# KVM Limits
## Arbitrary or Architectural?

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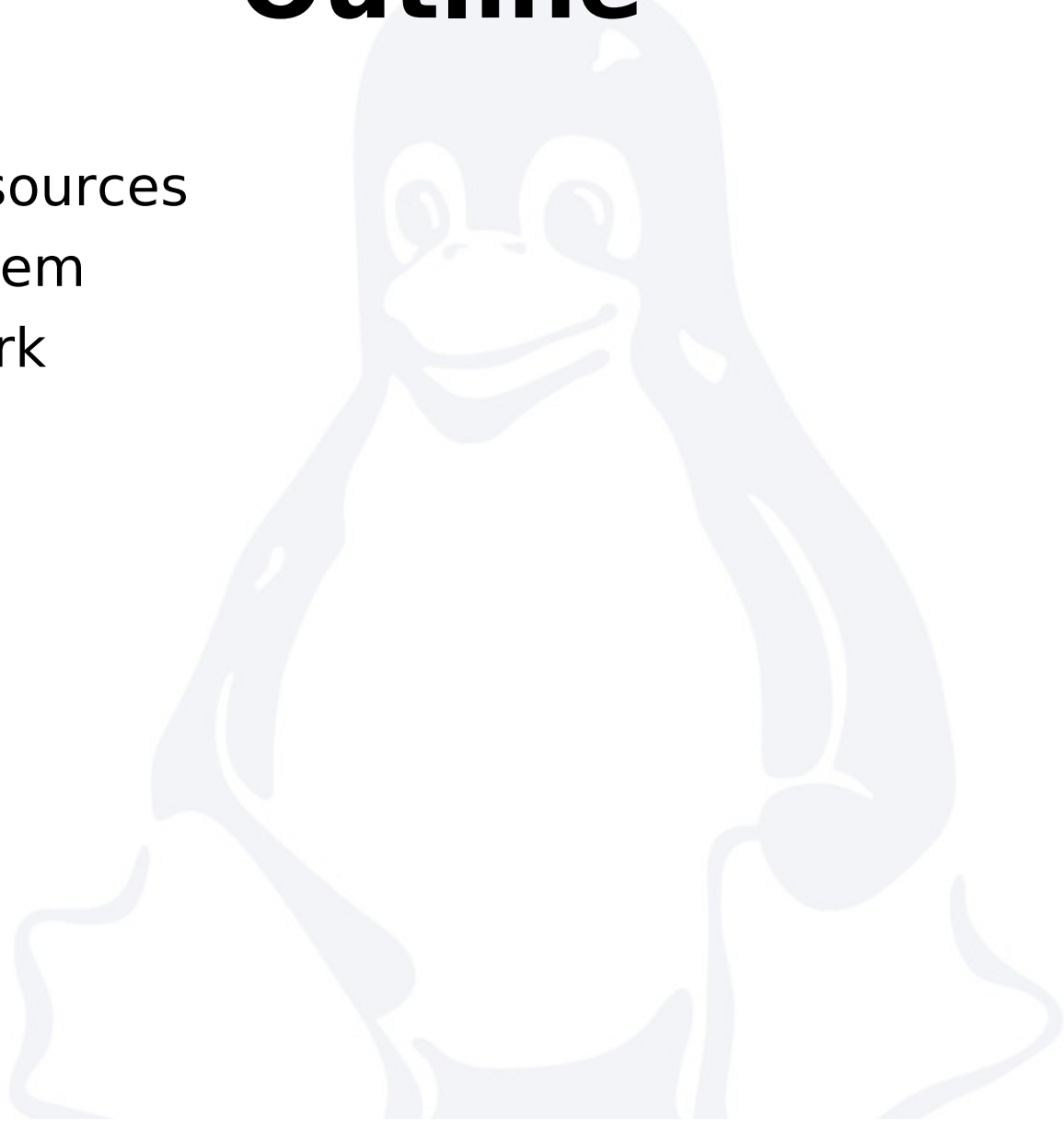
# Outline

- Goals
- Virtual Resources
- IO Subsystem
- Future Work



# Goals

- Determine for any resources (physical or virtual) whether the limit is arbitrary, or limited in some way by the architecture.
- X86-centric view
- Examine current limits
- Extend arbitrary limits
- Identify true architectural limits which inhibit scalability

# Testing Platform

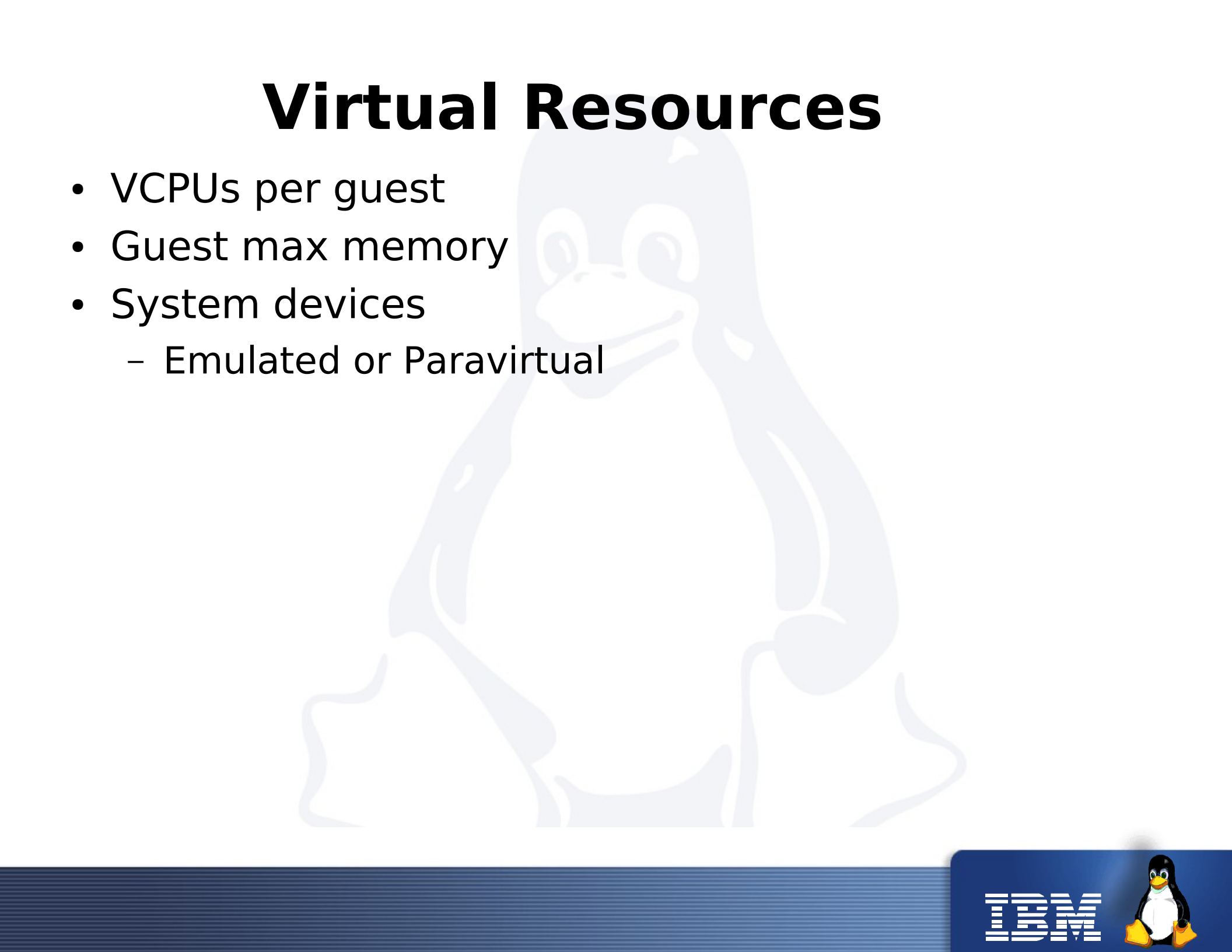
IBM System x3950 M2

IBM System Storage DS3400

- 2 x3950 M2 servers
  - 2 node configuration
- 64G per node
  - 128G total
- 4 Intel Quad Core
  - 4 sockets per node
  - 32 cores total
- 2 Qlogic 4Gb Fiber
- 2 DS3400 trays
  - 24 * 300G 15k SAS

# Virtual Resources

- VCPUs per guest
- Guest max memory
- System devices
  - Emulated or Paravirtual



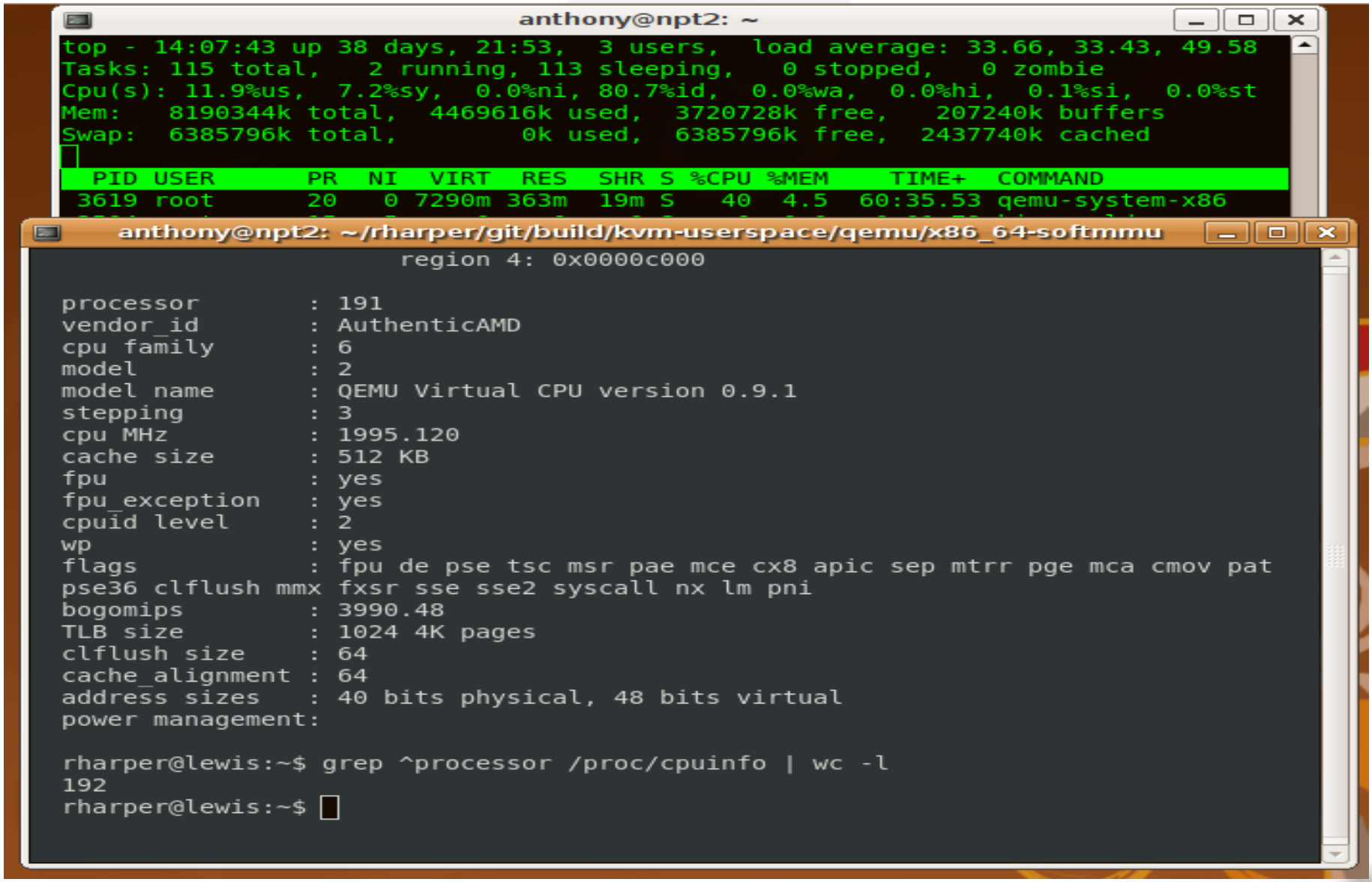
# VCPU Limitations

- Current limit at 16 VCPUs
  - Hard-coded array sizes
    - `kernel/include/asm/kvm_host.h (KVM_MAX_VCPUS)`
    - `libkvm/kvm-common.h (MAX_VCPUS)`
    - `bios/rombios.h (MAX_CPUS)`
- Change limit to 255
  - Max for x86-64 in Linux
- Guest now boots up to 32-way
  - X86 defconfig sets NR_CPUS to 32
- Recompile kernel with NR_CPUS=64
  - Guest boots as 64-way
  - Oops on >64 in `cpu_to_node()`
  - X86 defconfig sets NODE_SHIFT to 6 limiting CPUS to 64.

# VCPU Limitations cont.

- Changing NODES_SHIFT to 8 supports up to 256 CPUs
  - Guests now boot up to 128-way
  - > 128way exits with: `bios_table_end_addr_overflow!`
- MADT, MPTABLE, and SMBIOS tables generate per-cpu data
  - While some portion of the tables must be in low memory, the majority of the data can be relocated to high memory
  - Update BIOS to locate per-cpu data in ACPI_DATA e820 region
- Guest now boots 255-way -- partially
  - Guest wedges after starting up userspace

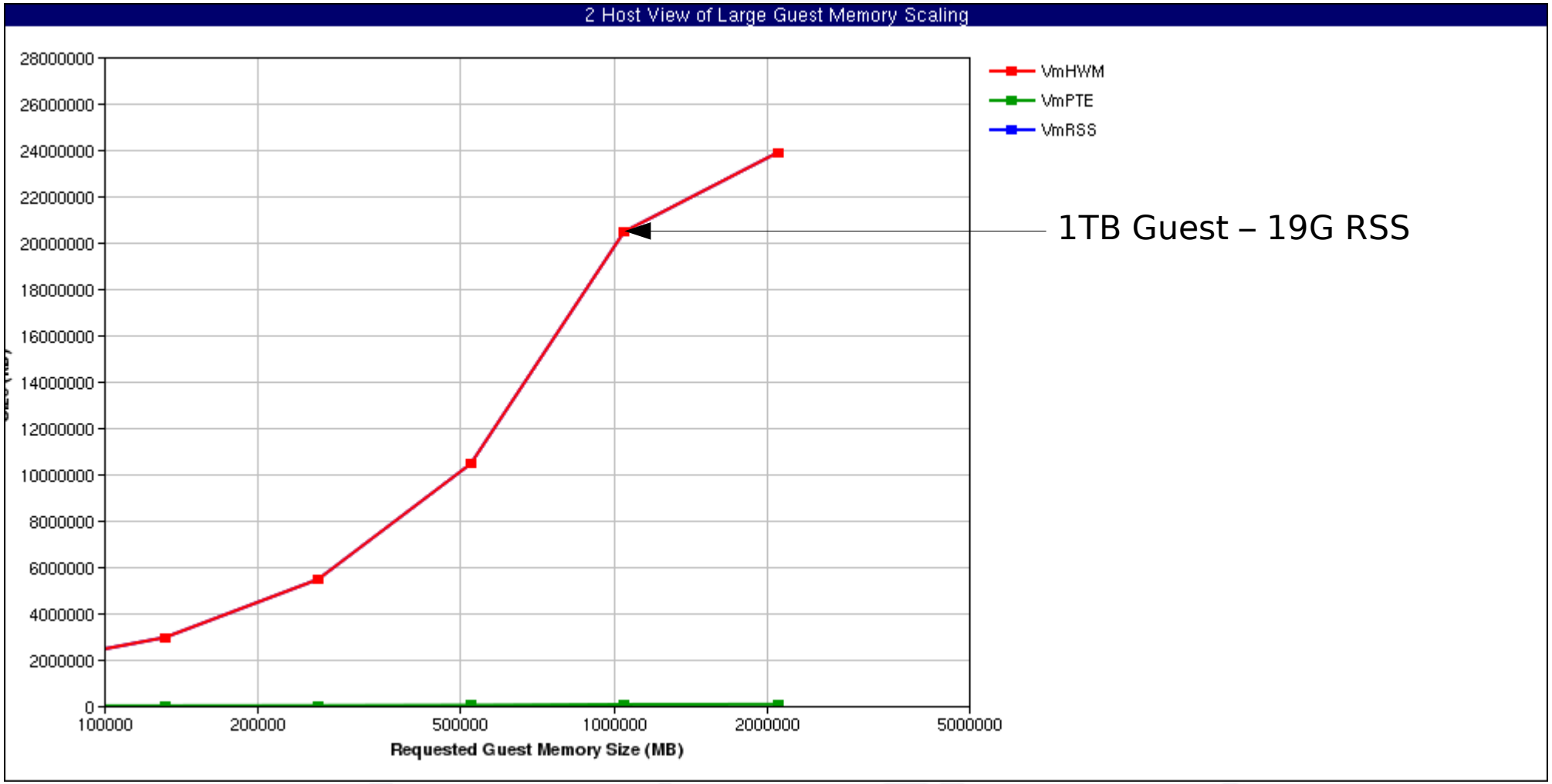
# VCPU Limitations Cont.



# Memory Limitations

- Host VA hardware limits
  - X86 64-bit processors support up to 48-bits
- QEMU imposed limit of 4TB(42 bits) for 64-bit builds
- Bochs BIOS e820 table writes 48-bit values
- KVM pages in memory on-demand (`get_user_pages()`)
- For large memory guests, (1-3%) of total guest memory will be consumed by OS frame table.
  - Booted 256G guest, ran test to consume all memory
    - Consumed 140G (128G of RAM, 12 of swap) and host swapper process started to OOM
  - Booted guest with 2TB of allocated memory
    - Linux detected about 1.4TB
  - Potentially a Host issue with very large swap (4TB)

# Frame Table Consumption



# PCI Device Limitations

- PCI Specification defines up to 32 slots
- Standard PC guests use 5 slots for typical guests
  - 1 disk, 1 nic, 1 vga, 1 isa, 1 pci host bridge
- Users requesting large disk and nic count support
- Two current approaches
  - Use multi-function devices
  - Add additional emulated PCI bridges
- Existing patch for virtio multi-function
  - Guest boots with 220 disks or nics
  - OSes aren't well tested with 220 PCI devices
- Additional PCI bridges patch
  - Extra bridges failed to work (IRQ delivery)

# KVM IO Architecture

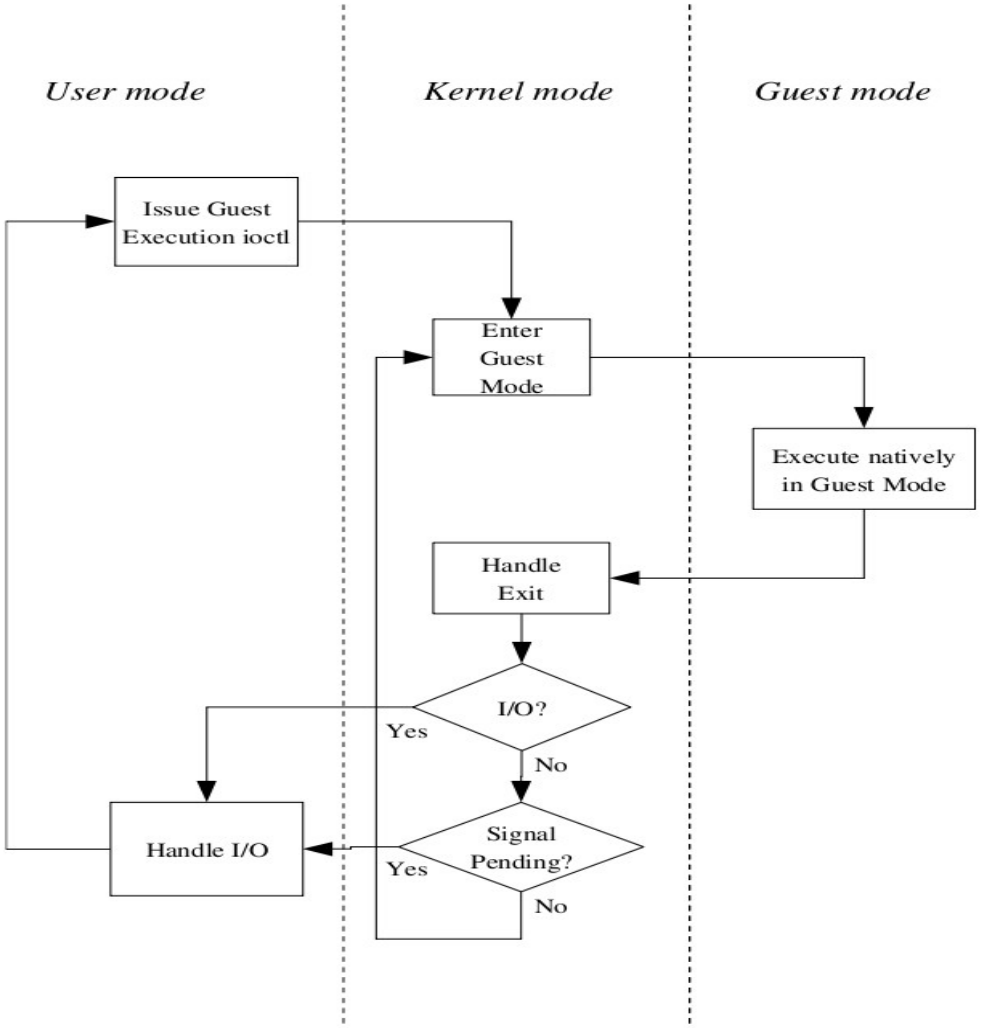
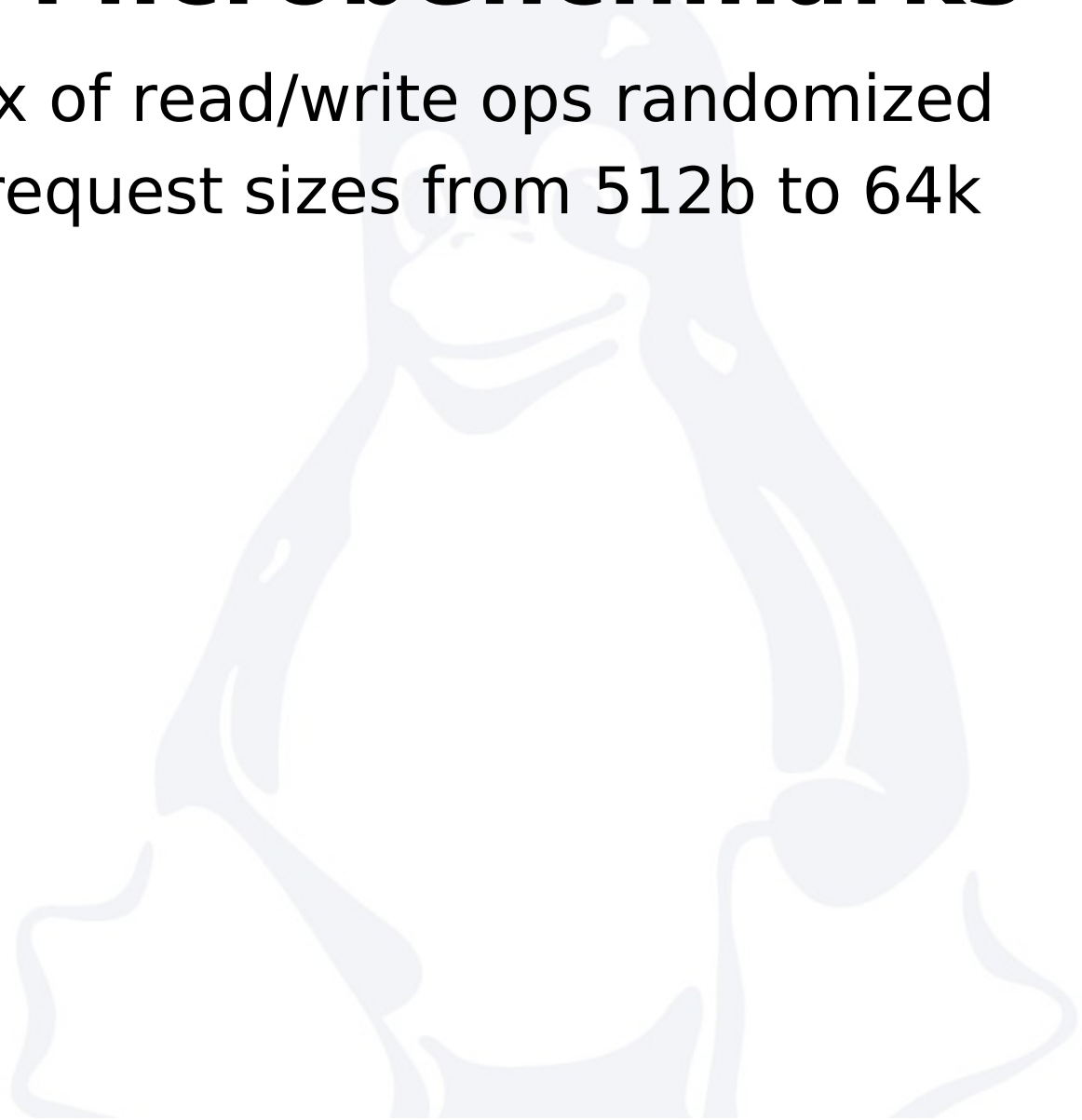


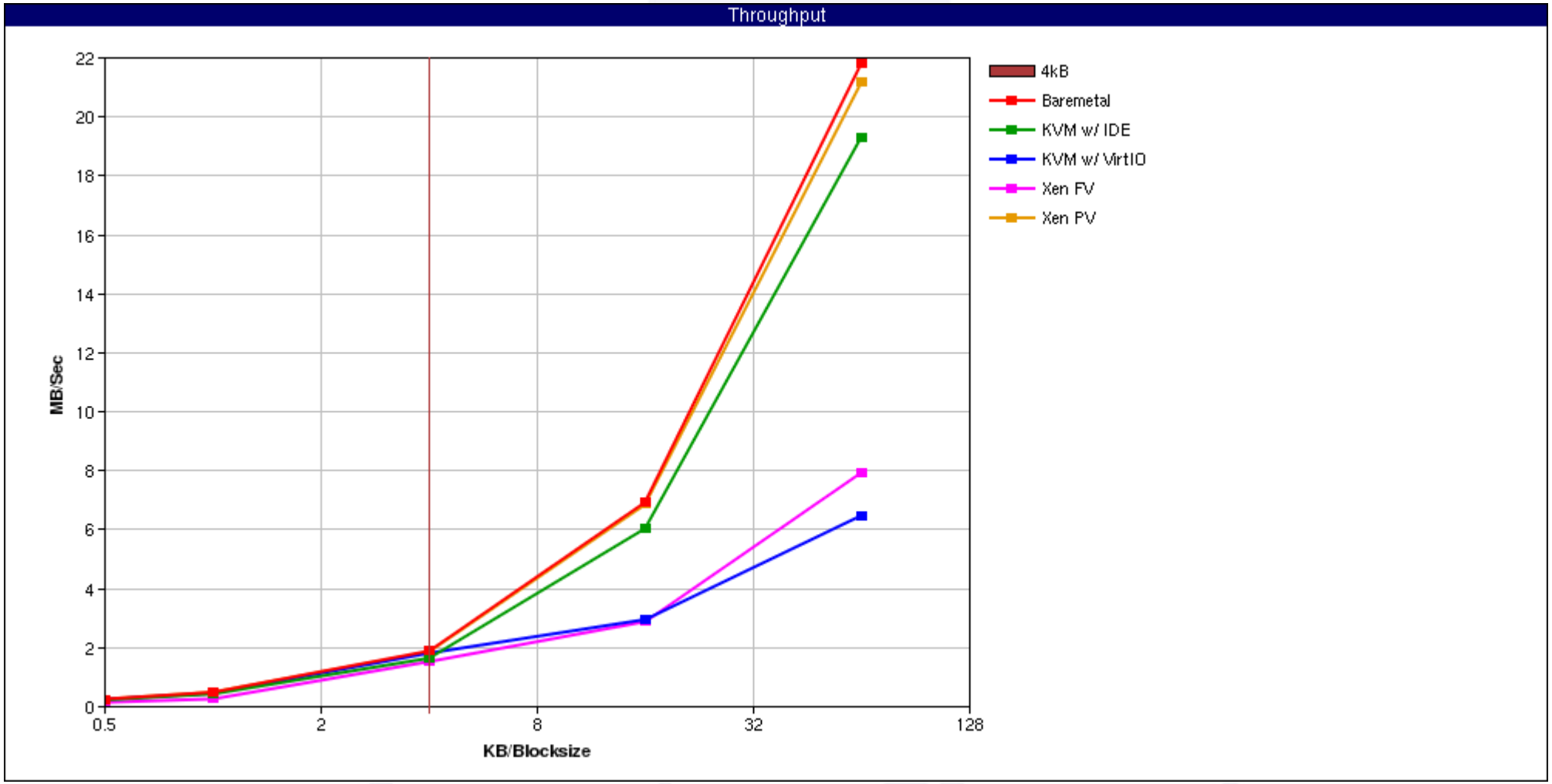

Figure 2: Guest Execution Loop

# IO Microbenchmarks

- 50/50 Mix of read/write ops randomized
- Varying request sizes from 512b to 64k



# IO Throughput – Cache off



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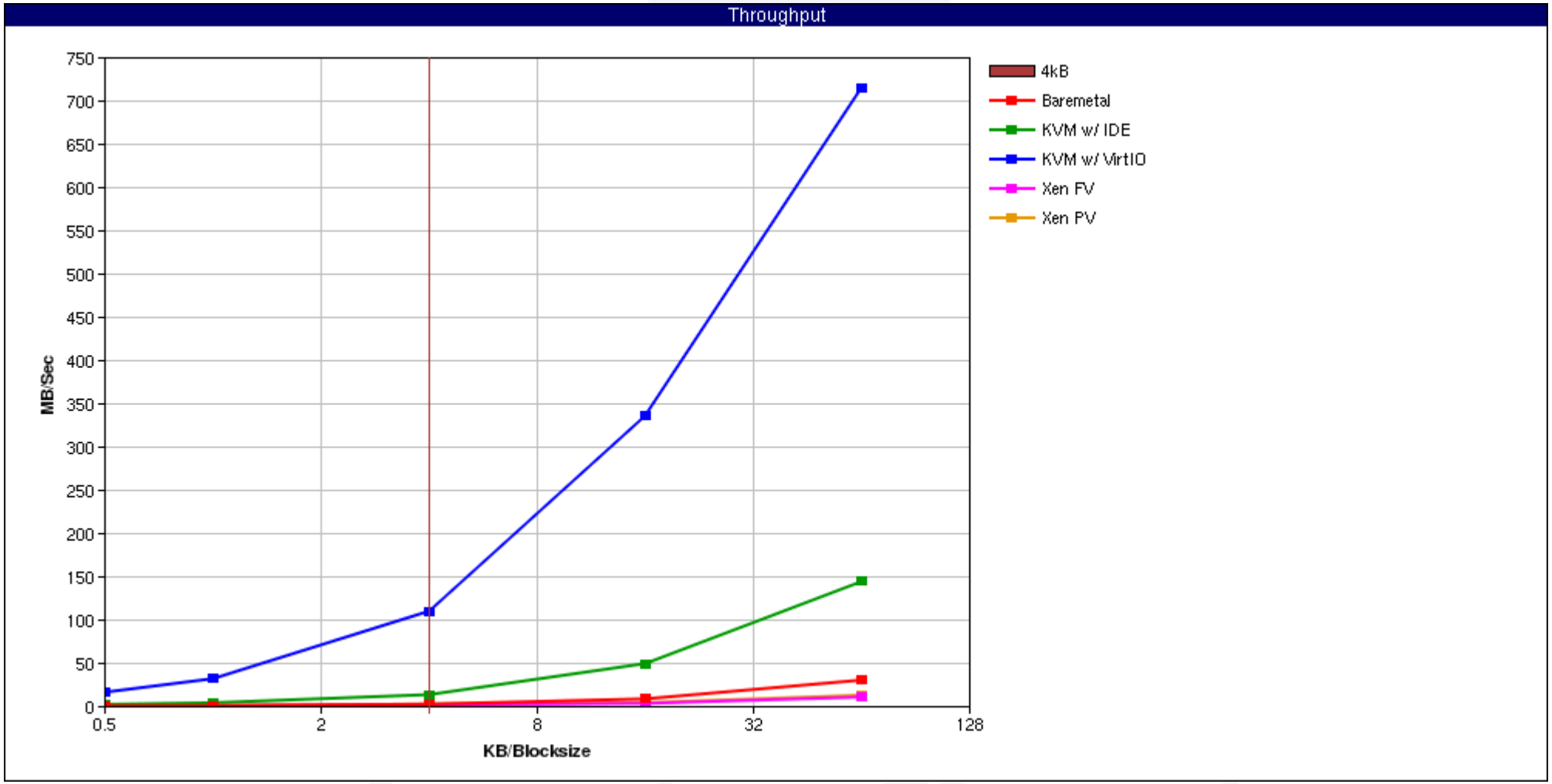
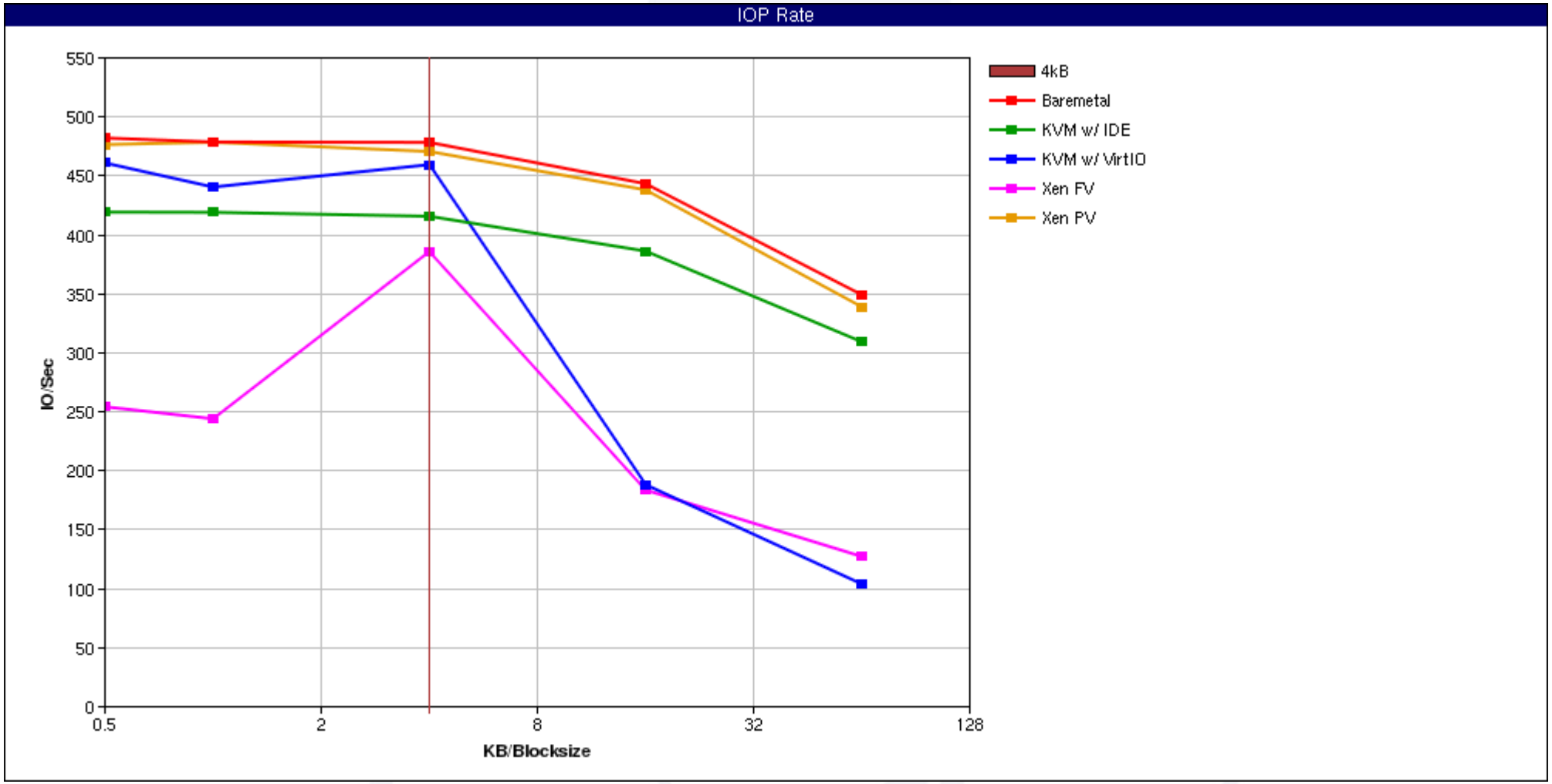


# IO OP Rate – Cache off



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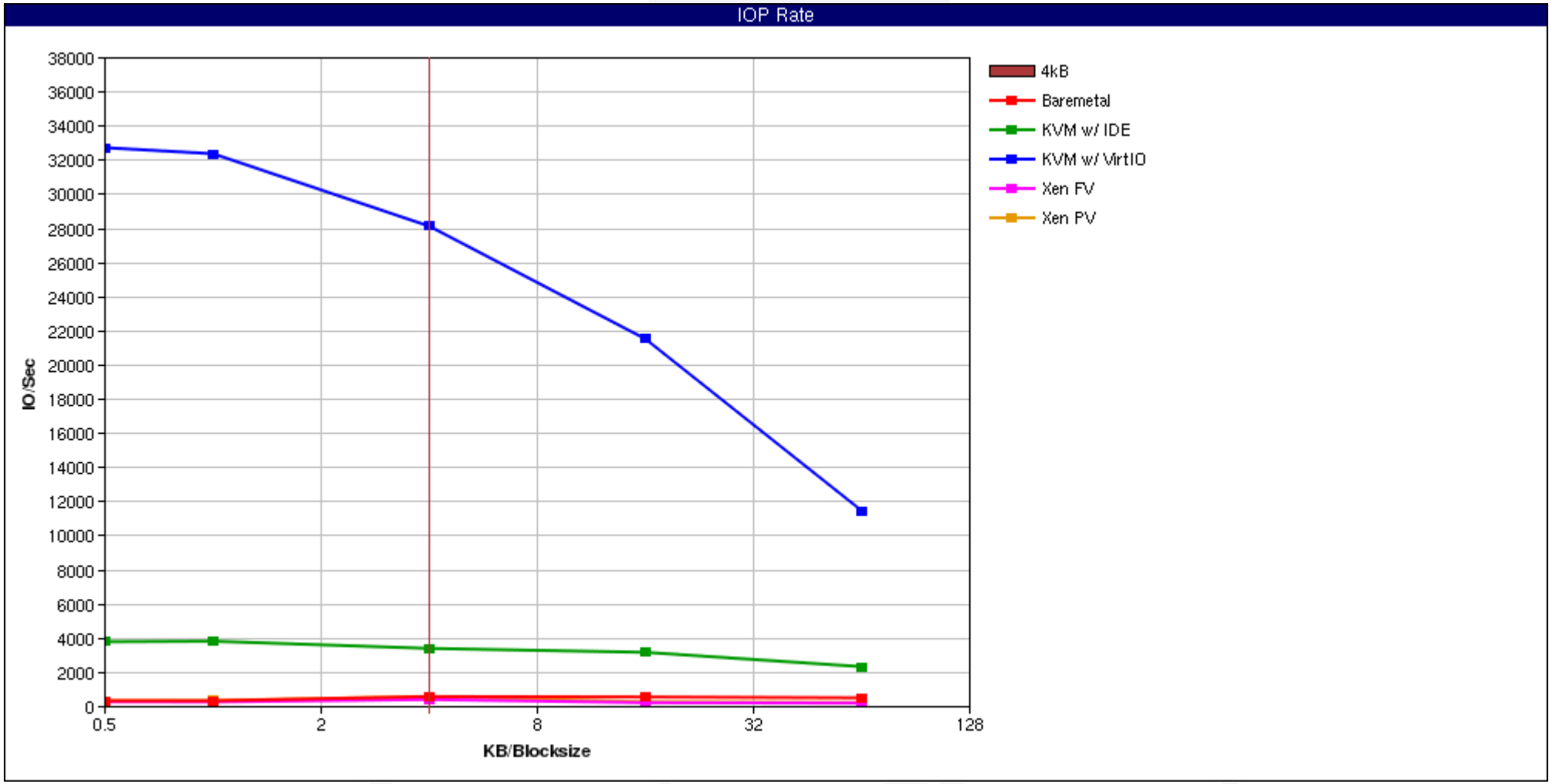
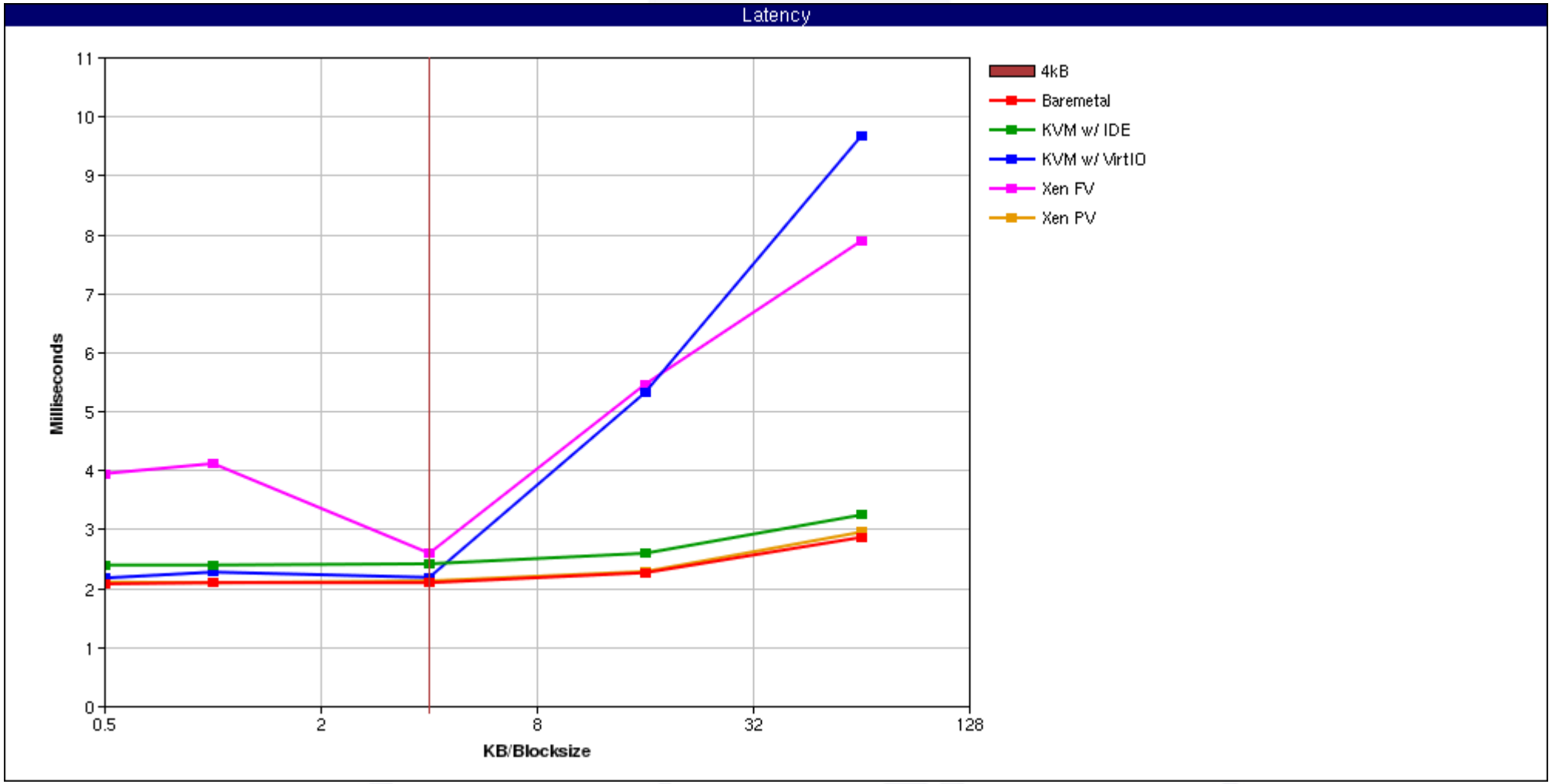


# IO Latency – Cache off



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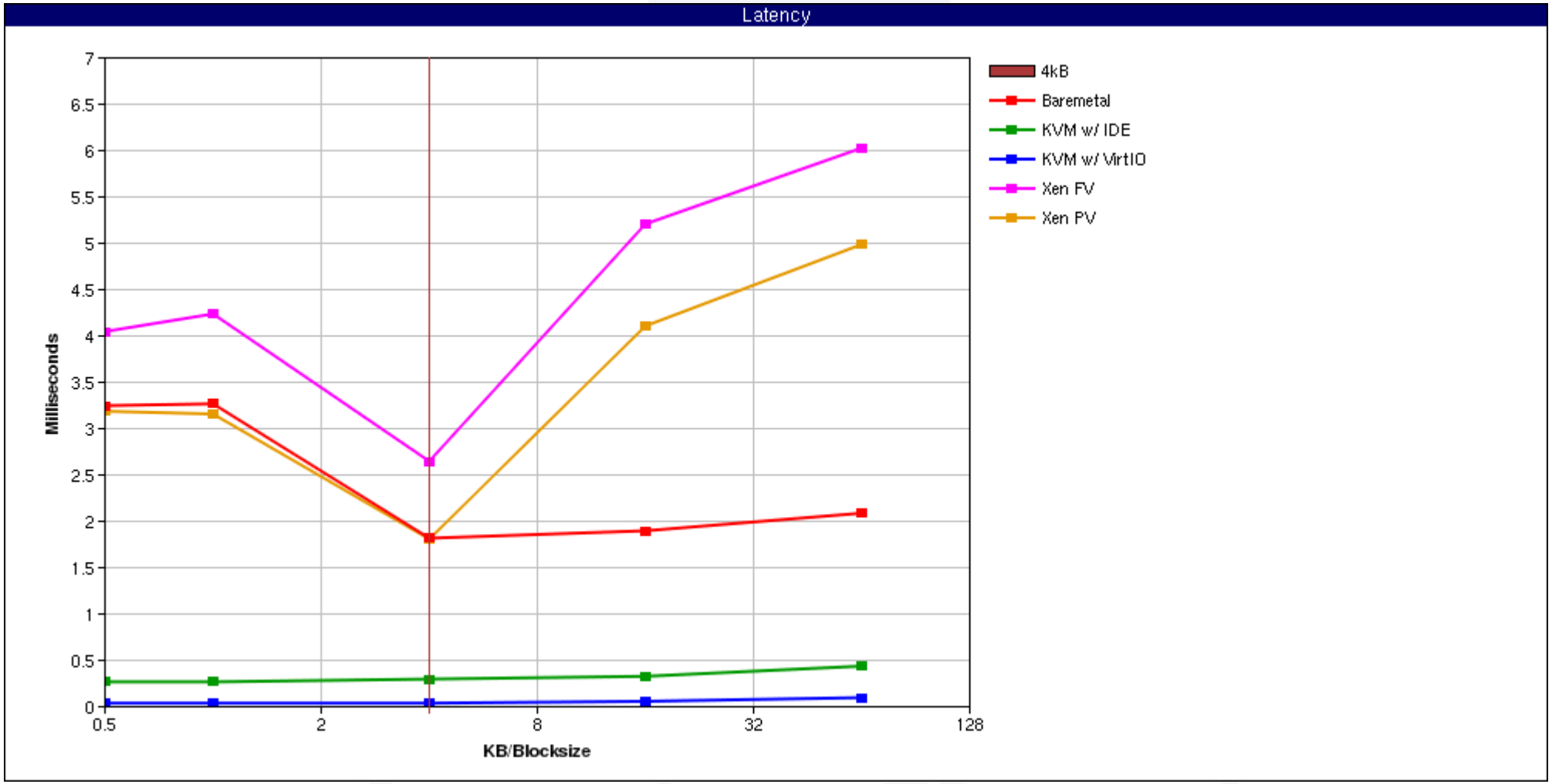
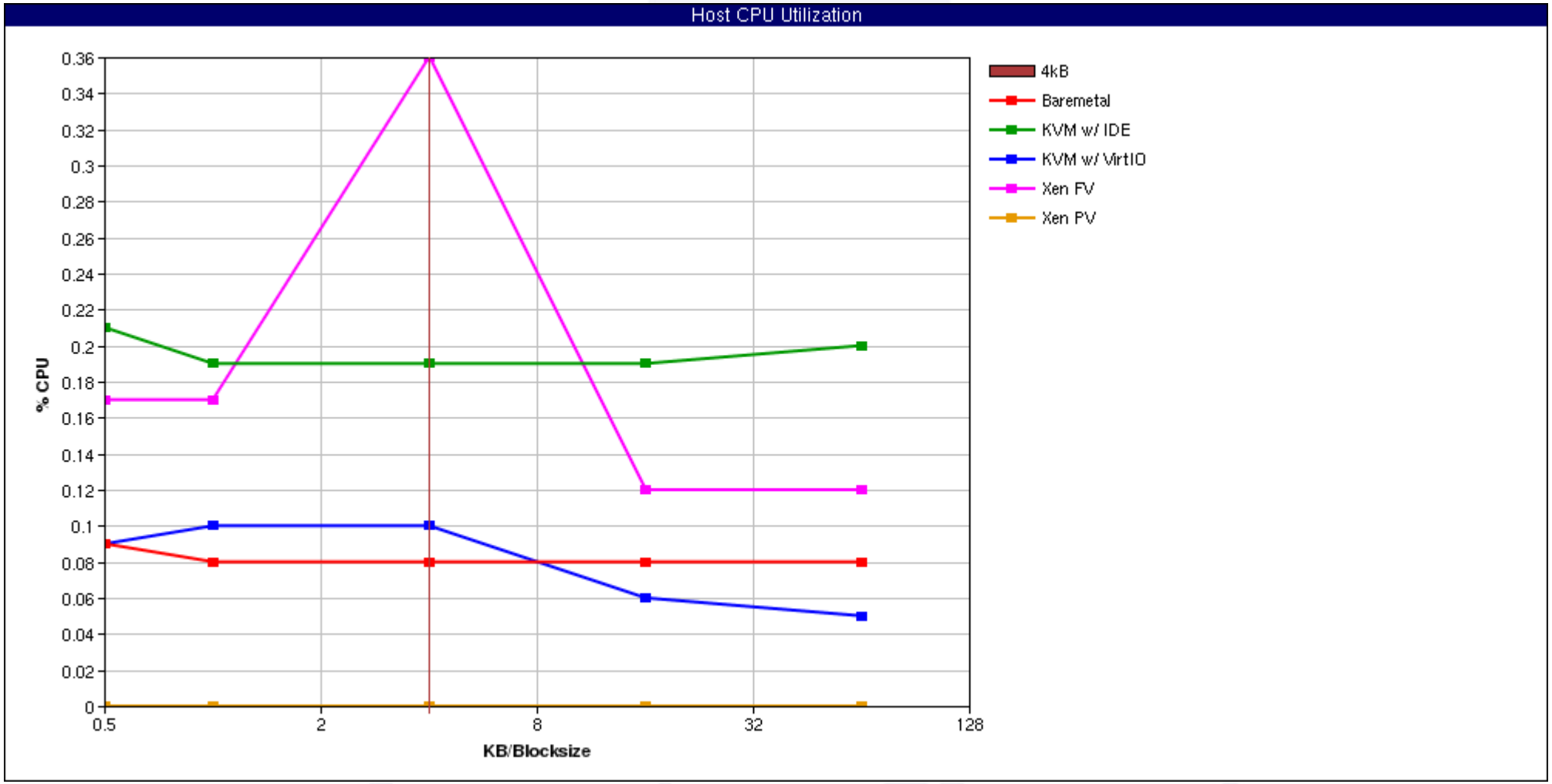
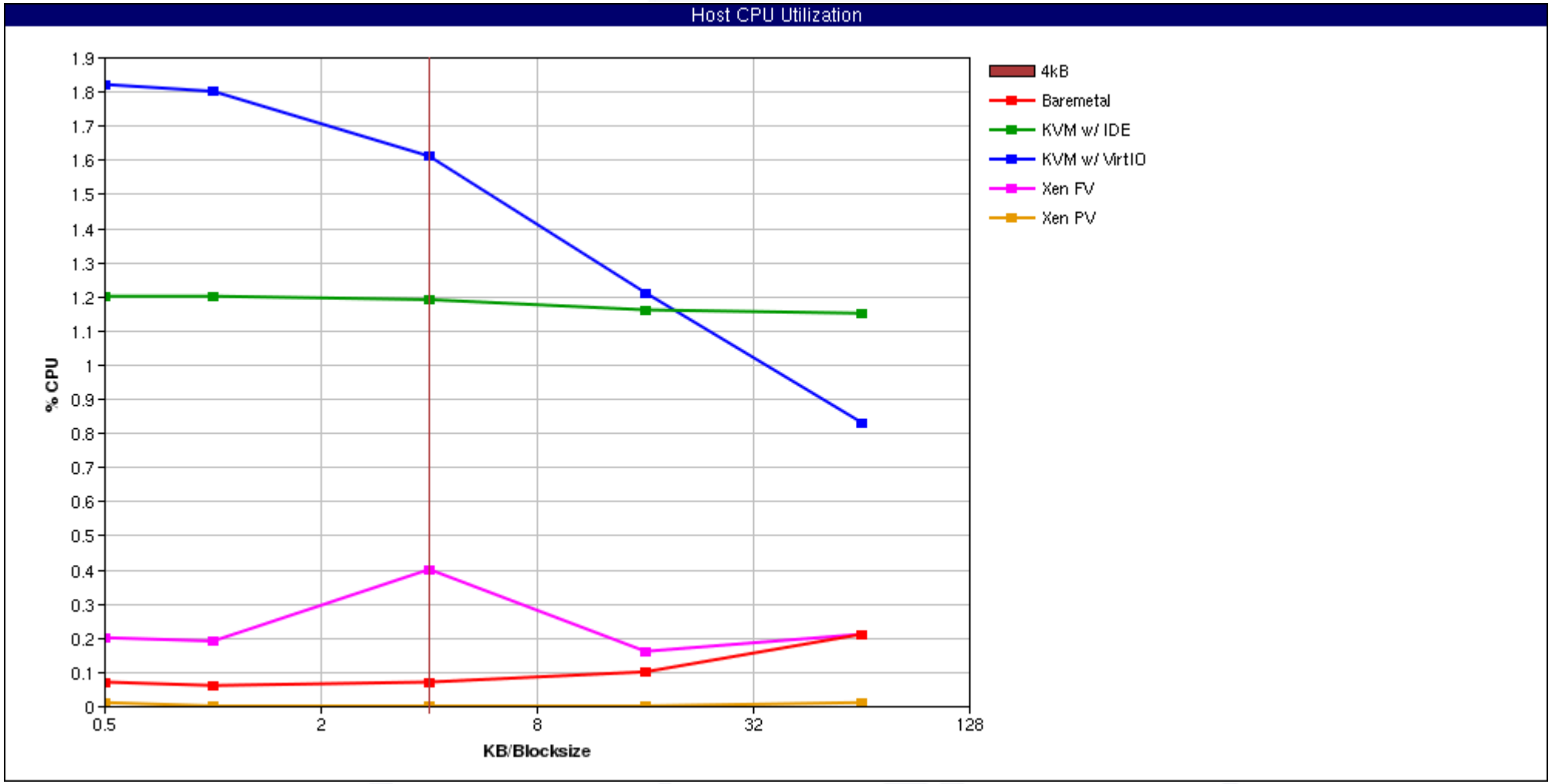


# IO Host CPU Load – Cache off



# IO Host CPU Load – Cache on



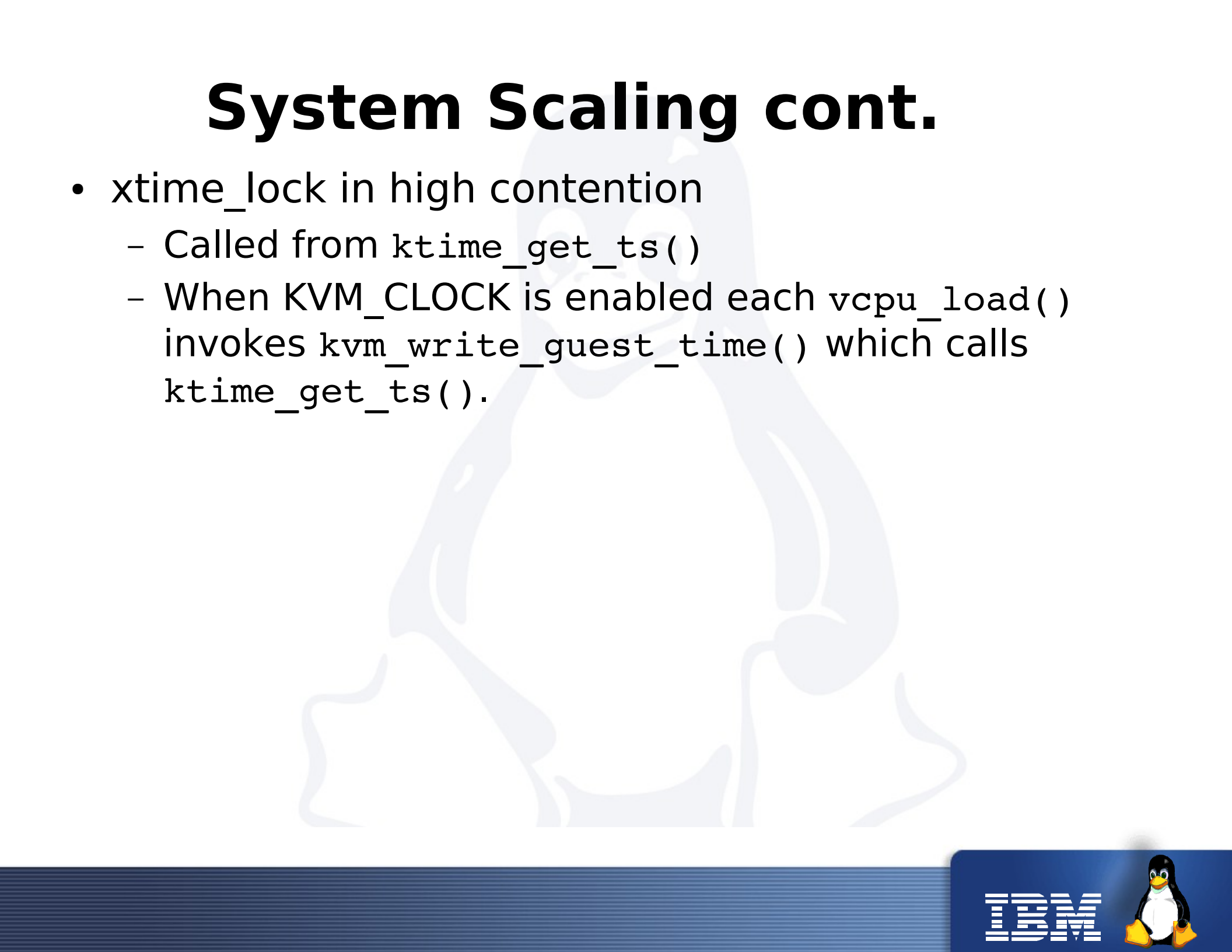
# System Scaling

- Idle guest scaling
  - Mildly interesting and useful for finding scaling issues
  - Booted 500 KVM guests
    - ~200 responsive
  - CPU-bound on the Host
    - Oprofile points to time code (hrtimer/jiffies updates)
  - Lockstat output

| class | name | con-bounces | contentions | waittime-min | waittime-max | waittime-total | acq-bounces | acquisitions |
|---|---|---|---|---|---|---|---|---|
| xtime_lock | 7468921 | 7482457 | 3.47 | 22231.72 | 868397199.73 | 13417786.16 | 2093.8 | |
| tty_ldisc_lock | 1217066 | 1477064 | 10.43 | 1042.04 | 2535049.05 | 2380528.81 | 469.62 | |
| &sem->wait_lock | 713840 | 734493 | 5.18 | 534.51 | 745288.65 | 7499089.63 | 928.08 | |
| &rq->rq_lock_key#2 | 152367 | 159743 | 4.63 | 1288.21 | 657369.39 | 1336917.18 | 1179.79 | |
| &rq->rq_lock_key#1 | 126642 | 133424 | 4.63 | 1503.75 | 586686.21 | 1243939.17 | 1276.63 | |
| &rq->rq_lock_key#2 | 121815 | 129158 | 5.22 | 1028.95 | 530599.21 | 1177768.17 | 1108.34 | |
| &rq->rq_lock_key#1 | 121646 | 127047 | 3.77 | 1428.16 | 533693.92 | 1180284.17 | 1172.43 | |
| &rq->rq_lock_key#1 | 117988 | 123783 | 3.59 | 1163.07 | 543945.53 | 1204265.17 | 1477.89 | |

# System Scaling cont.

- xtime_lock in high contention
  - Called from `ktime_get_ts()`
  - When KVM_CLOCK is enabled each `vcpu_load()` invokes `kvm_write_guest_time()` which calls `ktime_get_ts()`.



# Future Work

- Submit patches bumping KVM VCPU limit to 64
- KVM Tasklet patches
- Run System-wide Scaling with new KVM Tasklet patches
- Examine NUMA affects with cpusets/cgroup and page migration
- Run Large # of guest test w/o KVM_CLOCK
- Run System-wide scaling on large NPT/EPT systems when available.