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Achieving Top Network Performance

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06.27.12

Not Covered

- Bonding
- RHEL5
- Wireless
- Coding examples
  - Some mentions of tips

Take Aways

- Awareness of the issues
- Awareness of tools
- Guidelines

Take Aways

- You will leave this discussion with:
  - An understanding of some issues affecting server network performance
  - Tools to help you evaluate your network performance
  - Some guidelines to try in your environment

Some Quick Disclaimers

- We do not recommend one vendor over another
- Test data used is based on “performance mode”
  - Maximize a particular thing at the expense of other things
  - Not recommended for production
- Don't assume settings shown will work for you without some tweaks
  - Always experiment to find what works best in your environment

Agenda

- Why Bother ?
- Basic Concepts
- RHEL5 -> RHEL6
- Tuning Knobs and Auto Tuning
- Real World Debug
- Wrap Up

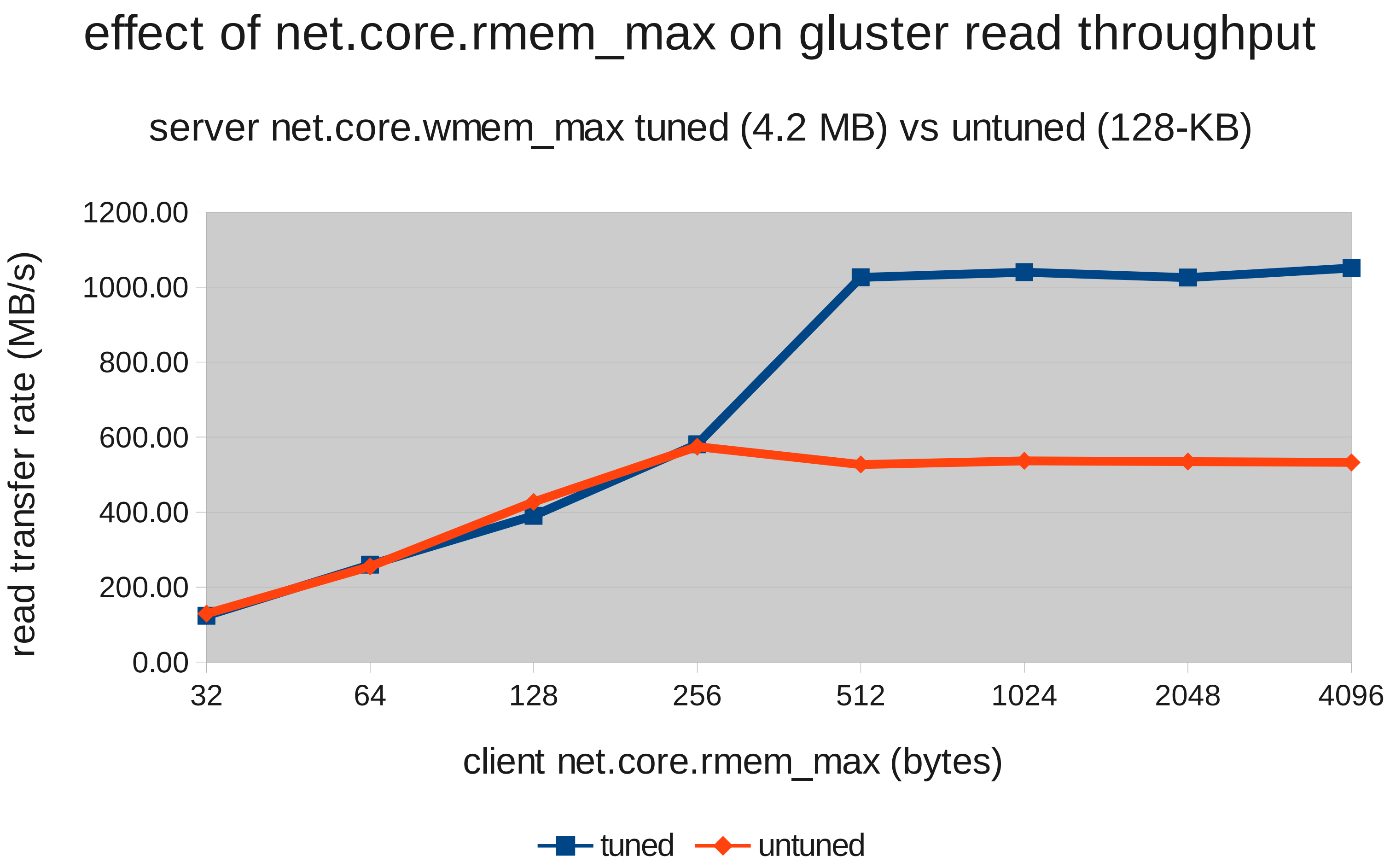
Agenda

- Why Bother ?
  - 40 gbit, gluster,latency
- Basic Concepts
  - Pci, cpu, numa
  - Offloads, rdma, solarflare, etc
  - The Virtual World
- RHEL5 -> RHEL6
  - Multiqueue, cgroups,steering, sctp, congestion control

Agenda

- Tunings
  - Drivers
    - Modinfo, modprobe, ethtool
  - Sysctl
  - Application, System
- Debug examples
  - Netperf throughput,Latency,Gluster
- Wrap up

Teaser 1 – Gluster



Teaser 2 – 40 Gbit / sec netperf

- Two 40Gbit cards back to back (no switch).

```
# ./netperf -l 30 -H 172.17.200.82
TCP STREAM TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to
172.17.200.82 (172.17.200.82) port 0 AF_INET : spin interval : demo
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec

 87380  16384  16384    30.00      8868.76
```

Teaser 3 – latency

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Basics Concepts

- NUMA
- PCI bus
- CPU Characteristics
- Power Management
- The Virtual World

Memory Characteristics

- Memory Speed is crucial
  - Faster is better
- Understand layout and its impact
  - On middle age systems, fully populating the memory will slow it down
- Triple check your BIOS settings
  - Make sure that you pick settings for optimal performance

What is NUMA ?

- NUMA – Non Uniform Memory Architecture
  - Make bigger systems scalable by distributing system memory near individual CPUs
- NUMA has been around for a long time
  - In the past was in specialized high end systems
  - now the norm across the board for servers
- Most current multi-socket systems...
  - Recent AMD systems have 2 nodes / socket

“Issues” that NUMA makes visible

- System scheduler
- Non-local memory accesses

“Issues” that NUMA makes visible

- RHEL6 system scheduler appears biased towards responsiveness and optimizing for CPU utilization
  - It will often align network app on same core as interrupt
- Tries to use idle CPUs, regardless of where process memory is located!
- Non-local memory accesses have higher access latency, which degrades performance

NUMA - Latency

```
[root@perf ~]# 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
```

Numa – Latency

- Sample inter-NUMA-node relative latency:
  - Intel 4 socket / 4 node: 1.5x
  - AMD 4 socket / 8 node: 2.7x
  - 8 socket / 8 node: 2.8x
  - 32 node blade system: 5.5x

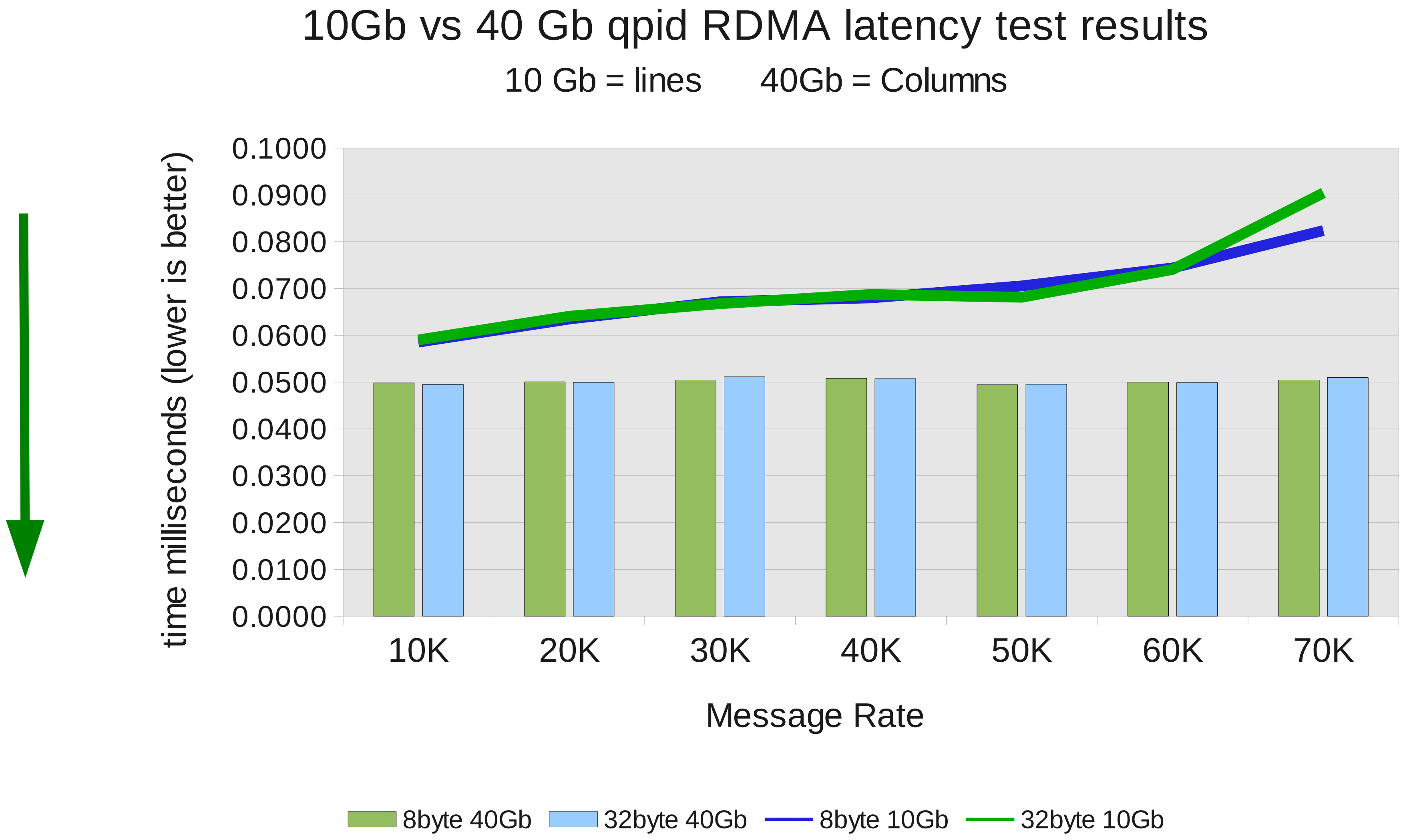
PCI Bus – and related issues

- Slot speed
- Multiple buses / Affinity
- Tools

PCI Bus – and related issues

- Make sure that you know the slot speed !
  - 10 Gbit needs 8X
    - At least with Gen2
  - 40 Gbit speeds need PCI-e 3
- Find if the slot is tied to a specific NUMA node
  - Know the bindings
  - Spread the load
- Can you change any of the parameters ?
  - setpci can change some of the parameters
    - It is tricky and dangerous

40 Gbit Gen3 vs 10 Gbit PCI Gen2 latency



CPU Characteristics – Basics

- Cache layout
- Hyperthreads
- cstates

CPU Characteristics – Basics

- Understand cache layout
  - It changes with different chip generations
  - Try to keep cache lines hot
- To use hyperthreads or not
  - No one stop answer
    - For latency sensitive probably not
    - For applications that block a lot probably yes
- cstates
  -

CPU – Power related characteristics

- Variable frequencies
- Multiple cores
- Power saving modes (cpuspeed governors)
  - performance
  - ondemand
  - Powersave

CPU – Performance Governors

- echo "performance" > \
  /sys/devices/system/cpu/cpu0/cpufreq/scaling_governor

- Best of both worlds – cron jobs to configure the governor mode using tuned-adm
  - tuned-adm profile latency-performance

Power Management– not always your friend

- Each HW generation power control evolves
  - Trend is towards power saving
  - Is good for the world
- BIOS / OS Control
  - Pstates in BIOS
  - Cstates in OS

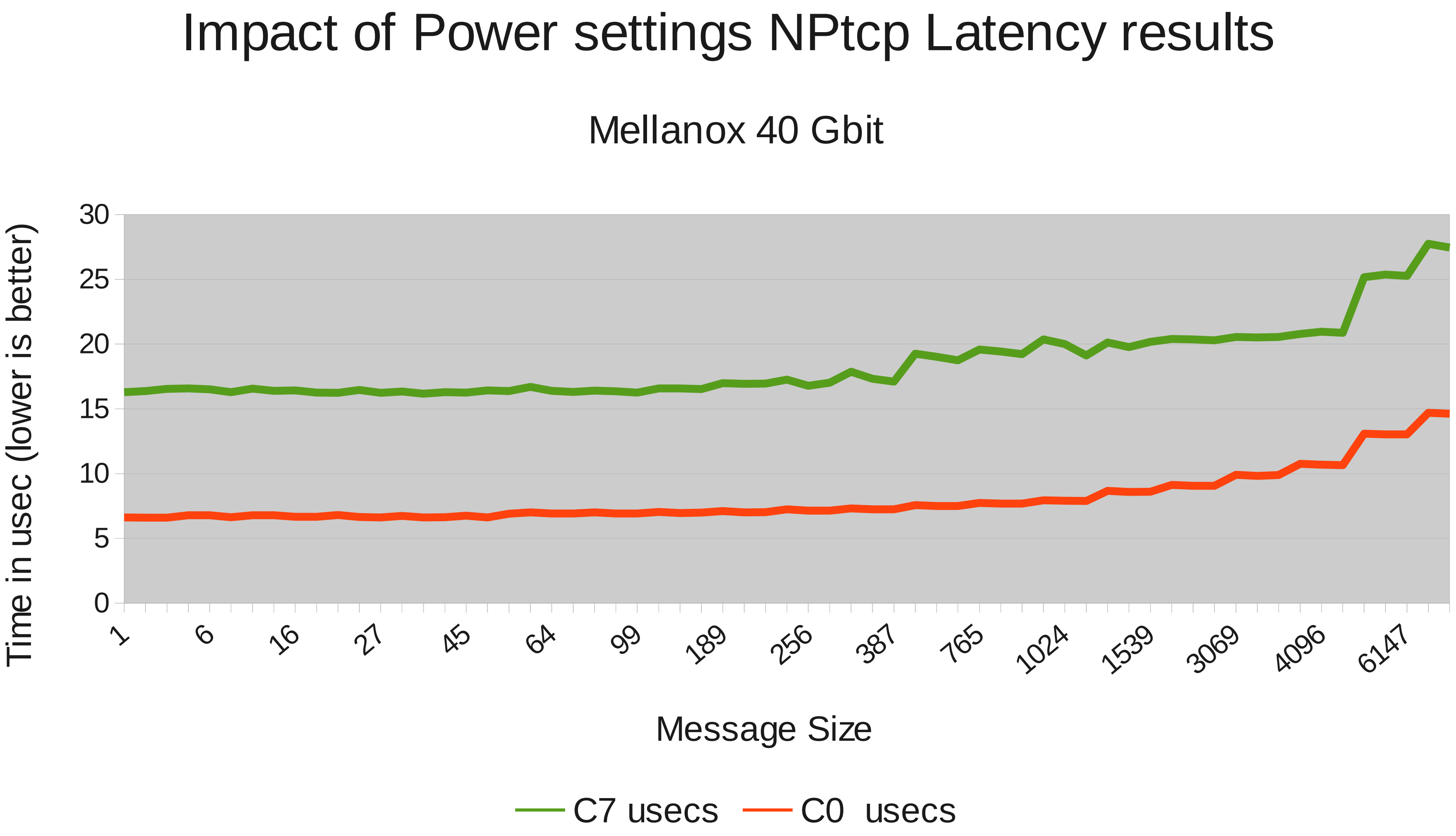
CSTATE default – C7 on this config

```
pk cor CPU    %c0  GHz  TSC    %c1    %c3    %c6    %c7  %pc2   %pc3  %pc6   %pc7   SMIs
             0.04 1.43 2.19   0.08   0.00   0.00  99.89  4.46   0.00  93.94  0.00      0
 0   0   0   0.41 1.28 2.19   0.93   0.01   0.00  98.66  3.13   0.01  93.91  0.00      0
 0   1   1   0.04 1.66 2.19   0.06   0.00   0.00  99.91  3.13   0.01  93.91  0.00      0
 0   2   2   0.01 1.73 2.19   0.01   0.00   0.00  99.98  3.13   0.01  93.92  0.00      0
 0   3   3   0.01 1.72 2.19   0.02   0.01   0.00  99.96  3.13   0.01  93.92  0.00      0
 0   4   4   0.01 1.85 2.19   0.01   0.00   0.00  99.98  3.13   0.01  93.92  0.00      0
 0   5   5   0.01 1.94 2.19   0.01   0.00   0.00  99.98  3.13   0.01  93.91  0.00      0
 0   6   6   0.01 1.92 2.19   0.02   0.00   0.00  99.98  3.13   0.01  93.91  0.00      0
 0   7   7   0.01 1.76 2.19   0.01   0.00   0.00  99.98  3.13   0.01  93.91  0.00      0
 1   0   8   0.01 1.71 2.19   0.02   0.01   0.00  99.96  5.80   0.00  93.96  0.00      0
 1   1   9   0.01 1.69 2.19   0.02   0.01   0.00  99.97  5.80   0.00  93.96  0.00      0
 1   2  10   0.01 1.75 2.19   0.02   0.00   0.00  99.97  5.80   0.00  93.96  0.00      0
 1   3  11   0.01 1.83 2.19   0.02   0.00   0.00  99.97  5.80   0.00  93.96  0.00      0
 1   4  12   0.01 1.84 2.19   0.02   0.00   0.00  99.97  5.80   0.00  93.96  0.00      0
 1   5  13   0.01 1.91 2.19   0.02   0.00   0.00  99.98  5.80   0.00  93.96  0.00      0
 1   6  14   0.01 1.96 2.19   0.02   0.00   0.00  99.98  5.80   0.00  93.96  0.00      0
 1   7  15   0.01 2.38 2.19   0.03   0.00   0.00  99.96  5.80   0.00  93.96  0.00      0
```

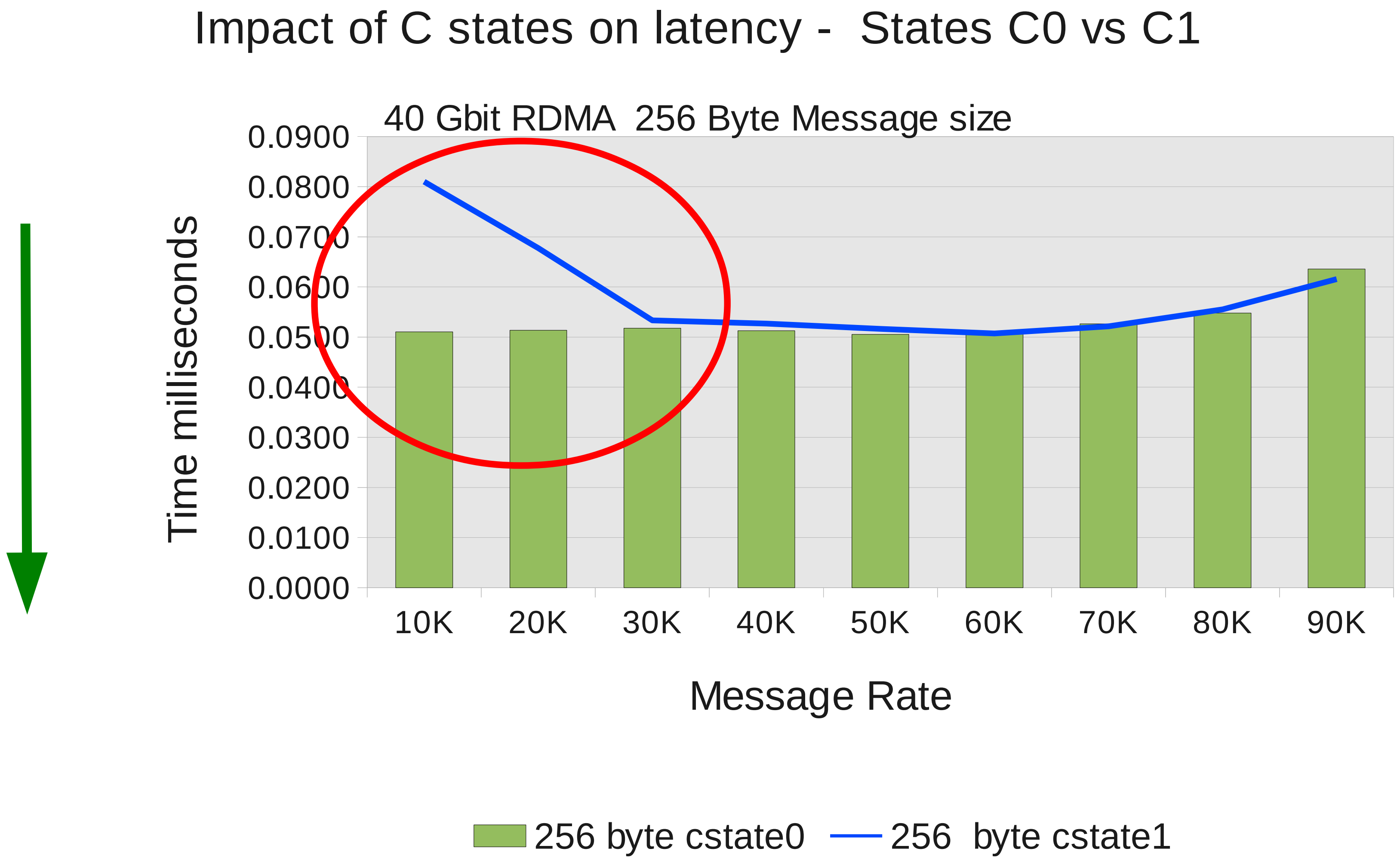
CSTATE disabled – Note speed

```
 pk cor CPU    %c0  GHz  TSC     %c1     %c3     %c6     %c7    %pc2    %pc3    %pc6    %pc7   SMIs
            100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  0   0   0 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  0   1   1 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  0   2   2 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  0   3   3 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  0   4   4 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  0   5   5 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  0   6   6 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  0   7   7 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  1   0   8 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  1   1   9 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  1   2  10 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  1   3  11 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  1   4  12 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  1   5  13 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  1   6  14 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
  1   7  15 100.00 2.69 2.19    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00      0
```

NPtcp latency vs cstates – c7 vs c0



Cstates impact on Latency



RHEL6 “tuned-adm” profiles

```
# tuned-adm list
Available profiles:
  - default
- latency-performance
- throughput-performance
- enterprise-storage
- virtual-host, virtual-guest *
```

Example

```
# tuned-adm profile enterprise-storage
```

* NEW for RHEL6.3

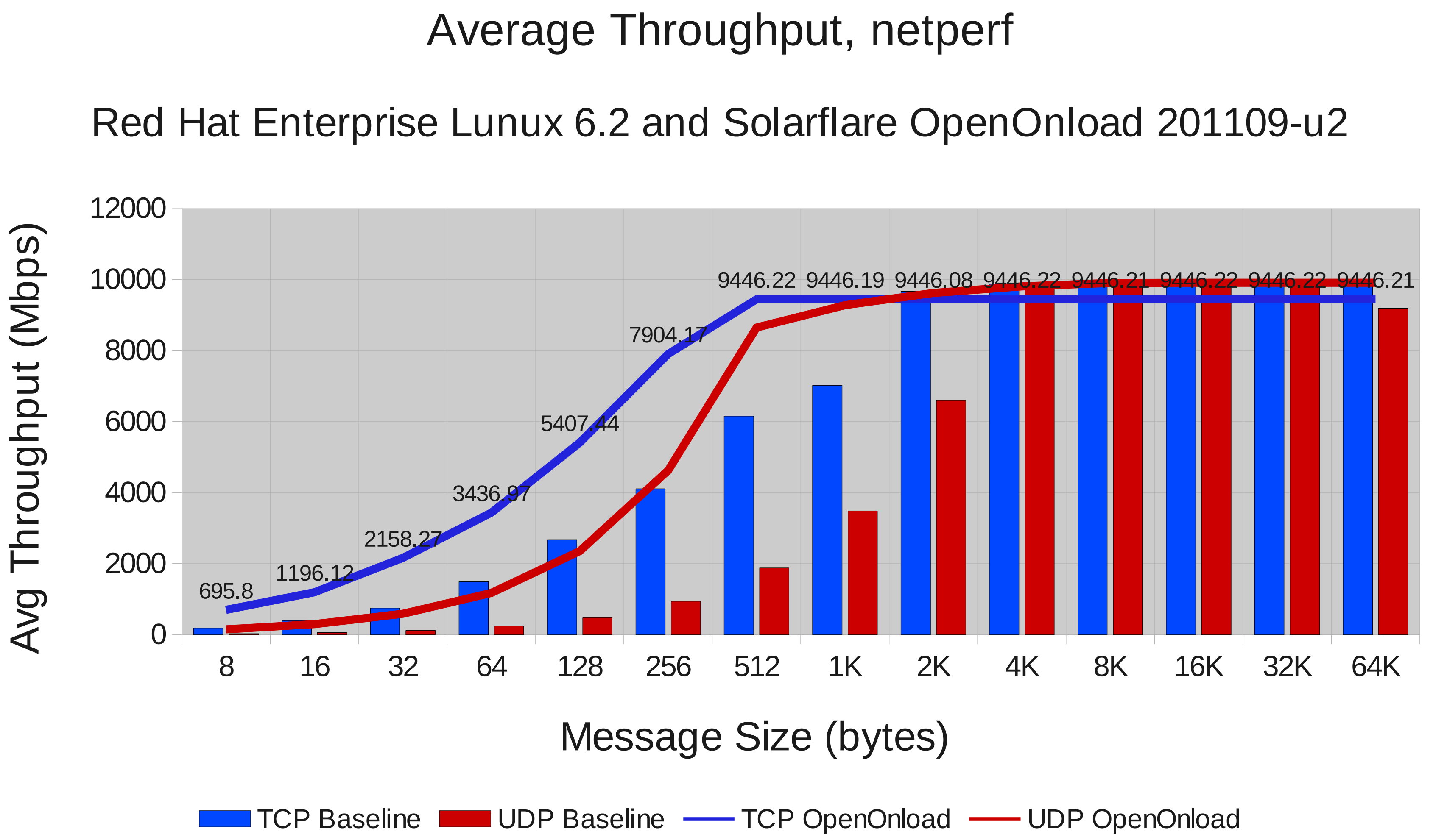
tuned profiles – virtual-host/guest new RHEL6.3

Tunable	default	latency-performance	throughput-performance	enterprise-storage	virtual-host	virtual-guest
kernel.sched_min_granularity_ns	4ms		10ms	10ms	10ms	10ms
kernel.sched_wakeup_granularity_ns	4ms		15ms	15ms	15ms	15ms
vm.dirty_ratio	20% RAM		40%	40%	10%	40%
vm.dirty_background_ratio	10% RAM				5%	
vm.swappiness	60				10	30
I/O Scheduler (Elevator)	CFQ	deadline	deadline	deadline	deadline	deadline
Filesystem Barriers	On			Off	Off	Off
CPU Governor	ondemand	performance	performance	performance	performance	performance
Disk Read-ahead				4x	4x	4x

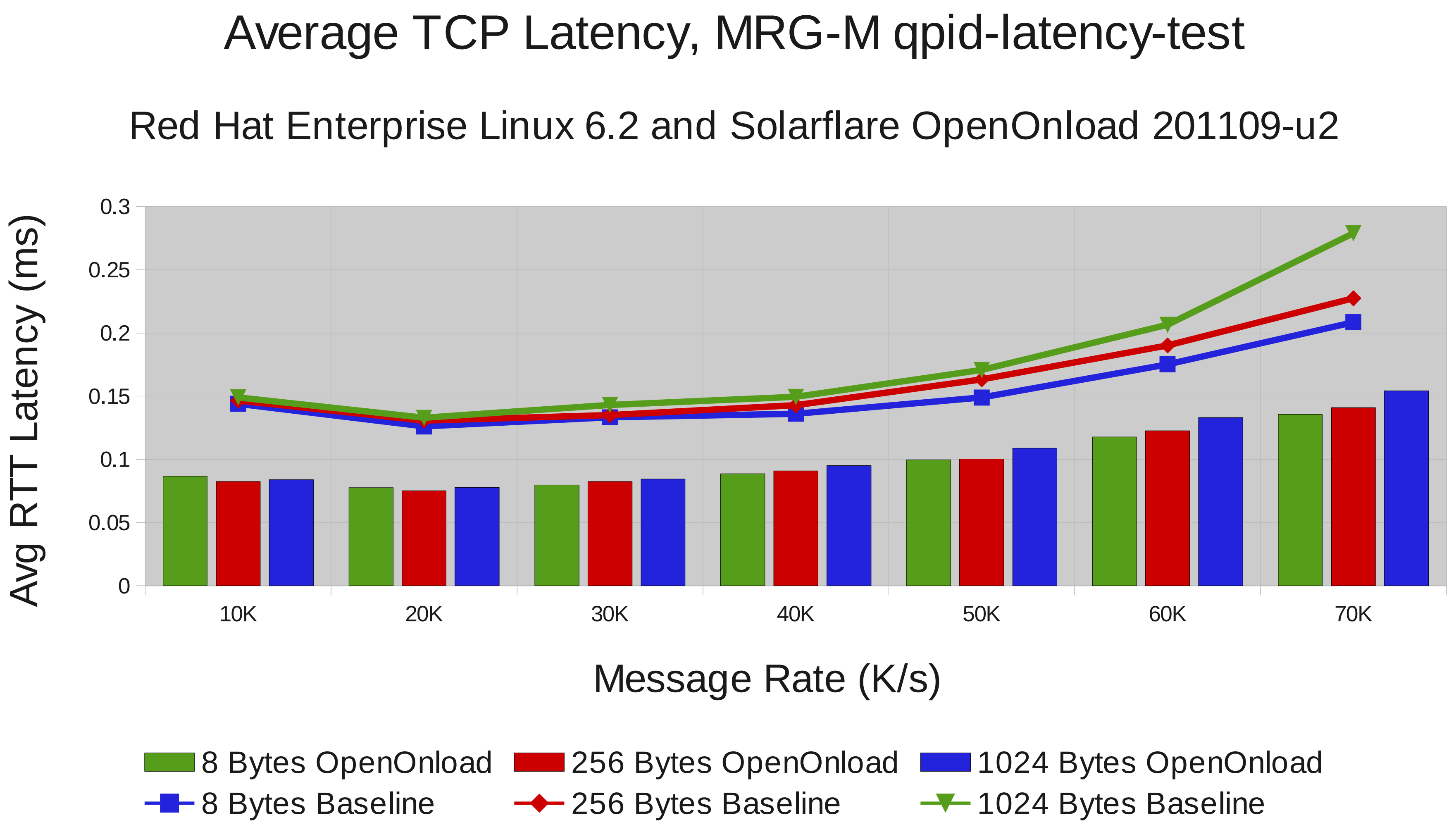
Kernel Bypass Technologies – Pros and Cons

- Multiple Technologies
- Some Proprietary
  - SolarFlare OpenOnload
- Coding Changes needed
  - RDMA

OpenOnload – Throughput

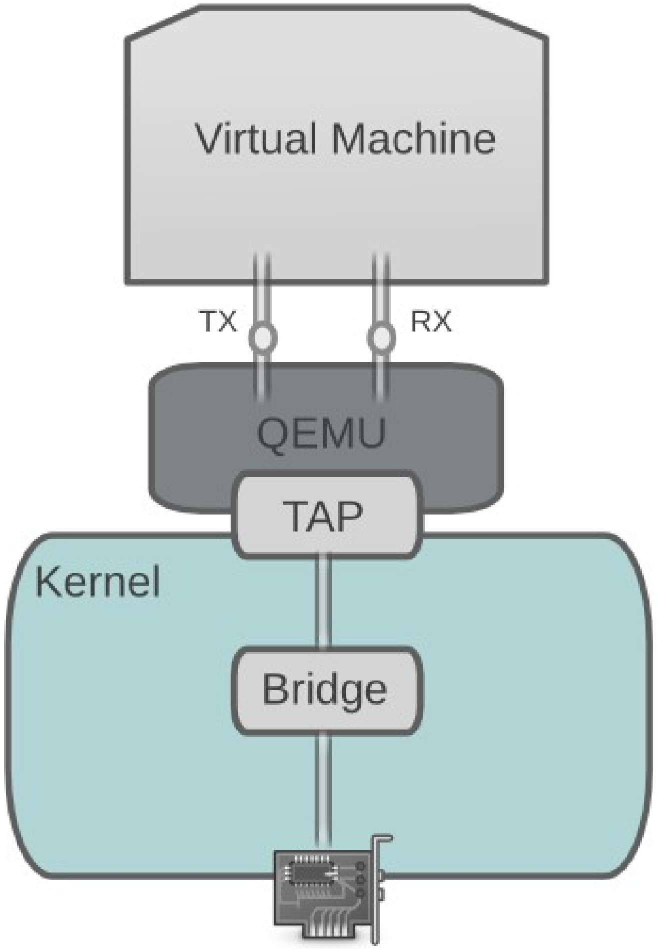


Offload – Solarflare OpenOnload



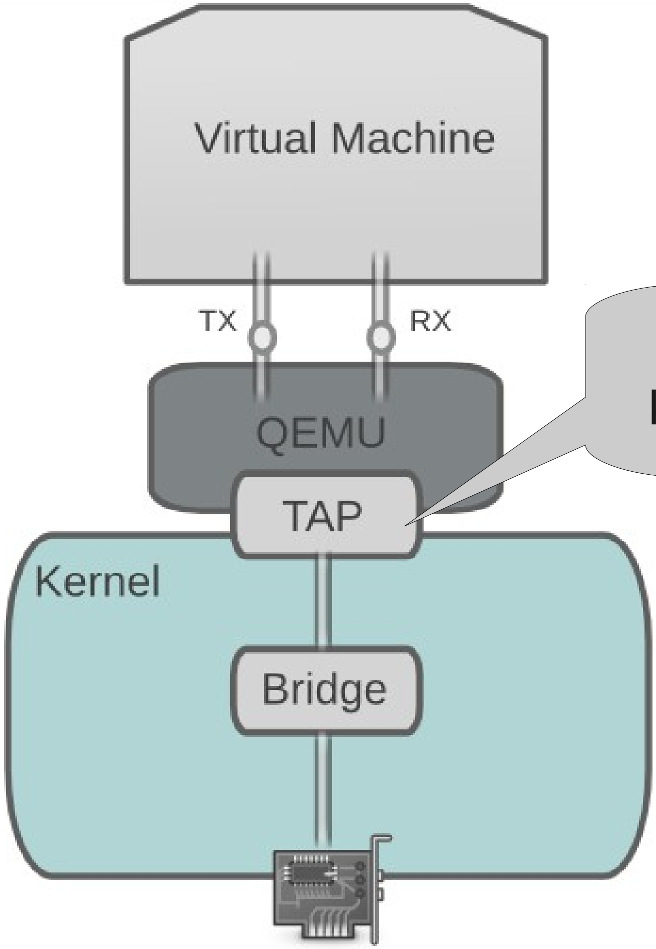
KVM Network Architecture - VirtIO

- Virtual Machine sees paravirtualized network device – VirtIO
  - VirtIO drivers included in Linux Kernel
  - VirtIO drivers available for Windows
- Network stack implemented in userspace



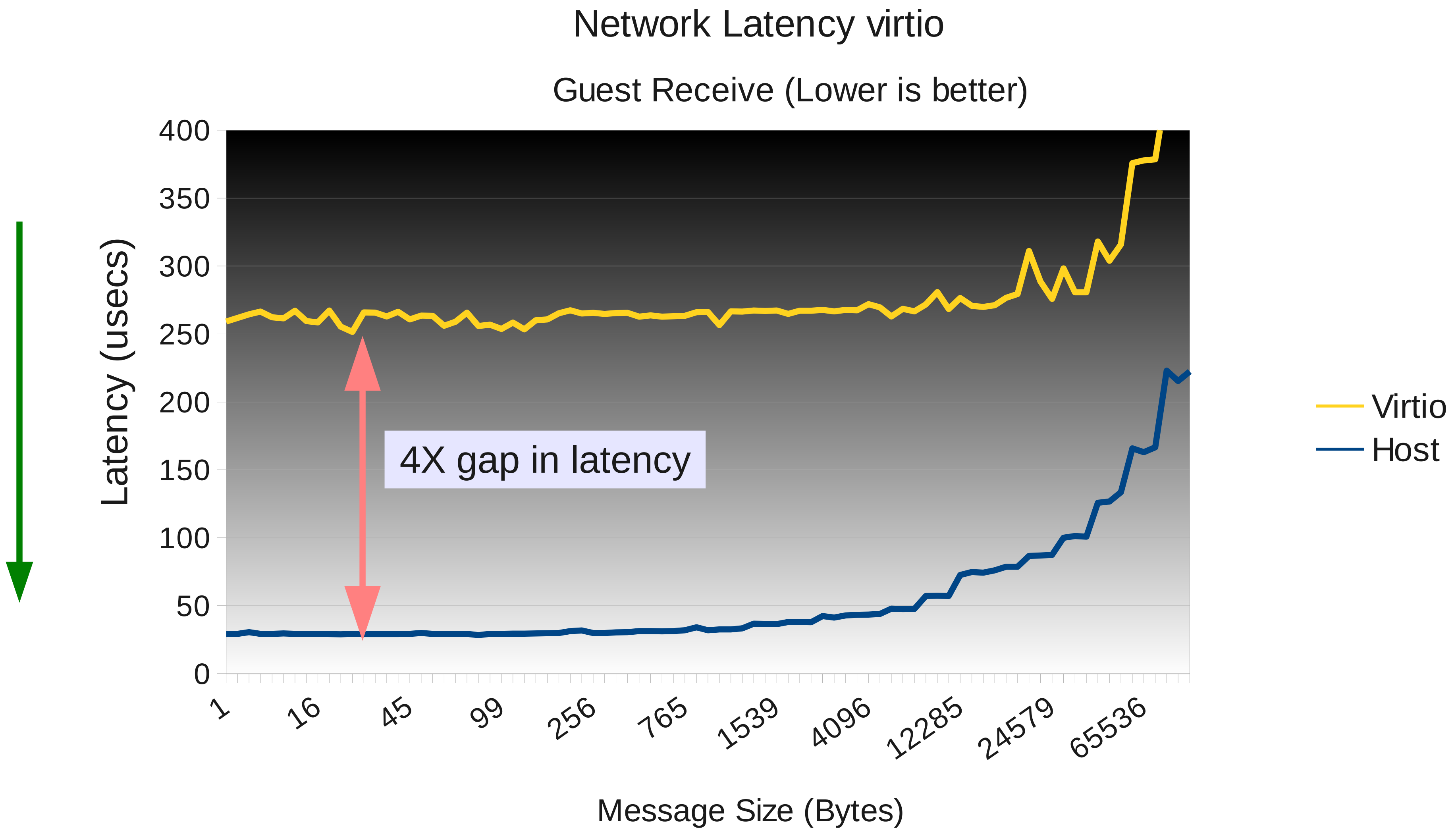
KVM Network Architecture

Virtio



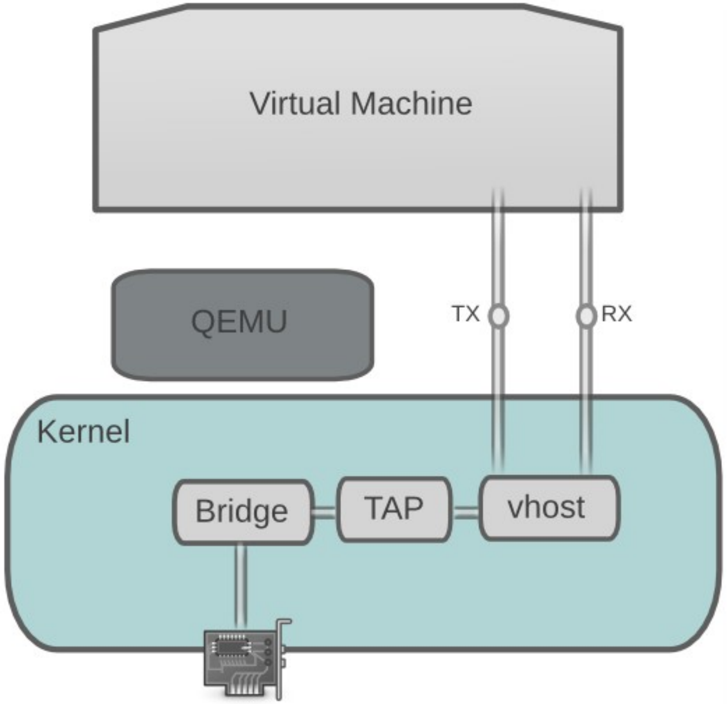
Context switch host kernel <-> userspace

Latency comparison – RHEL 6



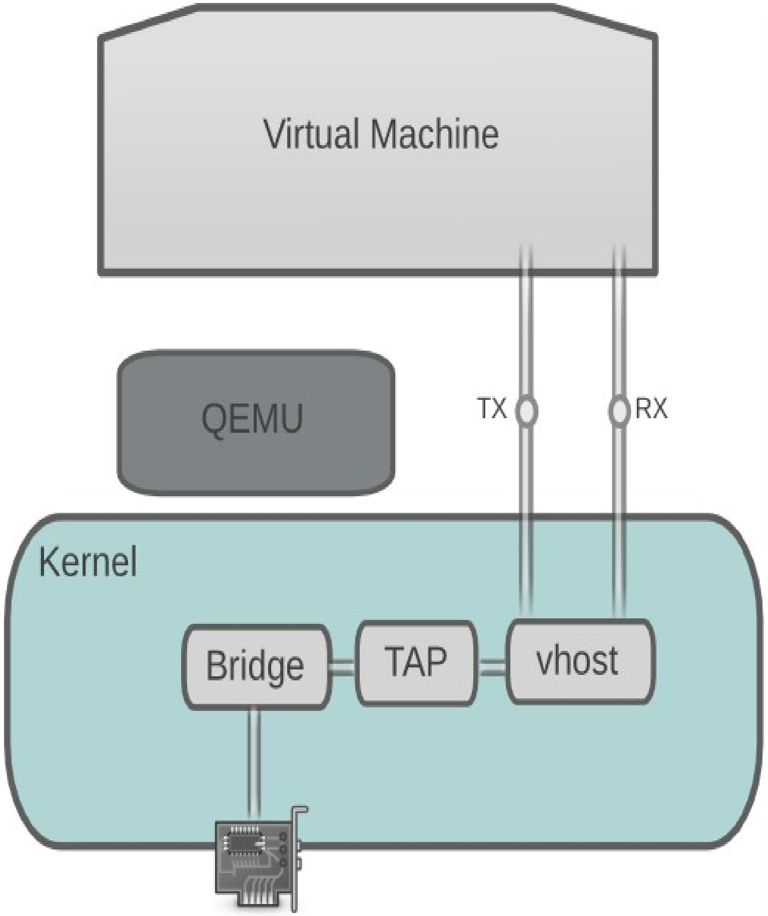
KVM Network Architecture – vhost_net

- New in RHEL6.1
- Moves QEMU network stack from userspace to kernel
- Improved performance
- Lower Latency
- Reduced context switching
- One less copy

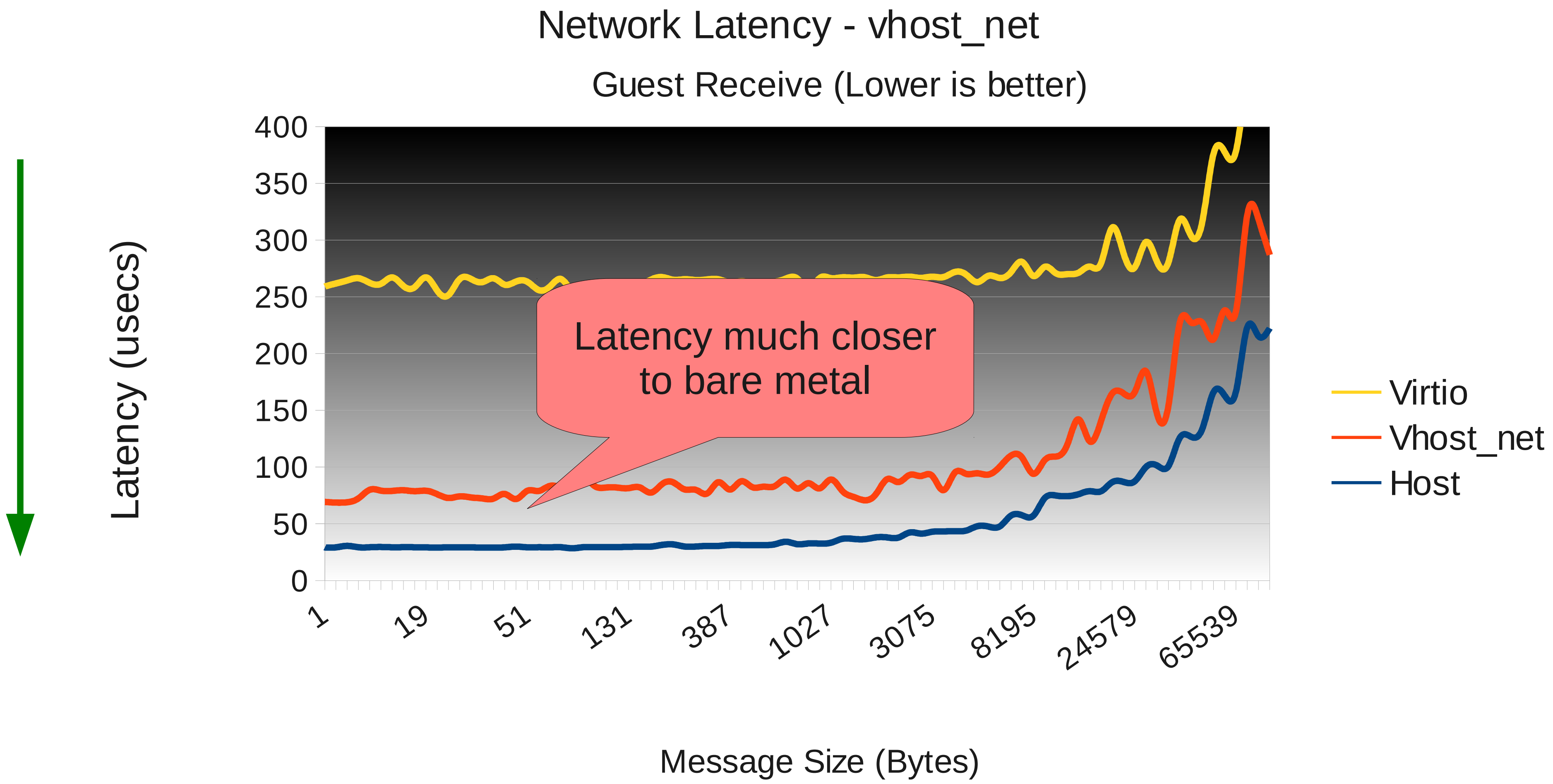


KVM Network Architecture – vhost_net

vhost_net



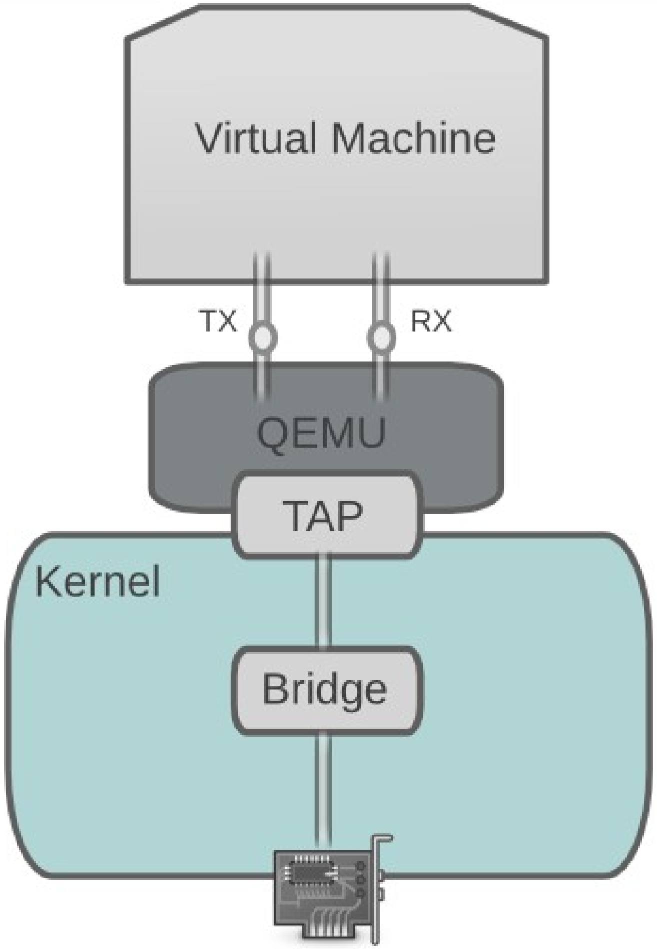
Latency comparison – RHEL 6



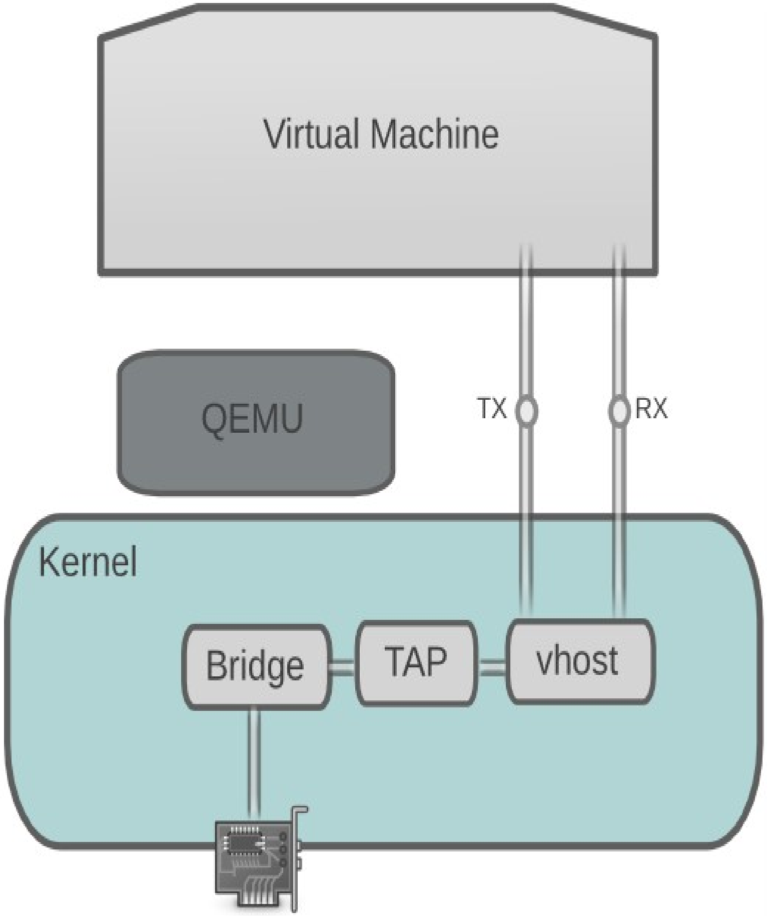
Latency much closer to bare metal

KVM Network Architecture – VirtIO vs vhost_net

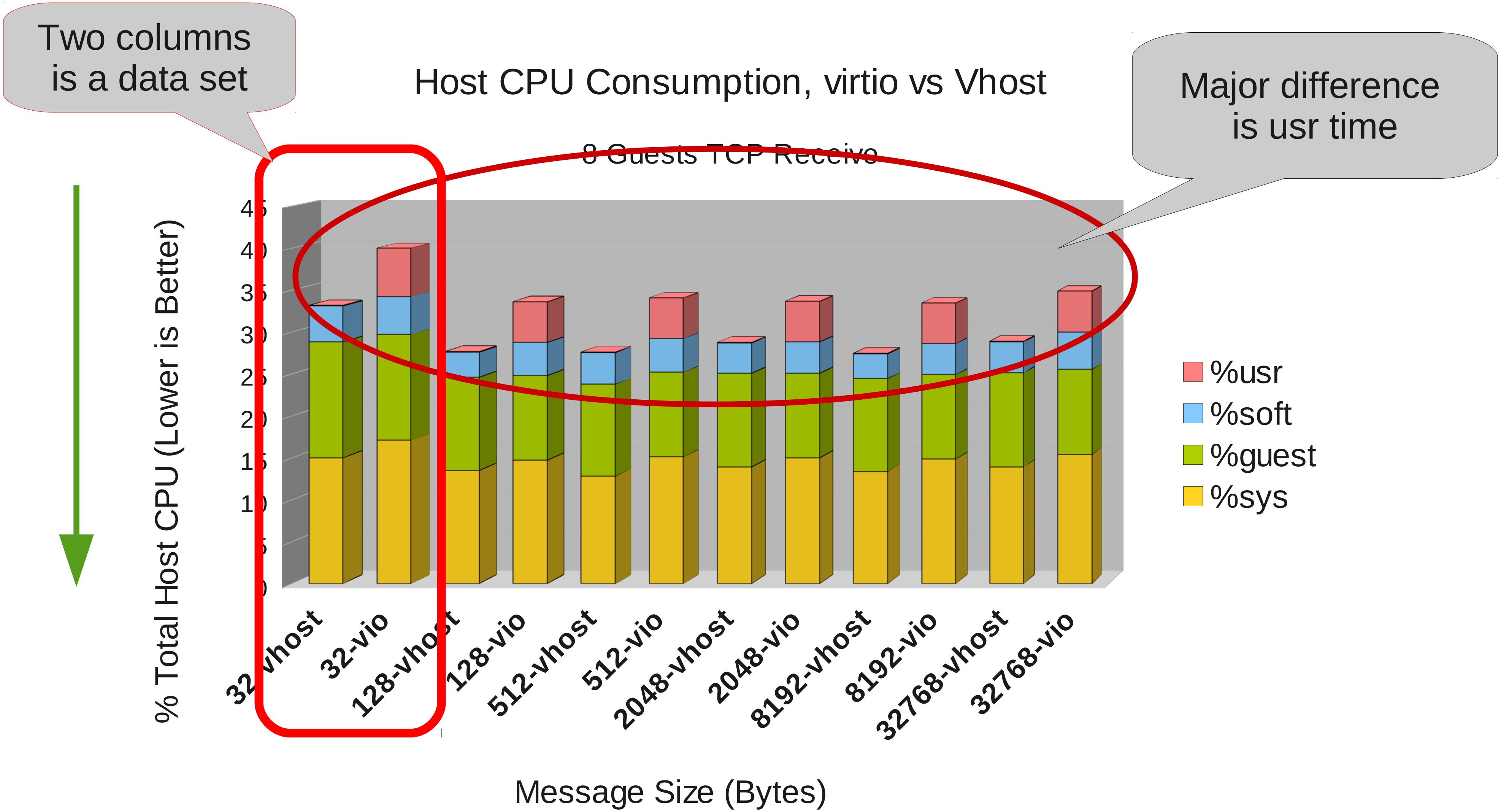
Virtio



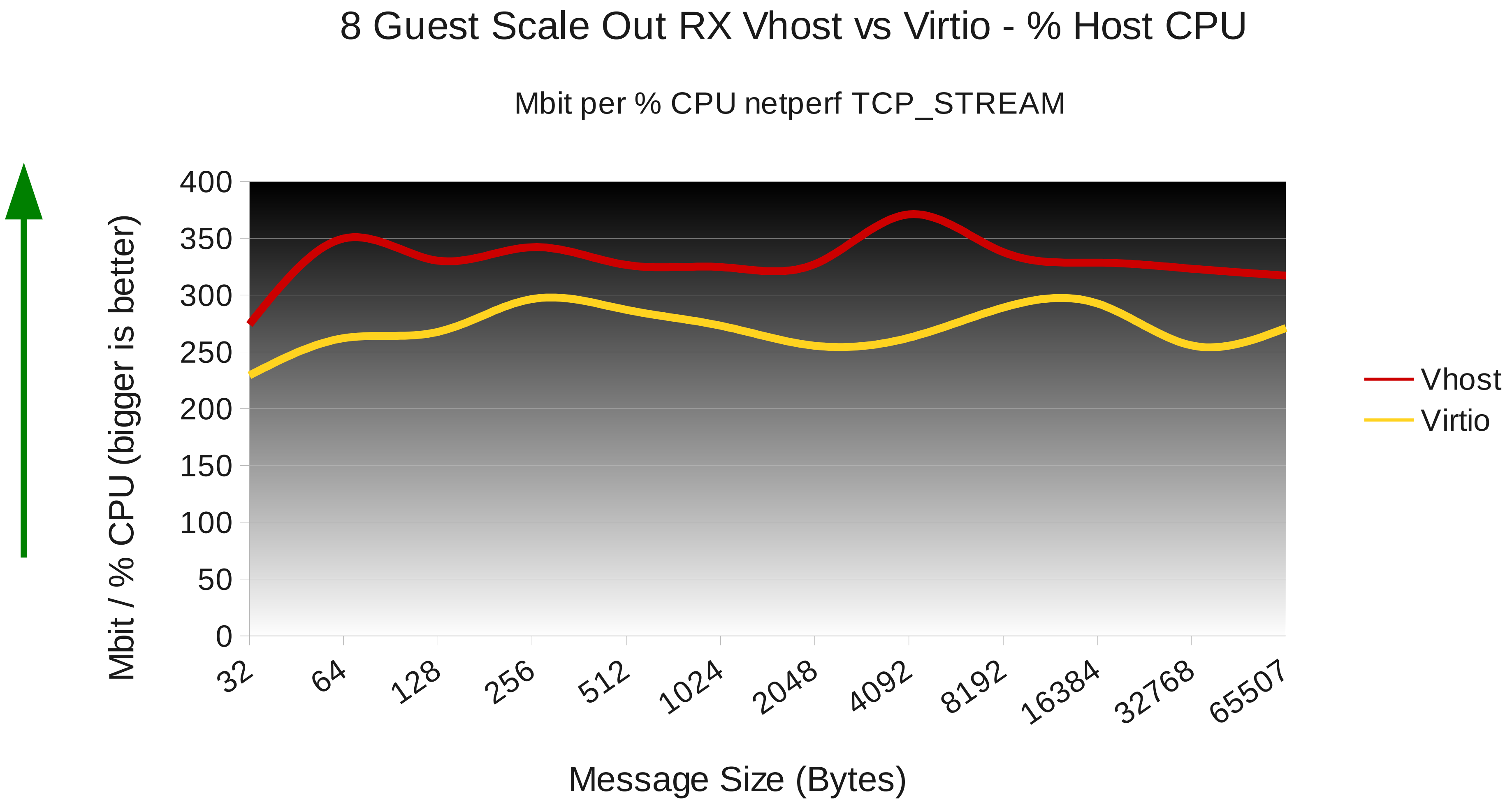
vhost_net



Host CPU Consumption virtio vs vhost_net



vhost_net Efficiency



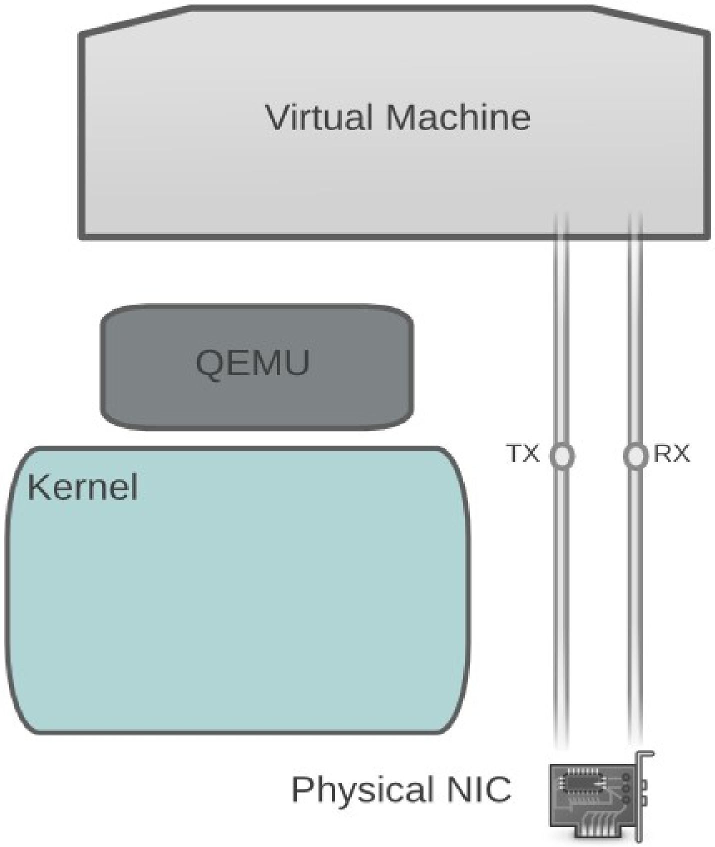
KVM Network Architecture – PCI Device Assignment

- Physical NIC is passed directly to guest
- Guest sees real physical device
  - Needs physical device driver
- Requires hardware support

  Intel VT-D or AMD IOMMU
- Lose hardware independence
- 1:1 mapping of NIC to Guest
- BTW - This also works on some I/O controllers

KVM Network Architecture – Device Assignment

Device Assignment



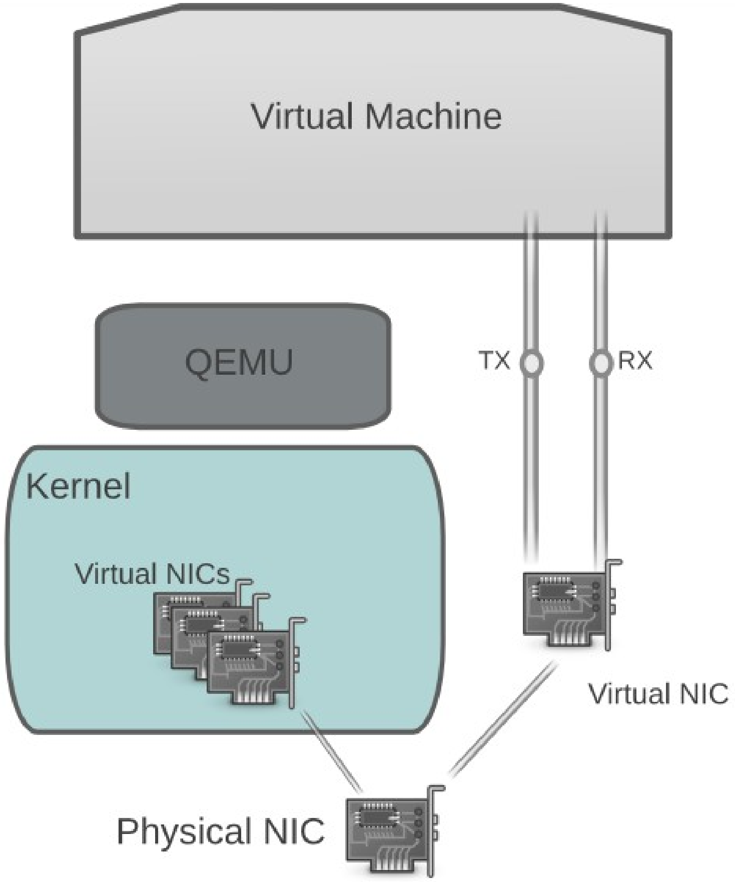
KVM Network Architecture – SR-IOV

- Single Root I/O Virtualization

  New class of PCI devices that present multiple virtual devices that appear as regular PCI devices
- Guest sees real physical device
  - Needs physical device driver
- Requires hardware support
- Low overhead, high throughput
- No live migration
- Lose hardware independence

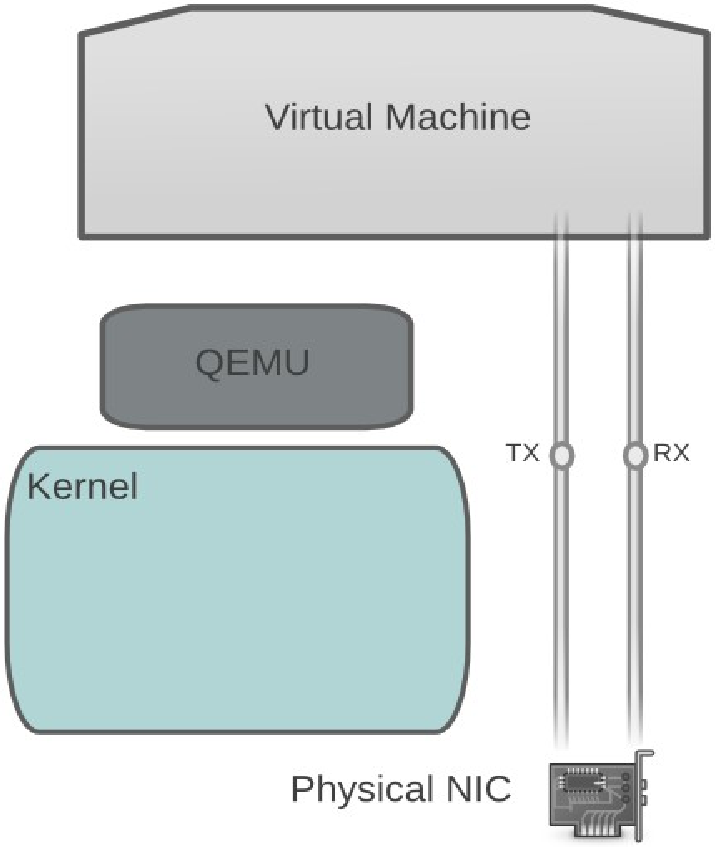
KVM Architecture – SR-IOV

SR-IOV

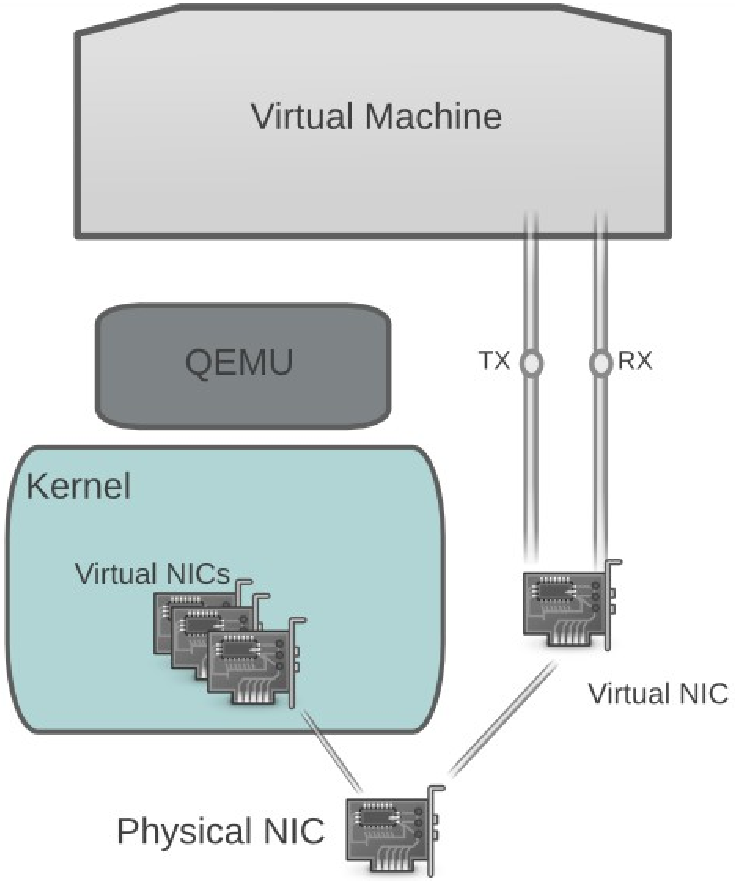


KVM Architecture – Device Assignment vs SR/IOV

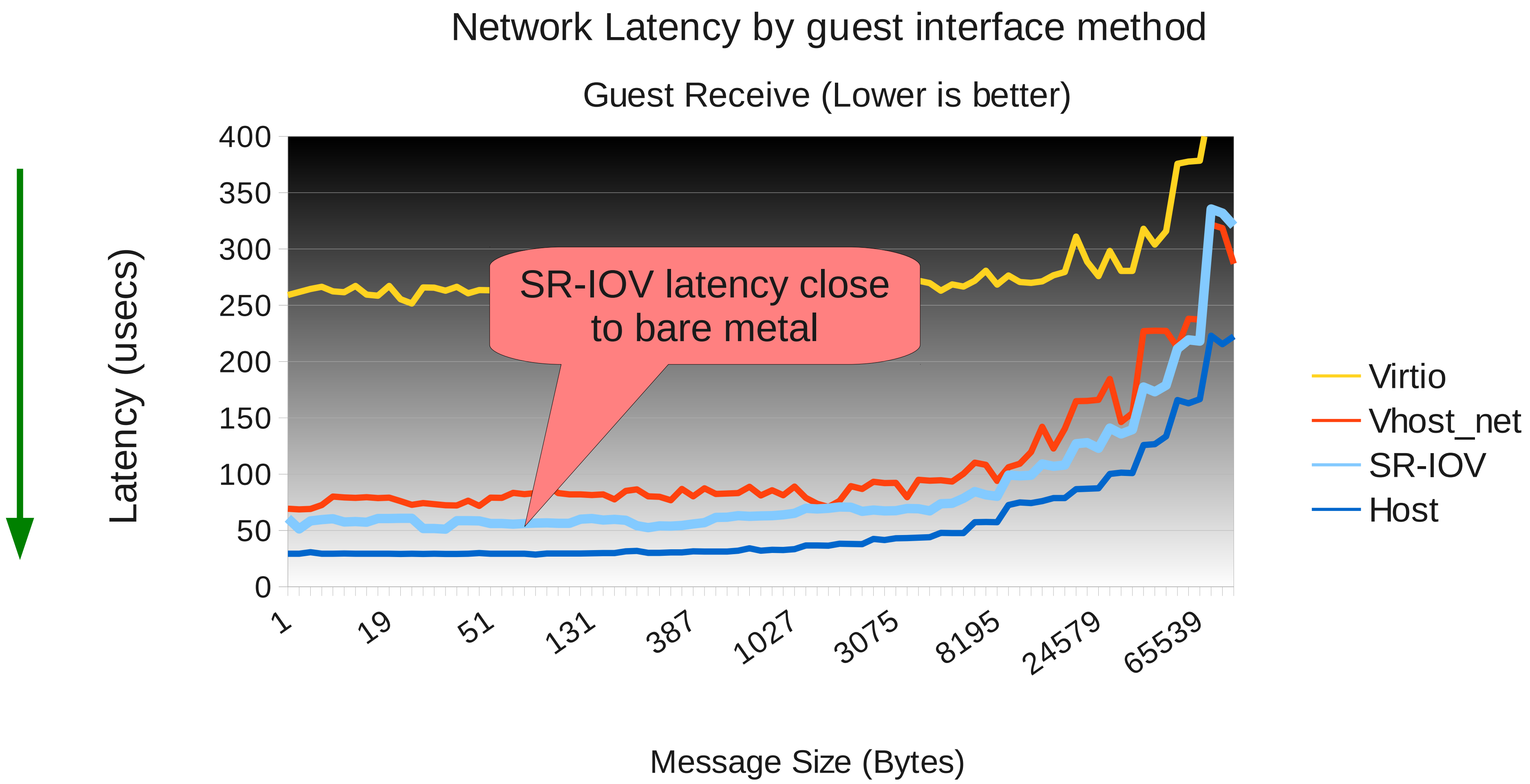
Device Assignment



SR-IOV



Latency comparison – RHEL 6 based methods



SR-IOV latency close to bare metal

RHEL6 – new features

- Multi-queue Transmit
- Tools to monitor dropped packets
- Traffic Steering
- Flow control
- Driver improvements
- Data center bridging DCB
  - FCoE performance improvements

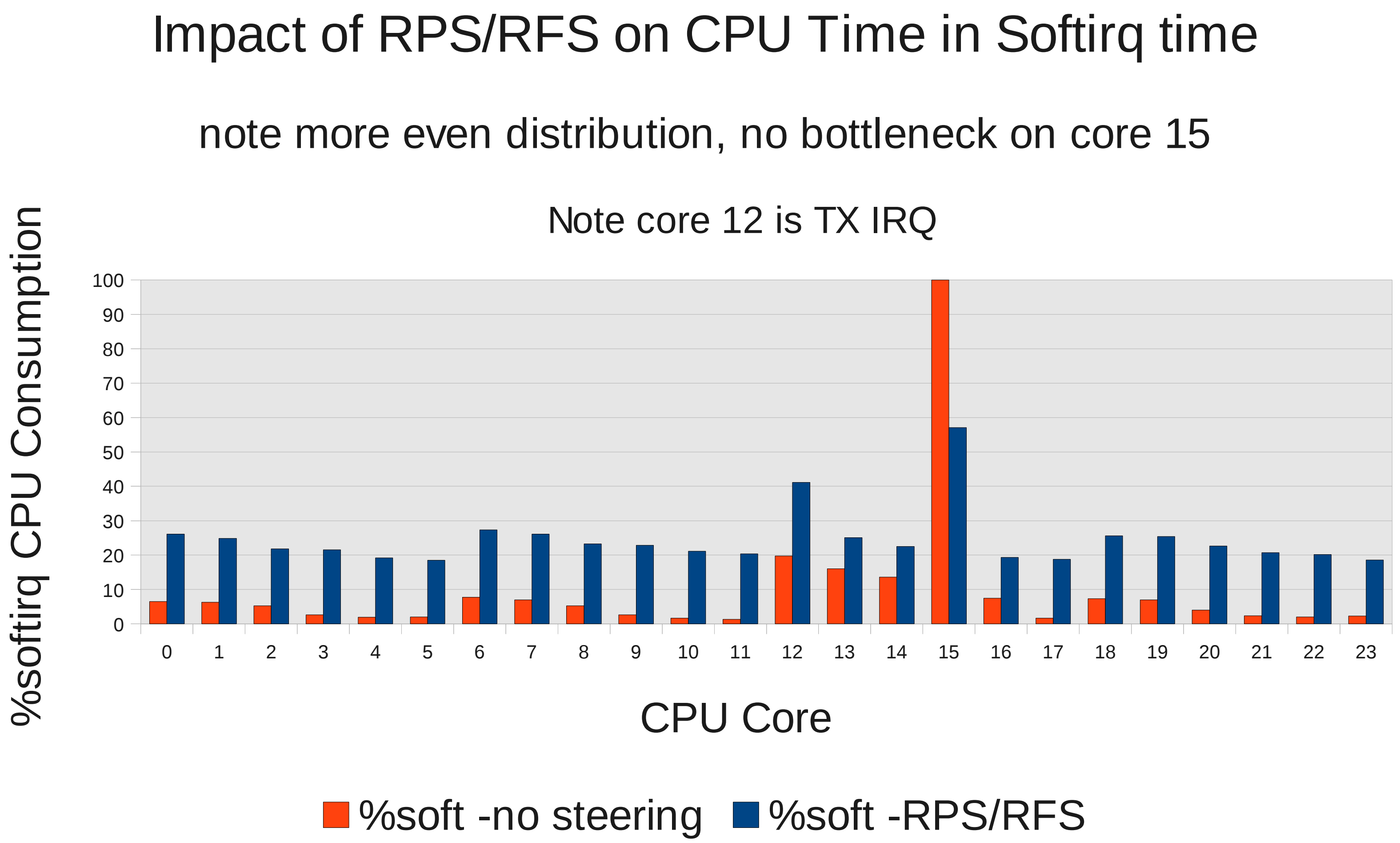
RHEL6 – new features

- Receive Packet Steering (RPS)
  - breaks the bottleneck of having to receive network traffic for a NIC on one CPU
- Receive Flow Steering (RFS)
  - allows the optimal CPU to receive network data intended for a specific application

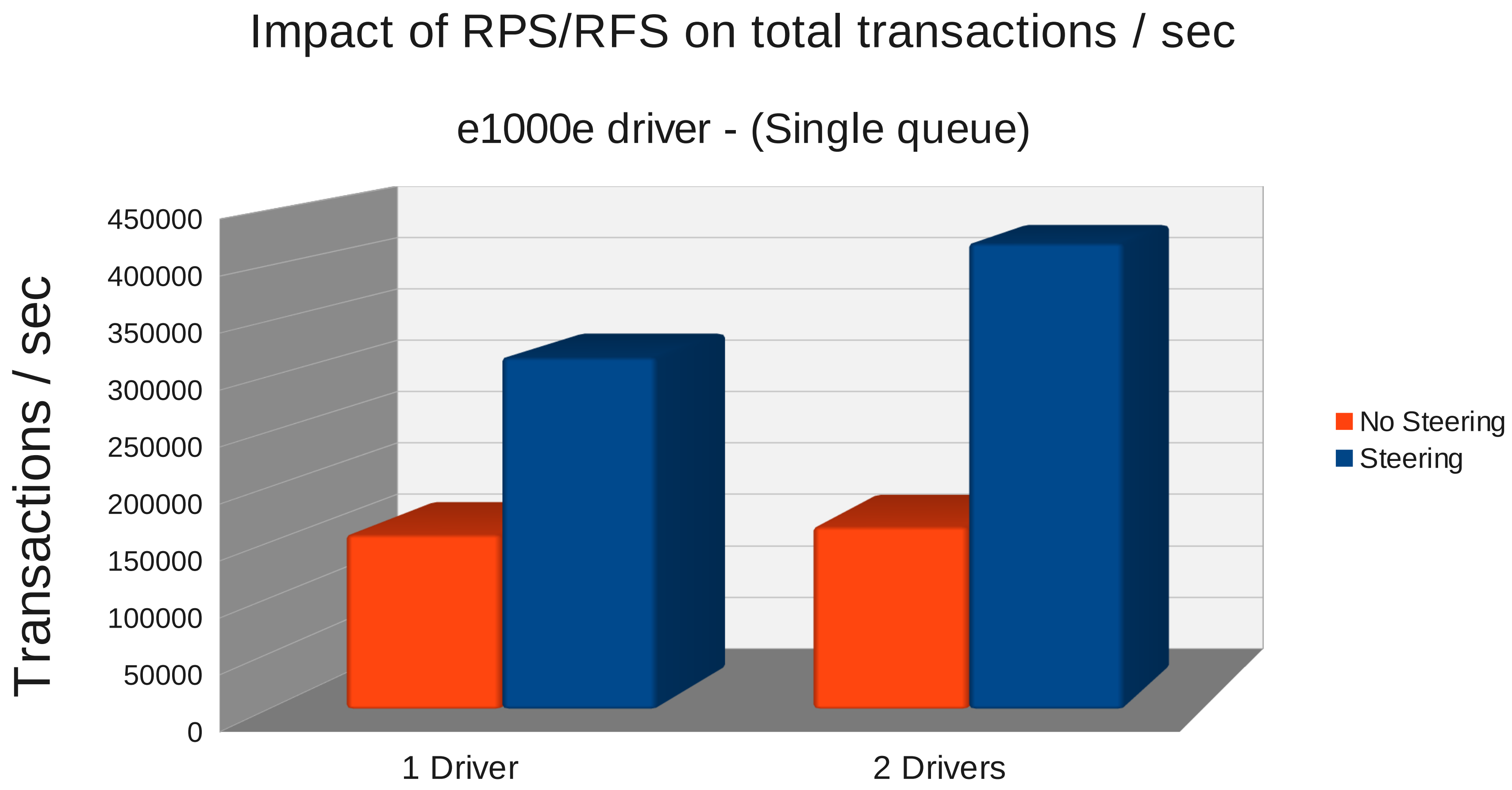
RHEL6 – new features

- Add getsockopt support for TCP thin-streams
  - reduce latency from retransmission of lost packets in time-sensitive applications
- Add Transparent Proxy (TProxy) support for non-locally bound IPv4 TCP and UDP sockets
  - similar to Linux 2.2
  - Allows packet interception and serving of response without client reconfiguration (transparent to client)

Impact of using RPS/RFS



Receive Steering – improved message rates



each driver running 100 concurrent netperf TCP_RR tests

Tuning Knobs – Overview

- Linux networking tuned for reliability
- Linux “autotunes” buffers for connections
- Watch BufferBloat !
- Don't forget UDP !
- Look at documentation in kernel tree

Tuning Knobs – Overview

- By default, Linux networking not tuned for max performance, more for reliability
  - Remember that Linux “autotunes” buffers for connections
  - Don't forget UDP !
- Try via command line
  - When you are happy with the results, add to /etc/sysctl.conf
- Look at documentation in `/usr/src`

sysctl – View and set */proc/sys* settings

- sysctl -a - lists all variables
- sysctl -q - queries a variable
- sysctl -w - writes a variable

sysctl – View and set */proc/sys* settings

- sysctl -w - writes a variable
  - When setting values, spaces are not allowed
    - sysctl -w net.ipv4.conf.lo.arp_filter=0
- Setting a variable via sysctl on the command line is **not persistent** The change is only valid until the next reboot
  - Write entries into the /etc/sysctl.conf file to have them applied at boot time

sysctl – popular settings

- These settings are often mentioned in tuning guides
- Experiment but don't take blindly!
  - net.ipv4.tcp_window_scaling
    - toggles window scaling
  - net.ipv4.tcp_timestamps
    - toggles TCP timestamp support
  - net.ipv4.tcp_sack
    - toggles SACK (Selective ACK) support

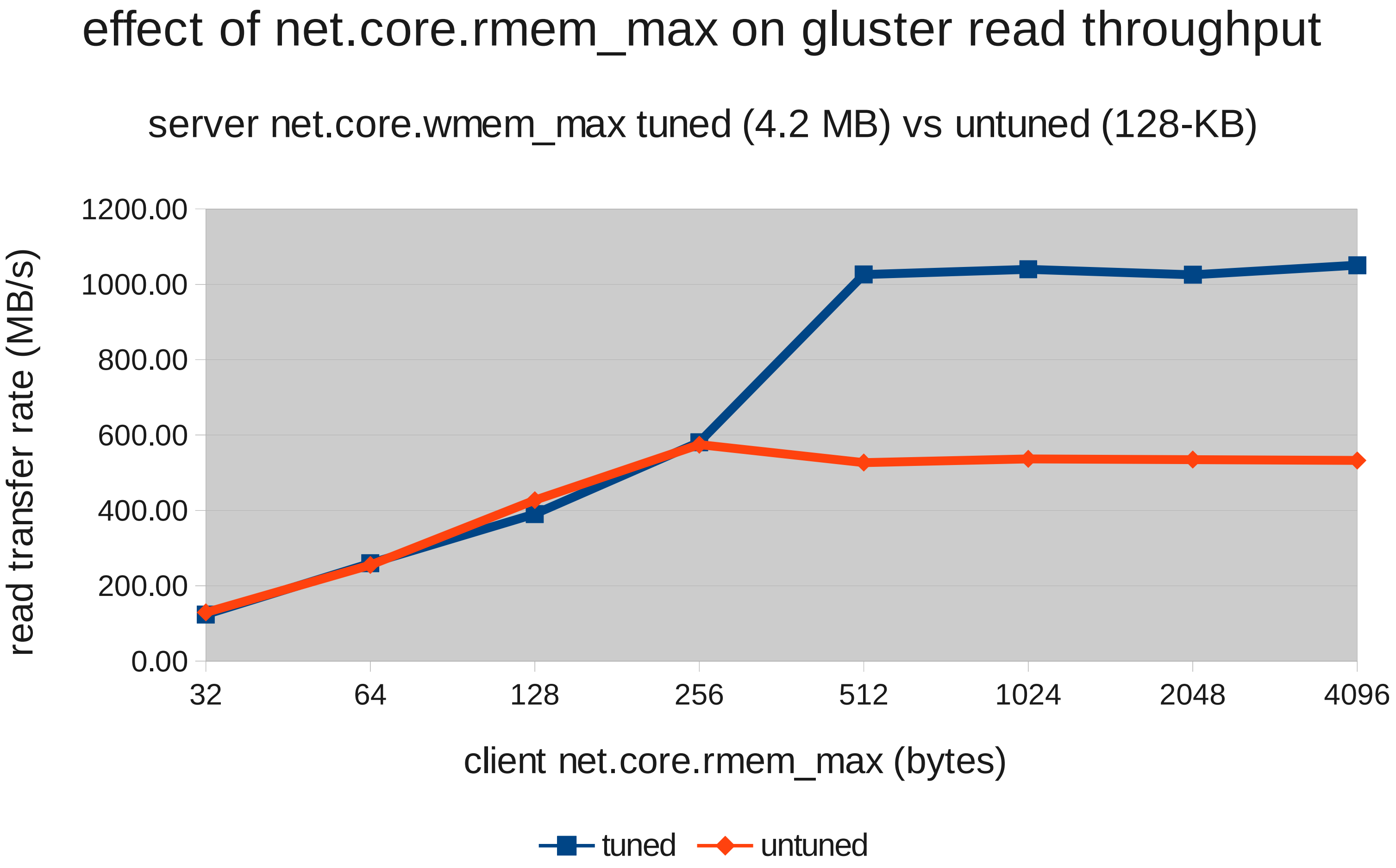
sysctl – TCP related settings

- TCP Memory Allocations - min/pressure/max
  - net.ipv4.tcp_rmem - TCP read buffer - in bytes
    - overriden by core.rmem_max
  - net.ipv4.tcp_wmem - TCP write buffer - in bytes
    - overridden by core/wmem_max
  - net.ipv4.tcp_mem   - TCP buffer space
    - measured in pages, not bytes !

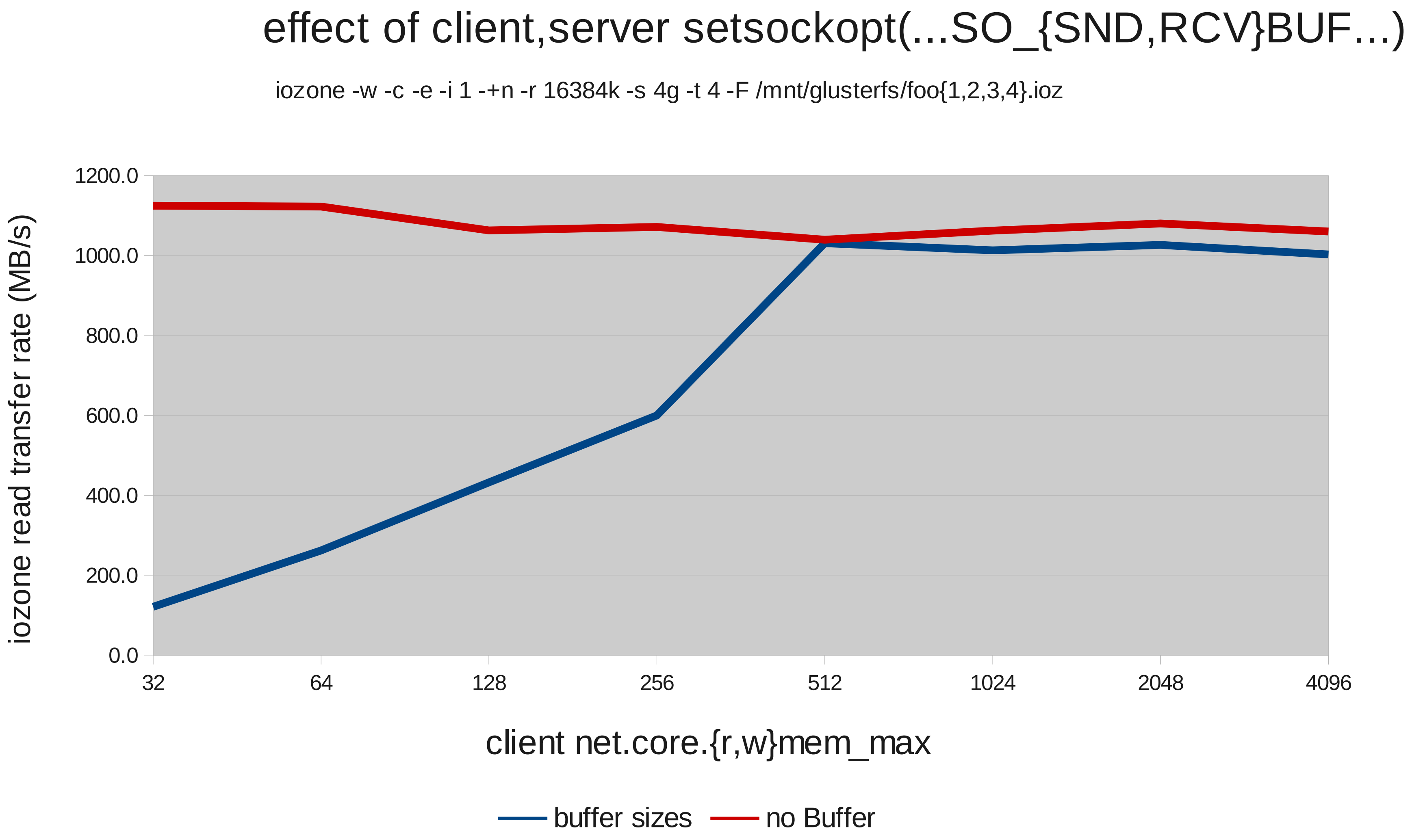
sysctl – ”core” memory settings

- CORE memory settings
  - net.core.(r/w)mem_max
    - max size of (r/w)x socket buffer
  - net.core.(r/w)mem_default
    - default (r/w)x size of socket buffer
  - net.core.optmem_max
    - maximum amount of option memory buffers
  - net.core.netdev_max_backlog
    - how many unprocessed rx packets before kernel starts to drop them
- These settings also impact UDP !

Why Bother ? – Teaser 1



Linux auto tuning – It ROCKS!



Why Bother – A quick teaser

- Two 40Gbit cards back to back (no switch).

```
# ./netperf -l 30 -H 172.17.200.82
TCP STREAM TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to
172.17.200.82 (172.17.200.82) port 0 AF_INET : spin interval : demo
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec

 87380  16384  16384    30.00      8868.76
```

lspci – details

```
# lspci -vvvs 81:00.0
81:00.0 Ethernet controller: Mellanox Technologies MT27500 Family [ConnectX-3]
        Subsystem: Mellanox Technologies Device 0035
        Control: I/O- Mem+ BusMaster+ SpecCycle- MemWINV- VGASnoop- ParErr+ Stepping- SERR+ FastB2B- DisINTx+
        Status: Cap+ 66MHz- UDF- FastB2B- ParErr- DEVSEL=fast >TAbort- <TAbort- <MAbort- >SERR- <PERR- INTx-
        Latency: 0, Cache Line Size: 64 bytes
        Interrupt: pin A routed to IRQ 56
        Capabilities: [48] Vital Product Data
                Product Name: CX313A - ConnectX-3 QSFP
                Read-only fields:
                        [PN] Part number: MCX313A-BCBT
                        [V0] Vendor specific: PCIe Gen3 x8
                        [RV] Reserved: checksum good, 0 byte(s) reserved
        Capabilities: [60] Express (v2) Endpoint, MSI 00
                DevCap:         MaxPayload 256 bytes, PhantFunc 0, Latency L0s <64ns, L1 unlimited
                        ExtTag- AttnBtn- AttnInd- PwrInd- RBE+ FLReset+
                DevCtl:         Report errors: Correctable+ Non-Fatal+ Fatal+ Unsupported-
                        RlxdOrd- ExtTag- PhantFunc- AuxPwr- NoSnoop- FLReset-
                        MaxPayload 256 bytes, MaxReadReq 4096 bytes
                DevSta:         CorrErr- UncorrErr- FatalErr- UnsuppReq- AuxPwr- TransPend-
                LnkCap:         Port #8, Speed unknown, Width x8, ASPM L0s, Latency L0 unlimited, L1 unlimited
                        ClockPM- Surprise- LLActRep- BwNot-
                LnkCtl:         ASPM Disabled; RCB 64 bytes Disabled- Retrain- CommClk+
                        ExtSynch- ClockPM- AutWidDis- BWInt- AutBWInt-
                LnkSta:         Speed unknown, Width x8, TrErr- Train- SlotClk+ DLActive- BWMgmt- ABWMgmt-
        Capabilities: [148] Device Serial Number 00-02-c9-03-00-05-6a-a8
        Capabilities: [18c] #19
        Kernel driver in use: mlx4_core
        Kernel modules: mlx4_core
```

NOTE Lots of data truncated for brevity

Why Bother – A quick teaser

- Check MTU

```
# ifconfig eth4

eth4      Link encap:Ethernet  HWaddr 00:02:C9:36:79:80
          inet addr:172.17.200.50  Bcast:172.17.200.255
Mask:255.255.255.0
          inet6 addr: fe80::202:c9ff:fe36:7980/64 Scope:Link
          UP BROADCAST RUNNING MULTICAST  MTU:1500  Metric:1
          RX packets:2634628 errors:0 dropped:0 overruns:0 frame:0
          TX packets:31433648 errors:0 dropped:0 overruns:0
carrier:0
          collisions:0 txqueuelen:1000
          RX bytes:184742056 (176.1 MiB)  TX bytes:47590480340
(44.3 GiB)
```

Why Bother – A quick teaser

- *ifconfig eth0 mtu 9000*

```
# ./netperf -l 30 -H 172.17.200.82
TCP STREAM TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to
172.17.200.82 (172.17.200.82) port 0 AF_INET : spin interval : demo
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec

 87380  16384  16384    30.00    23923.65
```

- Changing MTU 9 Gb/sec -> 24 Gbit /sec

Tuning – debug simple netperf TCP_STREAM test

- Found the bottleneck !
  - CPU bound on RX side

```
04:39:33 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
04:39:36 PM  all    0.02    0.00    2.88    0.00    0.00    3.38    0.00    0.00   93.73
04:39:36 PM    0    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    1    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    2    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    3    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    4    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    5    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    6    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    7    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    8    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM    9    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM   10    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM   11    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM   12    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM   13    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM   14    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
04:39:36 PM   15    0.33    0.00   45.67    0.00    0.00   54.00    0.00    0.00    0.00
```

Tuning– first pass bottleneck resolution

- Disable irqbalance
  - We will pin the interrupts where we want them
  - But where do they go ?
- Look in /sys to see if there are hints
  - A value of -1 could mean error or undefined
  - In this case we see that the pci slot is tied to NUMA node 1
  - Move the interrupts there
- Alternative is trial and error

Tuning– first pass bottleneck resolution

```
#dmesg | grep -i numa

NUMA: Allocated memnodemap from 9000 - 90c0
NUMA: Using 30 for the hash shift.
pci_bus 0000:00: on NUMA node 0 (pxm 0)
pci_bus 0000:80: on NUMA node 1 (pxm 1)

# lspci | grep Mellanox
81:00.0 Ethernet controller: Mellanox Technologies MT27500 Family
[ConnectX-3]

# find /sys  -name numa_node | grep 81:00.0
/sys/devices/pci0000:80/0000:80:02.0/0000:81:00.0/numa_node


# cat /sys/devices/pci0000:80/0000:80:02.0/0000:81:00.0/numa_node
1

# cat /sys/devices/pci0000:80/0000:80:02.0/0000:81:00.0/local_cpulist
8-15
```

Tuning – second pass setup

- Disable irqbalance
  - `irqbalance stop`
  - `chkconfig irqbalance off`
- Identify the interrupts
  - `grep eth4 /proc/interrupts`
- But wait, mlx also has an second driver!
  - `grep mlx /proc/interrupts`
- or

```
# ls /sys/devices/pci0000:80/0000:80:02.0/0000:81:00.0/msi_irqs
177  178  179  180  181  182  183  184  185  186  187  188  189
190  191  192  193  194  195  196  197
```

Tuning – move the interrupts

- Map the interrupts to the proper cores for the NUMA node
  - CPU cores designated by bitmap
  - Use `` `numactl --hardware` `` to check core mappings to numa nodes
  - Understand the layout of the cache in relationship to the cores
- Remember these values do not persistent across reboots!
- Set IRQ affinity
  - `echo 80 > /proc/irq/192/smp_affinity`
  - Use “tuna'

Tuning – irqbalance disabled, netperf pinning

- Rerun the tests, pin the netperf TX and RX to core 12

```
# ./netperf -l 30 -H 172.17.200.82 -T 12,12
TCP STREAM TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET
to 172.17.200.82 (172.17.200.82) port 0 AF_INET : spin
interval : demo : cpu bind
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec

 87380  16384  16384    30.00    25609.34
```

- Hmmm, not really much better

Tuning – second pass

- mpstat on the receiver

```
11:45:04 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
11:45:07 PM  all    0.02    0.00    5.02    0.00    0.00    0.02    0.00    0.00   94.94
11:45:07 PM    0    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    1    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    2    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    3    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    4    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    5    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    6    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    7    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    8    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM    9    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM   10    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM   11    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM   12    0.33    0.00   77.08    0.00    0.00    0.66    0.00    0.00   21.93
11:45:07 PM   13    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM   14    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:07 PM   15    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
```

Tuning – second pass

- mpstat on the transmit

```
11:45:03 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
11:45:06 PM  all    0.08    0.00    3.52    0.00    0.00    0.19    0.00    0.00   96.20
11:45:06 PM    0    0.33    0.00    0.00    0.00    0.00    0.00    0.00    0.00   99.67
11:45:06 PM    1    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM    2    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM    3    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM    4    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM    5    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM    6    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM    7    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM    8    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM    9    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM   10    0.00    0.00    0.00    0.00    0.00    0.43    0.00    0.00   99.57
11:45:06 PM   11    0.00    0.00    0.00    0.00    0.00    0.34    0.00    0.00   99.66
11:45:06 PM   12    0.70    0.00   57.49    0.00    0.00    2.44    0.00    0.00   39.37
11:45:06 PM   13    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:45:06 PM   14    0.00    0.00    0.33    0.00    0.00    0.00    0.00    0.00   99.67
11:45:06 PM   15    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
```

Tuning – step 2 not clear

- No apparent cpu bottleneck
- Lets try looking at process

```
# perf top -p 37590
Events: 14K cycles
 27.04%  [kernel]      [k] copy_user_generic_string
  6.01%  [kernel]      [k] alloc_pages_current
  5.61%  [kernel]      [k] __alloc_pages_nodemask
  4.87%  [kernel]      [k] get_page_from_freelist
  4.54%  [kernel]      [k] tcp_sendmsg
  2.36%  [kernel]      [k] put_page
  2.13%  [kernel]      [k] list_del
```

- netperf is spending a lot of time generating data

Tuning – step 3

- Try TCP_SENDFILE

```
# ./netperf -l 30 -H 172.17.200.82 -T 12,12 -t
TCP_SENDFILE
TCP SENDFILE TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET
to 172.17.200.82 (172.17.200.82) port 0 AF_INET : spin
interval : demo : cpu bind
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec

 87380  16384  16384    30.00    34106.58
```

- Looking Better !

Tuning – are we done ?

- Look for bottlenecks
    - Transmit is CPU bound

```
11:54:54 PM  CPU    %usr   %nice    %sys %iowait    %irq   %soft  %steal  %guest   %idle
11:54:57 PM  all    0.08    0.00    6.16    0.00    0.00    0.11    0.00    0.00   93.65
11:54:57 PM    0    0.33    0.00    0.33    0.00    0.00    0.00    0.00    0.00   99.34
11:54:57 PM    1    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM    2    0.33    0.00    0.00    0.00    0.00    0.00    0.00    0.00   99.67
11:54:57 PM    3    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM    4    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM    5    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM    6    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM    7    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM    8    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM    9    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM   10    0.00    0.00    0.00    0.00    0.00    0.39    0.00    0.00   99.61
11:54:57 PM   11    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM   12    1.00    0.00   97.66    0.00    0.00    1.34    0.00    0.00    0.00
11:54:57 PM   13    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM   14    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
11:54:57 PM   15    0.00    0.00    0.00    0.00    0.00    0.00    0.00    0.00  100.00
```

Tuning – checking ethtool -S eth4

- Check for errors, pause frames, etc.
- Check nic on TX side

```
# ethtool -S eth4
NIC statistics:
     rx_packets: 135224755
     tx_packets: 1137704051
     rx_bytes: 8729946637
     tx_bytes: 9906371184752
     rx_errors: 0
     tx_errors: 0
     rx_dropped: 0
     tx_dropped: 0
     tso_packets: 20844101
     queue_stopped: 92899164
     wake_queue: 92899164
```

Tuning – sysctl settings

- We need more buffers
  - net.core.netdev_max_backlog = 250000
  - net.core.wmem_max = 16777216
  - net.core.rmem_default = 16777216
  - net.core.wmem_default = 16777216
  - net.core.optmem_max = 16777216
  - net.ipv4.tcp_mem = 16777216 16777216 16777216
  - net.ipv4.tcp_rmem = 4096 87380 16777216
  - net.ipv4.tcp_wmem = 4096 65536 16777216
  - net.core.rmem_max = 16777216

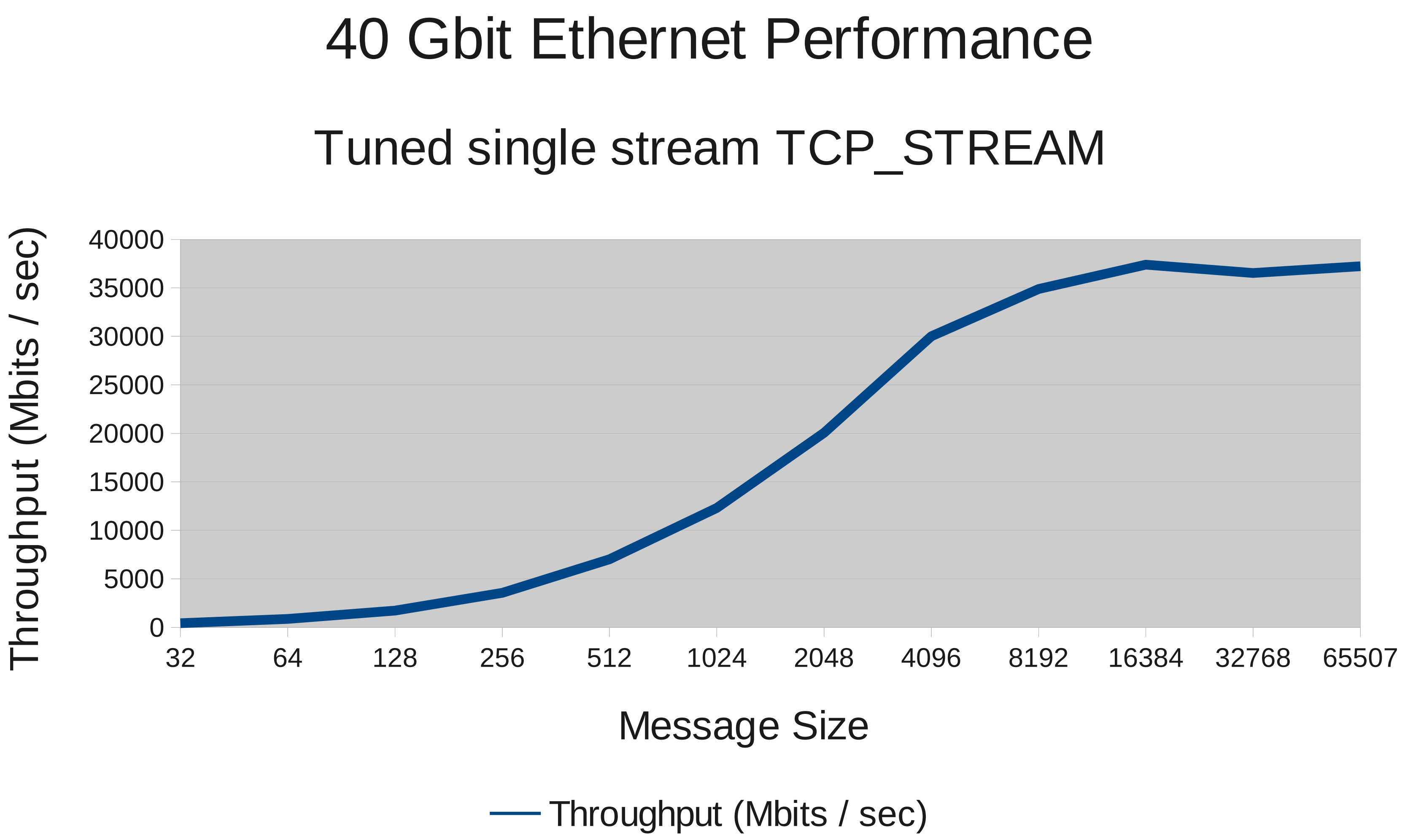
Tuning – step 4

- More buffers

```
# ./netperf -l 30 -H 172.17.200.82 -T 12,12 -t
TCP_SENDFILE
TCP SENDFILE TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET
to 172.17.200.82 (172.17.200.82) port 0 AF_INET : spin
interval : demo : cpu bind
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec

 87380  16384  16384    30.00    37354.41
```

- We are done !

Tuning – throughput graph



Tuning – sanity check

- Sometimes mistuning can show that it is working

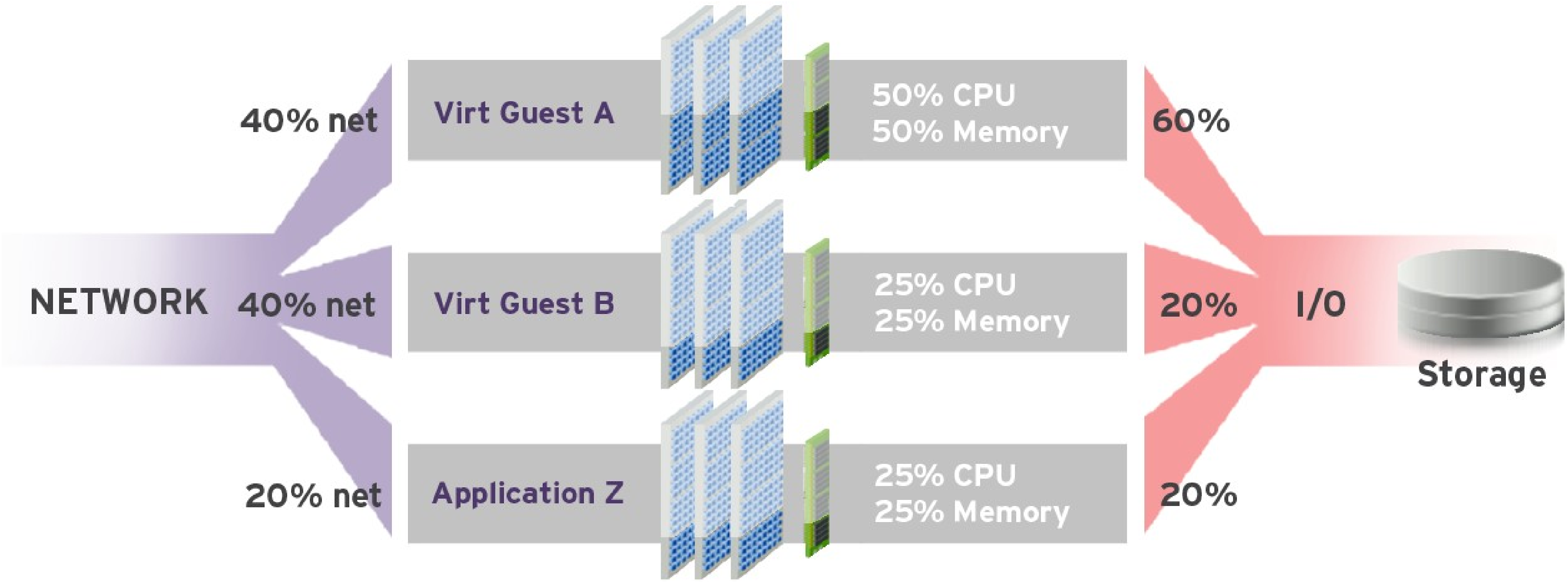
```
# ./netperf -l 30 -H 172.17.200.82 -T 12,2 -t TCP_SENDFILE
TCP SENDFILE TEST from 0.0.0.0 (0.0.0.0) port 0 AF_INET to
172.17.200.82 (172.17.200.82) port 0 AF_INET : spin interval : demo :
cpu bind
Recv   Send    Send
Socket Socket  Message  Elapsed
Size   Size    Size     Time     Throughput
bytes  bytes   bytes    secs.    10^6bits/sec


87380  16384  16384    30.00    13033.89
```

- 37 Gb -> 13 Gb due to crossing NUMA boundary
  - OUCH !

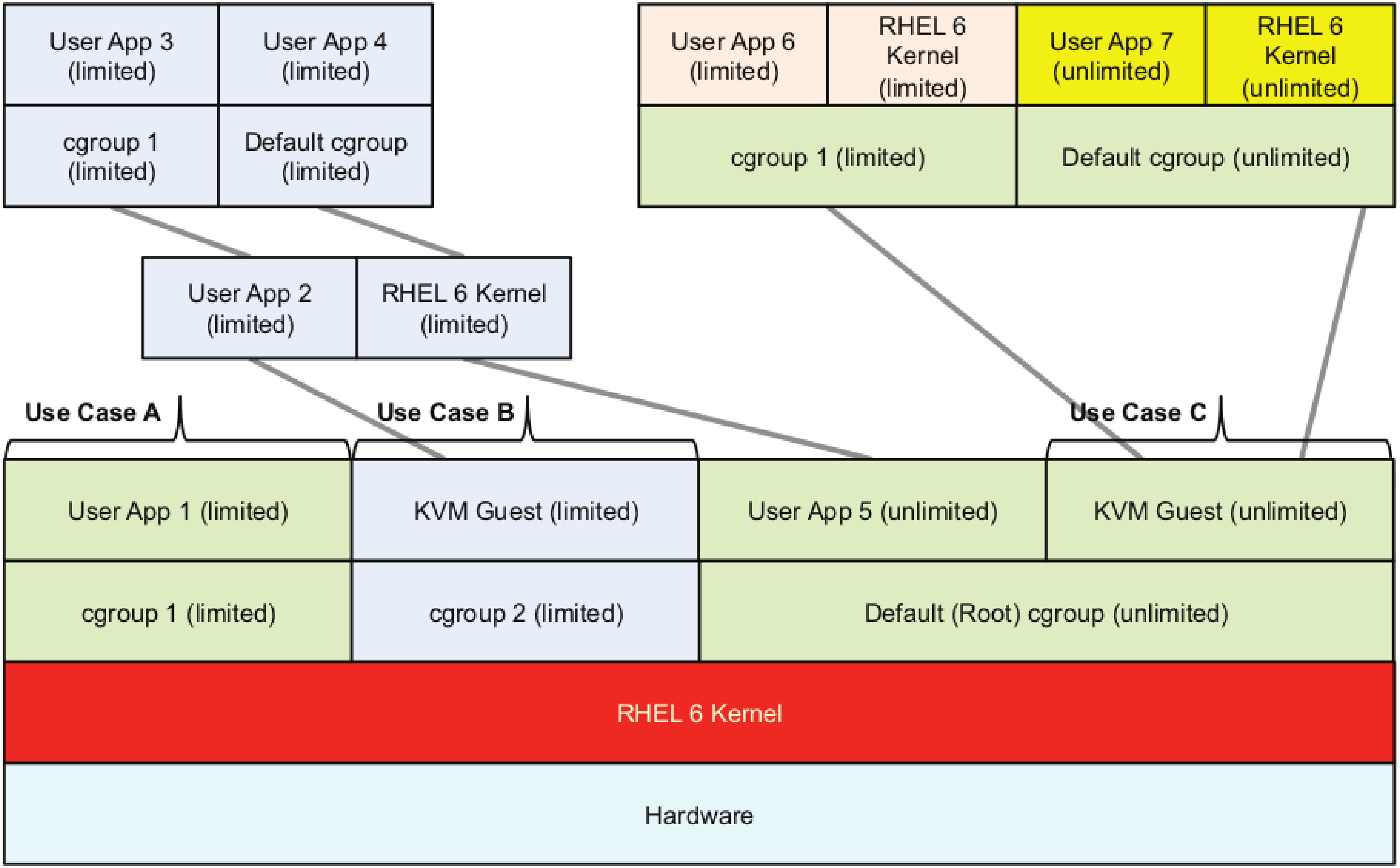
Throttling – cgroups

- Control Group (Cgroups) for
  - CPU/Memory/Network/Disk
- Benefit:
  - guarantee Quality of Service
  - dynamic resource allocation
- Ideal for managing any multi-application environment
- From back-ups to the Cloud

Throttling – cgroups in Action



cgroups Architecture



Cgroup default mount points

```
# cat /etc/cgconfig.conf

mount {
        cpuset      = /cgroup/cpuset;
        cpu   = /cgroup/cpu;
        cpuacct     = /cgroup/cpuacct;
        memory      = /cgroup/memory;
        devices     = /cgroup/devices;
        freezer     = /cgroup/freezer;
        net_cls     = /cgroup/net_cls;
        blkio = /cgroup/blkio;
}
```

```
# ls -l /cgroup

drwxr-xr-x 2 root root 0 Jun 21 13:33 blkio
drwxr-xr-x 3 root root 0 Jun 21 13:33 cpu
drwxr-xr-x 3 root root 0 Jun 21 13:33 cpuacct
drwxr-xr-x 3 root root 0 Jun 21 13:33 cpuset
drwxr-xr-x 3 root root 0 Jun 21 13:33 devices
drwxr-xr-x 3 root root 0 Jun 21 13:33 freezer
drwxr-xr-x 3 root root 0 Jun 21 13:33 memory
drwxr-xr-x 2 root root 0 Jun 21 13:33 net_cls
```

Cgroup how-to

1GB/2CPU subset of a 16GB/8CPU system

```
#numactl --hardware
#mount -t cgroup xxx /cgroups
#mkdir -p /cgroups/test
#cd /cgroups/test
#echo 1 > cpuset.mems
#echo 2-3 > cpuset.cpus
#echo 1G > memory.limit_in_bytes
#echo $$ > tasks
```

cgroups

```
[root@dhcp-100-19-50 ~]# forkoff 20MB 100procs &

[root@dhcp-100-19-50 ~]# top -d 5

top - 12:24:13 up  1:36,  4 users,  load average: 22.70, 5.32, 1.79

Tasks: 315 total,  93 running, 222 sleeping,   0 stopped,   0 zombie

Cpu0  :  0.0%us,  0.2%sy,  0.0%ni, 99.8%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st

Cpu1  :  0.0%us,  0.2%sy,  0.0%ni, 99.8%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st

Cpu2  :100.0%us,  0.0%sy,  0.0%ni,  0.0%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st

Cpu3  : 89.6%us, 10.0%sy,  0.0%ni,  0.0%id,  0.0%wa,  0.2%hi,  0.2%si,  0.0%st

Cpu4  :  0.4%us,  0.6%sy,  0.0%ni, 98.8%id,  0.0%wa,  0.0%hi,  0.2%si,  0.0%st

Cpu5  :  0.4%us,  0.0%sy,  0.0%ni, 99.2%id,  0.0%wa,  0.0%hi,  0.4%si,  0.0%st

Cpu6  :  0.0%us,  0.0%sy,  0.0%ni,100.0%id,  0.0%wa,  0.0%hi,  0.0%si,  0.0%st

Cpu7  :  0.0%us,  0.0%sy,  0.0%ni, 99.8%id,  0.0%wa,  0.0%hi,  0.2%si,  0.0%st

Mem:  16469476k total,  1993064k used, 14476412k free,    33740k buffers

Swap:  2031608k total,   185404k used,  1846204k free,   459644k cached
```

Verify correct bindings

```
[root@dhcp47-183 test]# echo 0 > cpuset.mems
[root@dhcp47-183 test]# echo 0-3 > cpuset.cpus
[root@dhcp47-183 test]# numastat
                       node0       node1
numa_hit             1648772      438778
numa_miss              23459     2134520
local_node           1648648      423162
other_node             23583     2150136

[root@dhcp47-183 test]# /common/lwoodman/code/memory 4
faulting took 1.616062s
touching took 0.364937s

[root@dhcp47-183 test]# numastat
                       node0       node1
numa_hit             2700423      439550
numa_miss              23459     2134520
local_node           2700299      423934
other_node             23583     2150136
```

incorrect bindings!

```
[root@dhcp47-183 test]# echo 1 > cpuset.mems
[root@dhcp47-183 test]# echo 0-3 > cpuset.cpus
[root@dhcp47-183 test]# numastat
                           node0         node1
numa_hit                 1623318        434106
numa_miss                  23459       1082458
local_node               1623194        418490
other_node                 23583       1098074

[root@dhcp47-183 test]# /common/lwoodman/code/memory 4
faulting took 1.976627s
touching took 0.454322s

[root@dhcp47-183 test]# numastat
                           node0         node1
numa_hit                 1623341        434147
numa_miss                  23459       2133738
local_node               1623217        418531
other_node                 23583       2149354
```

Throttle with cgroups

- Example:
  - Set a 9 Gbit / sec limit on the cgroup

```
# tc qdisc add dev eth1 root handle 10: htb default 10

# tc class add dev eth1 parent 10:10 classid 10:10 htb rate 9gbit ceil 9gbit

# tc filter add dev eth1 parent 10:0 protocol all prio 1 handle 1 cgroup

# echo 0x100010 > /cgroup/net_cls/net_cls.classid
```

Throttle with cgroups

- memory
  - associate a cgroup with a classid that 'tc' utility creates/manages
  - Set upper-bounds
- Example:
  - Set a 9 Gbit / sec limit on the cgroup

```
# tc qdisc add dev eth1 root handle 10: htb default 10
# tc class add dev eth1 parent 10:10 classid 10:10 htb rate 9gbit ceil 9gbit
# tc filter add dev eth1 parent 10:0 protocol all prio 1 handle 1 cgroup
# echo 0x100010 > /cgroup/net_cls/net_cls.classid
```

Network Tuning Tips

- Packet size - MTU
- Buffers
- IRQ affinity
- CPU affinity

Network Tuning Tips

- Separate networks for different functions
  - Use arp_filter to prevent ARP Flux
    - echo 1 > /proc/sys/net/ipv4/conf/all/arp_filter
    - Use /etc/sysctl.conf for permanent

Wrap UP

- Use this talk as suggestions of things to try
  - Our work is based on a private, local network – wide area network will be different
  - Do not assume “my” setting will work for you without some tweaks
  - Your environment is probably different then mine.
    - Experiment ! (but be careful)
- I should be around the Summit for the remainder of the week.
  - Feel free to stop me and ask questions, provide feedback, etc
- There will be members of the Performance team in the booth

For More Information – Other talks

- Performance Analysis & Tuning of Red Hat Enterprise Linux – Shak and Larry
  - Part 1 - Thurs 2:30
  - Part 2 - Thurs 3:40
- Tuning Red Hat Systems for Databases - Sanjay Rao
  - Thurs 4:50
- Red Hat Storage Performance - Ben England
  - Fri 9:45

For More Information

- Reference Architecture Website
  - https://access.redhat.com/knowledge/refarch/TBD
- Principled Technologies
  - http://www.principledtechnologies.com/clients/reports/Red%20Hat/Red%20Hat.htm
- New edition of the “Performance Tuning Guide”
  - http://docs.redhat.com/docs/en-US/Red_Hat_Enterprise_Linux/index.html
- IRQ Balance paper
  - https://access.redhat.com/knowledge/techbriefs/optimizing-red-hat-enterprise-linux-performance-tuning-irq-affinity

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Tools – Hardware / Driver Focus

- lspci
- ethtool
- modinfo
- hwloc

Configuration Tools – System Level

- numactl
- tuna
- ifconfig / ip
- tc
- cgroups
- sysctl
- **man**

Monitoring Tools – System Level

- numstat
- mpstat
- vmstat
- watch
- tcpdump / wireshark
- netstat
- oprofile / perf
- sar
- iptraf

sar – some common flags

- Some common flags for sar
    - Adding E gets failure stats
  - # sar -n EDEV - View failure statistics for interfaces
  - # sar -n NFS - View NFS client activity for interfaces
  - # sar -n NFSD - View NFS server activity for interfaces
  - # sar -n (E)IP - View IPv4 activity for interfaces
  - # sar -n (E)ICMP - View ICMPv4 activity for interfaces
  - # sar -n (E)TCP - View TCPv4 activity for interfaces

ethtool – View and change Ethernet card settings

- Works mostly at the HW level
  - ethtool -S – provides HW level stats
    - Counters since boot time, create scripts to calculate diffs
  - ethtool -c - Interrupt coalescing
  - ethtool -g - provides ring buffer information
  - ethtool -k - provides hw assist information
  - ethtool -i - provides the driver information