z/VM Guest Performance

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Overview

- General management of resources
- Processor
- I/O
- Storage and Paging
- Linux® guidelines
- Performance Monitoring

What do you mean by "Performance?"

- ITR = Internal Throughput Rate = a measure of work per CPU second
- ETR = External Throughput Rate = a measure of work per wallclock second
- CPU Utilization = how busy processor is; tied to ITR
- Response Time (Elapsed Time) = how long jobs take; tied to ETR
- Interactive Users vs. Batch Work
- How many phone calls you get

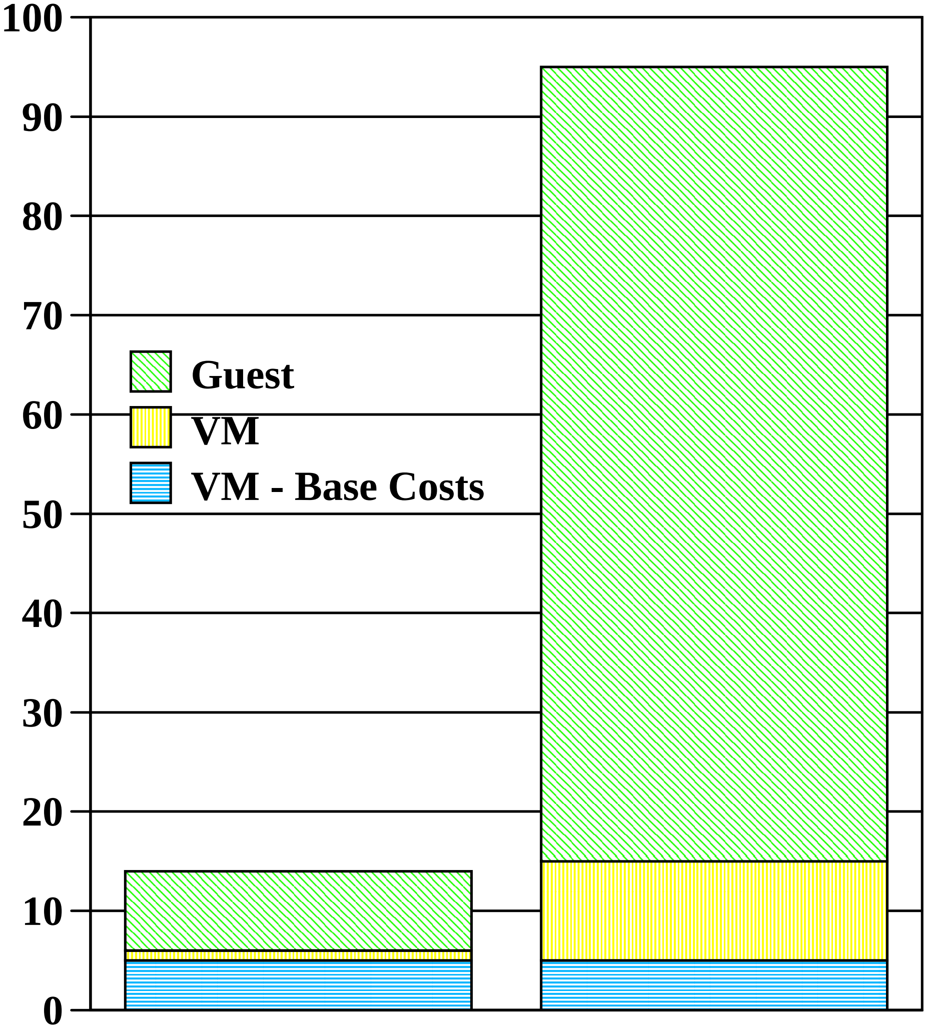
Processor Resources

- Configuration
  - Virtual 1- to 64-way, defined in user directory or via CP command
  - A real processor can be dedicated to a virtual machine
  - Do not recommend use of more virtual processors than there are real
  - Do not recommend mixing shared and dedicated processors
- Control and Limits
  - "Share" setting
  - Absolute or Relative
  - Target minimum and maximum values
  - Maximum values (limit shares) either hard or soft
  - "Share" for virtual machine, divided amongst its virtual processors

Processor Usage by VM

- Base costs and background work
  - Scheduling and dispatching
  - Accounting
  - Monitor
- Costs proportional to guest requests or requirements of VM

Guest Example



Processor: SIE Exits

- SIE = Start Interpretive Execution
- Used by z/VM™ to run a guest
- Exits from SIE indicate work for VM
- Rate of SIE executions available from most performance monitor products (e.g. VMPRF, RTM, etc.)
- Hardware assists can help avoid SIE exits
- Most common reasons for exiting SIE
  - I/O processing
  - Page fault resolution
  - Instruction simulation
  - Minor time slice expires
  - Loaded wait state

Avoiding Exits from SIE

- Data in memory techniques avoid I/O
- I/O Assist avoids SIE exit to handle:
  - I/O interrupt processing
  - CCW translation from virtual to real addresses
- CCW translation bypass for V=R guest
- Minor time slice: SET SRM DSPSLICE
- Avoid Paging
  - V=R/F
  - Reserved pages for V=V
  - Sufficient storage

I/O Resources

- Configuration
  - Dedicated devices (Tape Drives, DASD, Network devices)
  - Partitioned devices (minidisks)
  - Virtualized devices (minidisks, crypto)
  - Simulated devices (Guest LAN, virtual disks in storage)
  - Define or attach dynamically
- Control and Limits
  - Indirect control through "share" setting
  - Real devices can be throttled at device level
  - Priority can be set for virtual machine
    - CP uses to effect queue placement for DASD devices
    - HW uses to effect priority in channel usage
  - Minidisk Cache fair share limits can be turned off for virtual machine

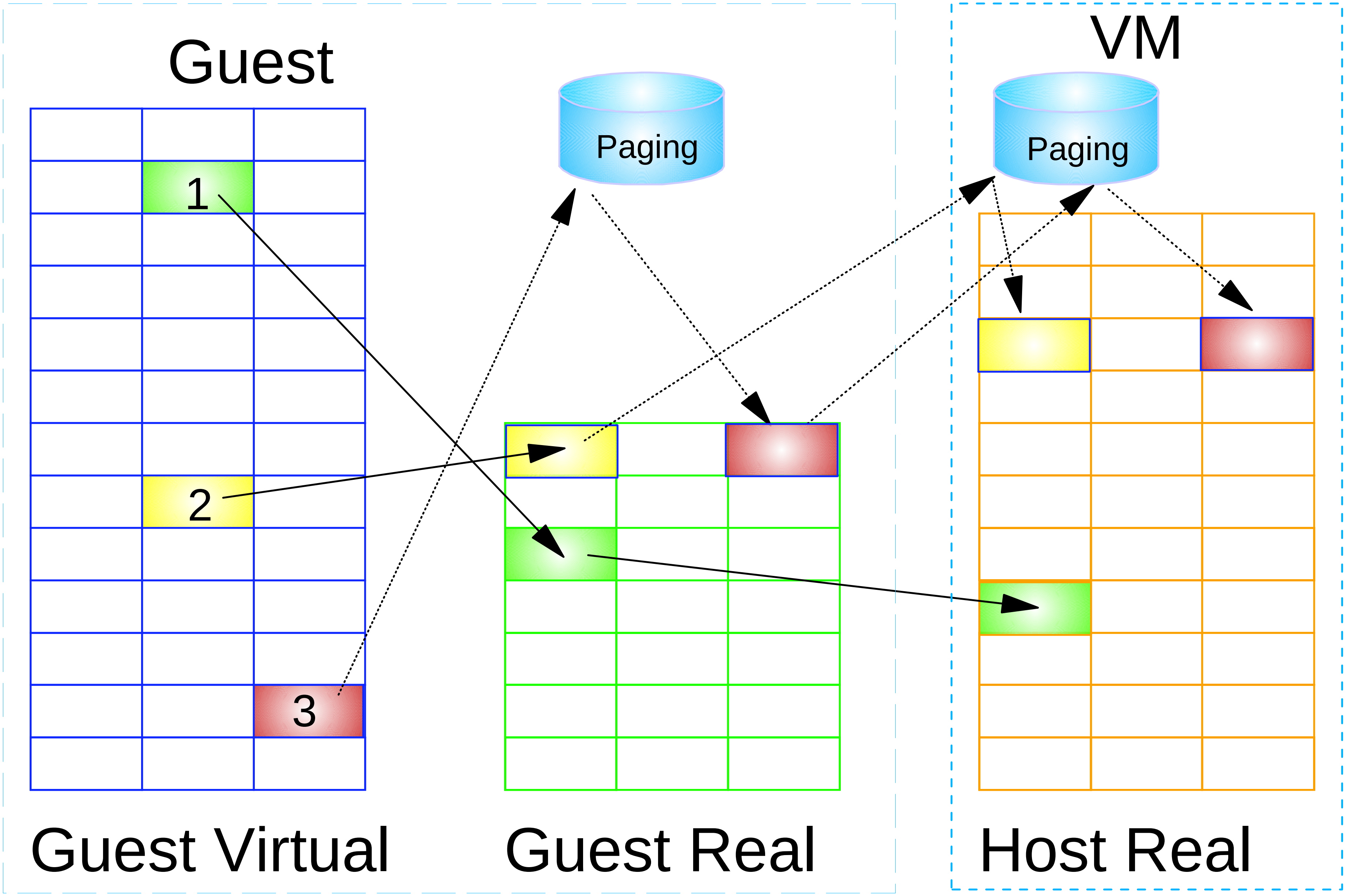
I/O Considerations

- Traditional benefit of V=R/F guests and I/O Assist usually does not apply to Linux guests
  - Integrated Facility for Linux (IFL) processors most often used for Linux
  - IFL requires LPAR which results in loss of I/O Assist
- Dedicated I/O is not eligible for Minidisk Cache (MDC)
- MDC read performance is as good as VM virtual disk in storage performance
- Both VM vdisks and MDC require sufficient storage

Storage Resources

- Configuration
  - Defined in user directory or via CP command
  - Can define storage with gaps (useful for testing)
  - Can attach expanded storage to virtual machine
  - Machine can be V=V, V=F, or V=R
- Control and Limits
  - Scheduler helps control over committing storage and paging resources
  - Virtual Machines that do not "fit" criteria placed in eligible list
  - Virtual Machine can be made exempt from eligible list via QUICKDSP
  - Can "reserve" or "lock" pages for V=V guests
    - Reserve a number of pages to influence storage management page steal algorithms (recommended approach)
    - Lock specific pages (less flexible and forces page below 2GB)

Paging Considerations



Paging Considerations

- For V=V guests the potential exists for "Double Paging"
- No VM paging for V=R/F
- The closer the virtual machine size is to the amount of memory the Linux guest truly needs, the lower the Linux swapping..
  - However, oversizing the virtual machine size for Linux guests has other negative effects
- PAGEX and Asynchronous Page Fault used where appropriate
- VM can use expanded storage for high speed paging device
- There can be an advantage to defining some processor memory as expanded storage
  - See www.vm.**ibm.com**/perf/tips/storconf.html

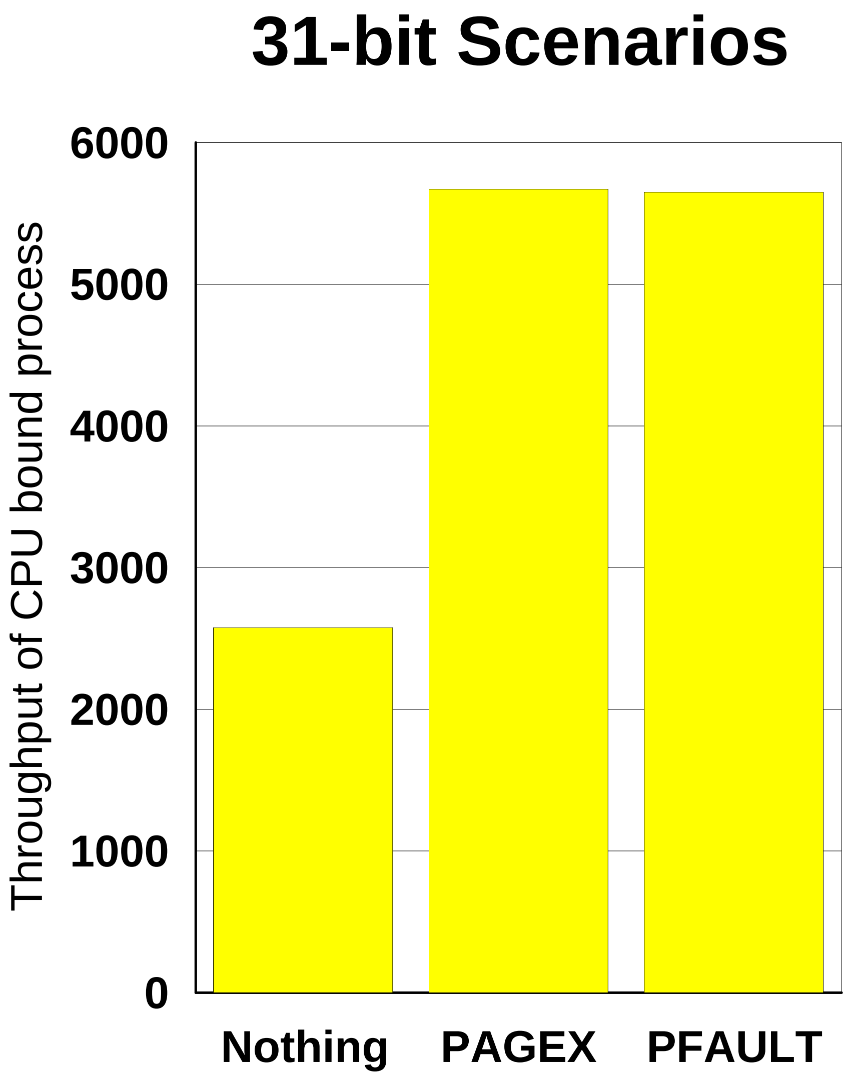
V=R/F/V Considerations

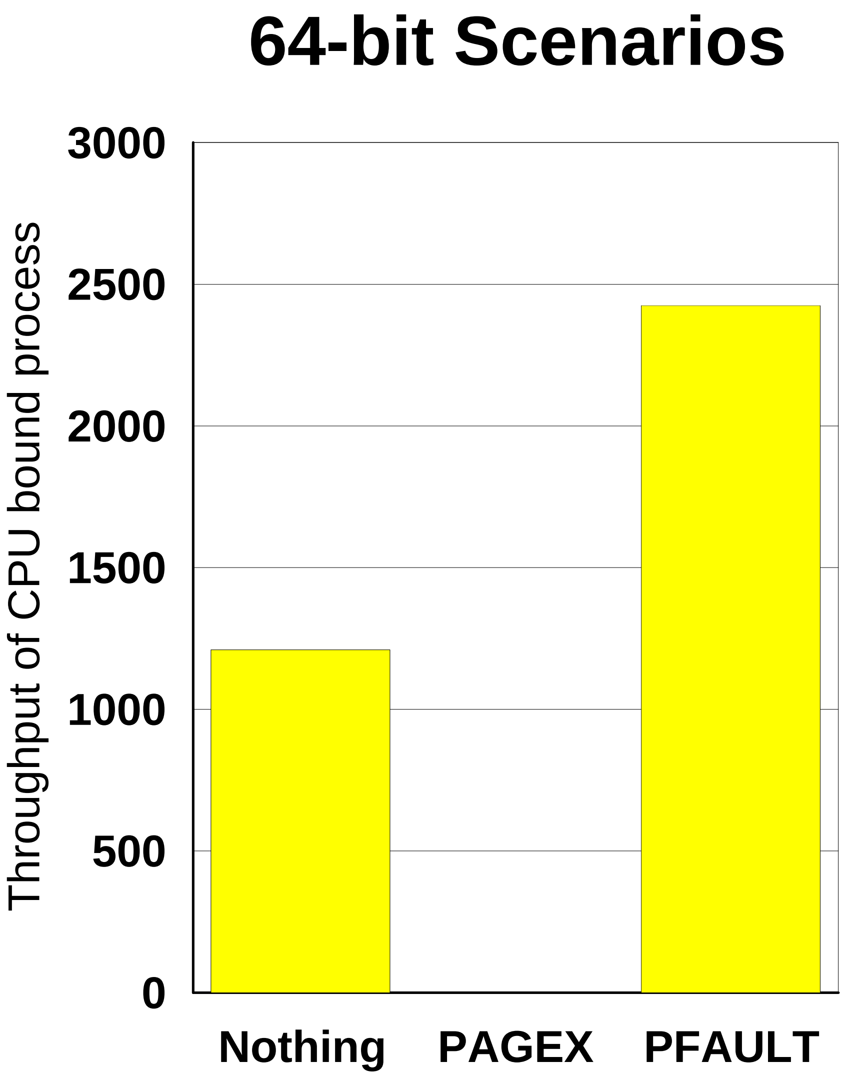
- V=R/F potential I/O assist benefit (saves CPU)
- V=F avoids overhead of recovering V=R
- 1 V=R + 5 V=F or 6 V=F
- V=V avoids dedicating storage
- V=R defaults to dedicating processors
- Running z/VM in an LPAR -
  - No V=F, only V=R, but without I/O Assist
  - Often better to use V=V and reserve pages

Asynchronous Page Fault Facility

- Ordinarily, page faults serialize the virtual machine. This can be a throughput and response time problem for guest systems
- Enhancements designed for Linux
- PFAULT macro
  - Accepts 64-bit inputs
  - Provides 64-bit PSW masks
- Diagnose x'258'
- Older PAGEX interface limited to 31-bit
- z/VM 4.2.0
- Linux 2.4 Kernel required

Page Fault Tests





Virtual MP Support

- Define additional processors dynamically
  - Directory include MACHINE ESA 2
  - CP DEFINE CPU vcpu_addr
- Or put everything in the directory
  - CPU 00 NODEDICATE
  - CPU 01 NODEDICATE
- Detaching vCPU resets virtual machine
- For testing: more virtual than real processors

Virtual MP Support

- CP commands of interest
  - QUERY VIRTUAL CPUS
  - CPU vcpu_addr cmd_line
  - DEDICATE and UNDEDICATE
- Share setting is for virtual machine, divided amongst all virtual processors
- Mixing dedicated and shared processors is not recommended
- Defined but inactive vCPU (stopped state) makes guest ineligible for I/O assist
- Dedicated processor appears 100% busy on various VM performance reports

Linux Guest Guidelines

- Why does my idle Linux consume Processor resources?
  - Timer pops
- Is the number and size of guests important?
  - Yes! It is virtual storage, but it isn't magic. It has to reside somewhere when Linux guest is running.
- How big should my Linux guest be?
  - Not bigger than you need
- Where should Linux swap?
  - Multiple choices: XPRAM, Mdisk, Tdisk, Vdisk
- Should I set QUICKDSP ON for my Linux Guest?
  - Production vs. Test vs. Development machines
- See the following URL for other information: www.vm.**ibm.com**/perf/tips/linuxper.html
- See APAR VM63282 for better dispatch list management

Swapping Configuration

- The trade-off
  - Defining virtual machine too large may cause excess memory to be used inefficiently for file and buffer cache.
  - Defining virtual machine too small may cause swapping which is expensive in processor time and impacts response time.
- Configure so that swap rate is zero or very low.
- Virtual disk in storage can be used to mitigate cost of swapping.
  - Pros:
    - very easy from administration view
    - virtual disk blocks not created unless referenced
    - performance
  - Cons:
    - DAT structures required below 2GB and are not pageable
    - Steal algorithms favor those pages over pages of idle users
    - Disk block pages below 2GB prior to z/VM 4.4.0
- Do not define virtual disks in storage larger than necessary

Networking Choices

- Lots of variations for connecting
  - guests to other guests
  - guests to another LPAR
  - guests to physical network
- Continued improvement in both Linux and VM stacks
- Workload dependent
  - MTU impact
  - Performance may improve as load increases
    - data rate and number of connections

Guest to Guest

- Guest LAN
  - Simulated HiperSockets slightly lower pathlength than Simulated GbE
  - Use with the virtual switch (z/VM 4.4)
- HiperSockets
  - Requires locking real memory below 2GB
  - Configuration limitations
  - Better performance for large data transfers

Guest to Another LPAR

- HiperSockets
  - Best solution
  - Pay attention to MFS (MTU)
- Shared OSA GbE
  - Additional overhead and latency even when shared card

Guests to External Network

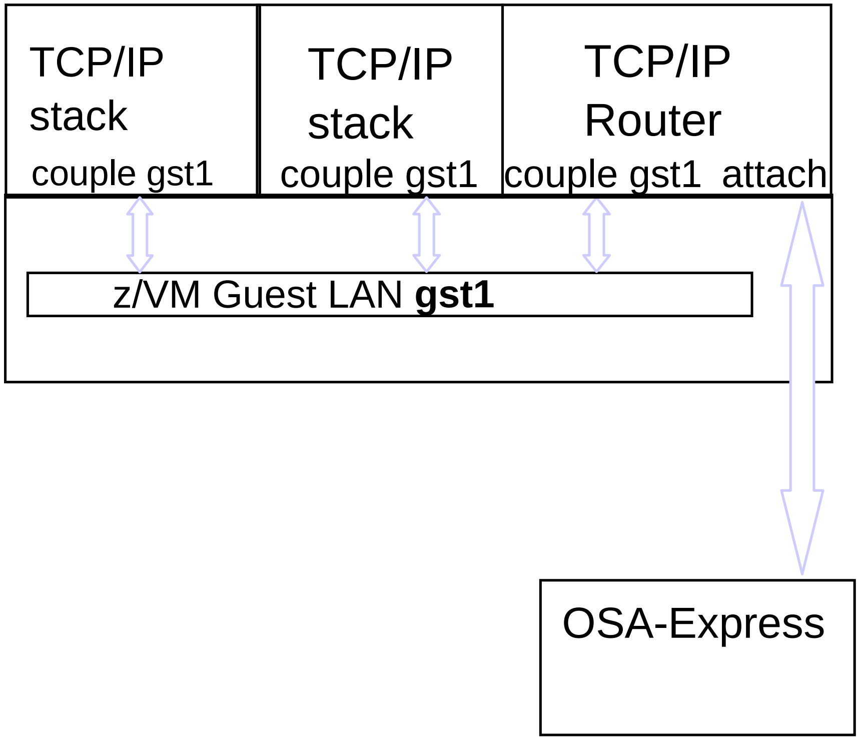
- Guests direct connect to OSA
  - lowest pathlength, especially with z/VM 4.4.0 with hardware that supports Adapter Interrupt Passthru (AIP)
  - requires locking real memory below 2GB
- Virtual switch
  - requires z/VM 4.4.0
- Virtual Machine Router
  - extra pathlength for moving and processing data

Virtual Switch - New in z/VM 4.4.0

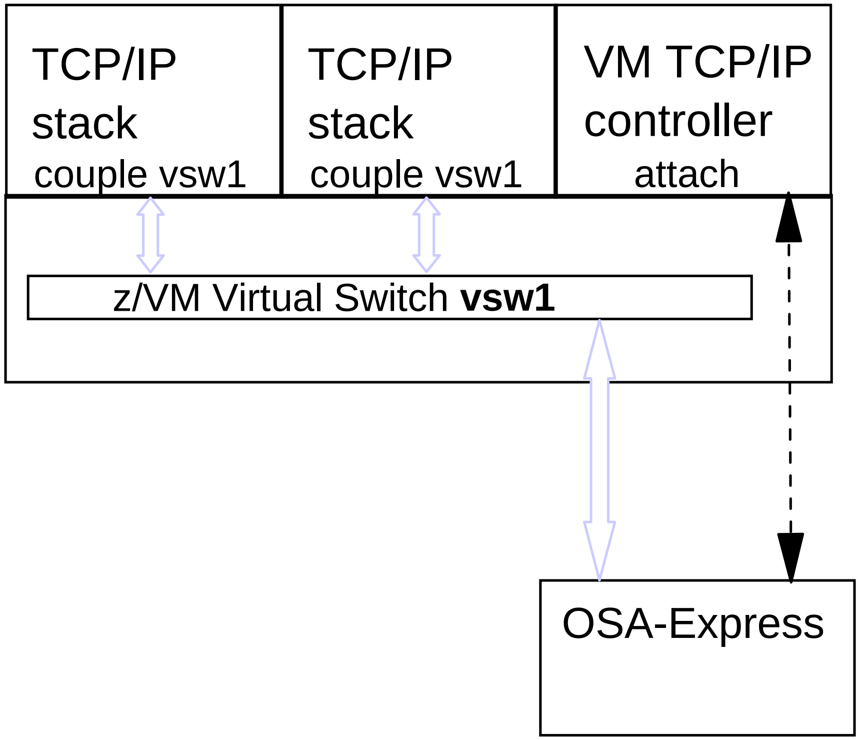
- Layer 3 switch
  - Switches packets between QDIO guest LAN and OSA Express physical network
  - Eliminates need for layer 3 router
  - Supports transparent VLAN specifications for guests connected to Virtual Switch
  - Switching function performed entirely by CP
  - z/VM TCP/IP stack used for setup and control functions
- Provides transparent bridging
  - Learning - automatic configuration of IP addresses
  - Flooding - deliver packets for unknown IP addresses to all stations
  - Aging - forget learned IP addresses after some period of inactivity

Virtual Switch Topology

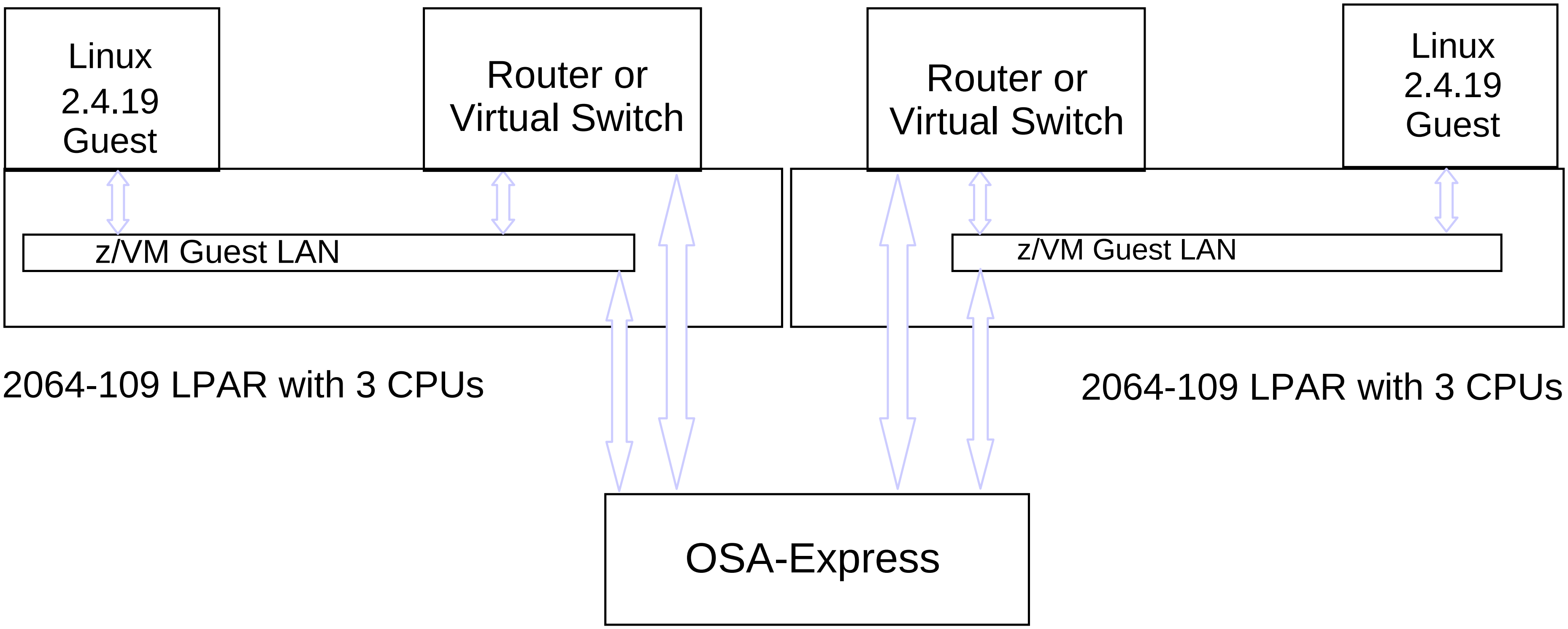
Traditional Guest LAN



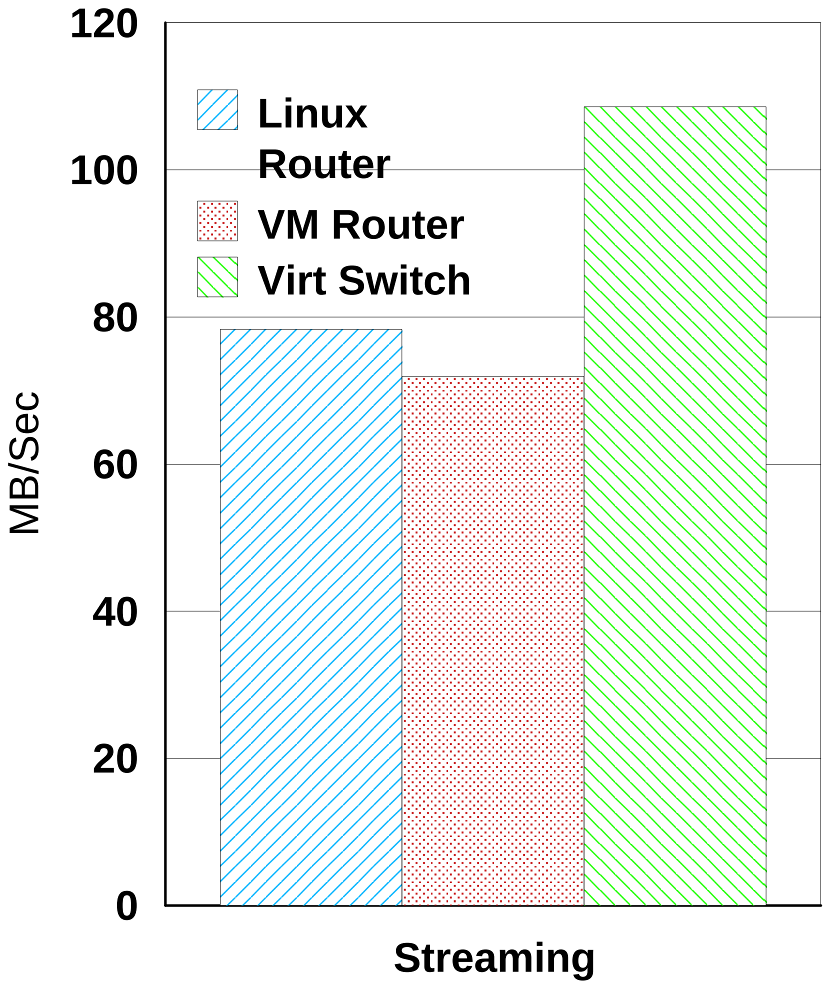
Virtual Switch Guest LAN

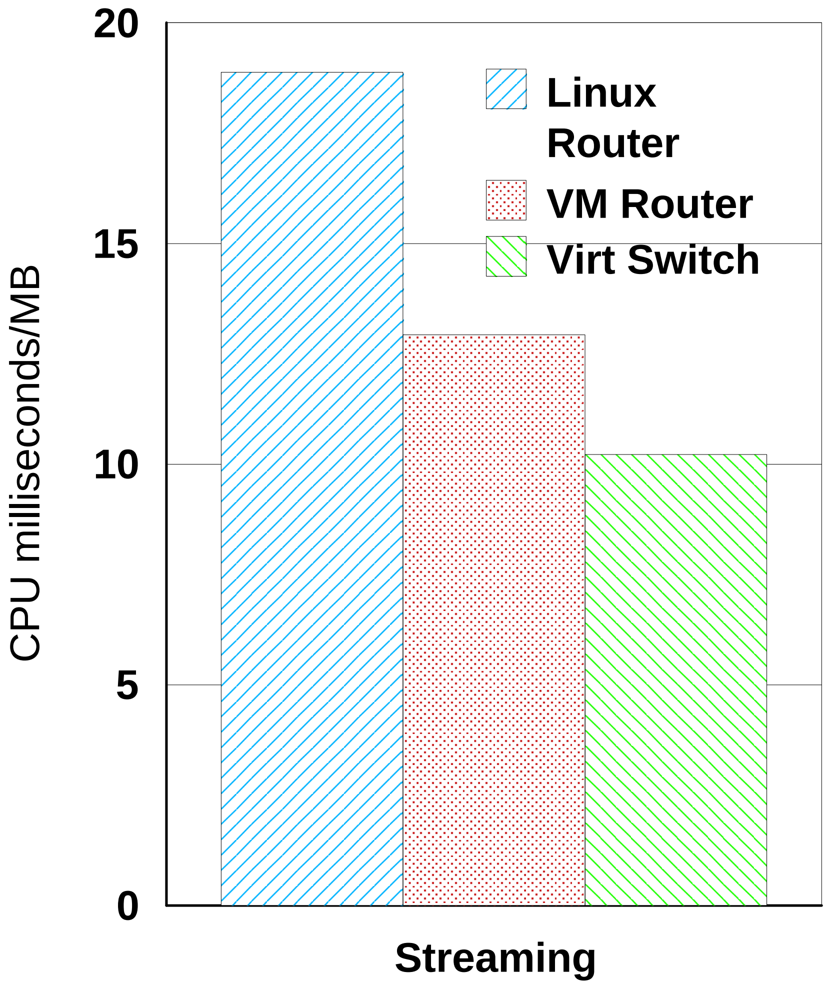


Virtual Switch Test Configuration

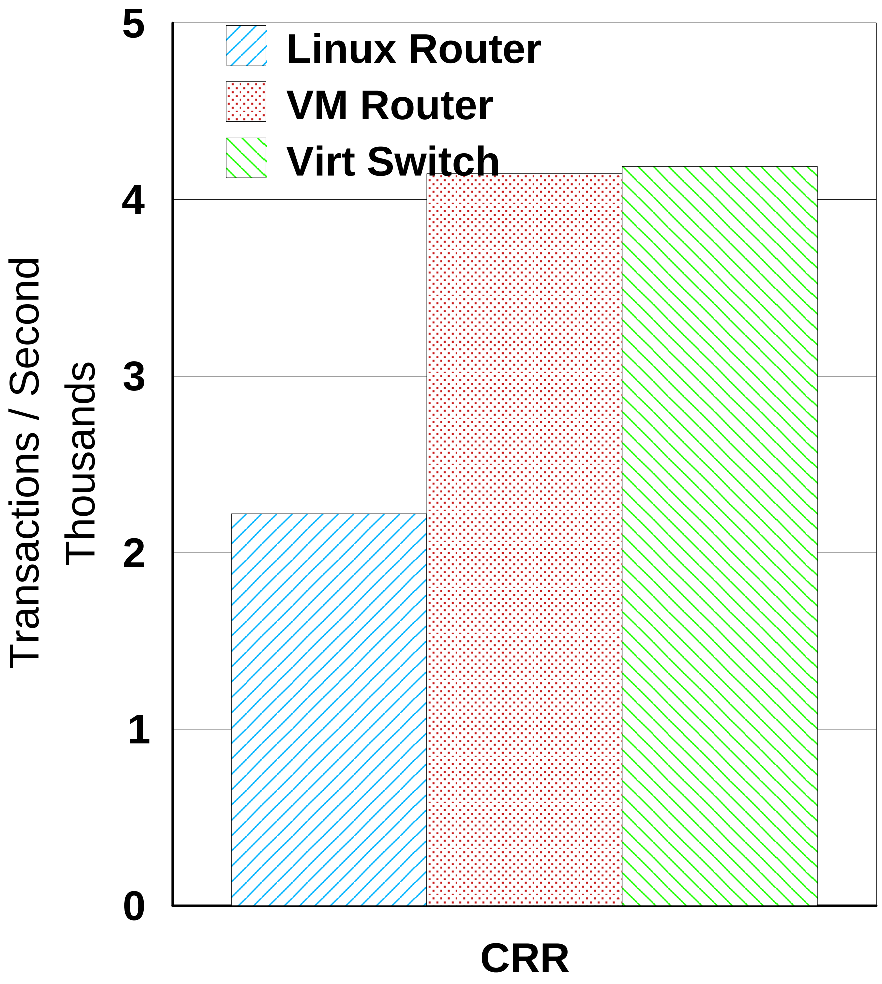


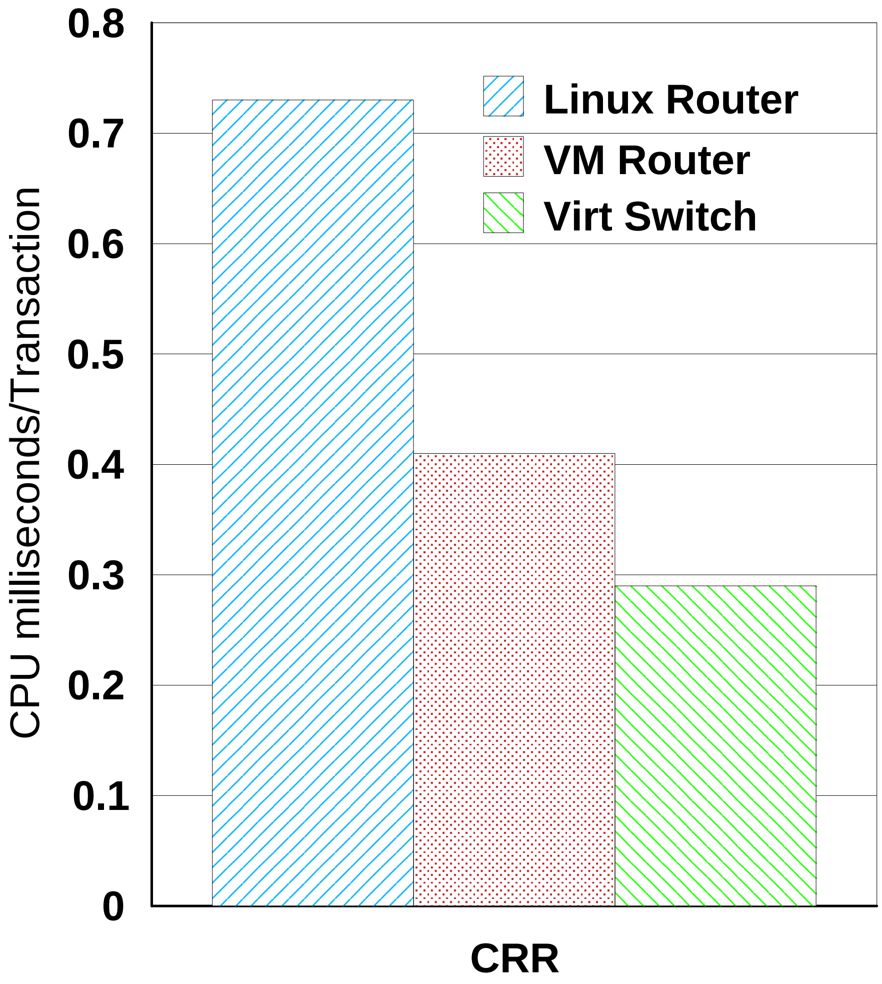
Virtual Switch - Streaming (MTU 8992)



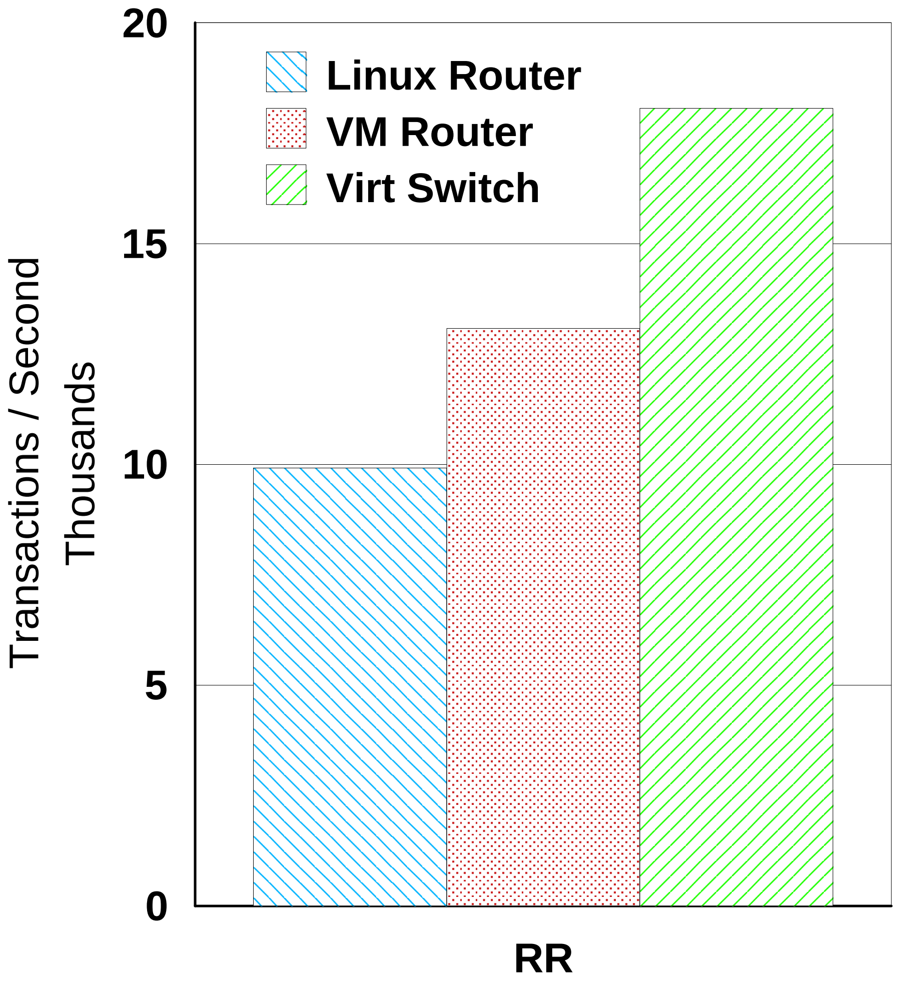


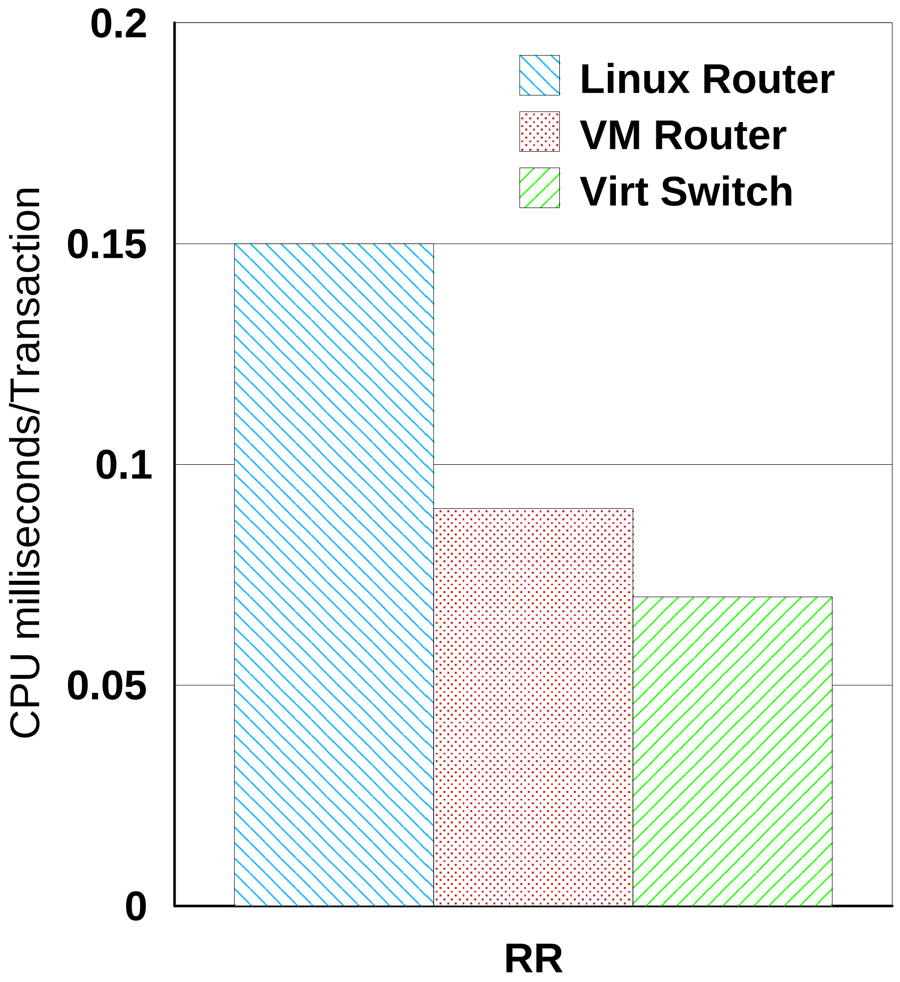
Virtual Switch - CRR (MTU 8992)





Virtual Switch - RR (MTU 1492)



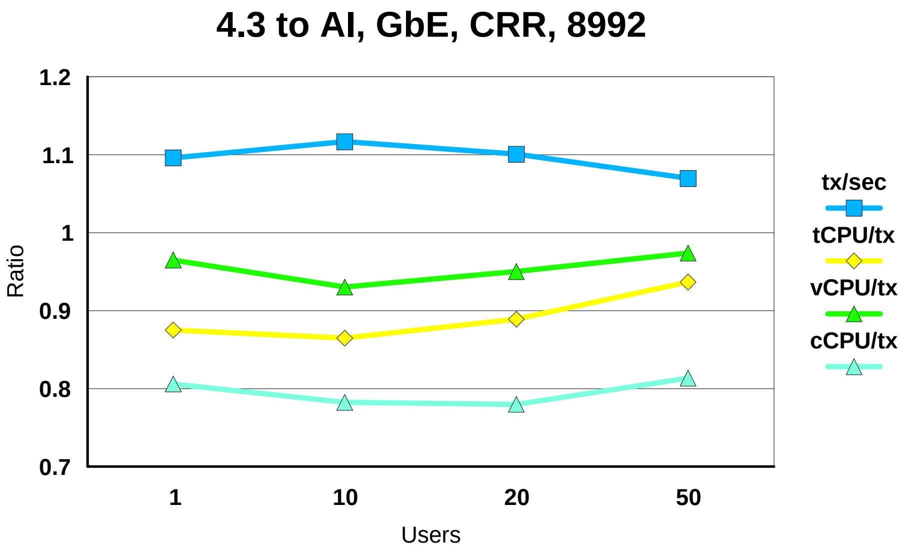


Queued I/O Assist

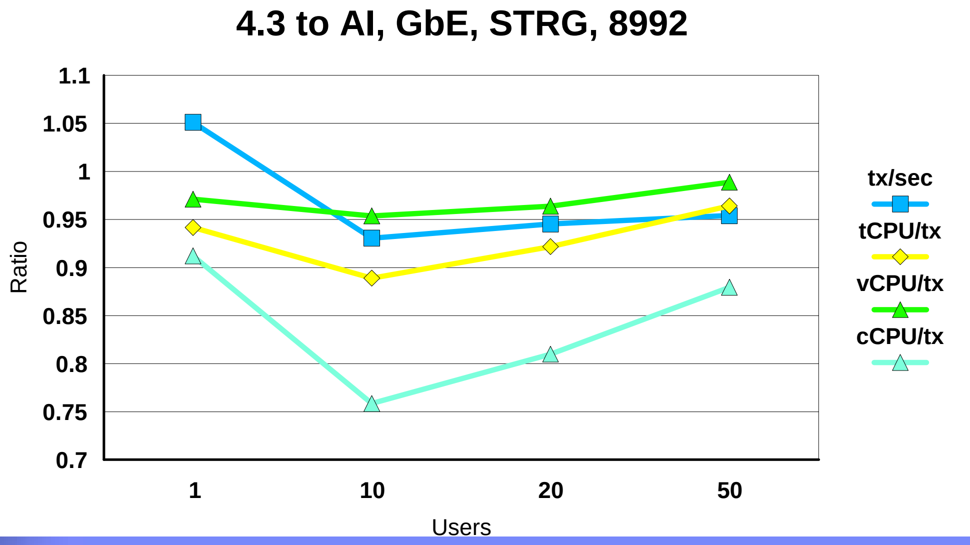
- QDIO devices (FCP, OSA Express, HiperSockets) induce overhead due to high interruption rates
  - z/VM Control Program has to mediate between hardware interruptions and guests
  - As interruption rates go up, this overhead increases
- New hardware facility designed to address this problem
  - Allows interruptions to be presented directly by hardware for active guest
  - Delivers "thin" signal to CP when interruption is for idle guest
  - Extends "thin interrupts" from iQDIO to QDIO and FCP
  - New feature limited to z990 and z890.
- Changes in z/VM and Linux to take advantage of assist
  - QUERY/SET QIOASSIST
- See http://www.vm.ibm.com/perf/aip.html for more information.

PCI to AI, Linux, GbE

Usually it's great!



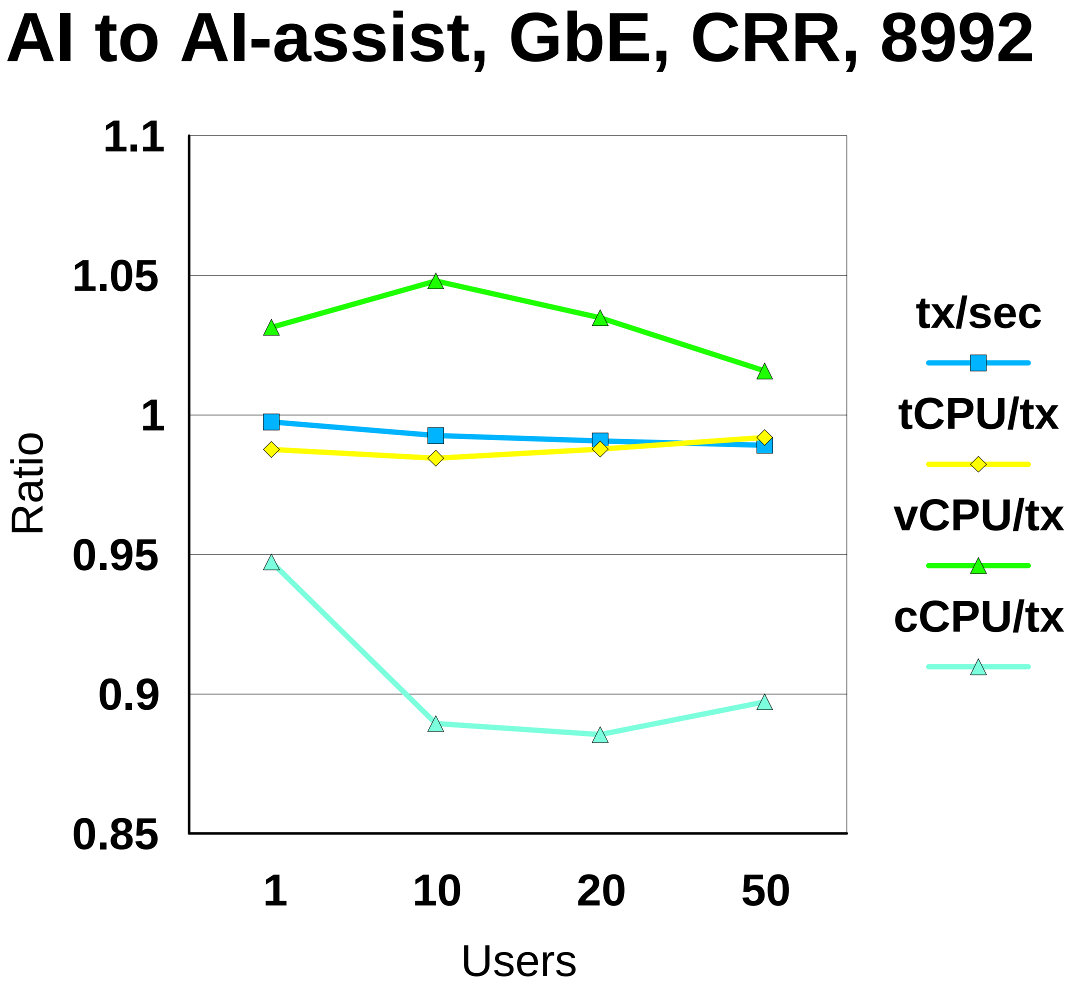
Rarely, it's marginal.



AI to AI-Assist, Linux, GbE

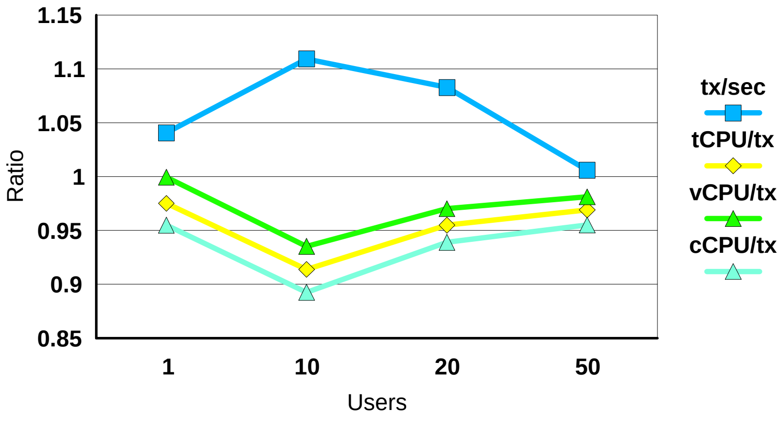
Generally, we see this:

- Tx/sec flat
- Small rise in virtual/tx
- Good drop in CP/tx



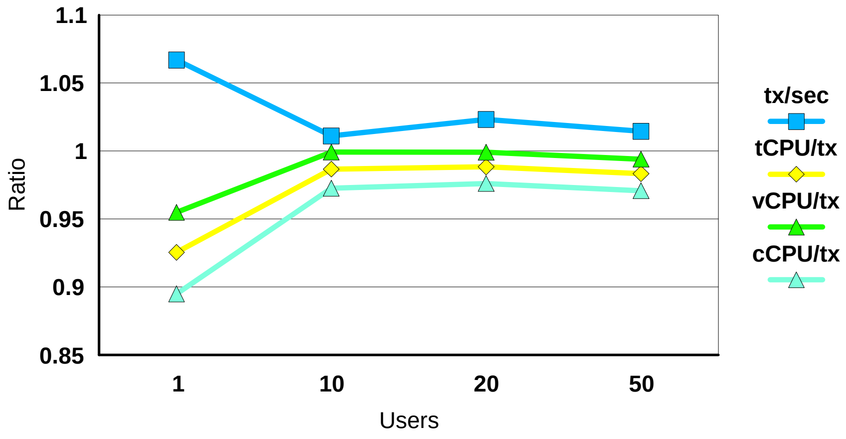
AI to AI-Assist, Linux, HiperSockets

AI to AI-assist, Hiper, RR, 57344



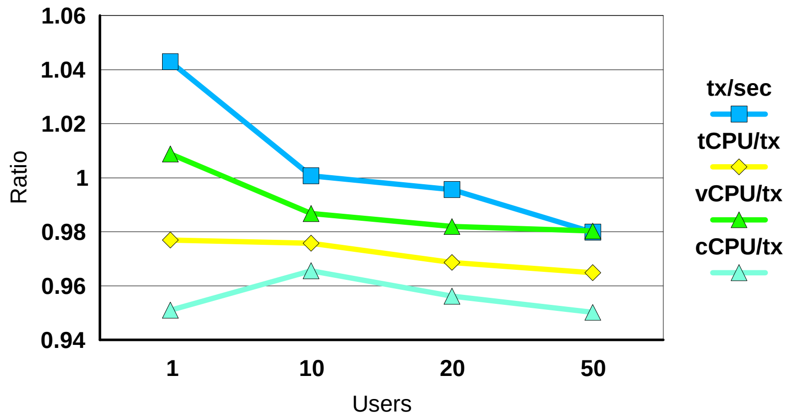
Nice!

AI to AI-assist, Hiper, STRG, 8992



Ho-hum.

AI to AI-assist, Hiper, CRR, 8992

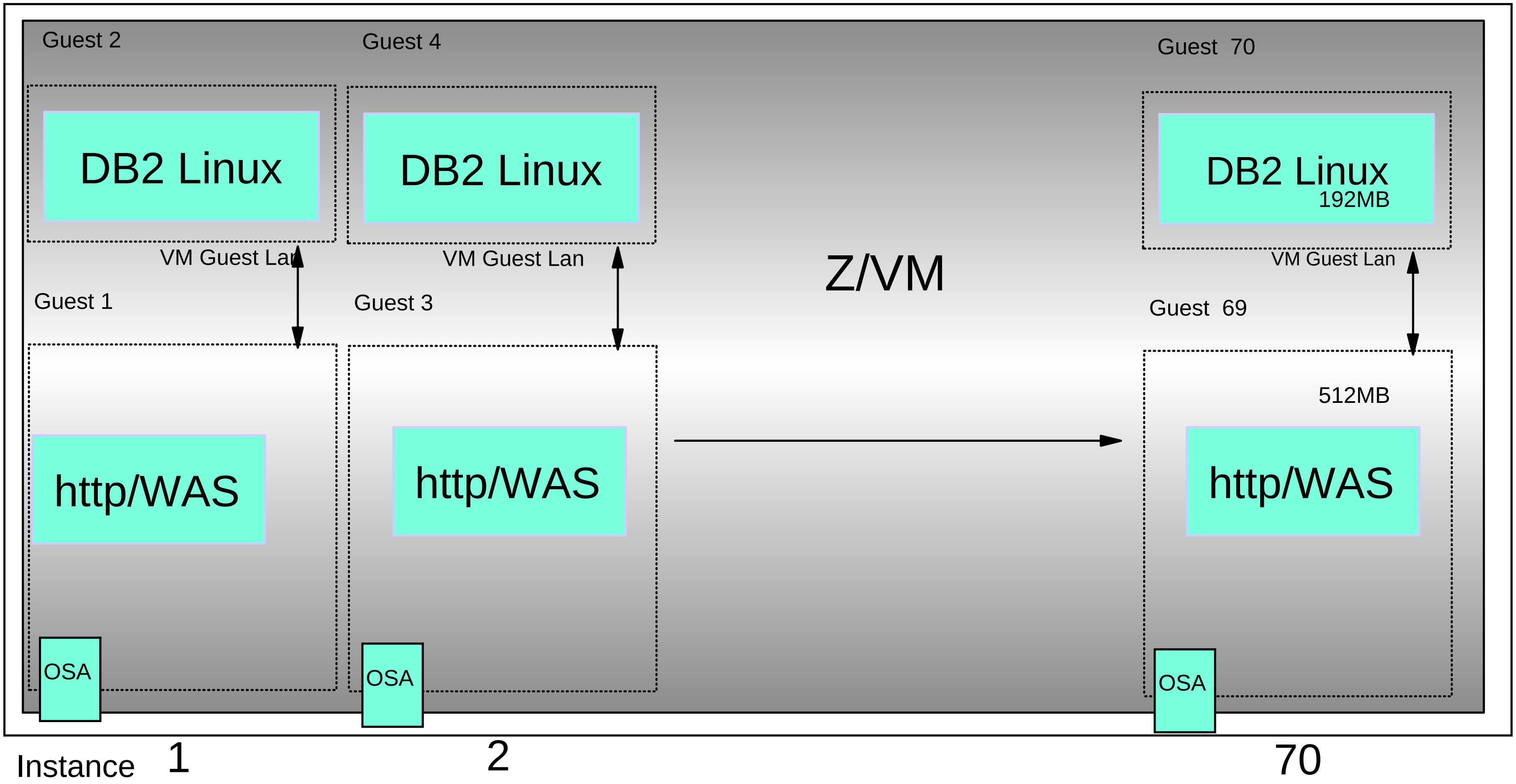


There are only a couple of "oops" cases.

Oops!

Physical Configuration

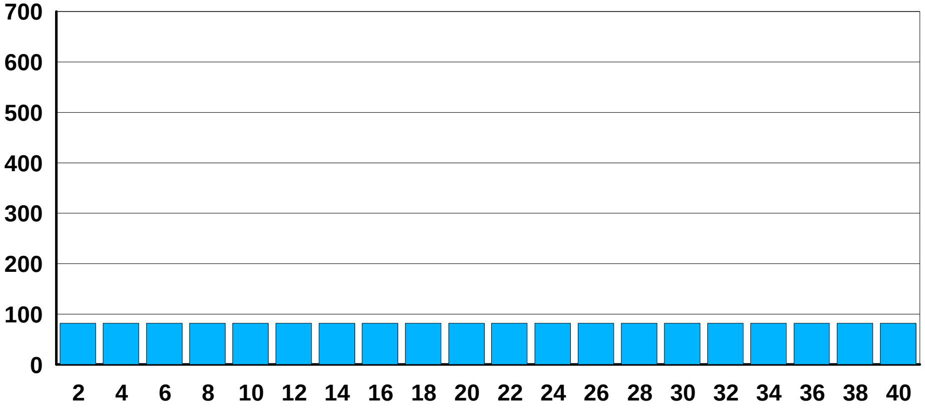
Z900 16 way



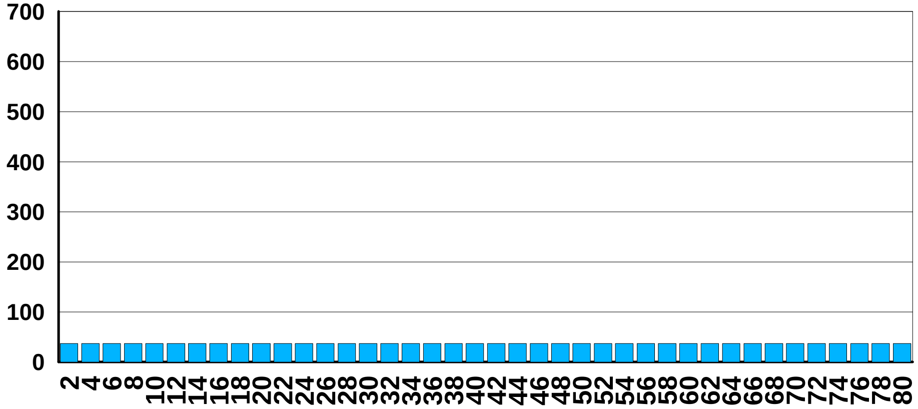
Load Distribution Reference

x axis = # of guests
y axis = transactions per second

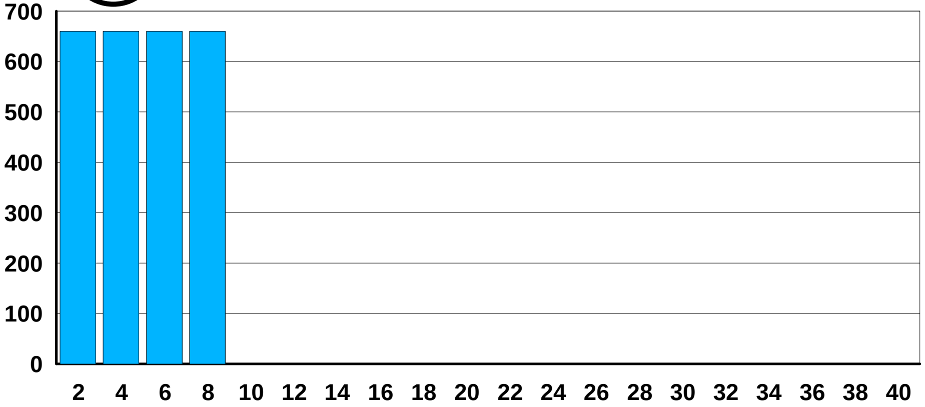
A Stress 20 streams



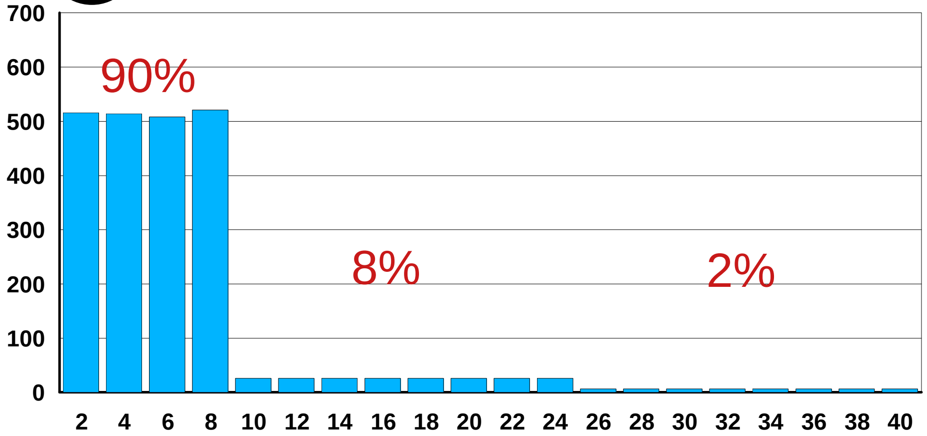
B Stress 40 streams



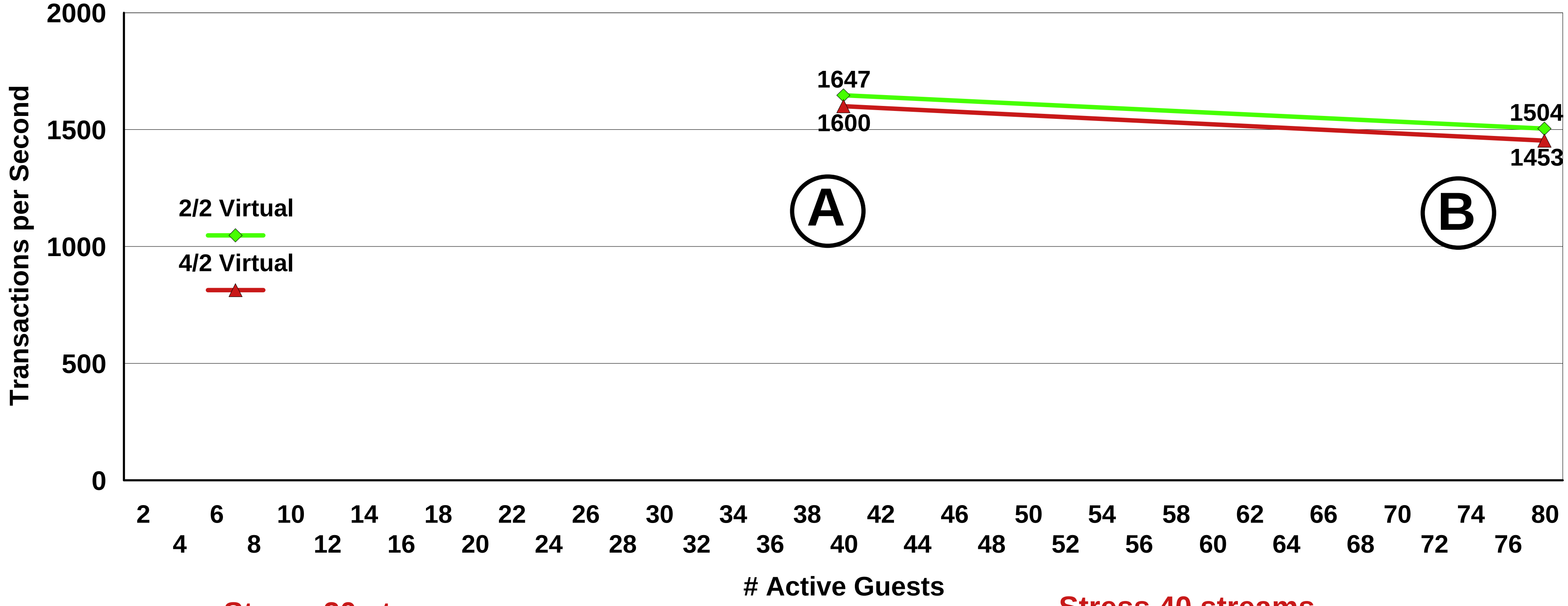
C Operational - 4 busy, 20 streams



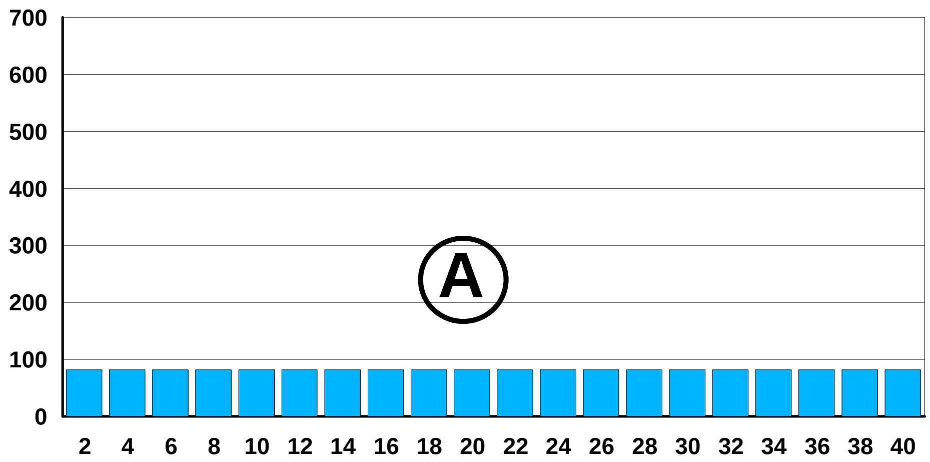
D Operational - 90/10 skew, 20 streams



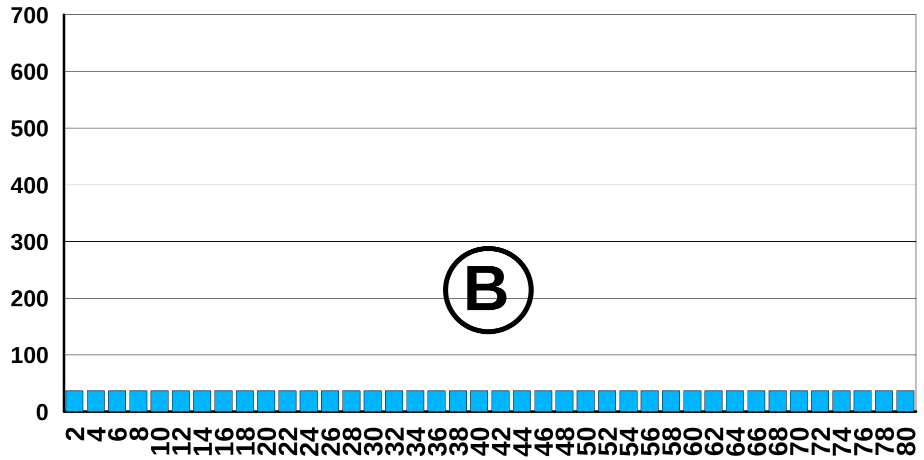
Benchmark Stress Test



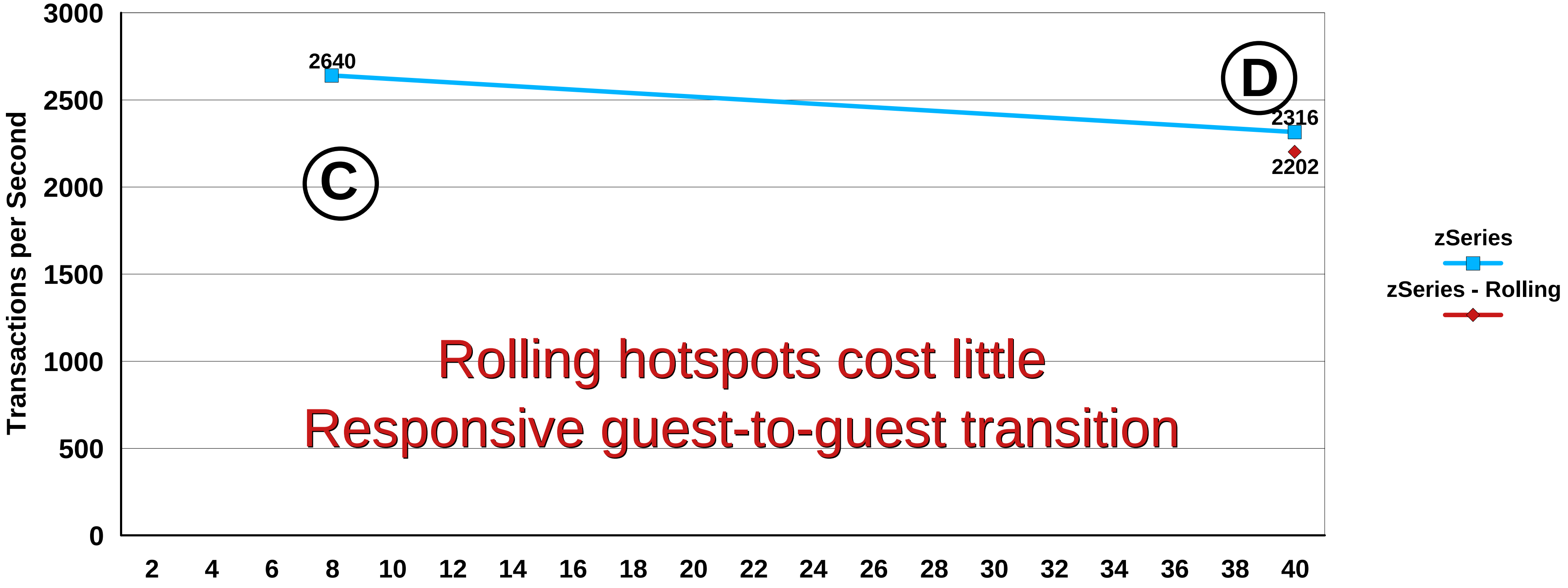
Stress 20 streams



Stress 40 streams



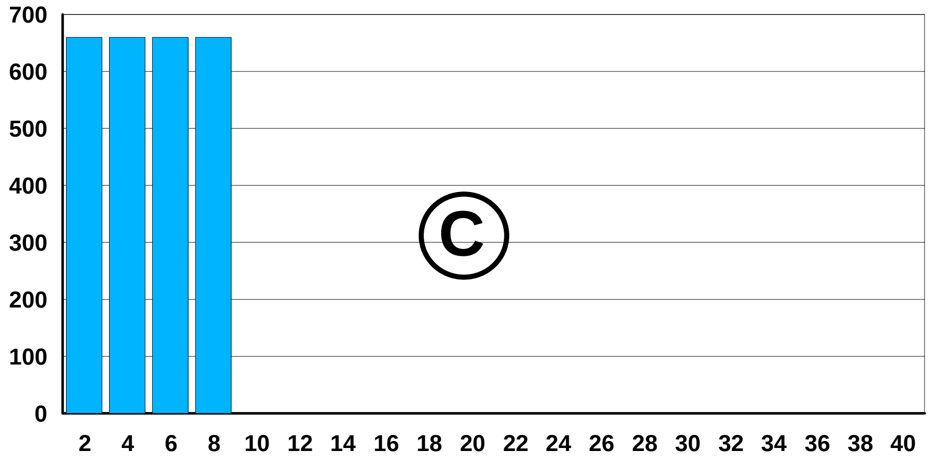
Operational Performance Test



Rolling hotspots cost little

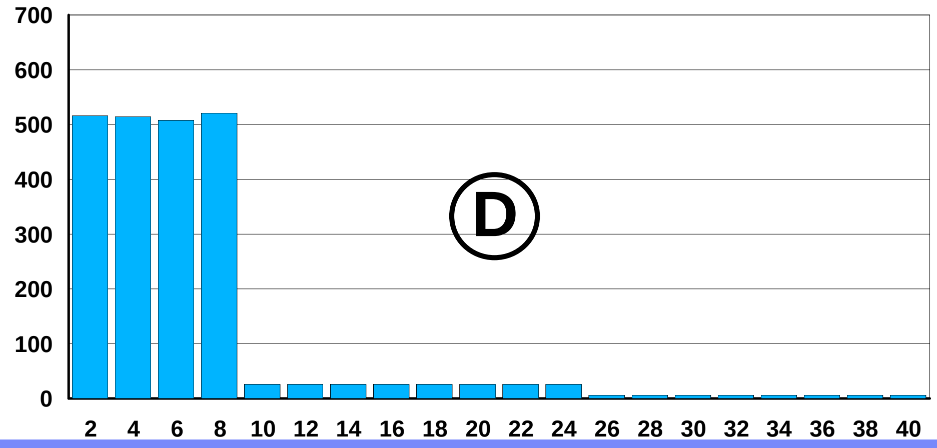
Responsive guest-to-guest transition

Operational - 4 busy, 20 streams

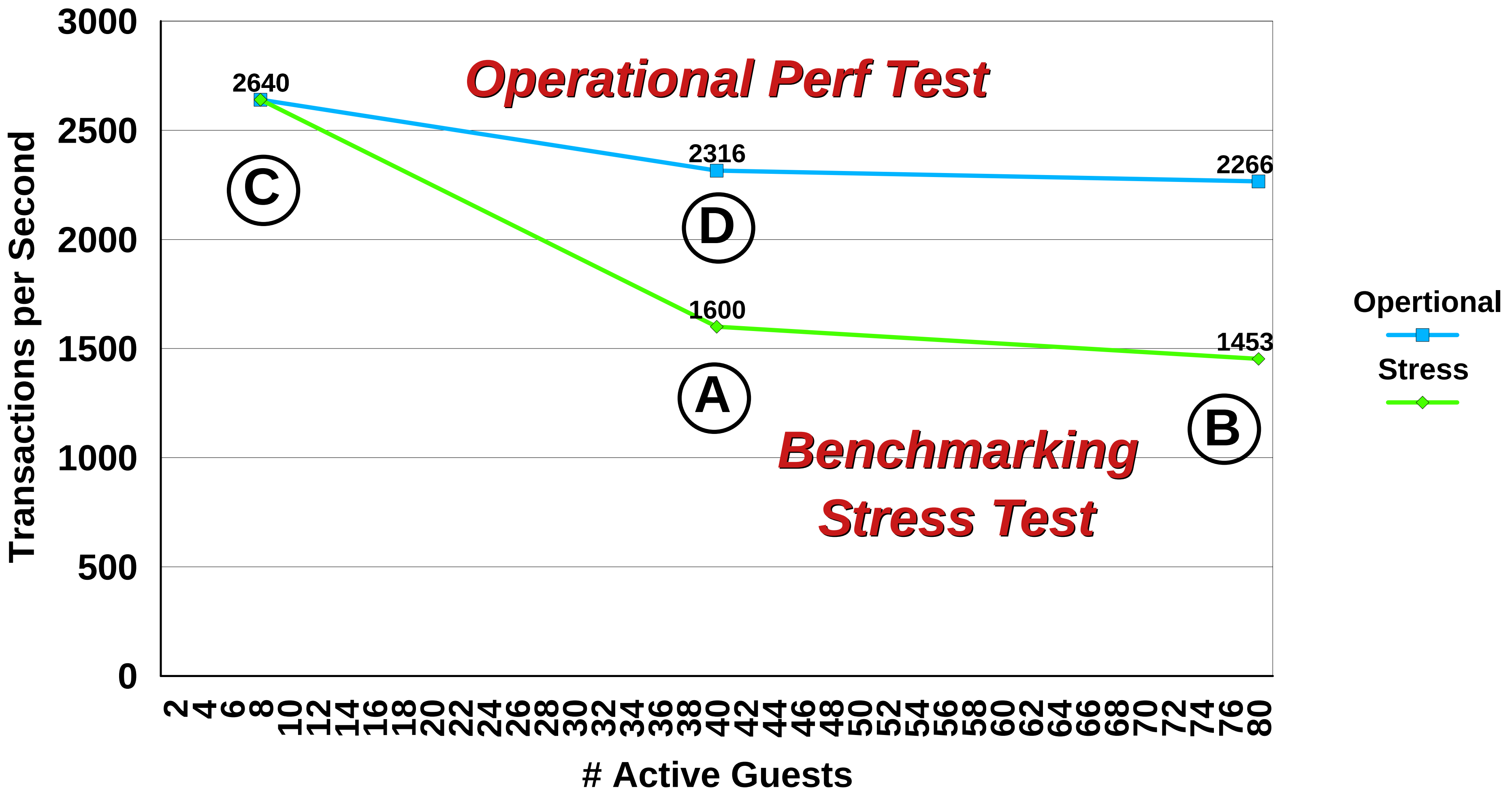


Operational - 90/10 skew, 20 streams

Static & 1 minute roll



Total System Throughput



45% increase in performance w/ real world skew

- with 40 guests - 160 virtual cpus on 16 physical cpus - 10:1 ratio

Summary

- Many features to be exploited
- The answer is "It depends. With Linux, it depends even more"
- Optimum configuration will depend on
  - What you mean by the term performance
  - What resources you have available
- See VM home page for additional information: www.vm.**ibm.com**/perf/