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Tuning Red Hat Enterprise Linux for Databases

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redhat.

Objectives of this session

- **Share tuning tips**
  - Aspects of tuning
  - Tuning parameters
  - Results of the tuning
    - Bare metal
    - KVM Virtualization
  - Oracle database tuning considerations
- **Tools**

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RHEL Kernel Architecture Support

- **Architectures**
  - 64 bits Only (with 32bit user space compatibility support)

	x86_64	PPC64	s390x
Kernel	X	X	X
Headers	X	X	X
Debug	X	X	X

- **Theoretical Limits on X86_64**
  - Logical CPU – maximum 5120 logical CPUs
  - Memory – maximum 64T

What To Tune

- I/O
- Memory
- CPU
- Network

What is “tuned” ?

- Tuning framework that dynamically modifies system parameters that affect performance
- Pre-existing list of profiles for different sub-systems / application classes
- Existing profiles can be modified (not recommended)
- Custom profiles can be created
- Installed by default in RHEL 7
  - Desktop/Workstation: balanced
  - Server/HPC: throughput-performance
- Can be rolled back

Tuned: Updates for RHEL7

- Re-written for maintainability and extensibility.
  - Configuration is now consolidated a single tuned.conf file
    - **/usr/lib/tuned/<profile-name>/tuned.conf**
  - Detail config
  - Optional hook/callout capability
  - Adds concept of Inheritance (just like httpd.conf)
  - Profiles updated for RHEL7 features and characteristics

Tuned: Throughput Profiles - RHEL7

Tunable	Units	Balanced	throughput-performance	network-throughput
Inherits From/Notes				throughput-performance
sched_min_ granularity_ns	nanoseconds	auto-scaling	10000000	
sched_wakeup_granularity_ns	nanoseconds	3000000	15000000	
dirty_ratio	Percent	20	40	
dirty_background_ratio	Percent	10	10	
swappiness	Weight 1-100	60	10	
I/O Scheduler (Elevator)		deadline		
Filesystem Barriers	Boolean	Enabled		
CPU Governor		ondemand	performance	
Disk Read-ahead	KB	128	4096	
Disable THP	Boolean	Enabled		
Energy Perf Bias		normal	performance	
kernel.sched_migration_cost_ns	nanoseconds	500000		
min_perf_pct (intel_pstate only)	Percent	auto-scaling	100	
tcp_rmem	Bytes	auto-scaling		Max=16777216
tcp_wmem	Bytes	auto-scaling		Max=16777216
udp_mem	Pages	auto-scaling		Max=16777216

Tuned: Latency Profiles - RHEL7

Tunable	Units	Balanced	latency-performance	network-latency
Inherits From/Notes				**latency-performance**
sched_min_ granularity_ns	nanoseconds	auto-scaling	10000000	
sched_wakeup_granularity_ns	nanoseconds	3000000		10000000
dirty_ratio	percent	20	10	
dirty_background_ratio	percent	10	3	
swappiness	Weight 1-100	60	10	
I/O Scheduler (Elevator)		deadline		
Filesystem Barriers	Boolean	Enabled		
CPU Governor		ondemand	performance	
Disable THP	Boolean	N/A	**No**	Yes
CPU C-States		N/A	Locked @ 1	
Energy Perf Bias		normal	performance	
kernel.sched_migration_cost_ns	nanoseconds	N/A	5000000	
min_perf_pct (intel_pstate only)	percent		100	
net.core.busy_read	microseconds			50
net.core.busy_poll	microseconds			50
net.ipv4.tcp_fastopen	Boolean			Enabled
kernel.numa_balancing	Boolean			Disabled

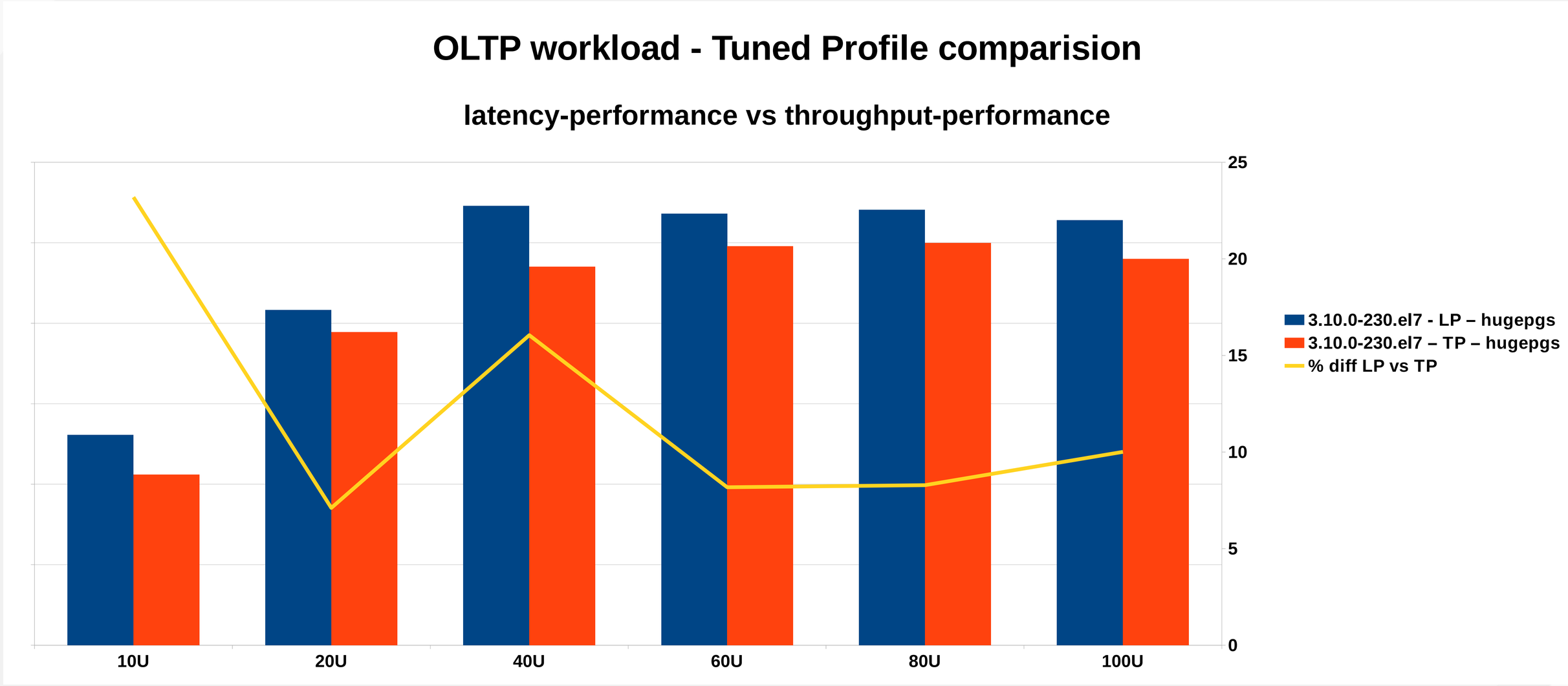
Tuned: Virtualization Profiles - RHEL7

Tunable	Units	throughput-performance	virtual-host	virtual-guest
Inherits From/Notes			throughput-performance	throughput-performance
sched_min_ granularity_ns	nanoseconds	10000000		
sched_wakeup_granularity_ns	nanoseconds	15000000		
dirty_ratio	percent	40		30
dirty_background_ratio	percent	10	5	30
swappiness	Weight 1-100	10		
I/O Scheduler (Elevator)				
Filesystem Barriers	Boolean			
CPU Governor		performance		
Disk Read-ahead	Bytes	4096		
Energy Perf Bias		performance		
kernel.sched_migration_cost_ns	nanoseconds		5000000	
min_perf_pct (intel_pstate only)	percent	100		

tuned profile list

```
# tuned-adm list
    Available profiles:
    - balanced
    - desktop
    - latency-performance
    - network-latency
    - network-throughput
    - powersave
    - sap
    - throughput-performance
    - virtual-guest
    - virtual-host
    Current active profile: throughput-performance
```

Tuned – Database workload



Please note : The latency profiles tweak the CPU power features and they will not work if the BIOS is not configured properly

I/O Tuning – Hardware

- **Know Your Storage**
  - SAS or SATA? (Performance comes at a premium)
  - Fibre Channel, Ethernet (**Check the PCI slot – PCI / PCI E – x4, x8**)
  - Bandwidth limits (I/O characteristics for desired I/O types)
- **Multiple HBAs**
  - Device-mapper multipath
    - Provides multipathing capabilities and LUN persistence
    - Check for your storage vendors recommendations (upto 20% performance gains with correct settings)
- **How to profile your I/O subsystem**
  - Low level I/O tools – dd, iozone, dt, etc.
  - I/O representative of the database implementation

I/O Tuning – Understanding I/O Elevators

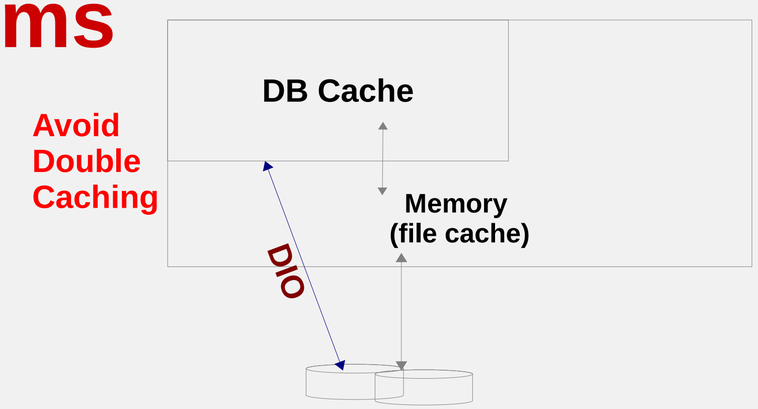
- **Deadline**
  - Two queues per device, one for read and one for writes
  - I/Os dispatched based on time spent in queue
  - Used for multi-process applications and systems running enterprise storage
- **CFQ**
  - Per process queue
  - Each process queue gets fixed time slice (based on process priority)
  - Default setting - Slow storage (SATA) – root file system
- **Noop**
  - FIFO
  - Simple I/O Merging
  - Lowest CPU Cost
  - Low latency storage and applications (Solid State Devices)

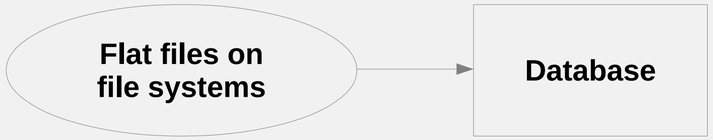
I/O Tuning – Configuring I/O Elevators

- **Boot-time**
  - Grub command line – elevator=deadline/cfq/noop
- **Dynamically, per device**
  - echo “deadline” > /sys/block/sda/queue/scheduler
- **tuned**
  - tuned-adm profile throughput-performance

I/O Tuning – File Systems

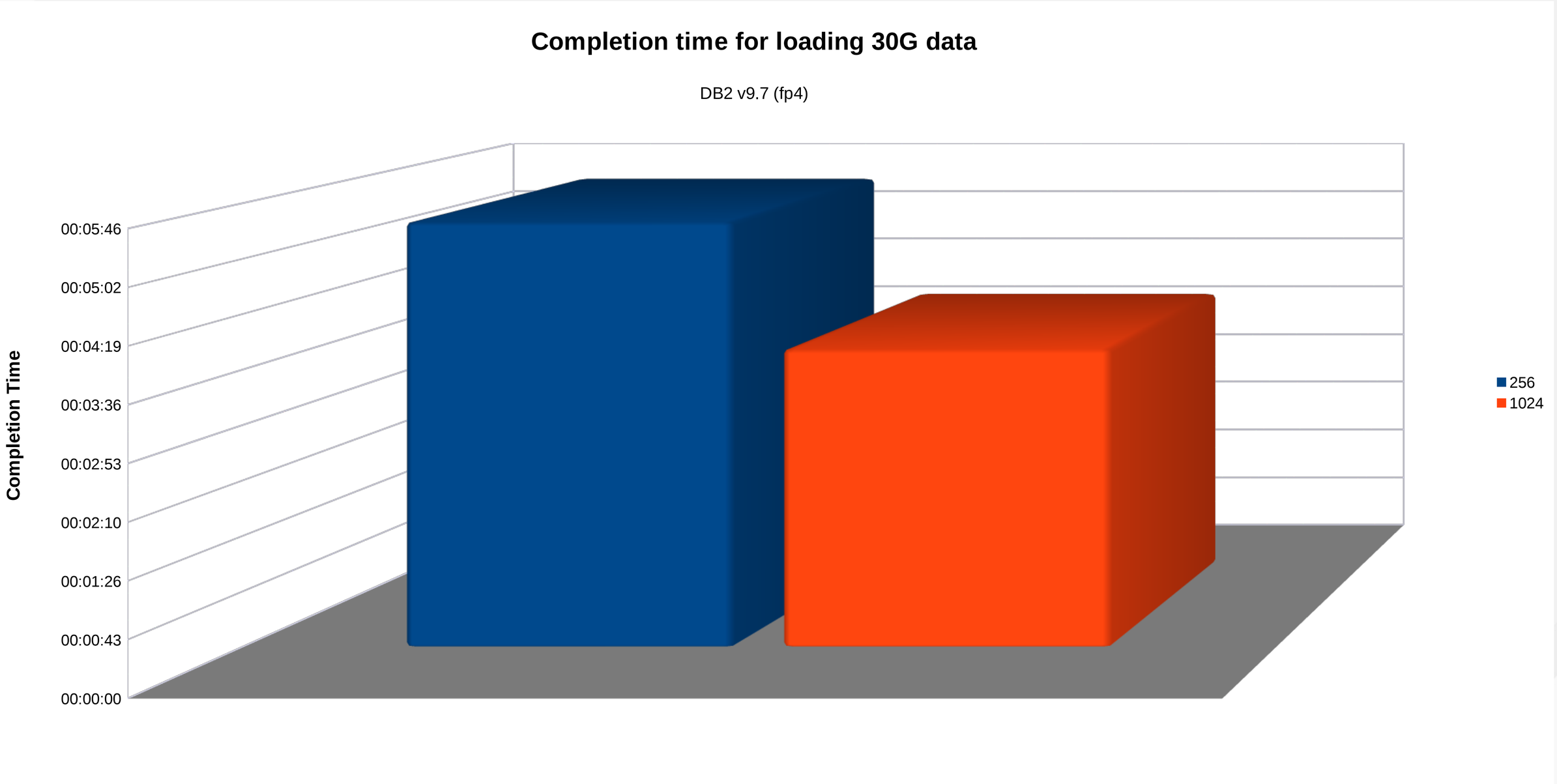
- **Direct I/O**
  - Avoid double caching
  - Predictable performance
  - Reduce CPU overhead
- **Asynchronous I/O**
  - Eliminate synchronous I/O stall
  - Critical for I/O intensive applications
- **Configure read ahead** (for sequential read operations)
  - Database (parameters to configure read ahead)
  - Block devices (commands – "**blockdev -- getra / setra**")
  - Configure device read ahead for large data loads
- **Choosing the right file system**
  - **xfs, ext4**



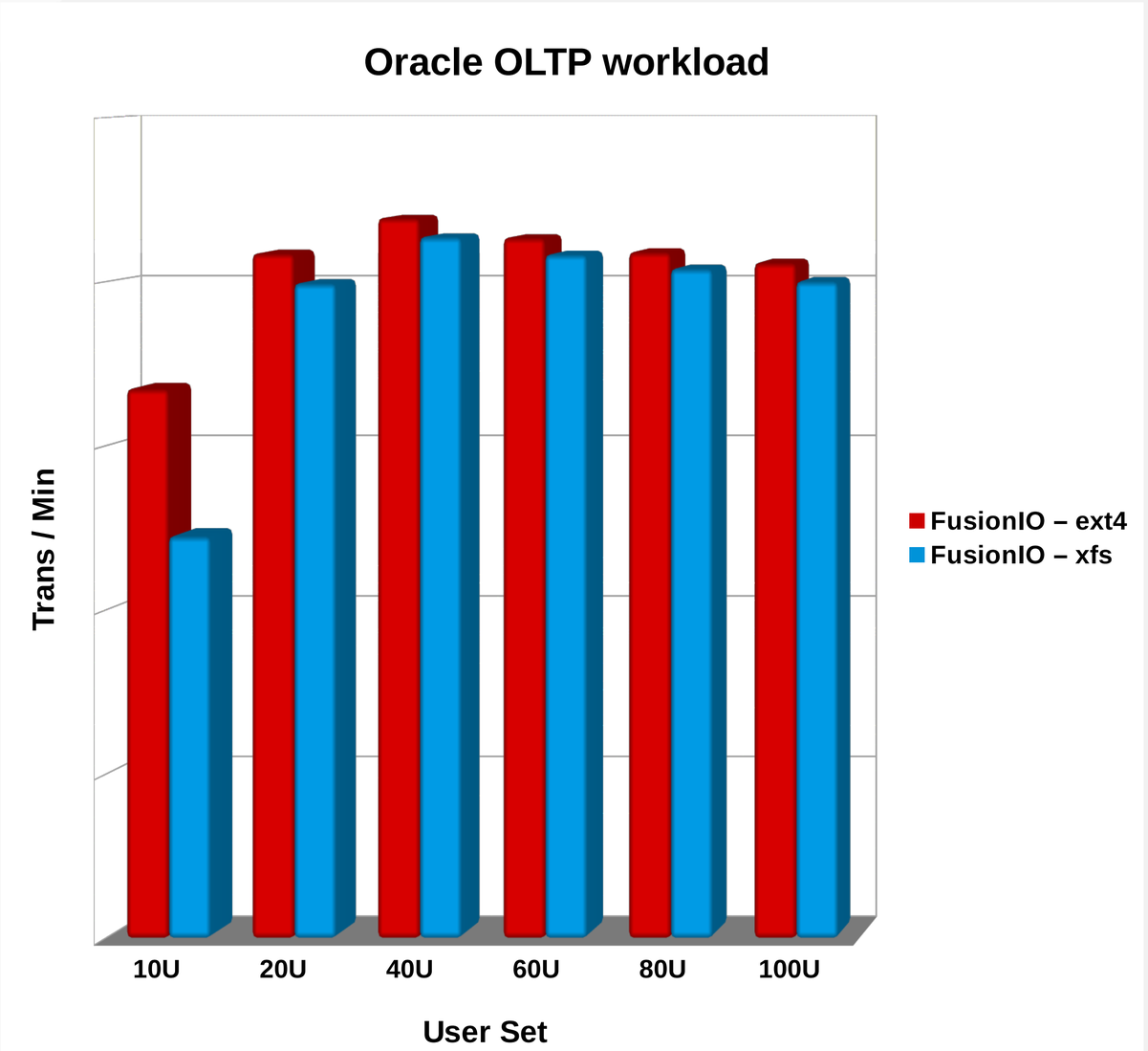


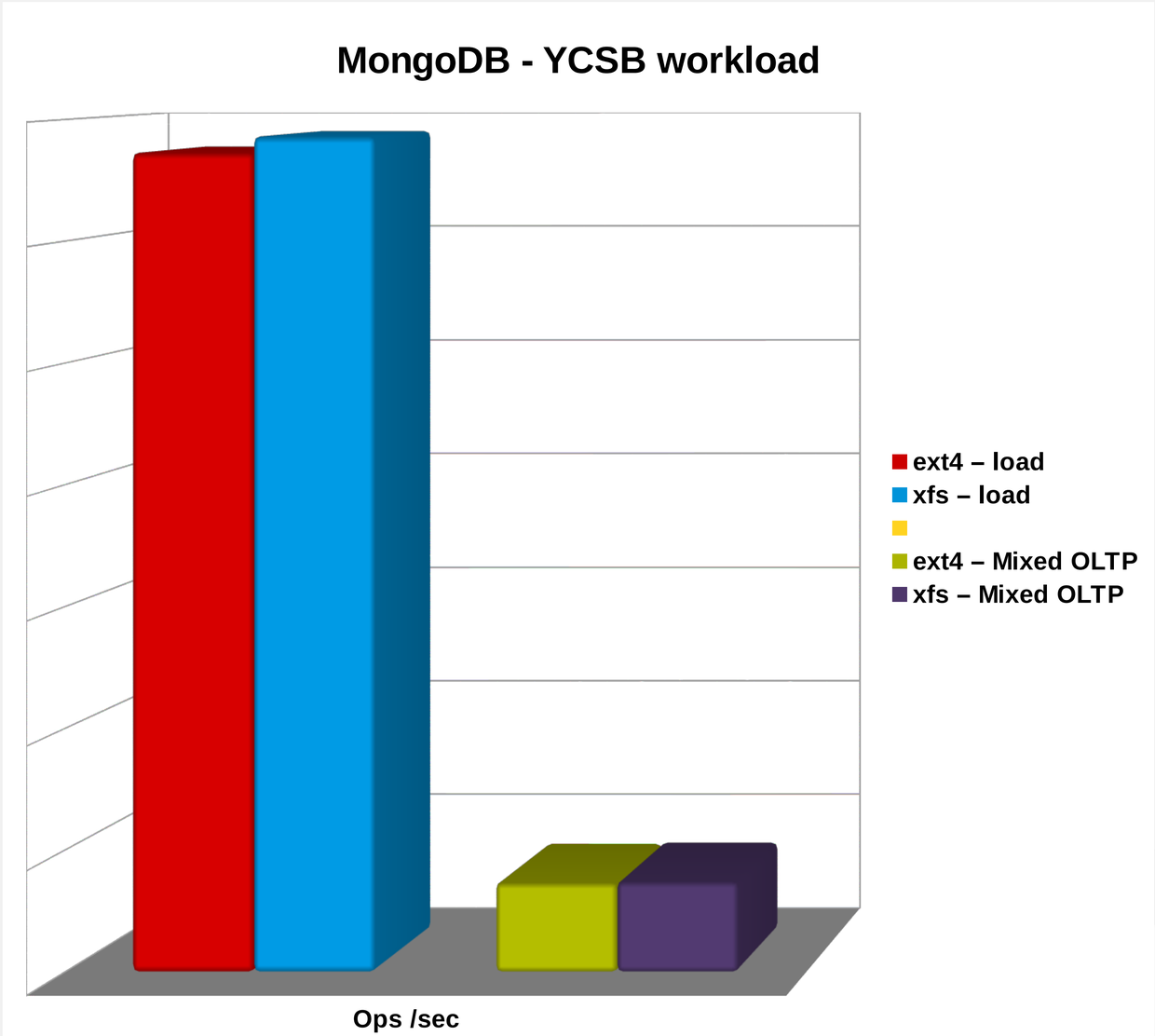
Configure read ahead

I/O Tuning – Effect of read ahead during data load



I/O Tuning – Choosing the right file system for your database





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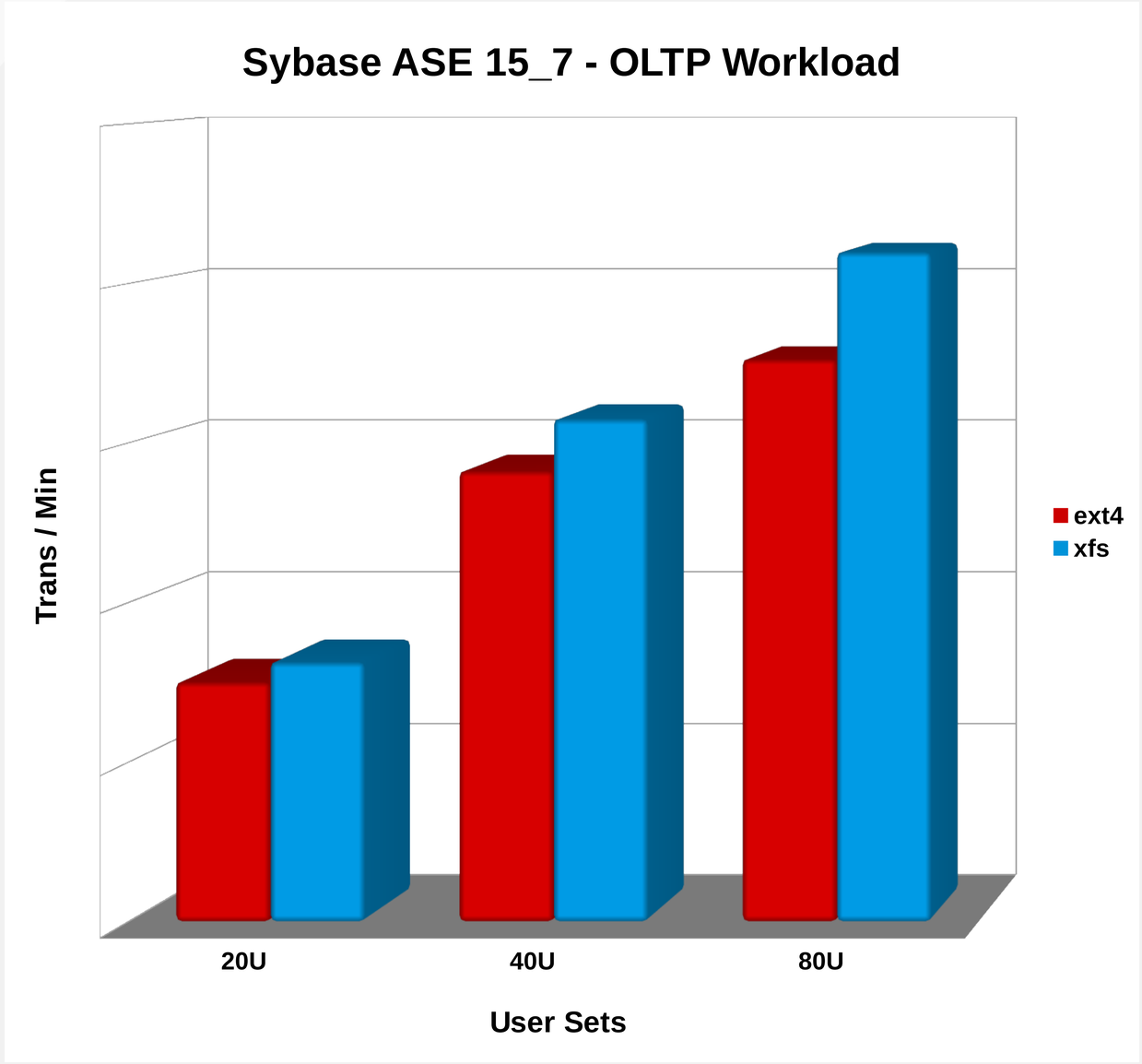
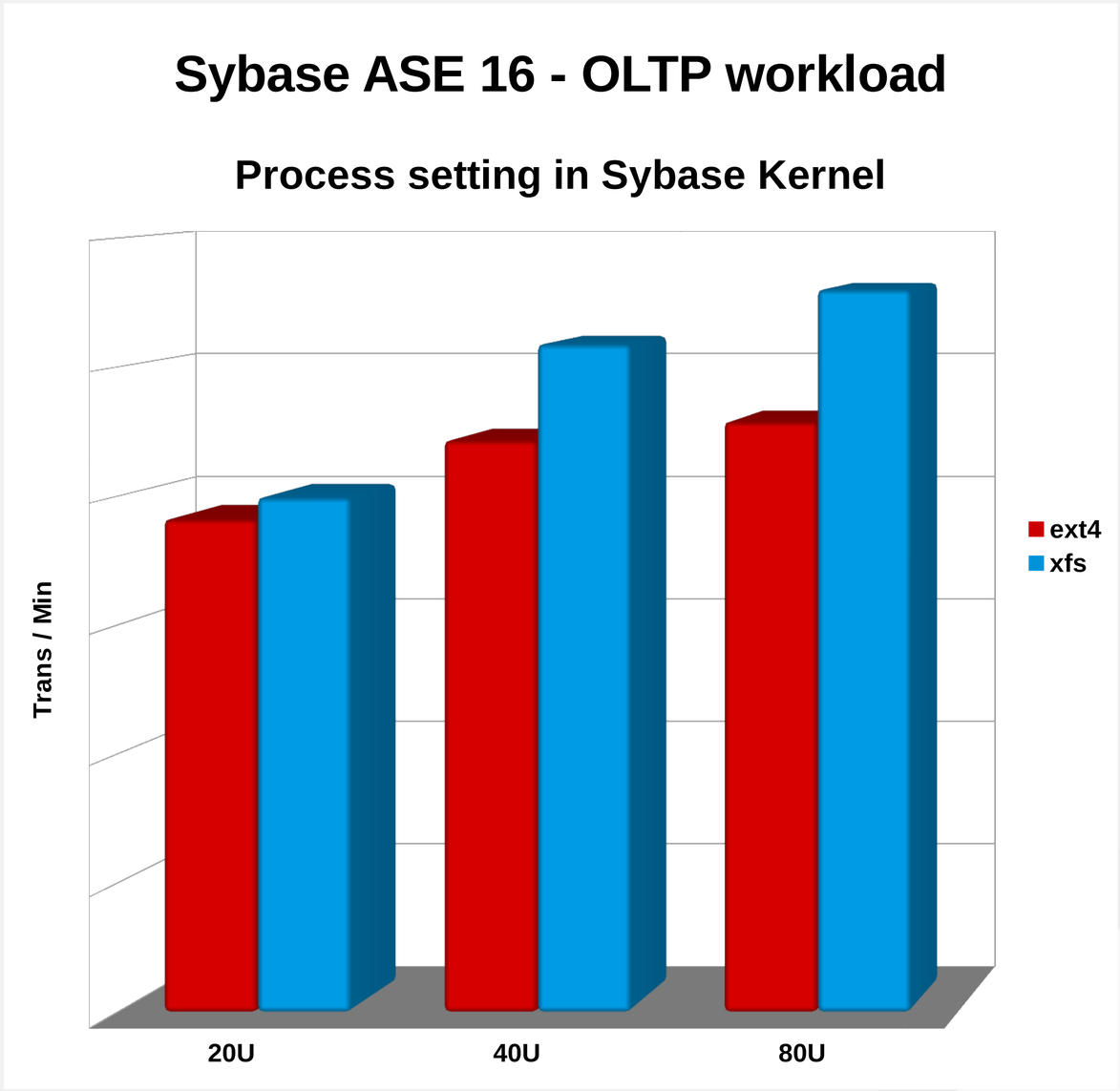
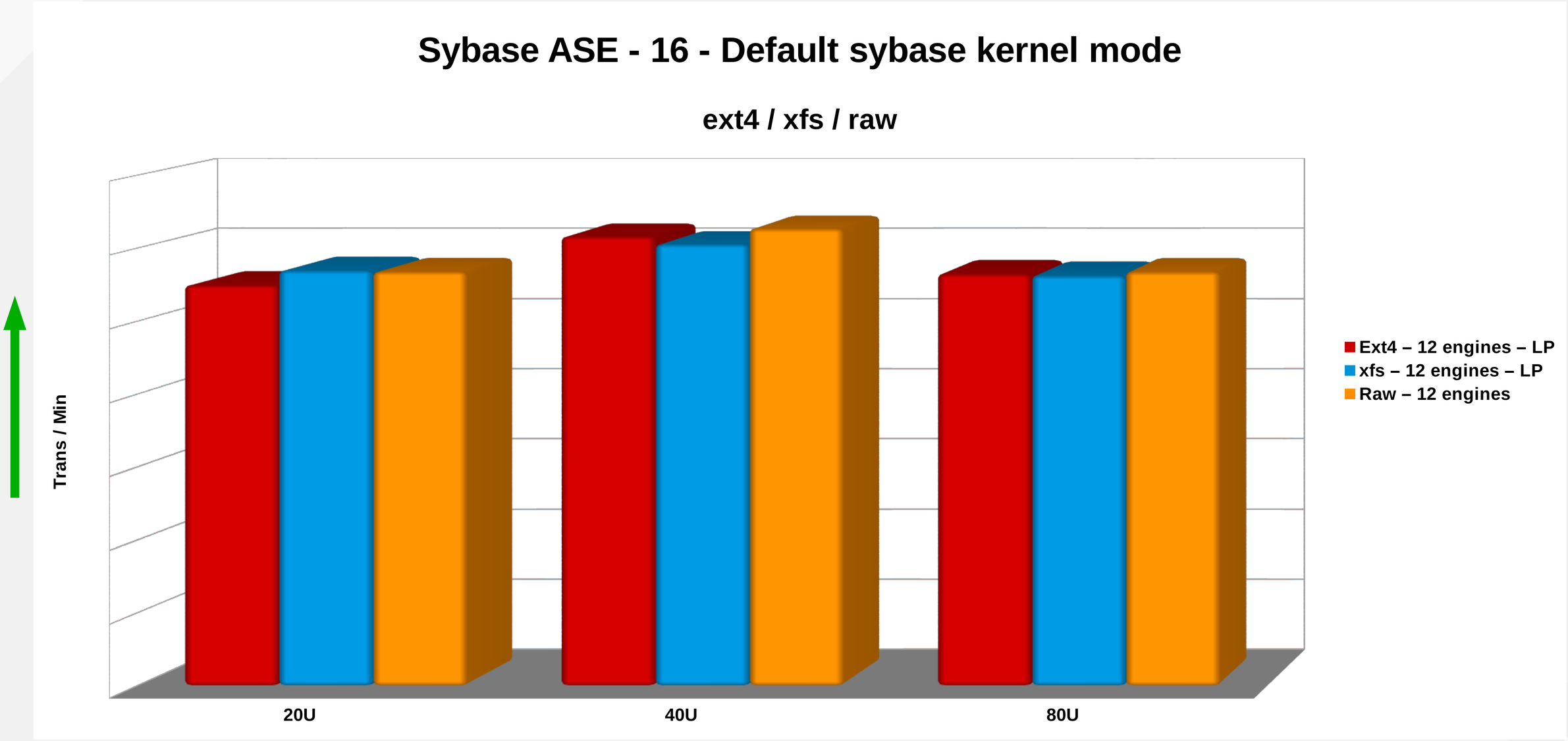




I/O Tuning – Choosing the right file system for your database



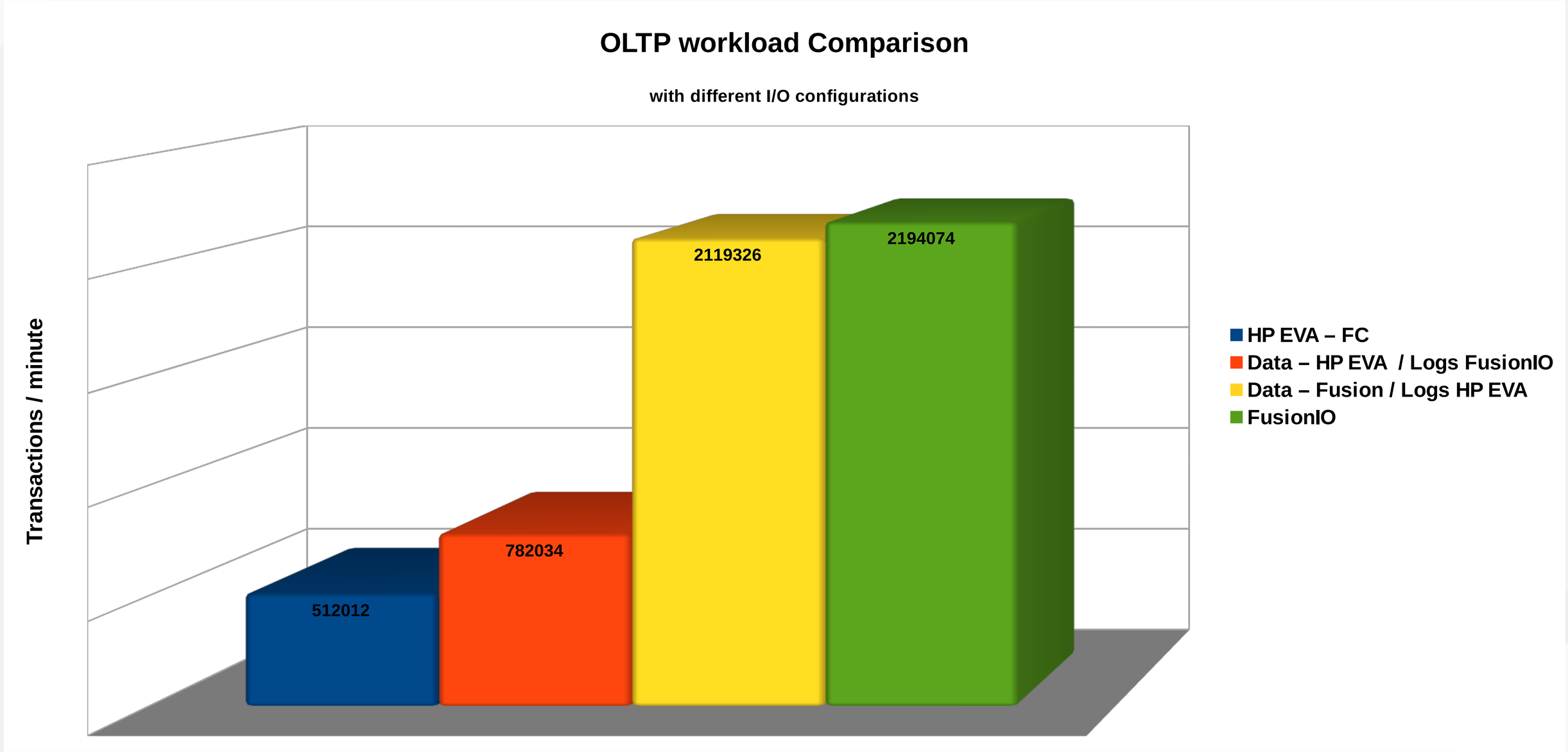
I/O Tuning – Database Layout

- Separate files by I/O (data , logs, undo, temp)
- **OLTP** – data files / undo / logs
  - All transactions generate logs and undo information
- **DSS** – data files / temp files
  - Merge / joins / indexes generally use temp segments
- Use low latency / high bandwidth devices for hot spots
  - Use database statistics

Linux Tool used for Identifying I/O hotspots

- *iostat -dmxz <interval>*
  - This shows I/O for only the disks that are in use

I/O Tuning – Database Layout



I/O Tuning
Database Layout

monitoring I/O
iostat -dmxz 3

Fibre Channel

Device:	rrqm/s	wrqm/s	r/s	w/s	rMB/s	wMB/s	avgrq-sz	avgqu-sz	await	r_await	w_await	svctm	%util
dm-2	0.00	0.00	0.00	10.20	0.00	0.64	127.64	0.25	24.98	0.00	24.98	1.27	1.30
dm-5	0.00	8.90	0.00	289.00	0.00	2.13	15.11	0.13	0.45	0.00	0.45	0.38	10.94
dm-6	0.00	213.20	0.00	1224.50	0.00	9.31	15.57	0.42	0.34	0.00	0.34	0.32	39.50
dm-7	0.00	72.90	0.00	903.60	0.00	6.06	13.73	0.27	0.29	0.00	0.29	0.27	24.01
dm-8	0.00	1.70	0.00	131.70	0.00	0.91	14.18	0.06	0.44	0.00	0.44	0.43	5.61
dm-18	0.10	0.20	1784.10	1.10	68.06	0.01	78.10	92.18	51.61	51.64	5.27	0.56	100.01
dm-19	0.00	0.10	1684.80	0.90	70.32	0.01	85.45	78.34	46.42	46.45	0.22	0.59	100.01
dm-20	0.00	0.20	1952.20	1.10	74.02	0.01	77.62	84.36	43.25	43.27	1.18	0.51	100.01
dm-21	0.00	0.10	1226.30	0.90	49.89	0.01	83.28	96.24	78.52	78.58	0.78	0.81	100.01
Log on PCI – SSD													
fiod	0.00	1340.20	0.00	1524.70	0.00	47.86	64.29	0.19	0.13	0.00	0.13	0.13	19.31
fioa	0.00	911.10	0.00	1499.10	0.00	31.11	42.49	0.16	0.11	0.00	0.11	0.10	15.74
fioc	0.00	1059.60	0.00	1379.10	0.00	38.69	57.45	0.16	0.11	0.00	0.11	0.11	15.64
fiob	0.00	991.60	0.00	1534.80	0.00	40.31	53.79	0.18	0.12	0.00	0.12	0.11	17.51
dm-18	0.00	0.40	293.70	555.60	9.82	24.92	83.76	19.19	22.96	61.97	2.34	1.15	97.53
dm-19	0.00	0.40	197.70	587.10	6.34	25.86	84.03	18.57	24.42	87.00	3.34	1.23	96.91
dm-20	0.00	0.40	221.40	431.40	7.18	19.94	85.08	19.74	30.86	84.25	3.46	1.50	98.17
dm-21	0.00	0.40	203.10	295.40	6.88	14.16	86.43	22.20	45.48	104.92	4.61	1.98	98.70
Data on PCI – SSD													
fiod	0.00	0.40	800.80	6101.60	6.28	167.21	51.48	10.37	1.50	2.93	1.32	0.14	95.10
fioa	0.00	0.40	671.60	6309.40	5.27	166.26	50.32	6.42	0.92	1.86	0.82	0.12	86.88
fioc	0.00	0.40	779.20	6195.60	6.10	173.99	52.88	10.15	1.46	3.28	1.23	0.14	96.19
fiob	0.00	9.40	813.80	6176.90	6.46	197.63	59.79	9.98	1.43	2.87	1.24	0.14	94.51
dm-18	0.00	1428.90	0.00	1029.70	0.00	46.56	92.60	0.54	0.52	0.00	0.52	0.50	51.89
dm-19	0.00	1475.00	0.00	1100.70	0.00	47.81	88.95	0.57	0.52	0.00	0.52	0.51	55.75
dm-20	0.00	1093.50	0.00	693.20	0.00	45.64	134.83	0.53	0.77	0.00	0.77	0.67	46.76
dm-21	0.00	1312.20	0.00	849.50	0.00	46.20	111.38	0.59	0.69	0.00	0.69	0.61	51.69
dm-1	0.00	0.00	0.00	0.80	0.00	0.02	49.12	0.01	6.25	0.00	6.25	4.25	0.34
SanDisk PCI - SSD													
fioa	0.00	1279.30	522.00	1049.70	13.99	54.21	88.87	0.27	0.17	0.22	0.15	0.13	20.50
fioc	0.00	1359.80	651.70	1247.70	5.10	57.99	68.03	0.34	0.18	0.18	0.18	0.13	23.84
fiob	0.00	1284.30	693.10	1221.10	5.47	85.05	96.84	0.72	0.38	0.26	0.45	0.15	27.88
fiod	0.00	1434.30	740.80	1512.20	5.81	66.73	65.94	0.80	0.36	0.20	0.44	0.11	25.32
fioa	0.00	1292.20	514.60	1043.70	5.24	55.90	80.36	0.30	0.20	0.19	0.20	0.13	19.86
fioc	0.00	909.10	674.20	826.00	5.29	59.69	88.71	0.41	0.28	0.21	0.33	0.15	22.10
fiob	0.00	1380.40	728.20	1458.80	5.71	66.02	67.17	0.99	0.45	0.20	0.58	0.13	27.53
fiod	0.00	1297.10	815.40	1494.90	6.43	65.28	63.57	0.90	0.39	0.21	0.49	0.12	26.78

I/O Tuning – Database layout – vmstat

OLTP Workload
Fibre Channel Storage

r	b	swpd	free	buff	cache	si	so	bi	bo	in	cs	us	sy	id	wa	st
62	19	5092	44894312	130704	76267048	0	0	8530	144255	35350	113257	43	4	45	9	0
3	20	5092	43670800	131216	77248544	0	0	6146	152650	29368	93373	33	3	53	11	0
21	27	5092	42975532	131620	77808736	0	0	2973	147526	20886	66140	20	2	65	13	0
7	20	5092	42555764	132012	78158840	0	0	2206	136012	19526	61452	17	2	69	12	0
25	18	5092	42002368	132536	78647472	0	0	2466	144191	20255	63366	19	2	67	11	0
4	21	5092	41469552	132944	79111672	0	0	2581	144470	21125	66029	22	2	65	11	0
1	32	5092	40814696	133368	79699200	0	0	2608	151518	21967	69841	23	2	64	11	0
4	17	5092	40046620	133804	80385232	0	0	2638	151933	23044	70294	24	2	64	10	0
17	14	5092	39499580	134204	80894864	0	0	2377	152805	23663	72655	25	2	62	10	0
35	14	5092	38910024	134596	81436952	0	0	2278	152864	24944	74231	27	2	61	9	0
20	13	5092	38313900	135032	81978544	0	0	2091	156207	24257	72968	26	2	62	10	0
1	14	5092	37831076	135528	82389120	0	0	1332	155549	19798	58195	20	2	67	11	0
23	24	5092	37430772	135936	82749040	0	0	1955	145791	19557	56133	18	2	66	14	0
34	12	5092	36864500	136396	83297184	0	0	1546	141385	19957	56894	19	2	67	13	0

OLTP Workload
PCI SSD Storage

r	b	swpd	free	buff	cache	si	so	bi	bo	in	cs	us	sy	id	wa	st
77	0	6604	55179876	358888	66226960	0	0	7325	266895	70185	149686	90	7	4	0	0
77	1	6604	50630092	359288	70476248	0	0	6873	306900	70166	149804	88	7	5	0	0
76	3	6604	46031168	360132	74444776	0	0	5818	574286	77388	177454	88	8	4	0	0
81	1	6604	41510608	360512	78641480	0	0	4970	452939	75322	168464	89	7	3	0	0
82	3	6604	35358836	361012	84466256	0	0	4011	441042	74022	162443	88	7	4	0	0
81	3	6604	34991452	361892	84740008	0	0	2126	440876	73702	161618	88	7	5	0	0
79	1	6604	34939792	362296	84747016	0	0	2323	400324	73091	161592	90	6	3	0	0
79	0	6604	34879644	362992	84754016	0	0	2275	412631	73271	160766	89	6	4	0	0
76	2	6604	34844616	363396	84760976	0	0	2275	415777	73019	158614	89	6	4	0	0
61	3	6604	34808680	363828	84768016	0	0	2209	401522	72367	159100	89	6	4	0	0
77	1	6604	34781944	364180	84774992	0	0	2172	401966	73253	159064	90	6	4	0	0
54	4	6604	34724948	364772	84803456	0	0	3031	421299	72990	156224	89	6	4	0	0
80	2	6604	34701500	365500	84809072	0	0	2216	573246	76404	175922	88	7	5	1	0

Memory Stats

I/O Stats

CPU stats

Swap stats

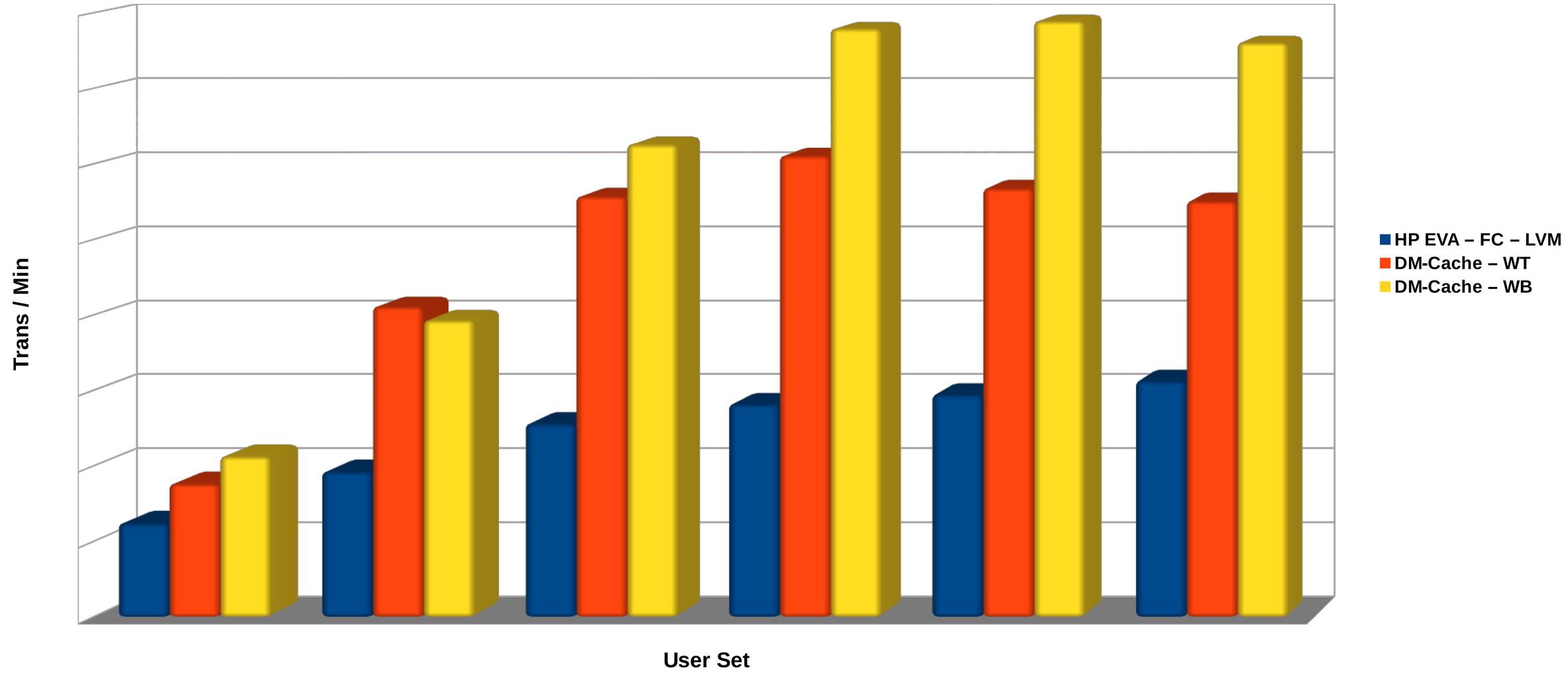
I/O Tuning – dm-cache

- Caching in the device mapper stack to improve performance
- Caching of frequently accessed data in a faster target

- For more information on how to configure cache device
  - man lvmcache

Database OLTP workload

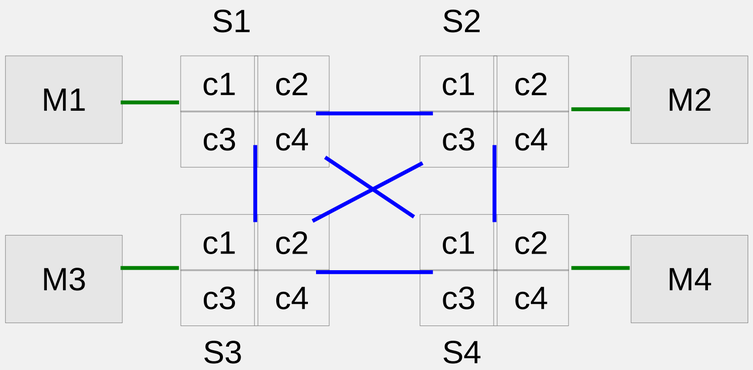
DM cache - 20G / Writethrough vs Writeback



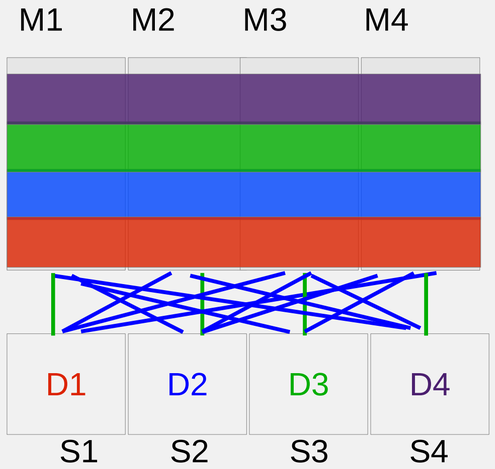
Memory Tuning

- **NUMA**
- **Huge Pages**
- **Manage Virtual Memory pages**
  - Flushing of dirty pages
  - Swapping behavior

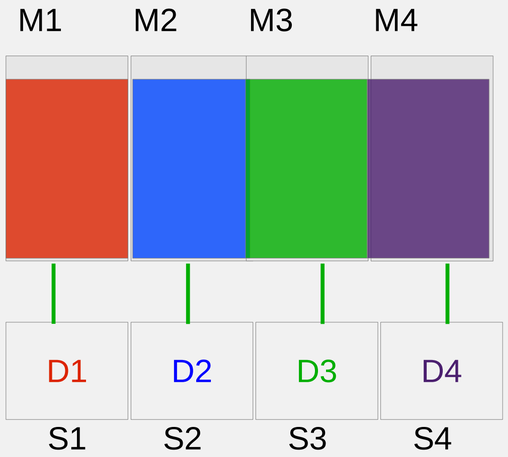
Understanding NUMA (Non Uniform Memory Access)



S – Socket
C – Core
M – Memory Bank – Attached to each Socket
D – Database
Access path between sockets
Access path between sockets and memory



No NUMA optimization



NUMA optimization

- Multi Socket – Multi core architecture
  - NUMA required for scaling
  - Autonuma code provides performance improvement
  - Additional performance gains by enforcing NUMA placement

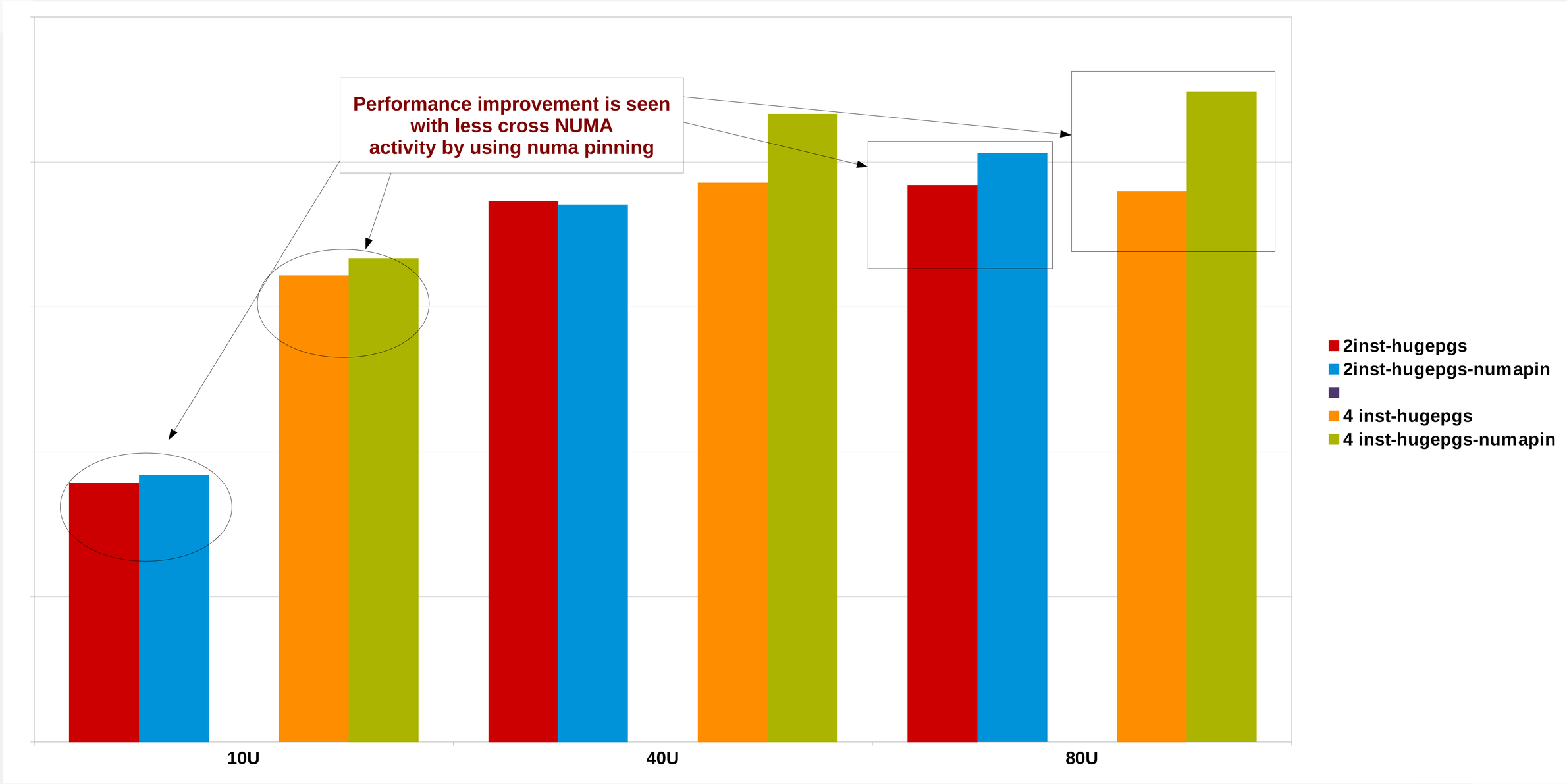
Memory Tuning – Finding NUMA layout

```
[root@perf30 ~]# numactl --hardware
available: 4 nodes (0-3)
node 0 cpus: 0 4 8 12 16 20 24 28 32 36 40 44 48 52 56 60
node 0 size: 32649 MB
node 0 free: 30868 MB
node 1 cpus: 1 5 9 13 17 21 25 29 33 37 41 45 49 53 57 61
node 1 size: 32768 MB
node 1 free: 29483 MB
node 2 cpus: 2 6 10 14 18 22 26 30 34 38 42 46 50 54 58 62
node 2 size: 32768 MB
node 2 free: 31082 MB
node 3 cpus: 3 7 11 15 19 23 27 31 35 39 43 47 51 55 59 63
node 3 size: 32768 MB
node 3 free: 31255 MB
node distances:
node   0   1   2   3
  0:  10  21  21  21
  1:  21  10  21  21
  2:  21  21  10  21
  3:  21  21  21  10
```

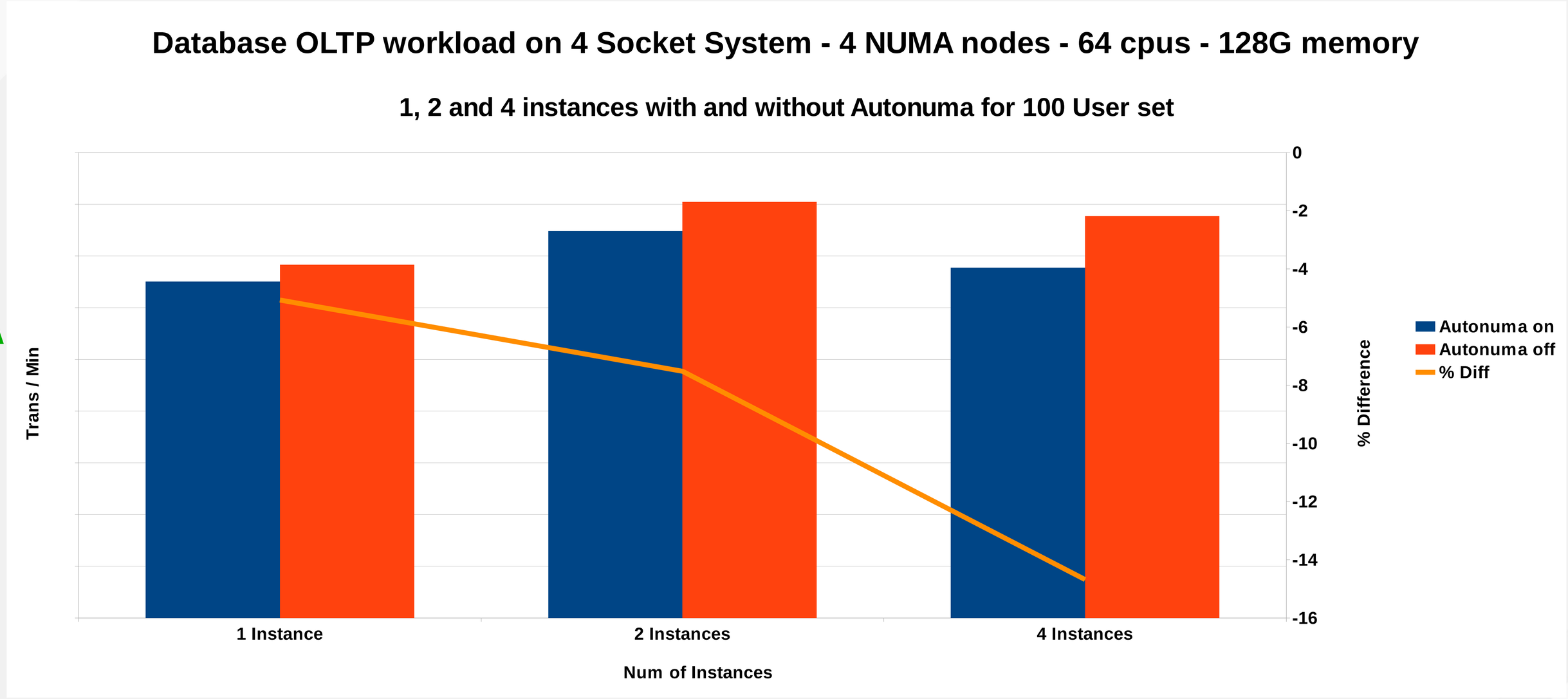
Memory Tuning – NUMA

- Enforce NUMA placement
  - Numactl
    - CPU and memory pinning
  - Taskset
    - CPU pinning
  - cgroups
    - cpusets
    - cpu and memory cgroup
  - Libvirt
    - for KVM guests – CPU pinning

Memory Tuning – Effect of NUMA Tuning

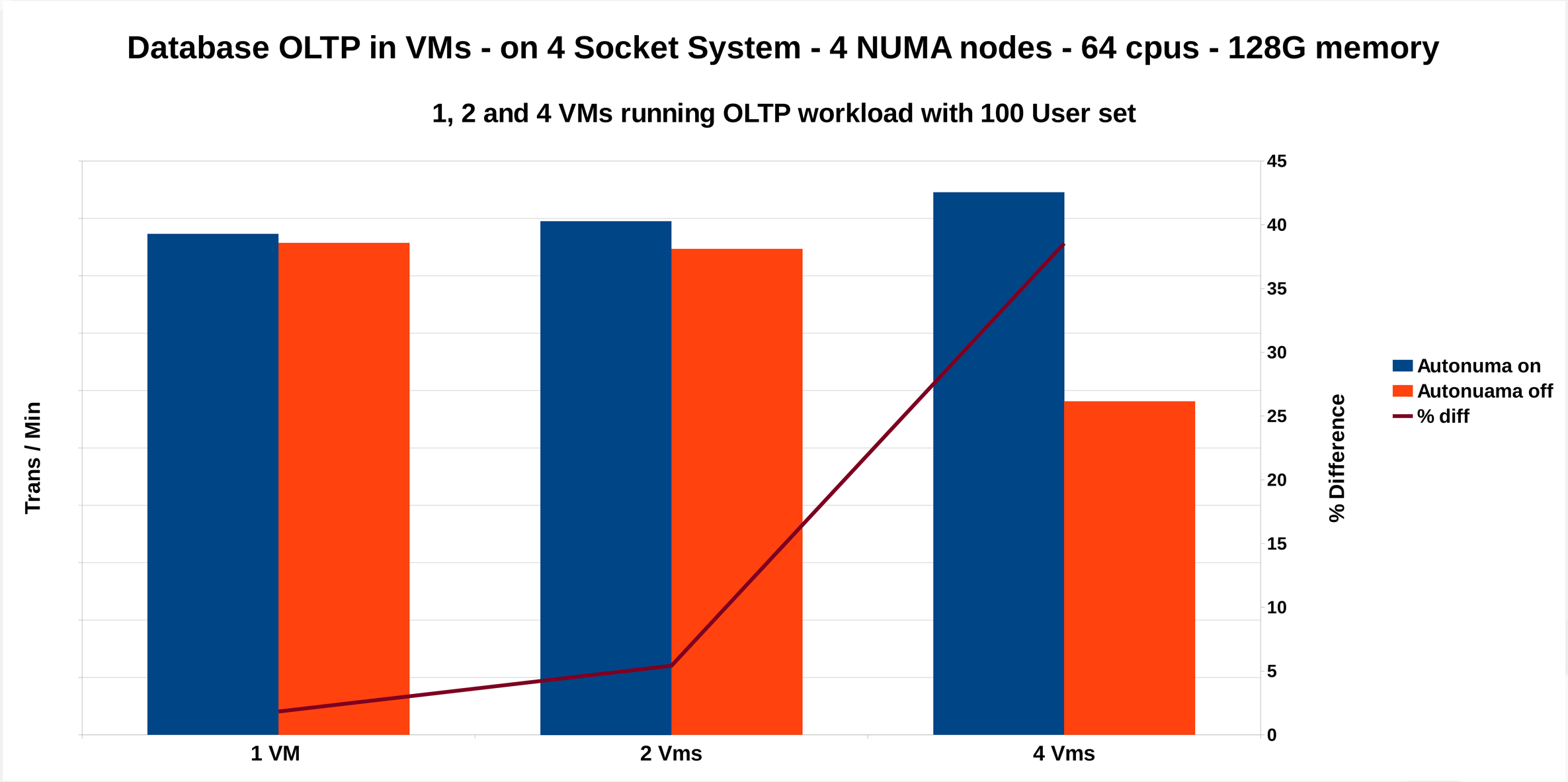


Memory Tuning – Autonuma



- With hugepages, there is no performance difference with Autonuma on or off because the memory is wired down
- # echo 0 > /proc/sys/kernel/numa_balancing

Memory Tuning – Autonuma

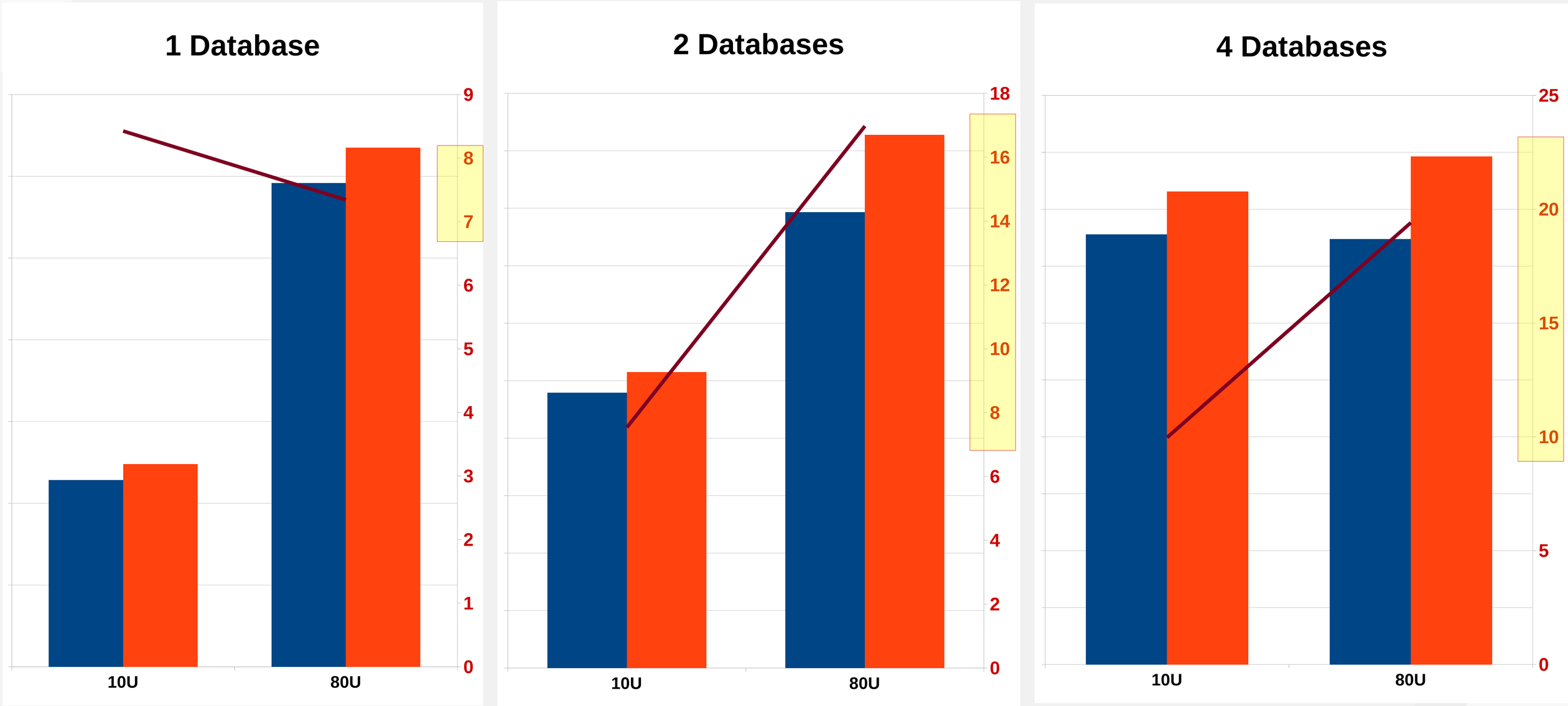


Memory Tuning – Huge Pages

- 2M pages vs 4K standard linux page
- Virtual to physical page map is 512 times smaller
- TLB can map more physical pages, resulting in fewer misses
- Traditional Huge Pages always pinned
- Most databases support Huge pages
- 1G pages supported on newer hardware
- Transparent Huge Pages in RHEL6 (cannot be used for Database shared memory – only for process private memory)

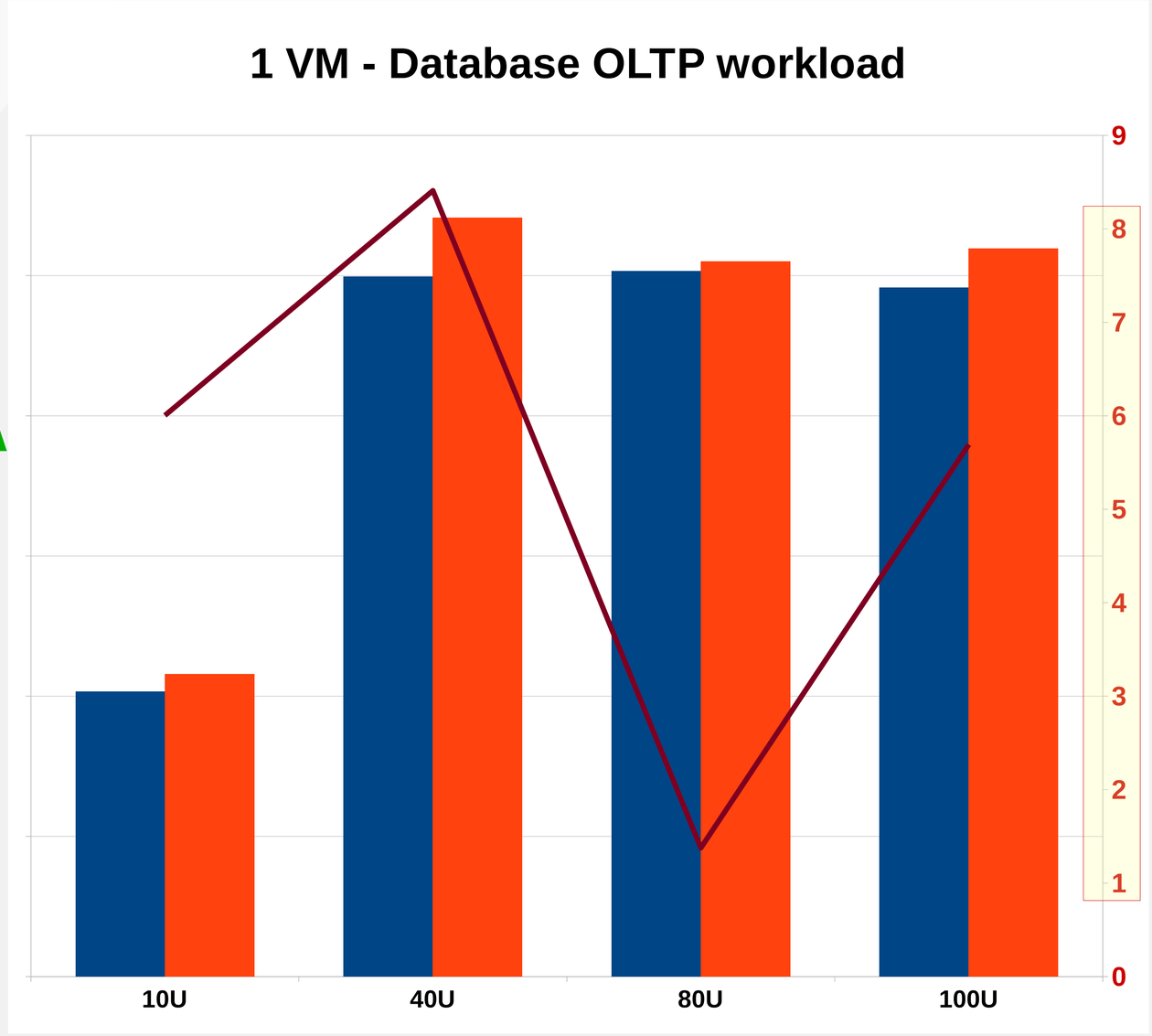
- **How to configure Huge Pages (16G)**
  - echo 8192 > /proc/sys/vm/nr_hugepages
  - vi /etc/sysctl.conf (vm.nr_hugepages=8192)

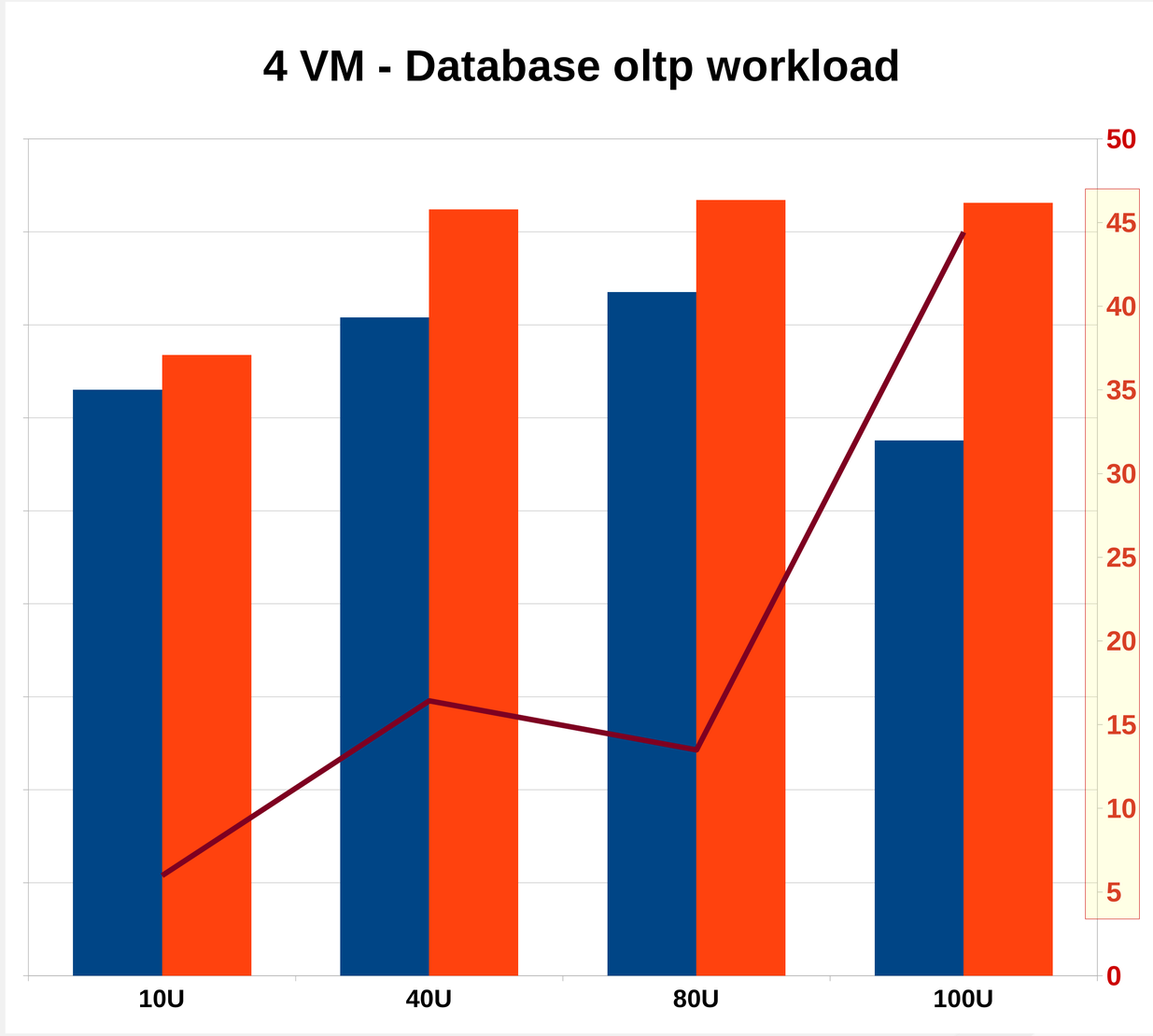
Memory Tuning – huge pages on Bare Metal



The effect of hugepages are more pronounced with multiple databases

Memory Tuning – huge pages in Virtual Machines





The effect of hugepages are more pronounced with multiple Vms

Tuning Memory – Flushing Caches

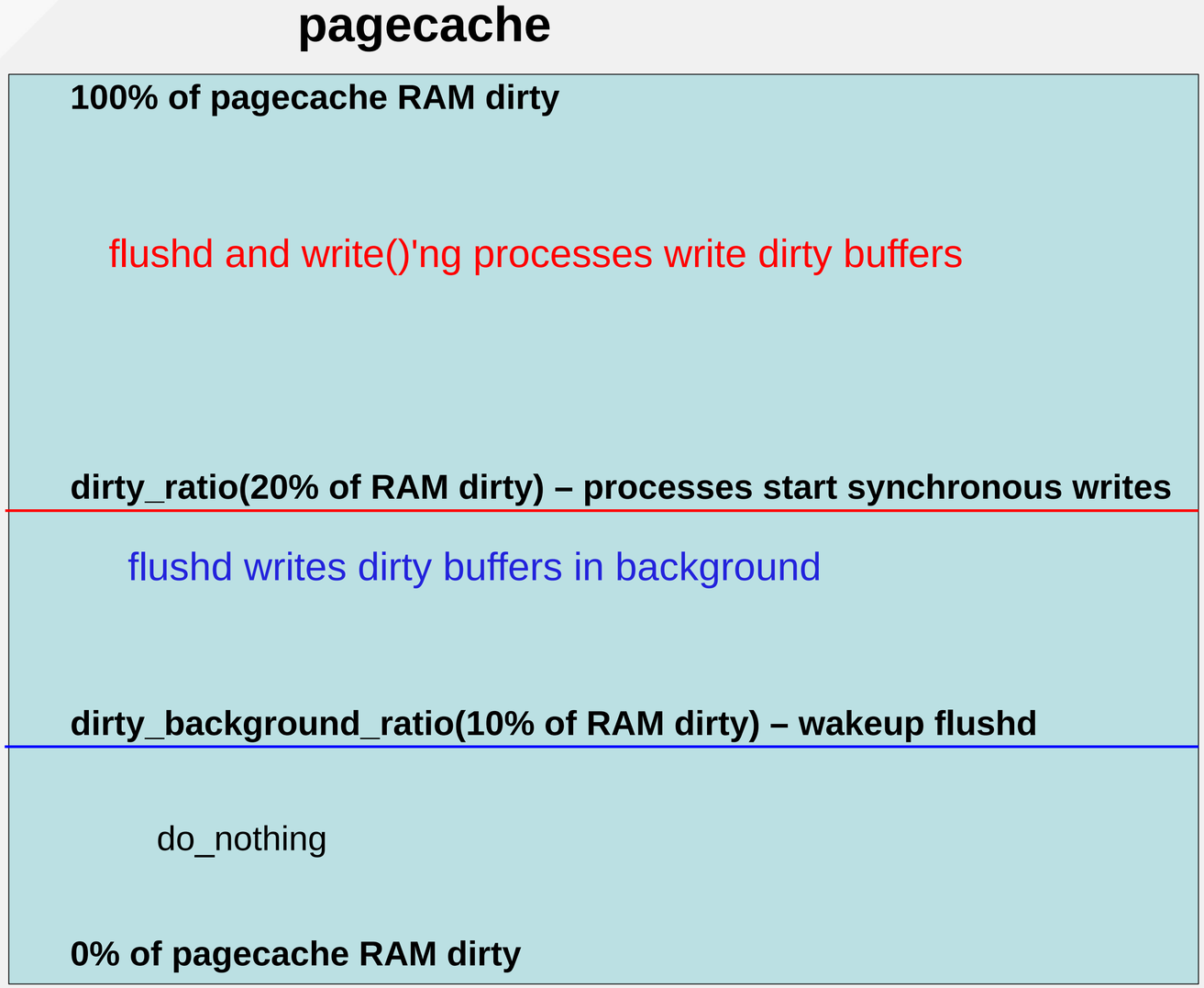
- Drop unused Cache
  - ✔Frees unused memory
  - ✔File cache
  - ✗If the DB uses cache, may notice slowdown

- **Free pagecache**
  - echo 1 > /proc/sys/vm/drop_caches
- **Free slabcache**
  - echo 2 > /proc/sys/vm/drop_caches
- **Free pagecache and slabcache**
  - echo 3 > /proc/sys/vm/drop_caches

Tuning Memory – swappiness

- Not needed as much in RHEL7
- Controls how aggressively the system reclaims “mapped” memory:
- Default - 60%
- Decreasing: more aggressive reclaiming of unmapped pagecache memory, thereby delaying swapping
- Increasing: more aggressive swapping of mapped memory

dirty_ratio and dirty_background_ratio



If there is a lot of pagecache pressure one would want to start background flushing sooner and delay the synchronous writes. This can be done by

- **Lowering the dirty_background_ratio**
- **Increasing the dirty_ratio**

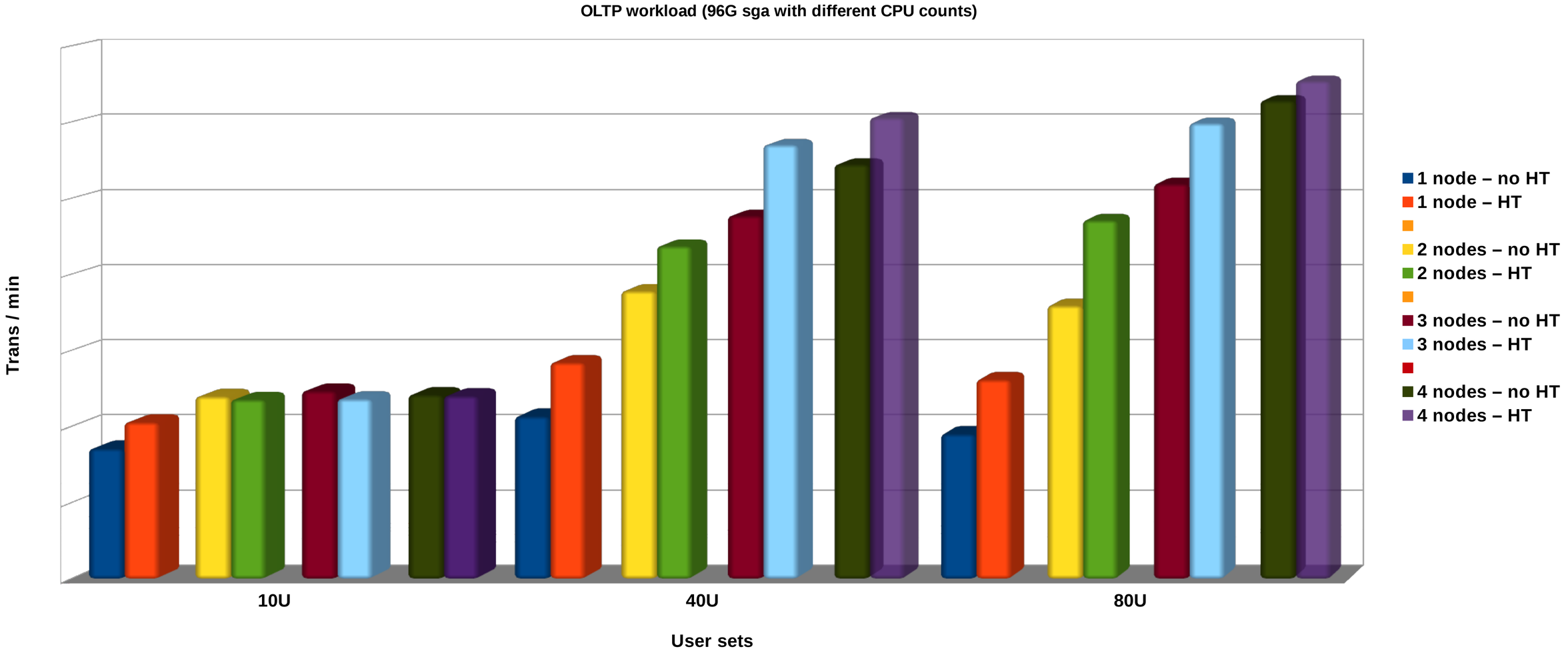
Anything “Hyper” has to be good for perfomance... right?

Using Hyperthreads improves performance with database workload but the mileage will vary depending on how the database workload scales.

Having more CPUs sharing the same physical cache can also help performance in some cases

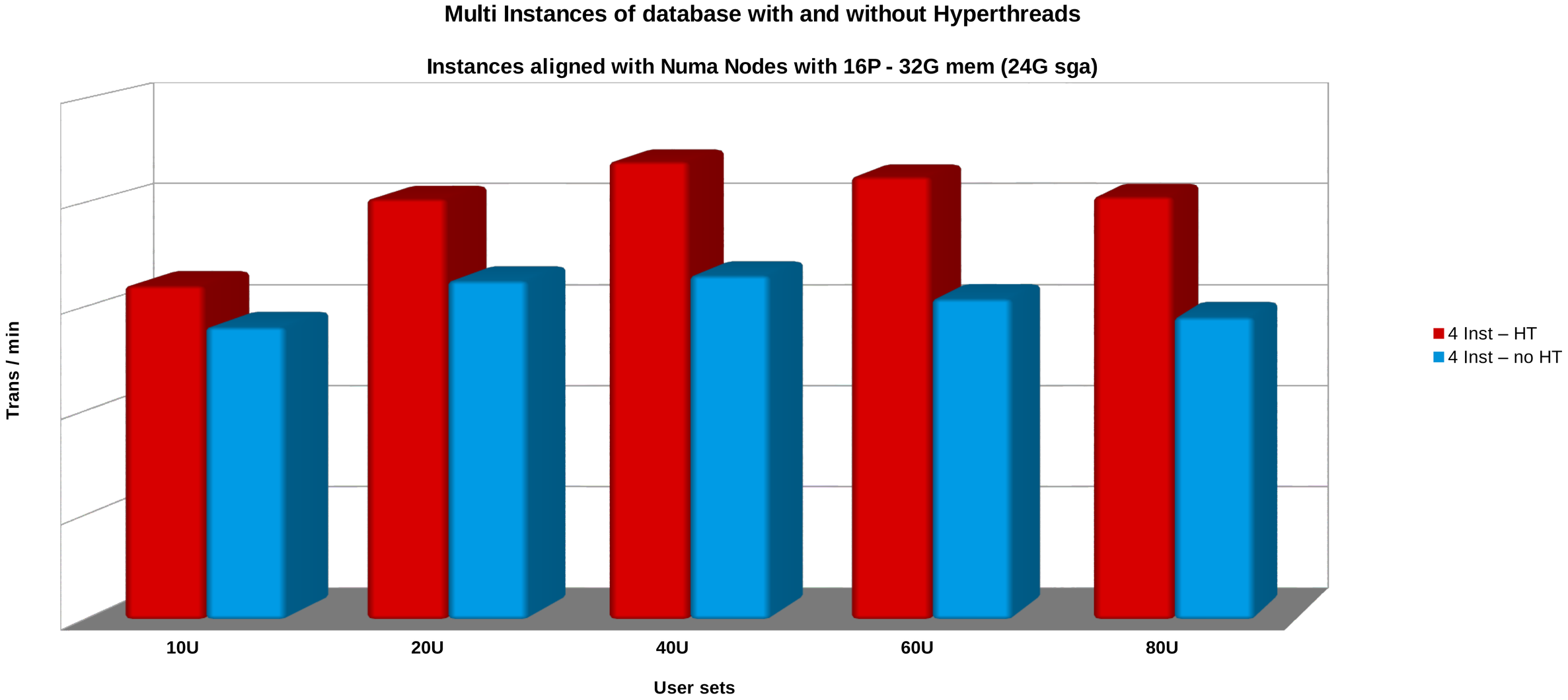
Some workloads lend themselves to scaling efficiently and they will do very well with hyperthreads but if the scaling factor for workloads are not linear with physical cpus, it probably won’t be a good candidate for scaling with hyperthreads.

Scaling test - Hyperthread vs no Hyperthead



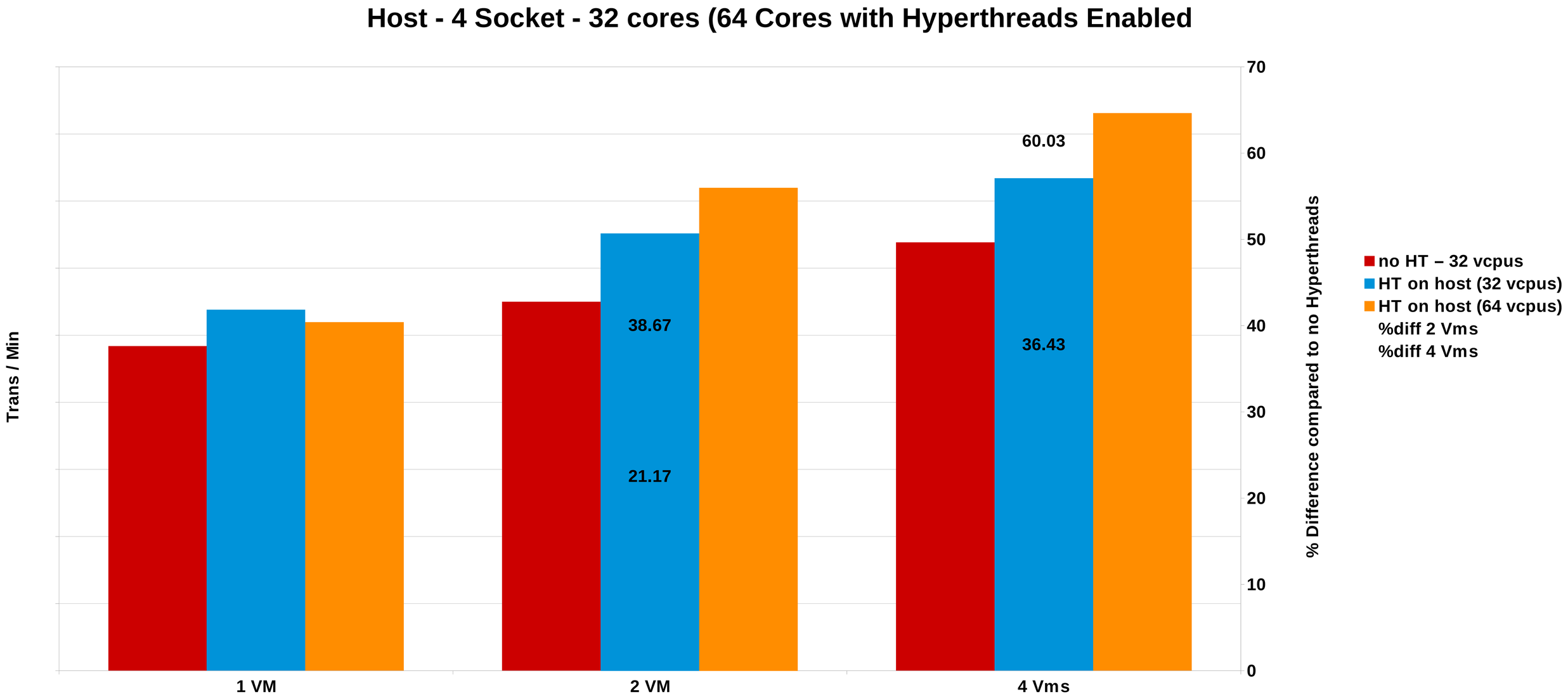
Single Instance scaled across NUMA nodes, one node at a time. The 1 node test shows the best gain in performance. As more NUMA nodes come into play, the performance difference is hard to predict because of the memory placement and the CPU cache sharing among physical threads and hyperthreads of the CPUs

Avg % gain – 1 Node – 30% / 2 Nodes – 20 % / 3 Nodes – 14 % / 4 Nodes – 5.5 %



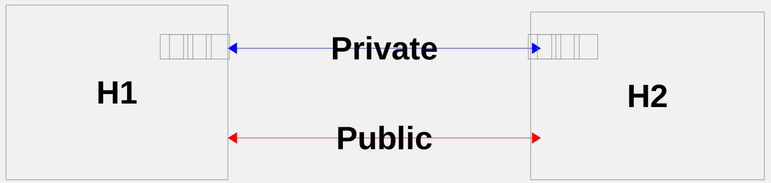
Each of the 4 instances were aligned to an individual NUMA node. This test shows the best gain in performances as other factors influencing performance like NUMA, I/O are not a factor

Hyperthreads Testing with KVM



Network Tuning – Databases

- Network Performance
  - Separate network for different functions (Private network for database traffic)
  - If on same network, use arp_filter to prevent ARP flux
  - echo 1 > /proc/sys/net/ipv4/conf/all/arp_filter



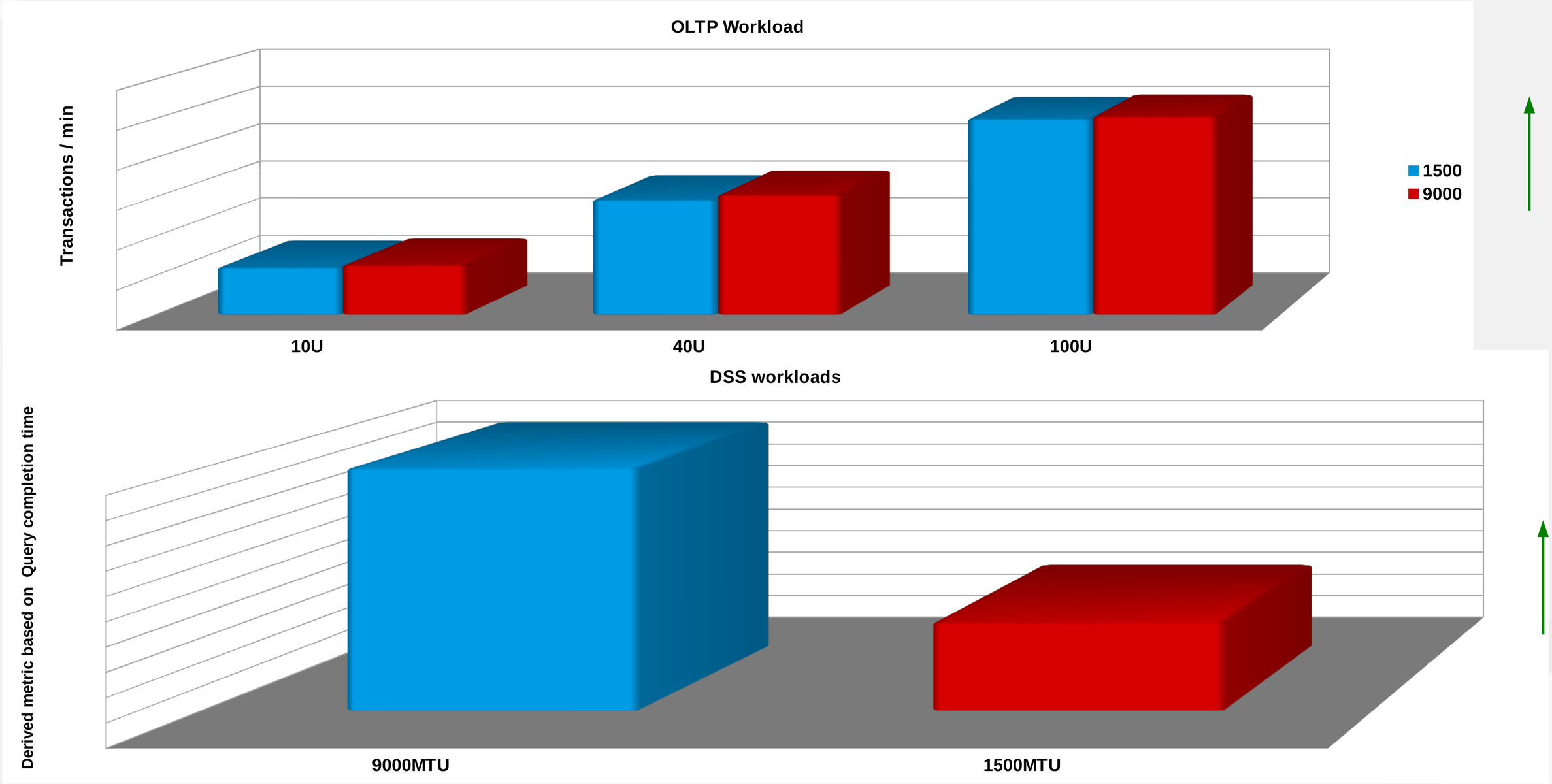
Hardware

  - 10GigE
    - Supports RDMA w/ RHEL6 high performance networking package (**ROCE**)
  - Infiniband (Consider the cost factor)
- Packet size (Jumbo frames)

Linux Tool used for monitoring network

- *sar -n DEV <interval>*

Network tuning – Jumbo Frames with iSCSI storage



Output of “sar -N DEV 3”
For a DSS workload running on iSCSI storage using different MTUs

1500 MTU

	IFACE	rxpck/s	txpck/s	rxkB/s	txkB/s	rxcmp/s	txcmp/s	rxmcst/s
01:40:08 PM								
01:40:11 PM	eth0	0.34	0.34	0.02	0.02	0.00	0.00	0.00
01:40:11 PM	eth5	135016.78	19107.72	199178.19	1338.53	0.00	0.00	0.34
01:40:14 PM	eth0	0.66	0.00	0.05	0.00	0.00	0.00	0.66
01:40:14 PM	eth5	133676.74	18911.30	197199.84	1310.25	0.00	0.00	0.66
01:40:17 PM	eth0	0.67	0.00	0.05	0.00	0.00	0.00	0.67
01:40:17 PM	eth5	134555.85	19045.15	198502.27	1334.19	0.00	0.00	0.33
01:40:20 PM	eth0	1.00	0.00	0.07	0.00	0.00	0.00	0.67
01:40:20 PM	eth5	134116.33	18972.33	197849.55	1325.03	0.00	0.00	1.00

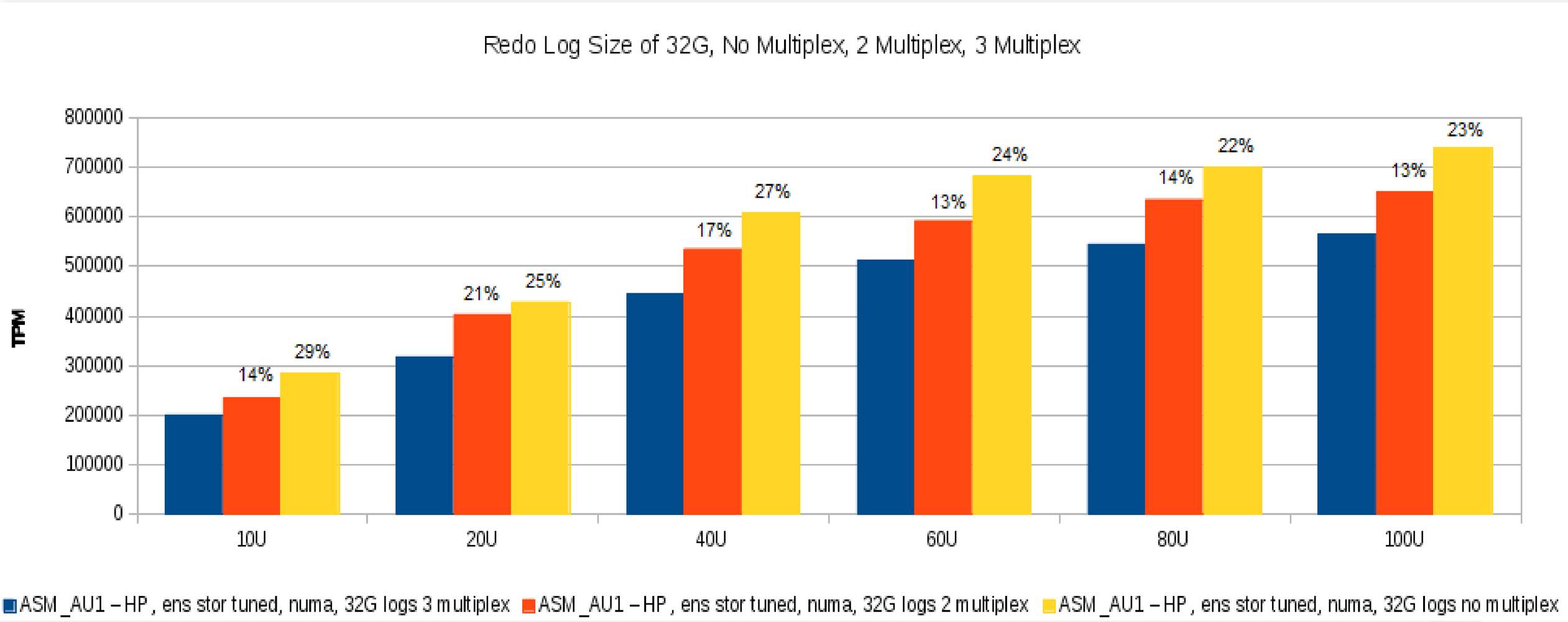
9000 MTU

	IFACE	rxpck/s	txpck/s	rxkB/s	txkB/s	rxcmp/s	txcmp/s	rxmcst/s
06:58:43 PM								
06:58:46 PM	eth0	0.91	0.00	0.07	0.00	0.00	0.00	0.00
06:58:46 PM	eth5	104816.36	48617.27	900444.38	3431.15	0.00	0.00	0.91
06:58:49 PM	eth0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06:58:49 PM	eth5	118269.80	54965.84	1016151.64	3867.91	0.00	0.00	0.50
06:58:52 PM	eth0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06:58:52 PM	eth5	118470.73	54382.44	1017676.21	3818.35	0.00	0.00	0.98
06:58:55 PM	eth0	0.94	0.00	0.06	0.00	0.00	0.00	0.00
06:58:55 PM	eth5	115853.05	53515.49	995087.67	3766.28	0.00	0.00	0.47

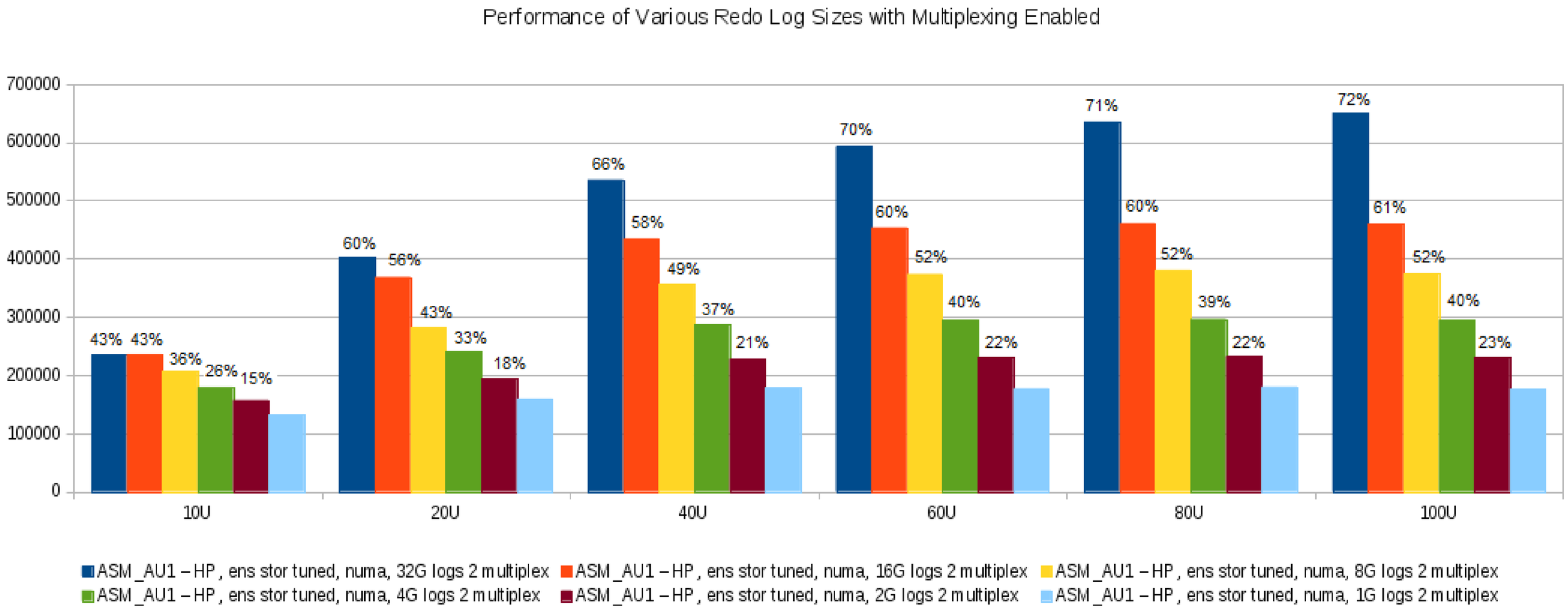
Database Performance

- **Application tuning**
  - Design
  - Reduce locking / waiting
  - Database tools (optimize regularly)
  - Resiliency is not a friend of performance

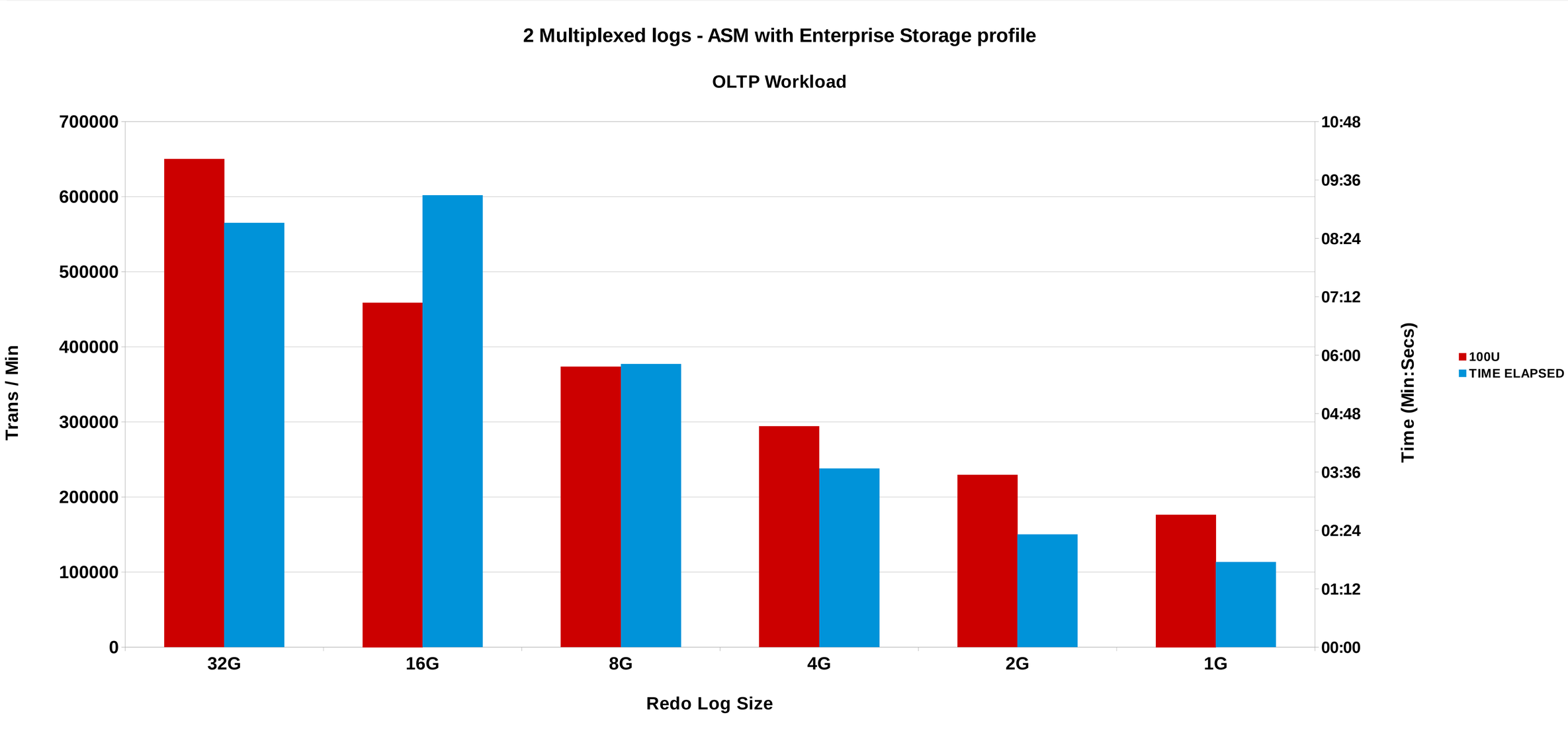
Redo Logs
Checkpoints, Redo Log Size, Multiplexing



Redo Logs
Checkpoints, Redo Log Size, Multiplexing



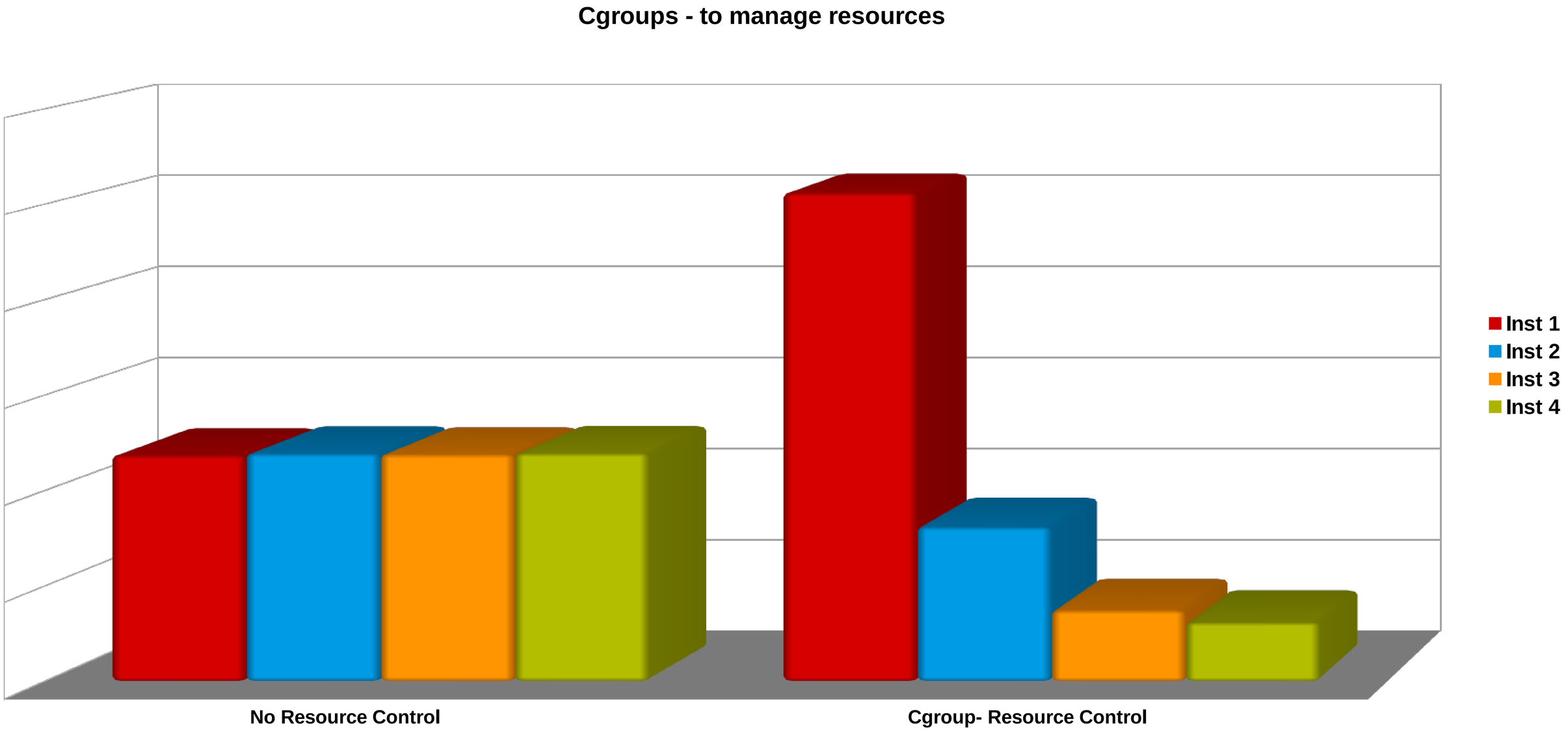
Redo Log size vs Recovery time



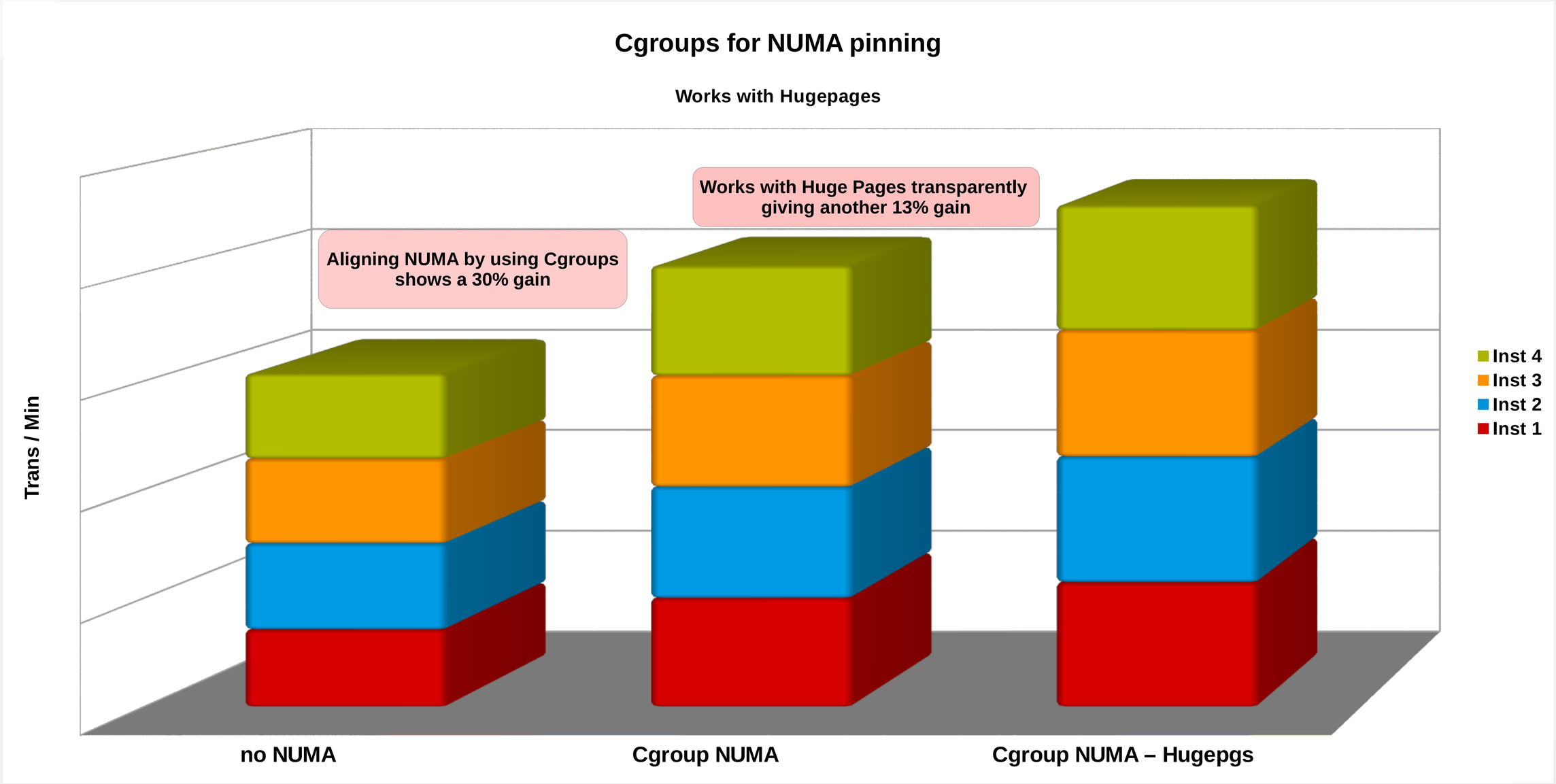
Cgroup

- **Resource Management**
  - Memory, cpus, IO, Network
  - For performance
  - For application consolidation
  - Dynamic resource allocation
- **Application Isolation**
- **I/O Cgroups**
  - At device level control the % of I/O for each Cgroup if the device is shared
  - At device level put a cap on the throughput

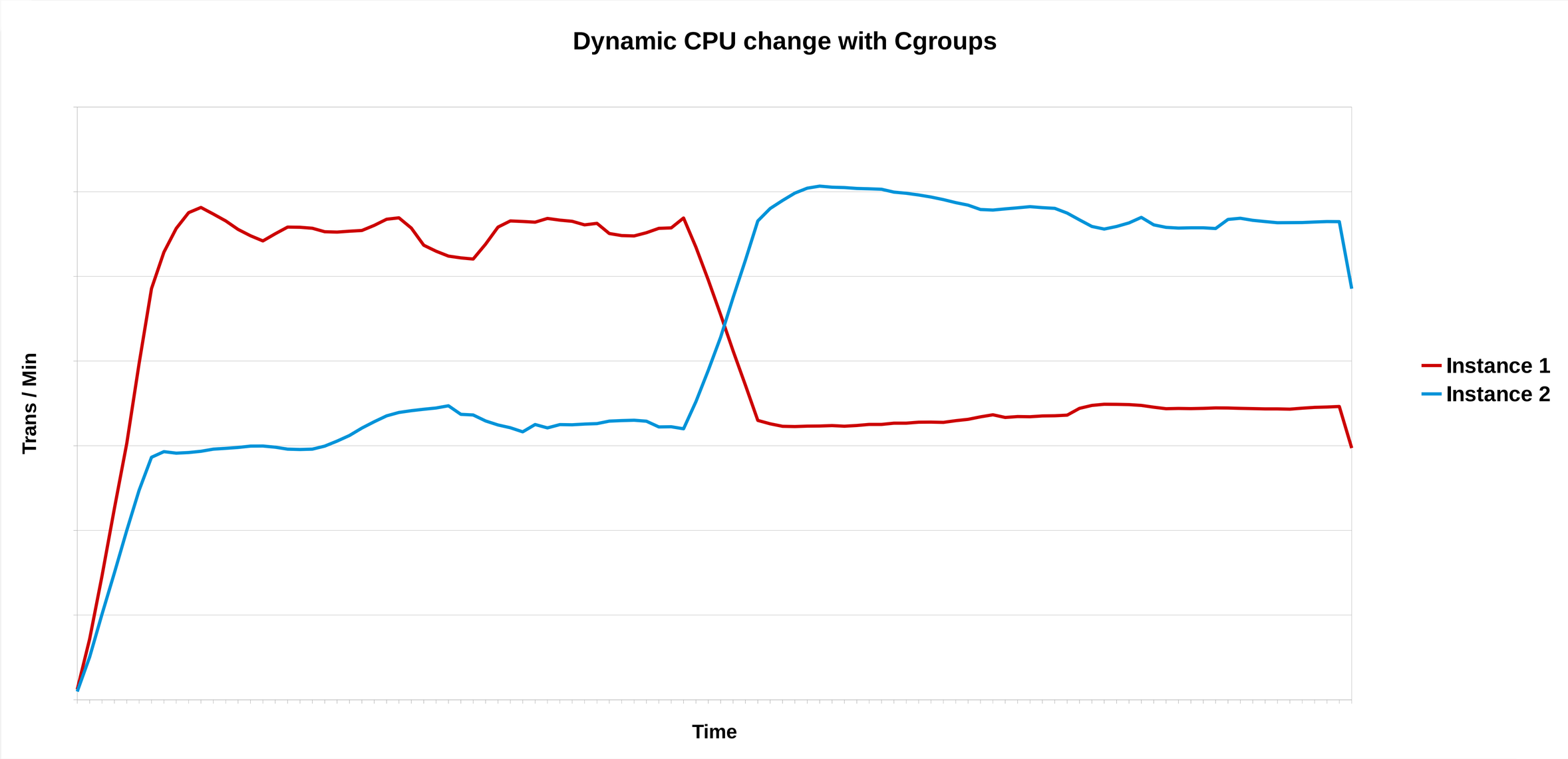
Cgroup – Resource management



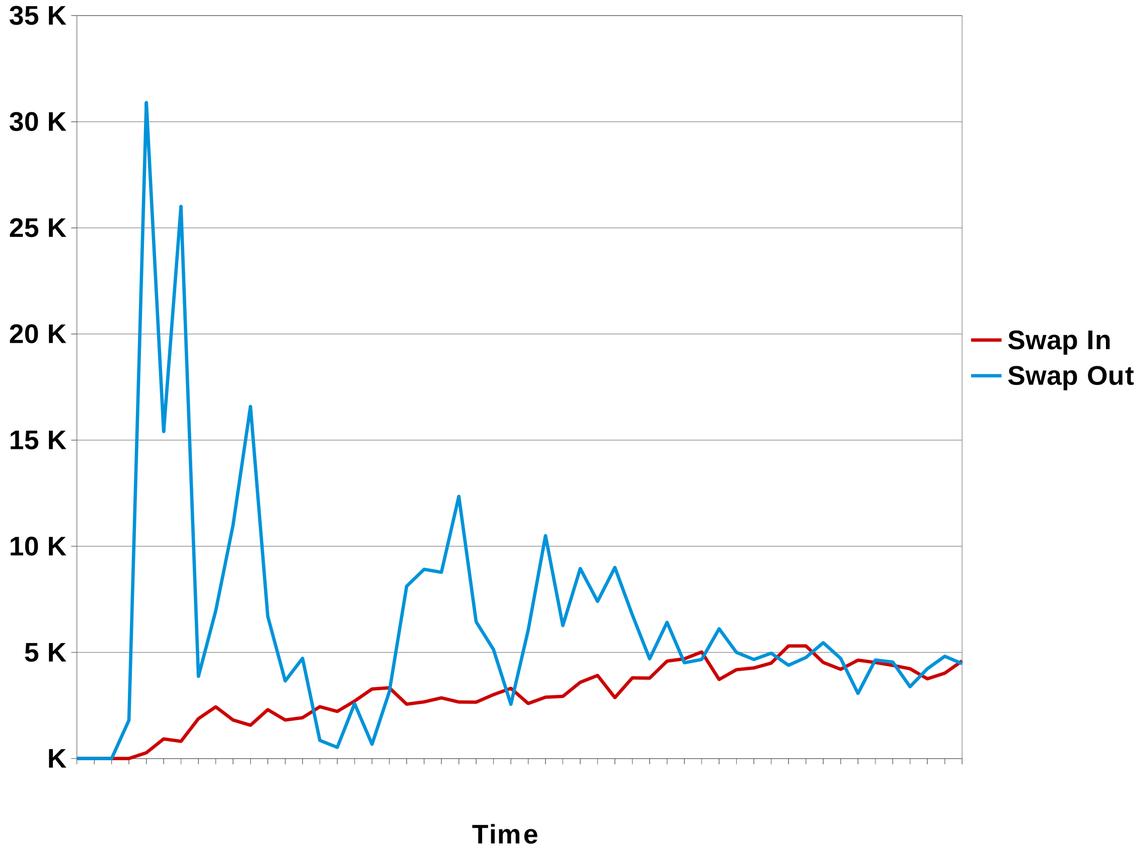
Cgroup – NUMA pinning

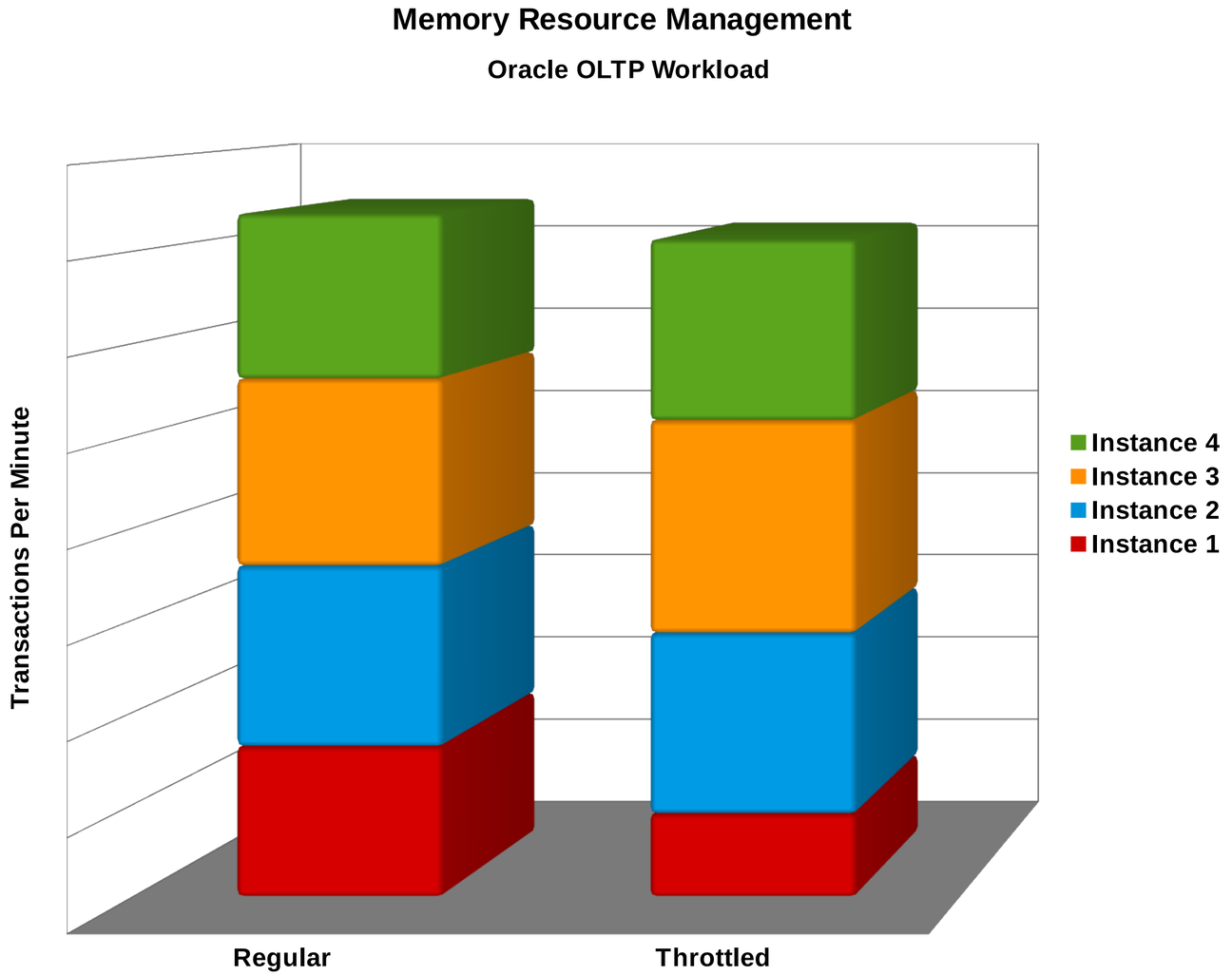


C-group - Dynamic resource control



Cgroup – Application Isolation





Even though one application does not have resources and starts swapping, other applications are not affected

Database on RHEV

Quick Overview – KVM Architecture

- Guests run as a process in userspace on the host
- A virtual CPU is implemented using a Linux thread
  - The Linux scheduler is responsible for scheduling a virtual CPU, as it is a normal thread
- Guests inherit features from the kernel
  - NUMA
  - Huge Pages
  - Support for new hardware

Virtualization Tuning – Caching

Figure 1

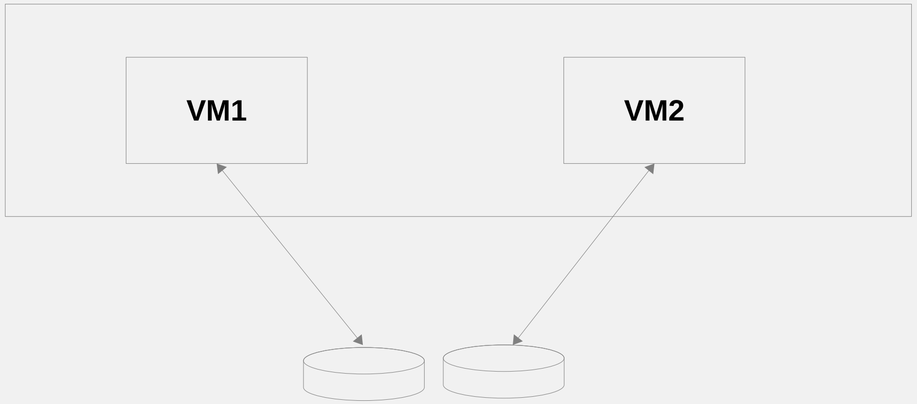
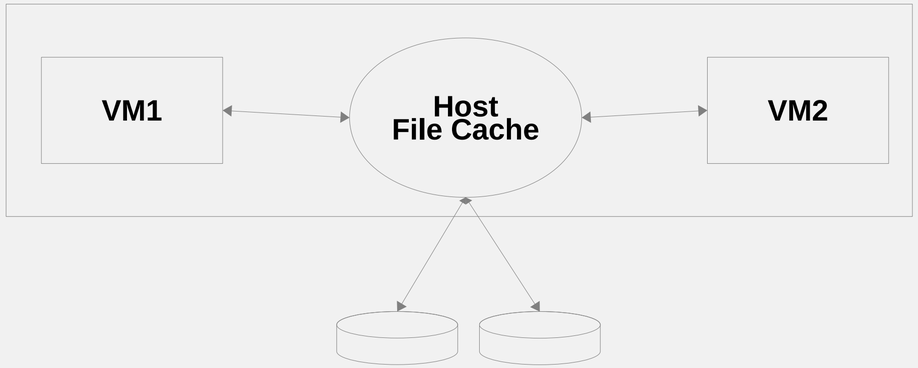
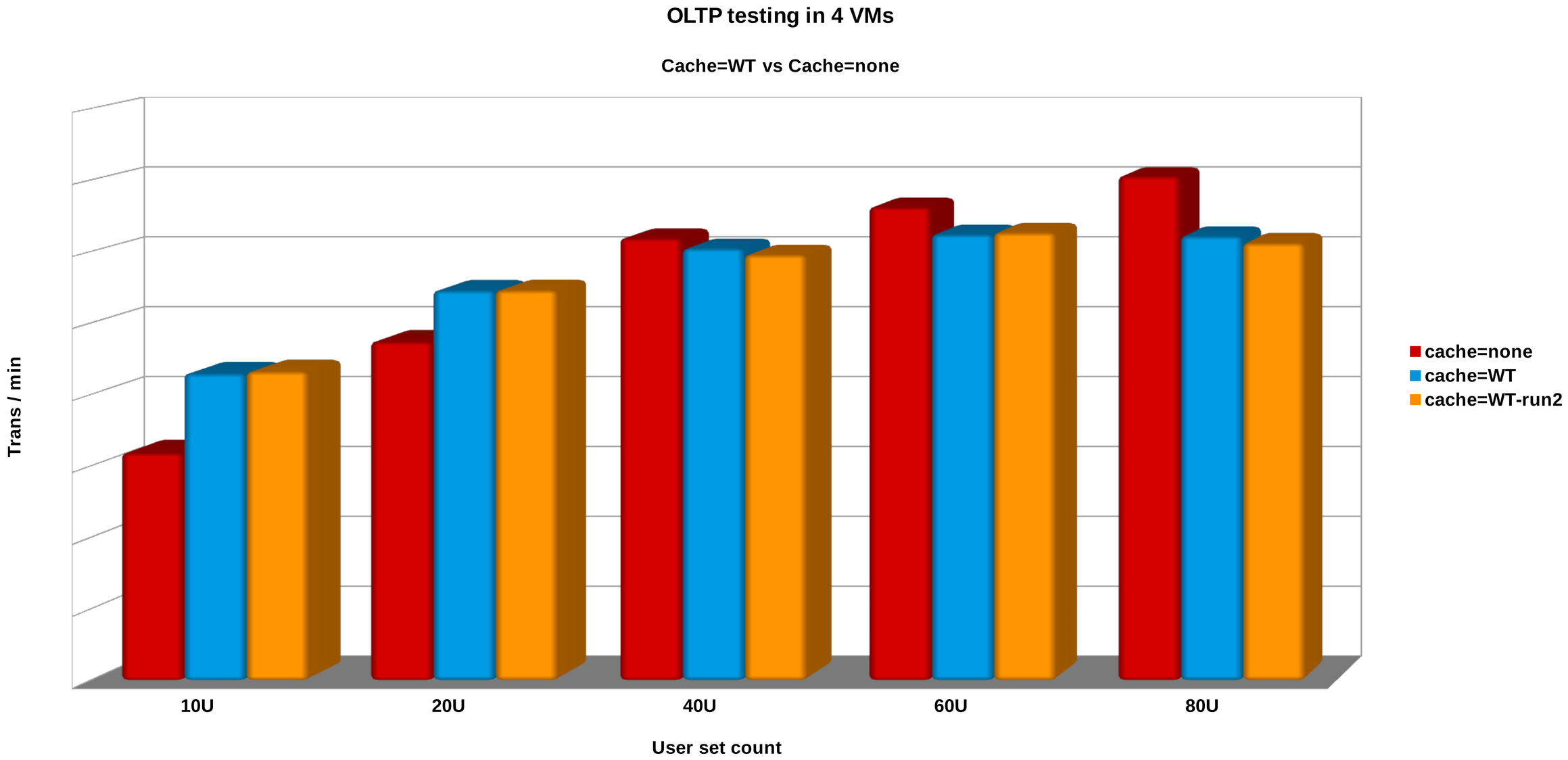


Figure 2

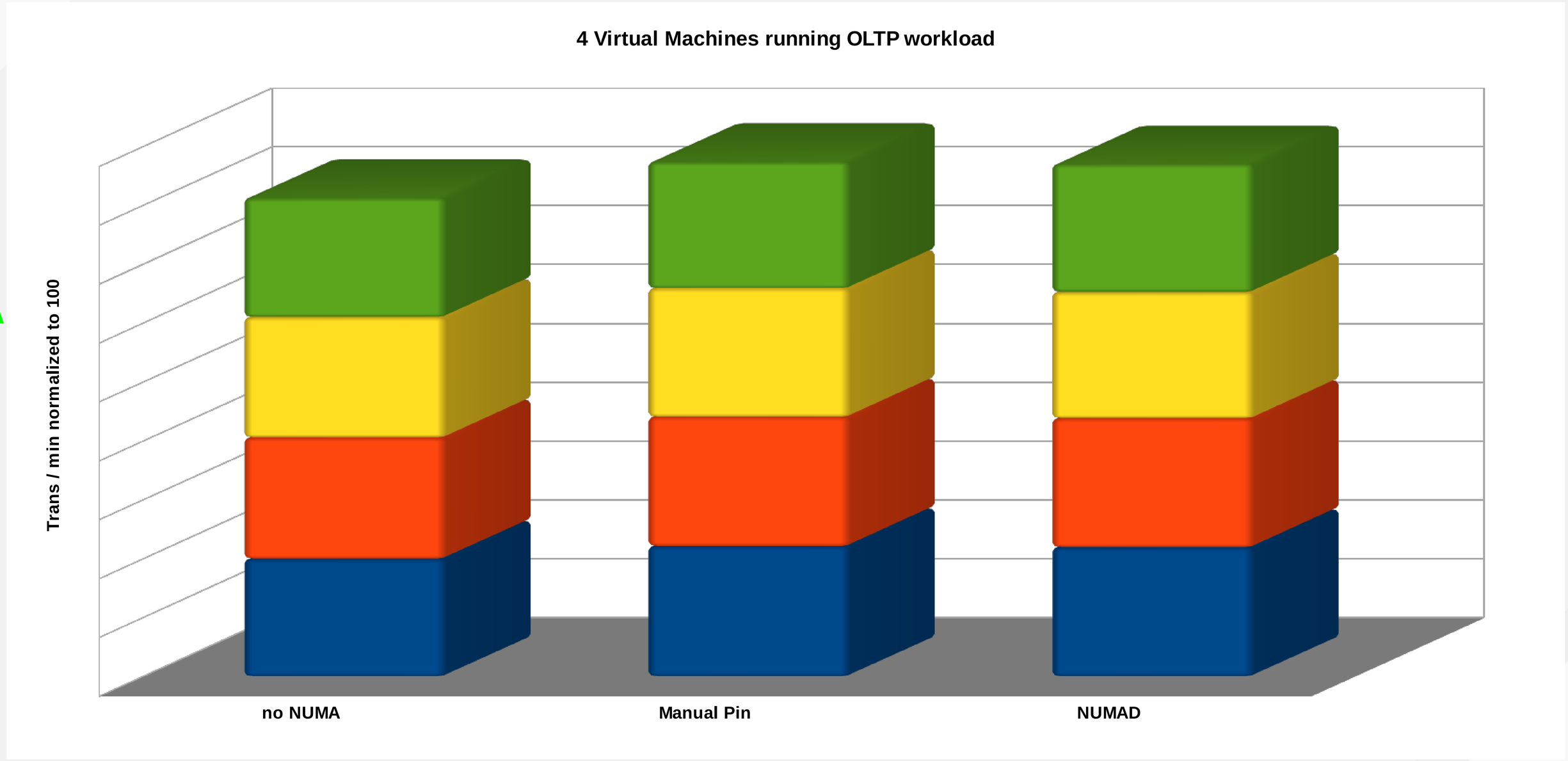


- **Cache = none (Figure 1)**
  - I/O from the guest is not cached on the host
- **Cache = writethrough (Figure 2)**
  - I/O from the guest is cached and written through on the host
    - Works well on large systems (lots of memory and CPU)
    - Potential scaling problems with this option with multiple guests (host CPU used to maintain cache)
    - Can lead to swapping on the host

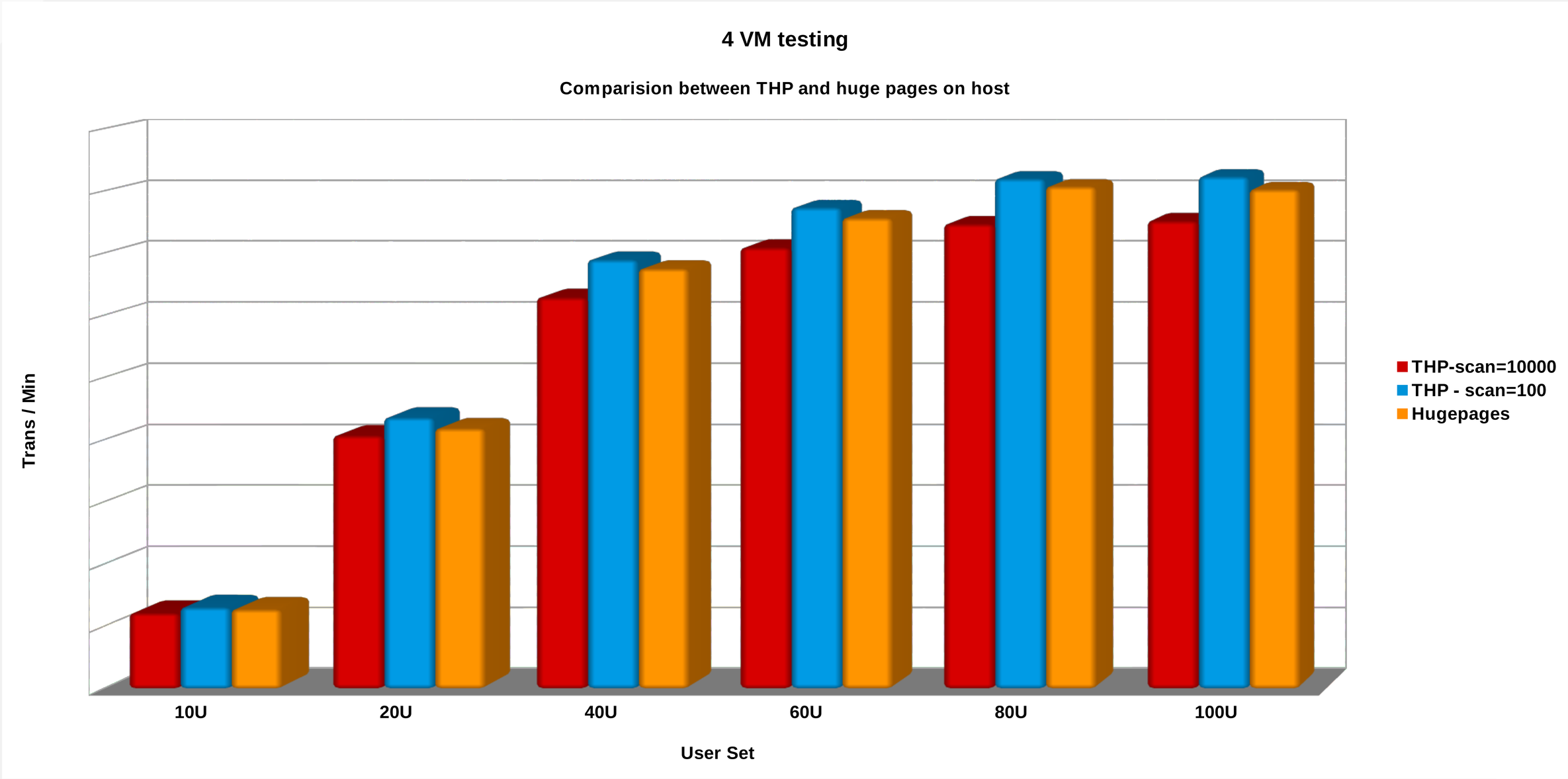
Virt Tuning – Effect of I/O Cache Settings



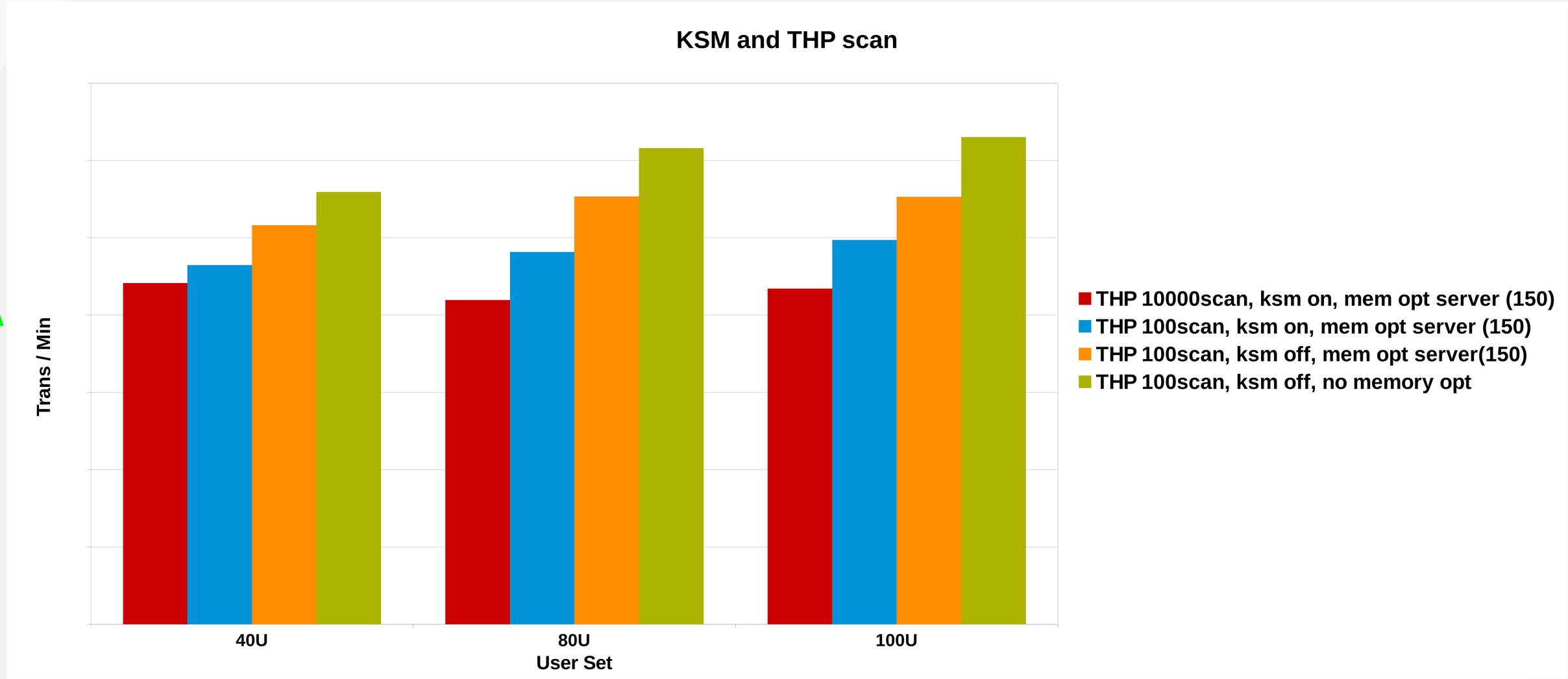
Virt Tuning – Using NUMA



Virt Tuning – Tuning Transparent Huge Pages



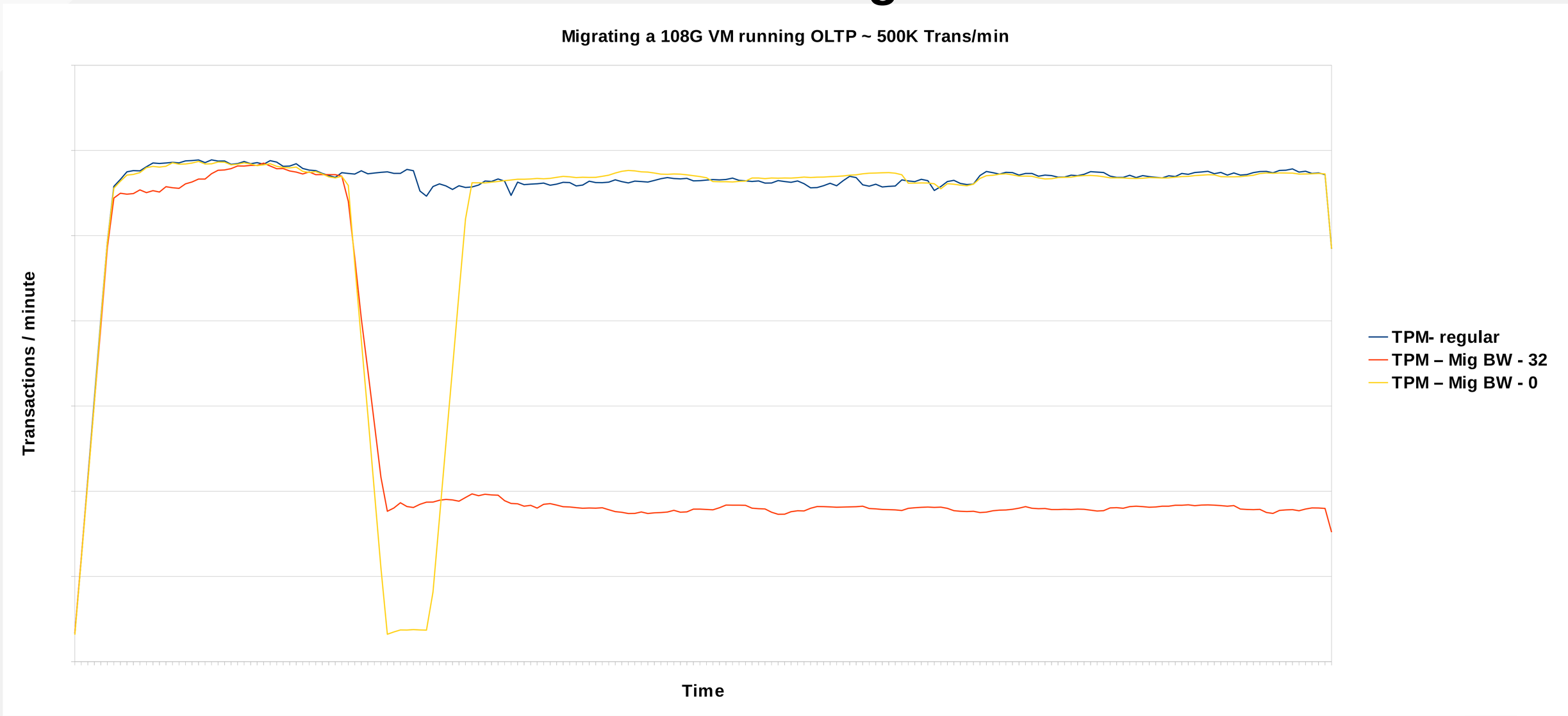
Virt Tuning – Kernel Samepage Merging (KSM)



Use KSM for

- **Running Windows Virtual Machines on RHEV**
- **Oversubscribing memory on the host**

RHEV 3.3 – Migration



Configure – migration_max_bandwidth = <Value> in /etc/vdsm/vdsm.conf

Virtualization Tuning – Network

- VirtIO
  - ✔VirtIO drivers for network
- vhost_net (low latency – close to line speed)
  - ✔Bypass the qemu layer
- PCI pass through
  - ✔Bypass the host and pass the PCI device to the guest
  - ✔Can be passed only to one guest
- SR-IOV (Single root I/O Virtualization)
  - ✔Pass through to the guest
  - ✔Can be shared among multiple guests
  - ✔Limited hardware support

Tools

Performance Monitoring Tools

- Monitoring tools
  - top, vmstat, ps, iostat, netstat, sar, perf
- Kernel tools
  - /proc, sysctl, AltSysRq
- Networking
  - ethtool, ifconfig
- Profiling
  - oprofile, strace, ltrace, systemtap, perf

Performance Monitoring Tool – perf

- Performance analysis tool
  - perf top (dynamic)
  - perf record / report (save and replay)
  - perf stat <command> (analyze a particular workload)

Performance Monitoring Tool – perf top

Multi Instance OLTP Run without Huge Pages

```
File  Edit  View  Search  Terminal  Help
Samples: 9M of event 'cycles', Event count (approx.): 1641057303107
  3.41%  oracle                    [.] kcbgtcr
  1.42%  oracle                    [.] ktrexc
  1.29%  oracle                    [.] __intel_new_memcpy
  1.22%  oracle                    [.] __intel_new_memset
  1.13%  oracle                    [.] kcbgtcr
  1.10%  oracle                    [.] kcbgcur
  1.01%  oracle                    [.] kdxlrs2
  0.90%  oracle                    [.] opiexe
  0.85%  oracle                    [.] kdxbrs1
  0.80%  [kernel]                  [k] page_fault
  0.76%  oracle                    [.] kcbgtcrf
  0.59%  [kernel]                  [k] ipt_do_table
  0.57%  oracle                    [.] ktbgfi
  0.54%  [kernel]                  [k] _raw_spin_lock
  0.53%  oracle                    [.] opipls
  0.48%  oracle                    [.] ktrexc
  0.47%  [kernel]                  [k] __radix_tree_lookup
  0.46%  perf                      [.] 0x0000000000065d66
  0.45%  [kernel]                  [k] tg_load_down
  0.45%  oracle                    [.] __intel_new_memcpy
  0.42%  oracle                    [.] __intel_new_memset
  0.41%  oracle                    [.] kduovw
  0.41%  perf                      [.] dso__find_symbol
  0.40%  oracle                    [.] kslfre
  0.38%  oracle                    [.] kcrfw_redo_gen
  0.38%  oracle                    [.] ktuchg2
  0.37%  oracle                    [.] kcbgcur
  0.37%  [vdso]                    [.] 0x0000000000000cd0
  0.37%  [kernel]                  [k] _raw_spin_lock_irqsave
  0.37%  [kernel]                  [k] update_cfs_rq_blocked_load
  0.37%  oracle                    [.] kslgetl
  0.36%  oracle                    [.] kdudcp
```

Performance Monitoring Tool – perf record / report

Multi Instance OLTP Run with Huge Pages

root@perf30:~

File Edit View Search Terminal Help

```
amples: 1M of event 'cycles', Event count (approx.): 656344167175
 2.62%           oracle  oracle                   [.] kcbgtcr
 1.55%           oracle  oracle                   [.] ktrexc
 1.36%           oracle  oracle                   [.] __intel_new_memcpy
 1.35%           oracle  oracle                   [.] __intel_new_memset
 1.07%           oracle  oracle                   [.] kdxlrs2
 0.96%           oracle  oracle                   [.] kcbgcur
 0.92%           oracle  oracle                   [.] opiexe
 0.91%           oracle  oracle                   [.] kcbgtcr
 0.90%           oracle  oracle                   [.] kdxbrs1
 0.63%           oracle  oracle                   [.] ktbgfi
 0.59%           oracle  oracle                   [.] ktrexc
 0.57%           oracle  oracle                   [.] opipls
 0.54%           oracle  oracle                   [.] kcbgtcrf
 0.52%           oracle  oracle                   [.] __intel_new_memcpy
 0.50%           oracle  oracle                   [.] __intel_new_memset
 0.47%           oracle  [kernel.kallsyms]        [k] tg_load_down
 0.44%           oracle  oracle                   [.] kslfre
 0.44%           oracle  oracle                   [.] kcbchg1_main
 0.44%           oracle  oracle                   [.] kcrfw_redo_gen
 0.44%           oracle  oracle                   [.] kduovw
 0.42%           oracle  [vdso]                   [.] 0x0000000000000cd0
 0.42%           oracle  oracle                   [.] ktuchg2
 0.41%           oracle  oracle                   [.] kdxlrs2
 0.40%           oracle  oracle                   [.] kdudcp
 0.39%          swapper  [kernel.kallsyms]        [k] intel_idle
 0.38%           oracle  oracle                   [.] kpobii
 0.36%  runoastoltpb.ex  libclntsh.so.11.1        [.] ttcacr
 0.35%           oracle  oracle                   [.] kslgetl
 0.34%           oracle  oracle                   [.] kcbgcur
 0.34%           oracle  [kernel.kallsyms]        [k] ipt_do_table
 0.33%           oracle  [kernel.kallsyms]        [k] update_cfs_rq_blocked_load
 0.33%           oracle  oracle                   [.] opiexe
 0.33%           oracle  oracle                   [.] kdimodnu0
 0.32%           oracle  oracle                   [.] kdiins0
```

Performance Monitoring Tool – perf stat

- perf stat <command>
  - monitors any workload and collects variety of statistics
  - can monitor specific events for any workload with -e flag (“perf list” give list of events)

“perf stat” – with regular 4k pages

```
 Performance counter stats for <database workload>

    7344954.315998 task-clock                #    6.877 CPUs utilized
        64,577,684 context-switches          #    0.009 M/sec
        23,074,271 cpu-migrations            #    0.003 M/sec
         1,621,164 page-faults               #    0.221 K/sec
16,251,715,158,810 cycles                    #    2.213 GHz                      [83.35%]
12,106,886,605,229 stalled-cycles-frontend   #   74.50% frontend cycles idle     [83.33%]
 8,559,530,346,324 stalled-cycles-backend    #   52.67% backend  cycles idle     [66.66%]
 5,909,302,532,078 instructions              #    0.36  insns per cycle
                                             #    2.05  stalled cycles per insn [83.33%]
 1,585,314,389,085 branches                  #  215.837 M/sec                    [83.31%]
    43,276,126,707 branch-misses             #    2.73% of all branches          [83.35%]

    1068.000304798 seconds time elapsed
```

Performance Monitoring Tool – perf stat

“perf stat” - with 2M huge pages

```
 Performance counter stats for <database workload>

    9262233.382377 task-clock                #    8.782 CPUs utilized
        66,611,453 context-switches          #    0.007 M/sec
        25,096,578 cpu-migrations            #    0.003 M/sec
         1,304,385 page-faults               #    0.141 K/sec
20,545,623,374,830 cycles                    #    2.218 GHz                      [83.34%]
15,032,568,156,397 stalled-cycles-frontend   #   73.17% frontend cycles idle     [83.33%]
10,633,625,096,508 stalled-cycles-backend    #   51.76% backend  cycles idle     [66.66%]
 7,533,778,949,221 instructions              #    0.37  insns per cycle
                                             #    2.00  stalled cycles per insn [83.33%]
 2,109,143,617,292 branches                  #  227.714 M/sec                    [83.33%]
    45,626,829,201 branch-misses             #    2.16% of all branches          [83.33%]

    1054.730657871 seconds time elapsed
```

Performance Monitoring Tool – sar

Output of "sar -N DEV 3"
For a DSS workload running on iSCSI storage using different MTUs

1500 MTU

	IFACE	rxpck/s	txpck/s	rxkB/s	txkB/s	rxcmp/s	txcmp/s	rxmcst/s
01:40:08 PM								
01:40:11 PM	eth0	0.34	0.34	0.02	0.02	0.00	0.00	0.00
01:40:11 PM	eth5	135016.78	19107.72	199178.19	1338.53	0.00	0.00	0.34
01:40:14 PM	eth0	0.66	0.00	0.05	0.00	0.00	0.00	0.66
01:40:14 PM	eth5	133676.74	18911.30	197199.84	1310.25	0.00	0.00	0.66
01:40:17 PM	eth0	0.67	0.00	0.05	0.00	0.00	0.00	0.67
01:40:17 PM	eth5	134555.85	19045.15	198502.27	1334.19	0.00	0.00	0.33
01:40:20 PM	eth0	1.00	0.00	0.07	0.00	0.00	0.00	0.67
01:40:20 PM	eth5	134116.33	18972.33	197849.55	1325.03	0.00	0.00	1.00

9000 MTU

	IFACE	rxpck/s	txpck/s	rxkB/s	txkB/s	rxcmp/s	txcmp/s	rxmcst/s
06:58:43 PM								
06:58:46 PM	eth0	0.91	0.00	0.07	0.00	0.00	0.00	0.00
06:58:46 PM	eth5	104816.36	48617.27	900444.38	3431.15	0.00	0.00	0.91
06:58:49 PM	eth0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06:58:49 PM	eth5	118269.80	54965.84	1016151.64	3867.91	0.00	0.00	0.50
06:58:52 PM	eth0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06:58:52 PM	eth5	118470.73	54382.44	1017676.21	3818.35	0.00	0.00	0.98
06:58:55 PM	eth0	0.94	0.00	0.06	0.00	0.00	0.00	0.00
06:58:55 PM	eth5	115853.05	53515.49	995087.67	3766.28	0.00	0.00	0.47

Wrap Up – Bare Metal

- I/O
  - Choose the right elevator
  - Eliminated hot spots
  - Direct I/O or Asynchronous I/O
  - Virtualization – Caching
- Memory
  - NUMA
  - Huge Pages
  - Swapping
  - Managing Caches
- RHEL has many tools to help with debugging / tuning

Wrap Up – Bare Metal (cont.)

- CPU
  - Check cpuspeed settings
- Network
  - Separate networks
  - arp_filter
  - Packet size

LEARN. NETWORK.
EXPERIENCE OPEN SOURCE.