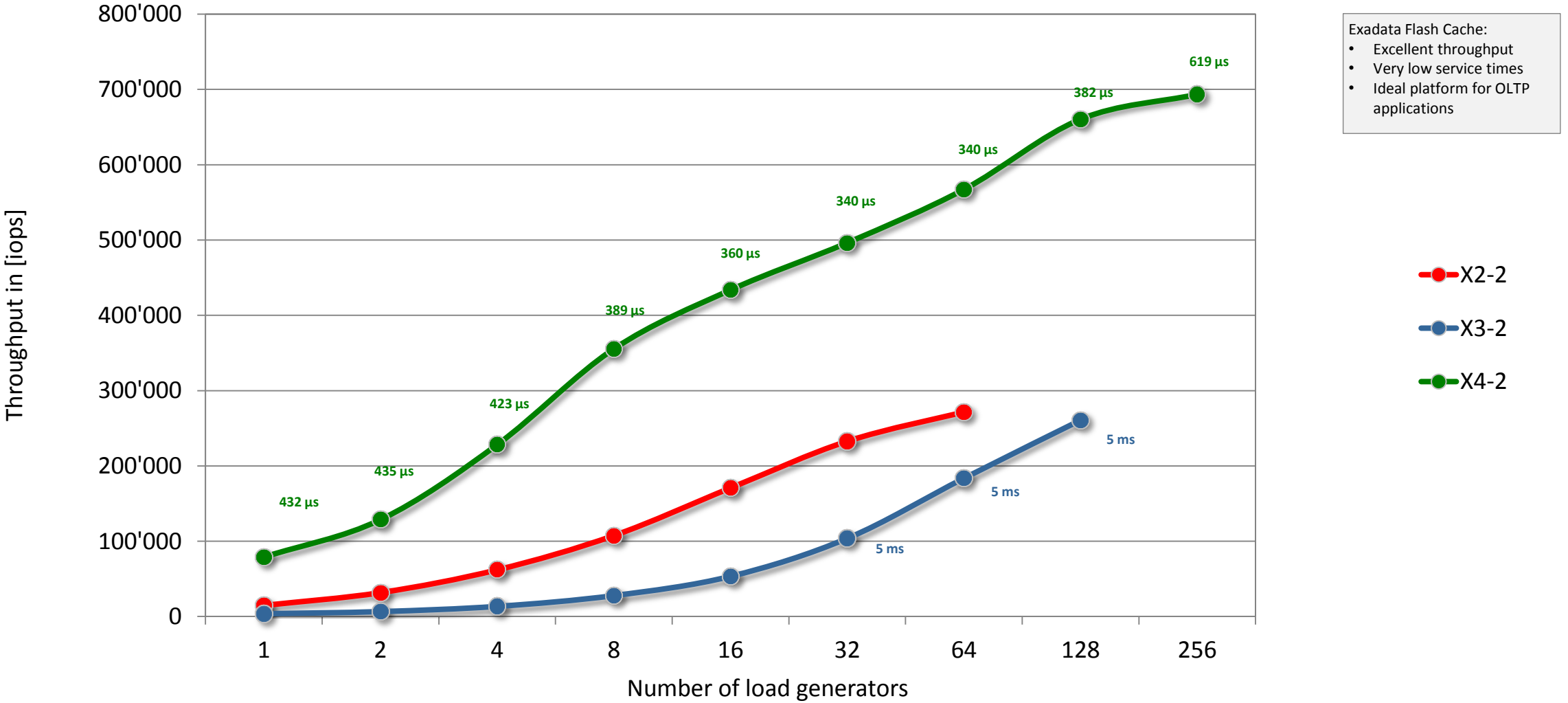
Exadata Storage Grid

Oracle storage performance: sequential read, Cluster



Exadata Storage Grid

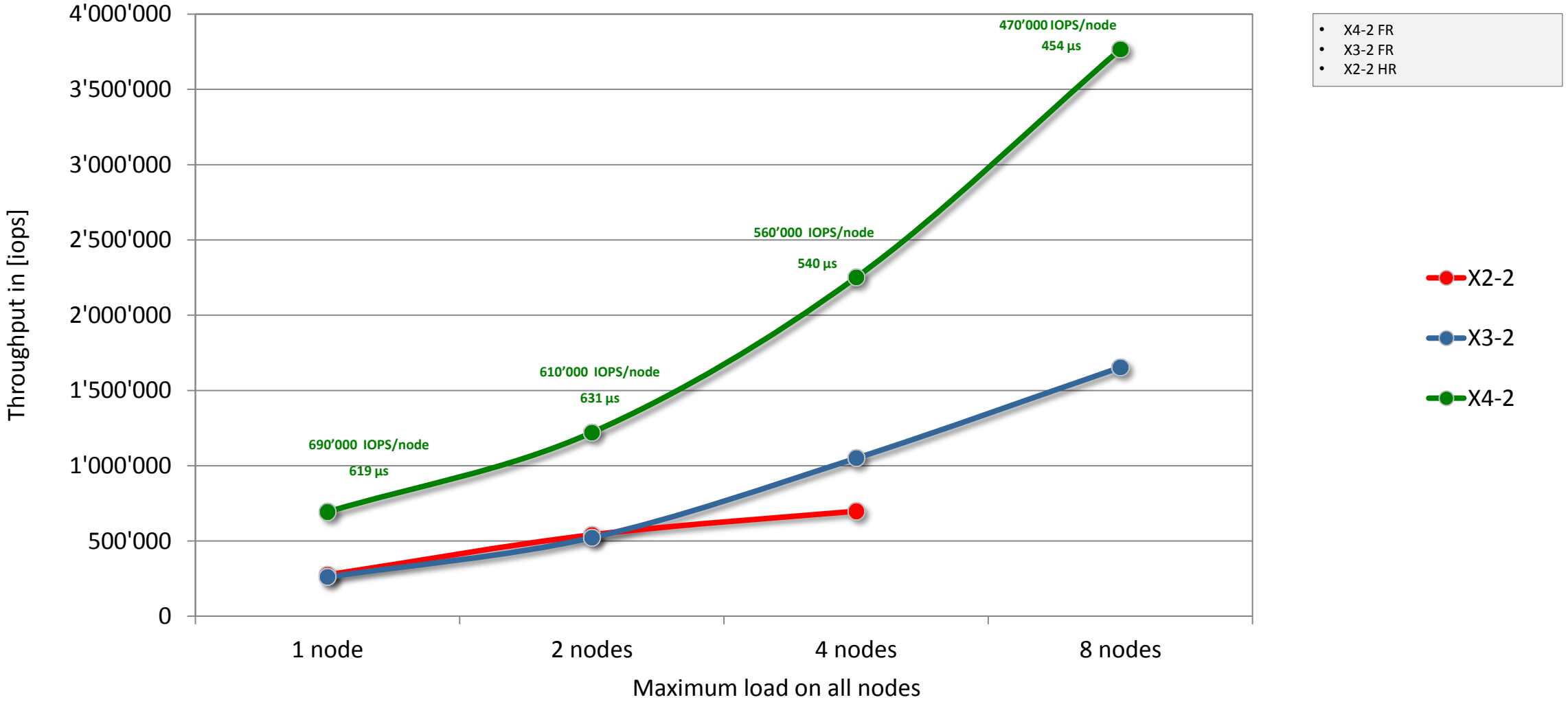
Oracle storage performance: random read, 1 DB server



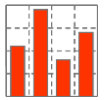
Exadata Flash Cache:
- Excellent throughput
- Very low service times
- Ideal platform for OLTP applications

Exadata Storage Grid

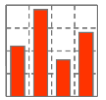
Oracle storage performance: random read, Cluster



Contents



Summary



- Do you need MORE storage I/O performance?
  - Avoid shared storage systems
  - Replace last century hard disk drive technology
- Where is the pain
  - Quick fix for some specific systems?
  - Overall poor performance on shared storage system?
- Smooth integration?

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