



IBM Systems & Technology Group

Introduction to Virtualization: z/VM Basic Concepts and Terminology

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Credits

People who contributed ideas and charts:

- Alan Altmark
- Bill Bitner
- John Franciscovich
- Reed Mullen
- Brian Wade
- Romney White

Thanks to everyone who contributed!

Introduction

We'll explain basic concepts of System z:

- Terminology
- Processors
- Memory
- I/O
- Networking

We'll see that z/VM *virtualizes* a System z machine:

- Virtual processors
- Virtual memory
- ... and so on

Where appropriate, we'll compare or contrast:

- PR/SM or LPAR
- z/OS
- Linux

Why z/VM?

Infrastructure Simplification

- Consolidate distributed, discrete servers and their networks
- IBM Mainframe qualities of service
- Exploit built-in z/VM system management

Speed to Market

- Deploy servers, networks, and solutions **fast**
- React quickly to challenges and opportunities
- Allocate server capacity when needed

Technology Exploitation

- Linux with z/VM offers more function than Linux alone
- Linux exploits unique z/VM technology features
- Build innovative on demand solutions

Terminology & Background

System z Architecture

Every computer system has an *architecture*.

- Formal definition of how the hardware operates
- It's the hardware's functional specification
- What the software can expect from the hardware
- *It's what the hardware does, not how it does it*

IBM's book [z/Architecture Principles of Operation](#) defines System z architecture

- Instruction set
- Processor features (registers, timers, interruption management)
- Arrangement of memory
- How I/O is to be done

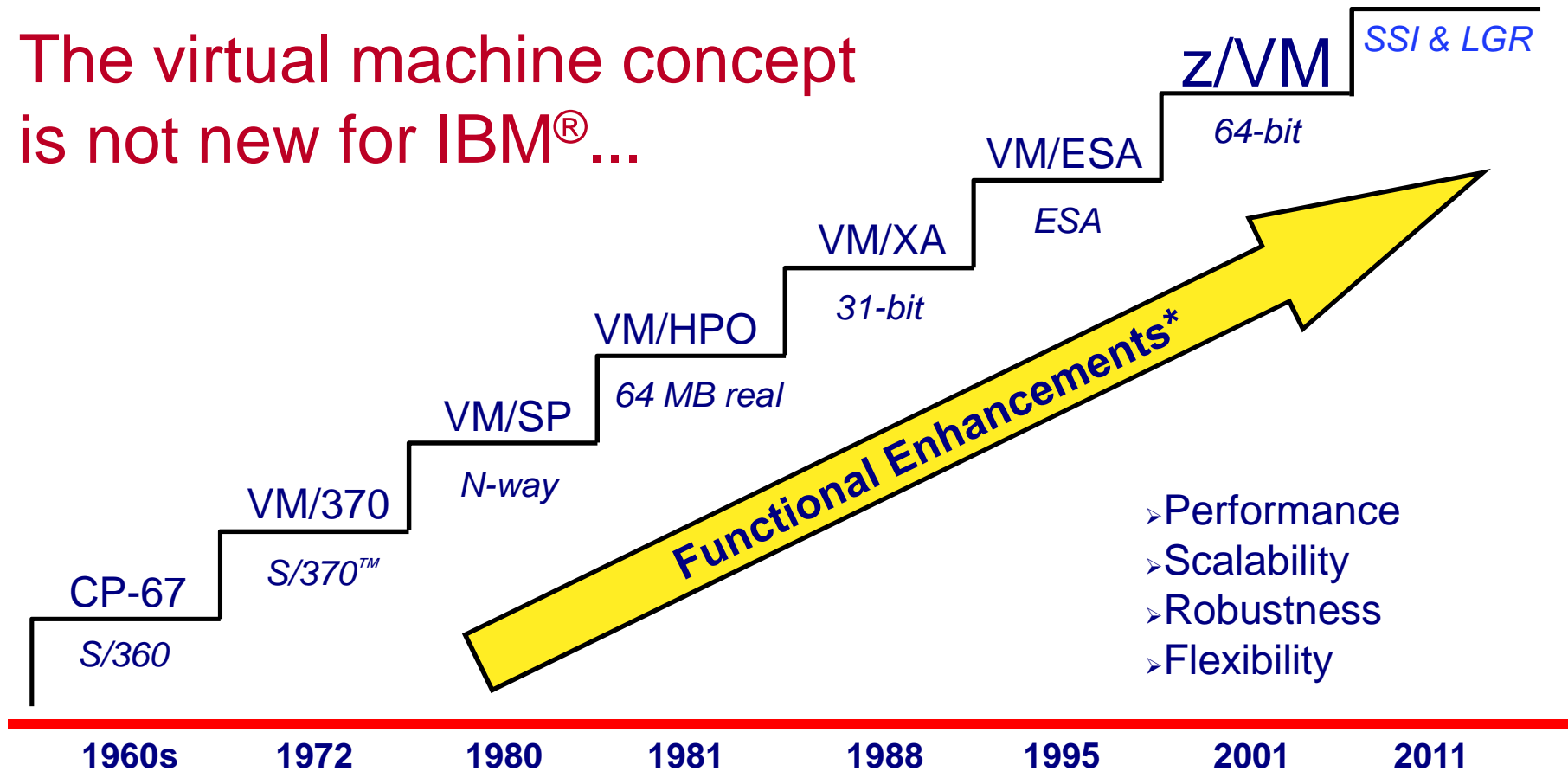
Different *models* implement the architecture in different ways.

- How many processors are there
- How do the processors connect to the memory bus
- How is the cache arranged
- How much physical memory is there
- How much I/O capability is there

z800, z900, z890, z990, z9, z10, z196, z114 are all *models* implementing z/Architecture.

IBM Virtualization Technology Evolution

The virtual machine concept is not new for IBM®...



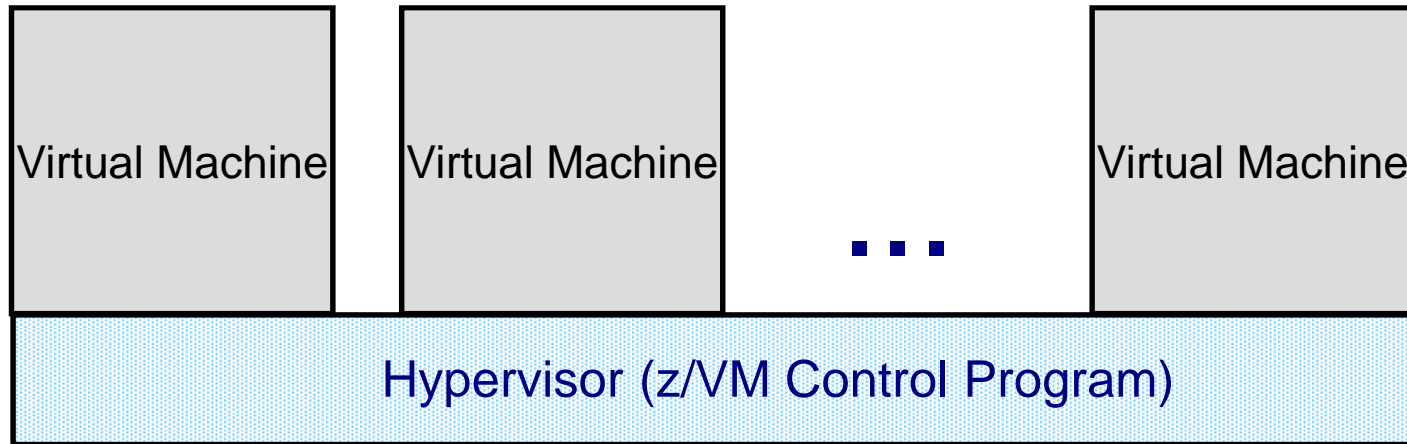
* Investments made in hardware, architecture, microcode, software

System z Parts Nomenclature

Intel, System p, etc.	System z
Memory	Storage (Central Storage or Expanded Storage)
Disk, Storage	DASD- Direct Access Storage Device
Processor	Processor, CPU (central processing unit), engine, IFL (Integrated Facility for Linux), IOP (I/O processor), SAP (system assist processor), CP (central processor), PU (processing unit), zAAP (zSeries Application Assist Processor), zIIP (zSeries Integrated Information Processor)
Computer	CEC (central electronics complex) Server

Virtual Machines

What: Virtual Machines



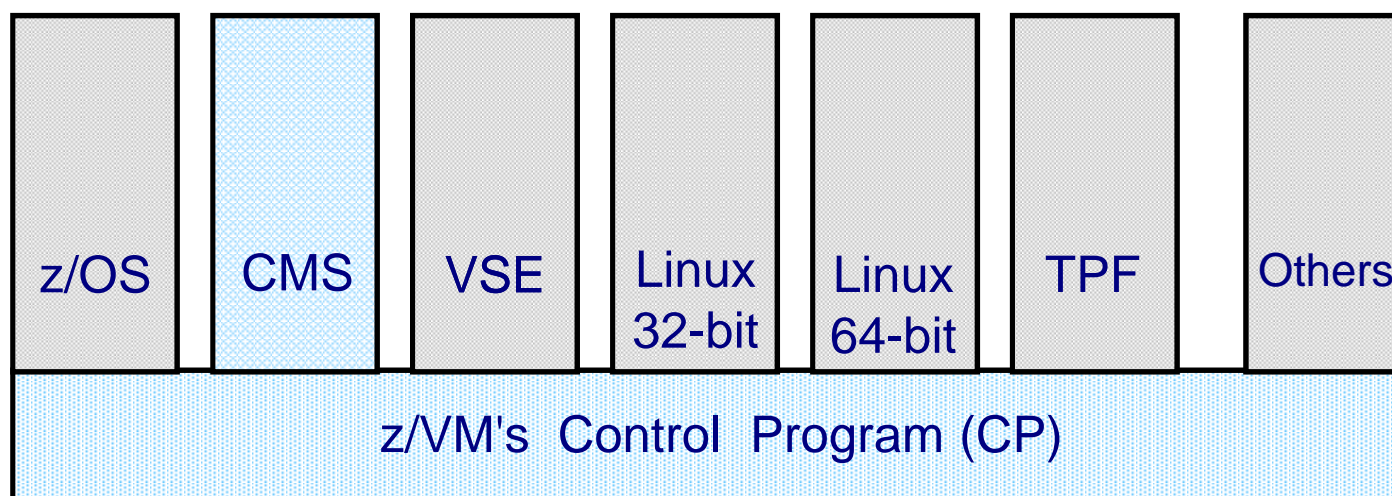
A **virtual machine** is an execution context that obeys the architecture.

The purpose of z/VM is to **virtualize** the real hardware:

- Faithfully replicate the z/Architecture Principles of Operation
- Permit any virtual configuration that could legitimately exist in real hardware
- Let many virtual machines operate simultaneously
- Allow overcommitment of the real hardware (processors, for example)
- Your limits will depend on the size of your physical zSeries computer

Virtual machine aka VM user ID, VM logon, VM Guest, Virtual Server

What: Virtual Machines in Practice



- Control Program Component - manages virtual machines that adhere to 390- and z-architecture
- Extensions available through CP system services and features
- CMS is special single user system and part of z/VM
- Control Program interaction via console device

Phrases associated with Virtual Machines

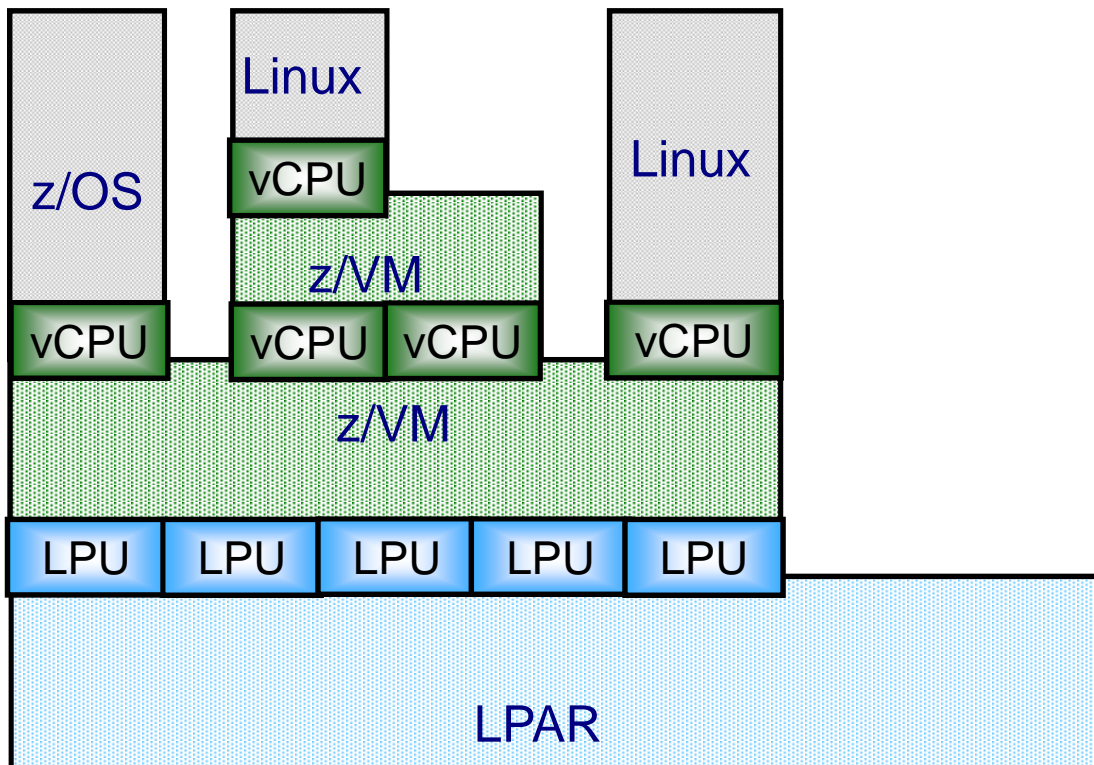
In VM...

- *Guest*: a system that is operating in a virtual machine, also known as user or userid.
- *Running under VM*: running a system as a guest of VM
- *Running on (top of) VM*: running a system as a guest of VM
- *Running second level*: running a z/VM system as a guest of z/VM
- A virtual machine may have multiple *virtual processors*
- Sharing is very important.

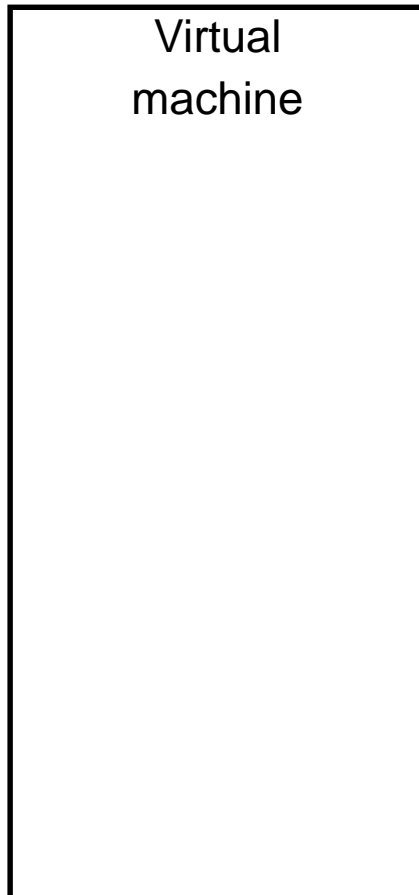
In relationship to LPAR (partitioning)...

- *Logical Partition*: LPAR equivalent of a virtual machine
- *Logical Processor*: LPAR equivalent of a virtual processor
- *Running native*: running without LPAR
- *Running in BASIC mode*: running without LPAR
- Isolation is very important.

Phrases Associated with Virtual Machines



What: A Virtual Machine



z/Architecture

512 MB of memory

2 processors

Basic I/O devices:

- A console

- A card reader

- A card punch

- A printer

Some read-only disks

Some read-write disks

Some networking devices

We permit any configuration that a real System z machine could have.

In other words, we completely implement the z/Architecture Principles of Operation.

There is no "standard virtual machine configuration".

How: VM User Directory

Definitions of:	USER LINUX01 MYPASS 512M 1024M G
	MACHINE ESA 2
- memory	IPL 190 PARM AUTOCR
- architecture	CONSOLE 01F 3270 A
	SPOOL 00C 2540 READER *
- processors	SPOOL 00D 2540 PUNCH A
	SPOOL 00E 1403 A
- spool devices	SPECIAL 500 QDIO 3 SYSTEM MYLAN
- network device	LINK MAINT 190 190 RR
	LINK MAINT 19D 19D RR
- disk devices	LINK MAINT 19E 19E RR
	MDISK 191 3390 012 001 ONEBIT MW
- other attributes	MDISK 200 3390 050 100 TWOBIT MR

How: CP Commands

CP DEFINE

- Adds to the virtual configuration somehow
- CP DEFINE STORAGE
- CP DEFINE PROC
- CP DEFINE *{device} {device_specific_attributes}*

CP ATTACH

- Gives an entire real device to a virtual machine

CP DETACH

- Removes a device from the virtual configuration

CP LINK

- Lets one machine's disk device also belong to another's configuration

CP SET

- Change various characteristics of virtual machine

Changing the virtual configuration after logon is considered normal.
Usually the guest operating system detects and responds to the change.

Getting Started

IML

- Initial Machine Load or Initial Microcode Load
- Power on and configure processor complex
- VM equivalents are:
 - **LOGON** uses the **MACHINE** statement in the **CP directory entry**
 - The **CP SET MACHINE** command
- Analogous to LPAR *image activation*

IPL

- Initial Program Load
- Like *booting* a Linux system
- System z hardware allows you to *IPL* a system
- z/VM allows one to *IPL* a system in a virtual machine via the **CP IPL** command
- Linux *kernel* is like VM *nucleus*
- Analogous to the LPAR *LOAD* function

Processors

What: Processors

Configuration

- Virtual 1- to 64-way
 - Defined in user directory, or
 - Defined by CP command
 - Specialty or General Purpose
- Called virtual processors or virtual CPUs
- A real processor can be dedicated to a virtual machine

Control and Limits

- Scheduler selects virtual processors according to apparent CPU need
- "Share" setting - prioritizes real CPU consumption
 - Absolute or relative
 - Target minimum and maximum values
 - Maximum values (limit shares) either hard or soft
- "Share" for virtual machine is divided among its virtual processors

How: Start Interpretive Execution (SIE)

- SIE = "Start Interpretive Execution", an instruction
- z/VM (like the LPAR hypervisor) uses the SIE instruction to "run" virtual processors for a given virtual machine.
- SIE has access to:
 - A control block that describes the virtual processor state (registers, etc.)
 - The Dynamic Address Translation (DAT) tables for the virtual machine
- z/VM gets control back from SIE for various reasons:
 - Page faults
 - I/O channel program translation
 - Privileged instructions (including CP system service calls)
 - CPU timer expiration (dispatch slice)
 - Other, including CP asking to get control for special cases
- CP can also shoulder-tap SIE from another processor to remove virtual processor from SIE (e.g. perhaps to reflect an interrupt)

How: Scheduling and Dispatching

VM

- *Scheduler* determines priorities based on *share* setting and other factors
- *Dispatcher* runs a virtual processor on a real processor
- Virtual processor runs for (up to) a *minor time slice*
- Virtual processor keeps competing for (up to) an *elapsed time slice*

LPAR hypervisor

- Uses *weight* settings for partitions, similar to share settings for virtual machines
- Dispatches logical processors on real engines

Linux

- *Scheduler* handles prioritization and dispatching processes
- Processes run for a time slice or *quantum*

Memory

What: Virtual Memory

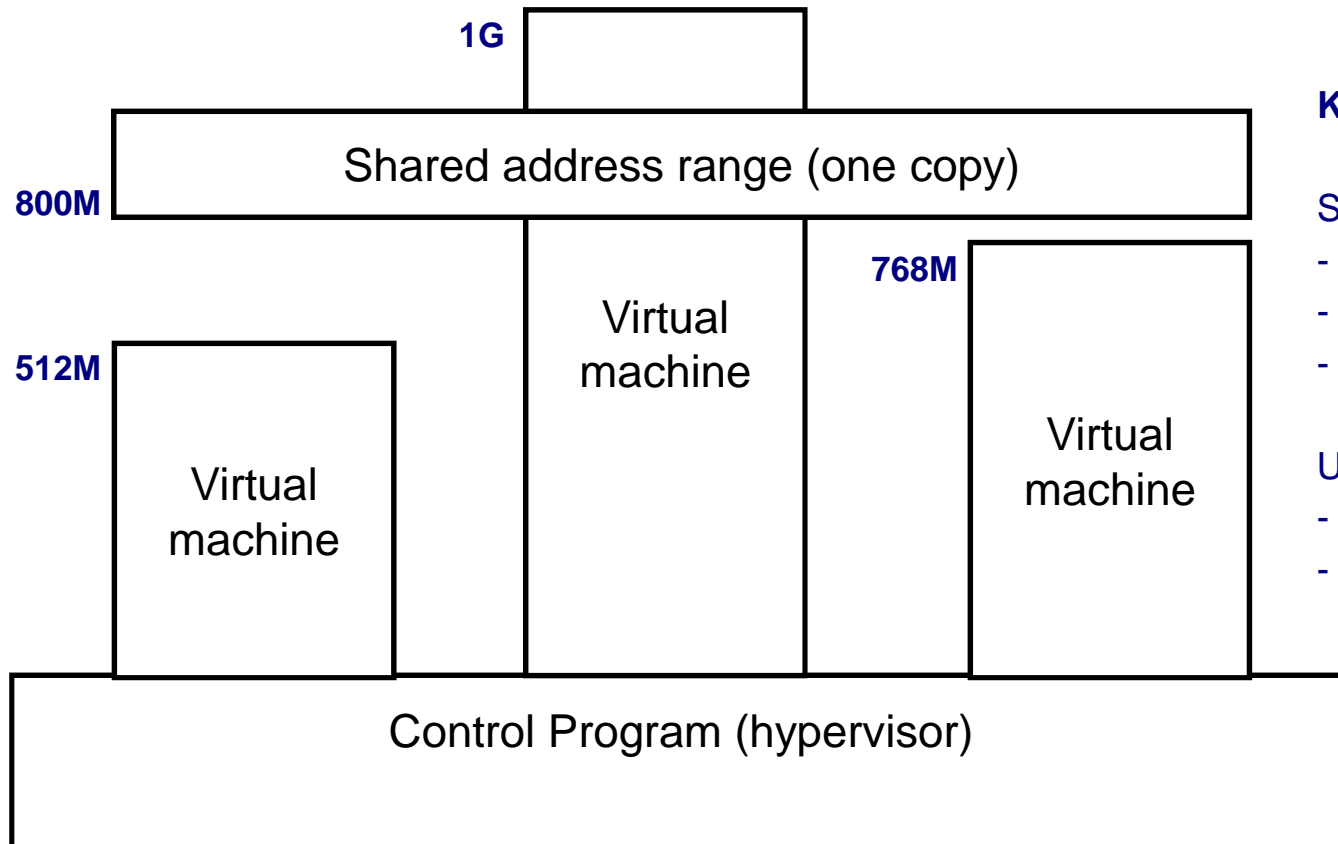
Configuration

- Defined in CP directory entry or via CP command
- Can define storage with gaps (useful for testing)
- Can attach expanded storage to virtual machine

Control and Limits

- Scheduler selects virtual machines according to apparent need for storage and paging capacity
- Virtual machines that do not fit criteria are placed in the *eligible list*
- Can reserve an amount of real storage for a guest's pages

What: Shared Memory



Key Points:

Sharing:

- Read-only
- Read-write
- Security knobs

Uses:

- Common kernel
- Shared programs

How: Memory Management

VM

- Demand paging between central and expanded
- Block paging with DASD (disk)
- Steal from central based on LRU with reference bits
- Steal from expanded based on LRU with timestamps
- Paging activity is traditionally considered normal

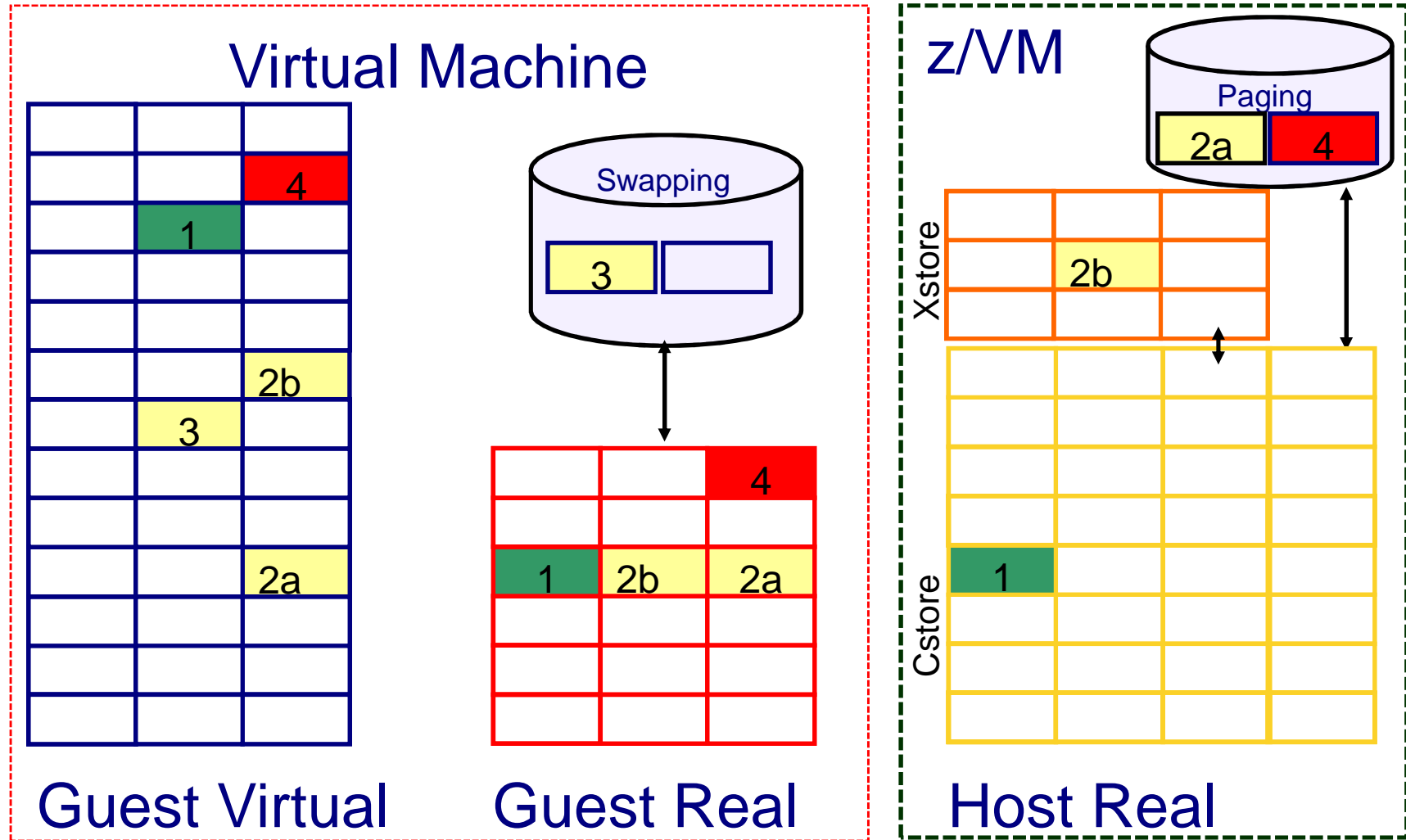
LPAR

- Dedicated storage, no paging

Linux

- Paging on per-page basis to swap disks
- Often referred to as swapping, but really is paging
- Traditionally considered bad

z/VM Memory Virtualization



I/O Resources

What: Device Management Concepts

- **Dedicated** or **Attached**
 - The guest has exclusive use of the entire real device.
- **Virtualized**
 - Present a slice of a real device to multiple virtual machines
 - Slice in time or slice in space
 - E.g., DASD, crypto devices
- **Simulated**
 - Provide a device to a virtual machine without the help of real hardware
 - Virtual CTCAs, virtual disks, guest LANs, spool devices
- **Emulated**
 - Provide a device of one type on top of a device of a different type
 - FBA emulated on FCP SCSI

What: Device Management Concepts

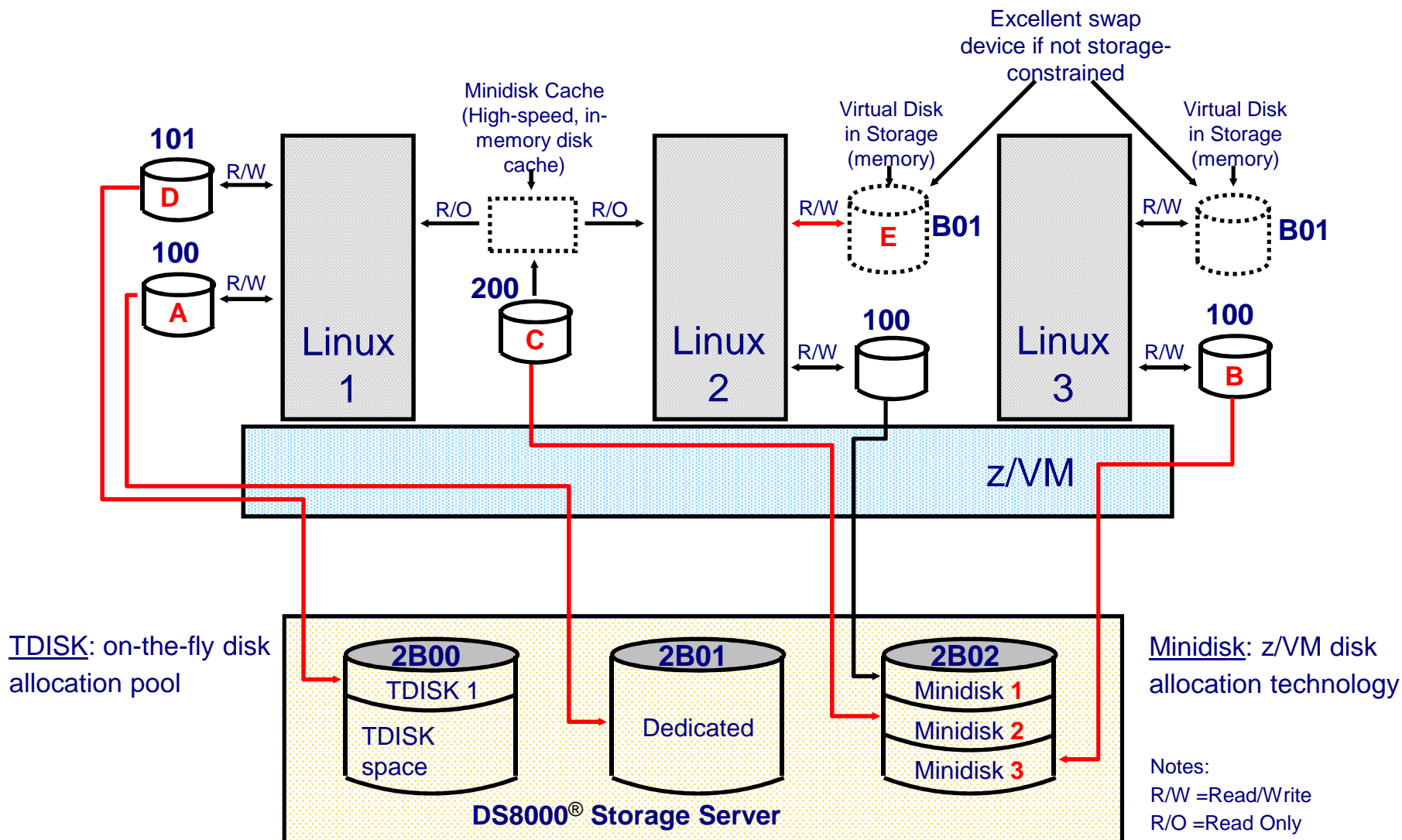
- **Terminology**

- RDEV is Real Device
 - can refer to the device address or the control block
- VDEV is Virtual Device
 - can refer to the device address or the control block
- UCB is Unit Control Block
 - used in hardware definitions
- RDEV=UCB=subchannel=device=adapter

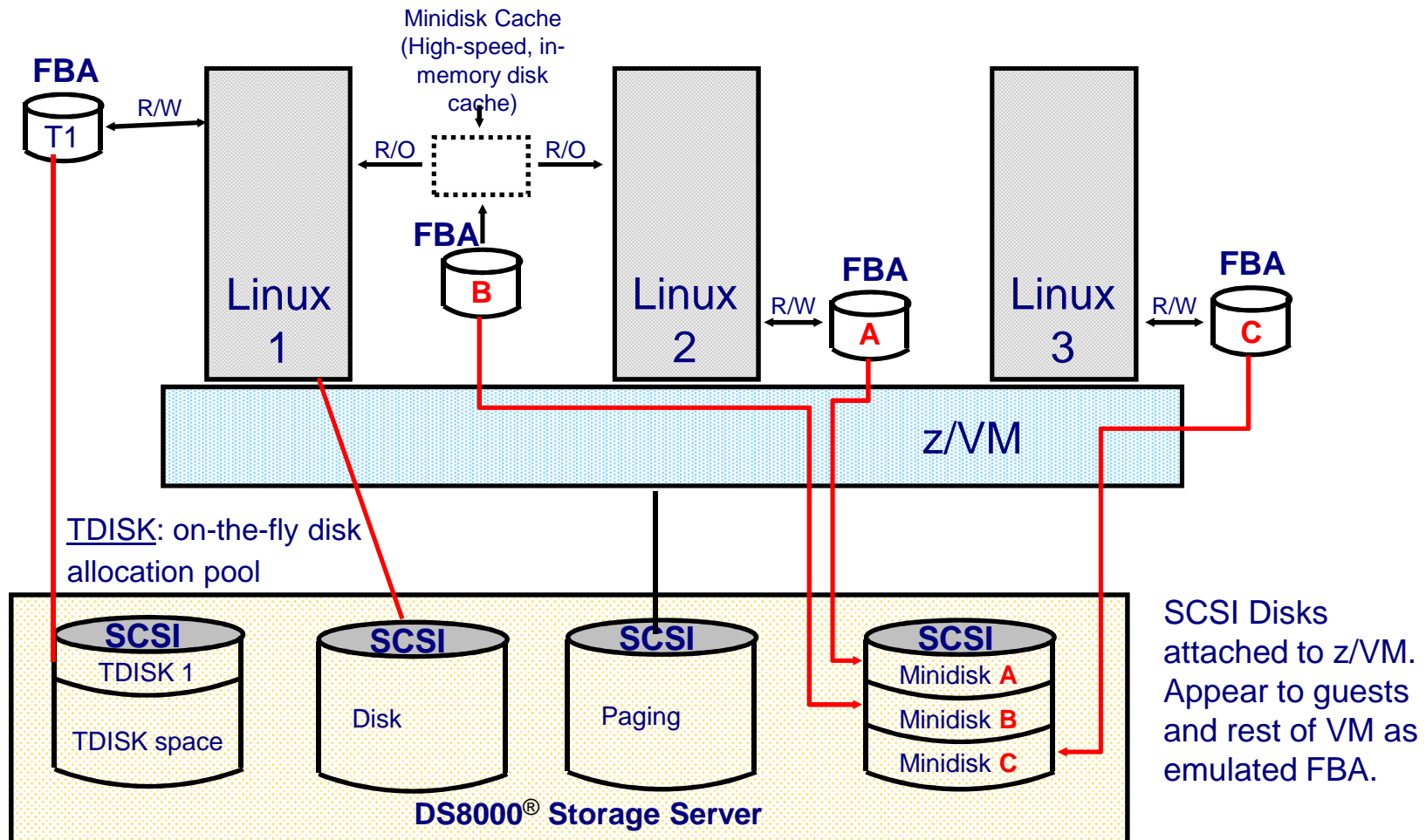
- **Control and Limits**

- Indirect control through "share" setting
- Real devices can be "throttled" at device level
- Channel priority can be set for virtual machine
- MDC fair share limits (can be overridden)

What: Virtualization of Disks



z/VM Disk Technology - SCSI



What: Data-in-Memory

Minidisk Cache

- Write-through cache for non-dedicated disks
- Cached in central and/or expanded storage
- Pseudo-track cache
- Great performance - exploits access registers
- Lots of tuning knobs

Virtual Disk in Storage

- Like a RAM disk that is pageable
- Volatile
- Appears like an FBA disk
- Can be shared with other virtual machines
- Plenty of knobs here too

Networking

What: Virtual Networks

Connecting virtual machines to one another

- Guest LAN
 - QDIO or HiperSockets
- Virtual Switch Guest LAN
 - IP or MAC oriented (Layer 3 or Layer 2)

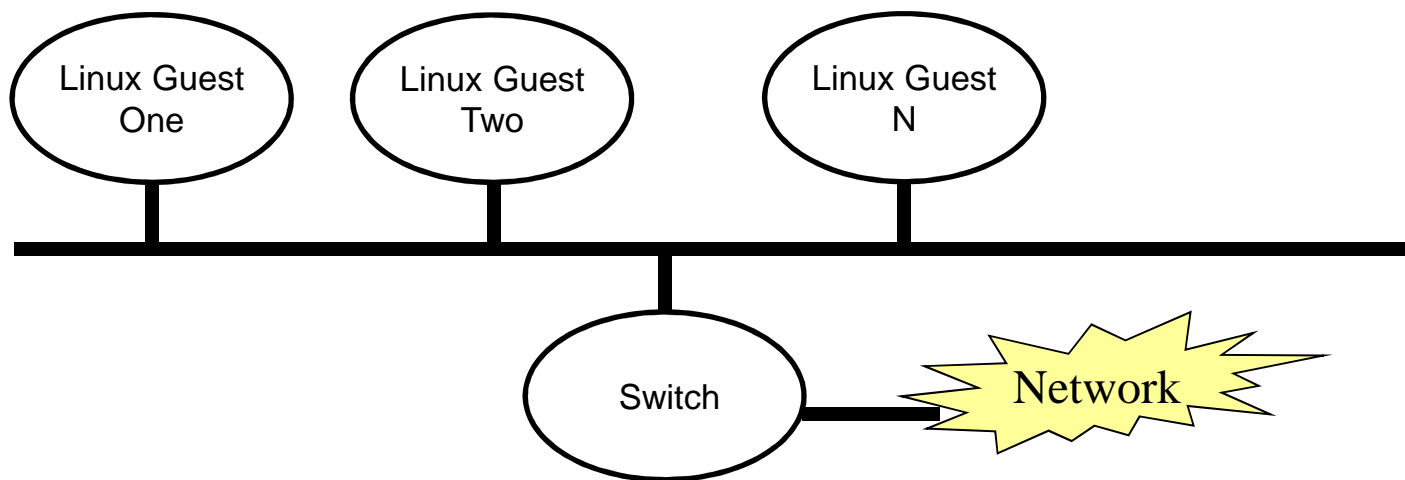
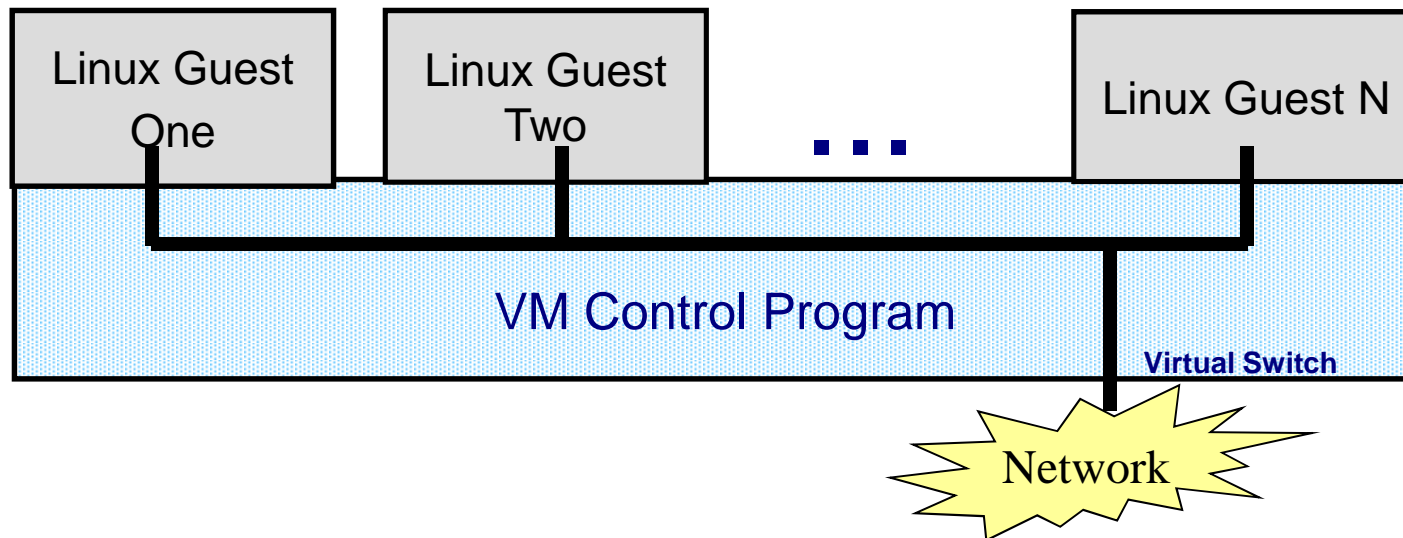
Connecting virtual machines to another LPAR

- HiperSockets
- Shared OSA

Connecting virtual machines to the physical network

- Dedicated OSA device
- Virtual Switch
 - IP or MAC oriented

What: Virtual Switch Guest LAN



Beyond Virtualization

What: Other Control Program (CP) Interfaces

Commands

- Query or change virtual machine configuration
- Debug and tracing
- Commands fall into different privilege classes
- Some commands affect entire system

Inter-virtual-machine communication

- Connectionless or connection-oriented protocols
- Most pre-date TCP/IP

System Services

- Enduring connection to hypervisor via a connection-oriented program-to-program API
- Various services: Monitor (performance data), Accounting, Security

Diagnose Instructions

- These are really programming APIs (semantically, procedure calls)
- Operands communicate with hardware (or in this case the virtual hardware) in various ways
- Large number of functions provided via diagnose instructions

What: Debugging a Virtual Machine

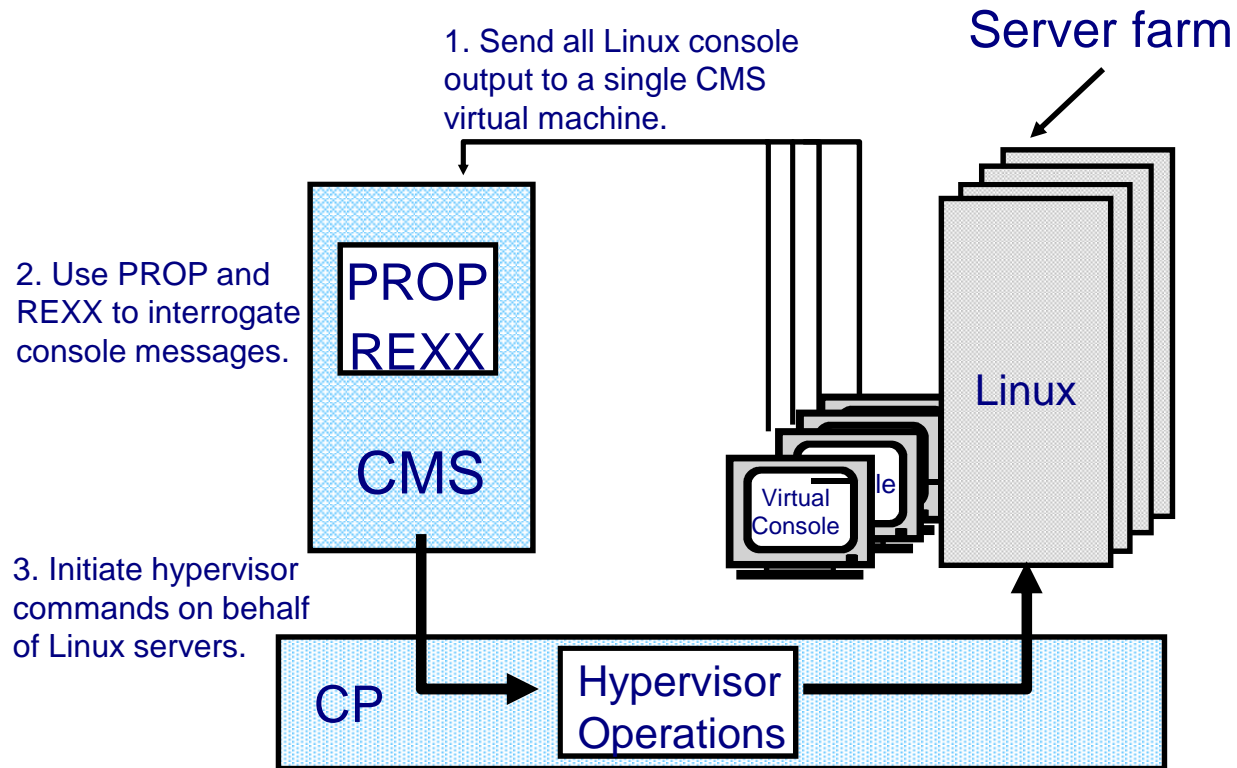
Tracing of virtual machine

- CP TRACE command has >40 pages of documentation on tracing of:
 - instructions
 - storage references
 - some specific opcodes or privileged instructions
 - branches
 - various address space usage
 - registers
 - etc
- Step through execution or run and collect information to spool
- Trace points can trigger other commands

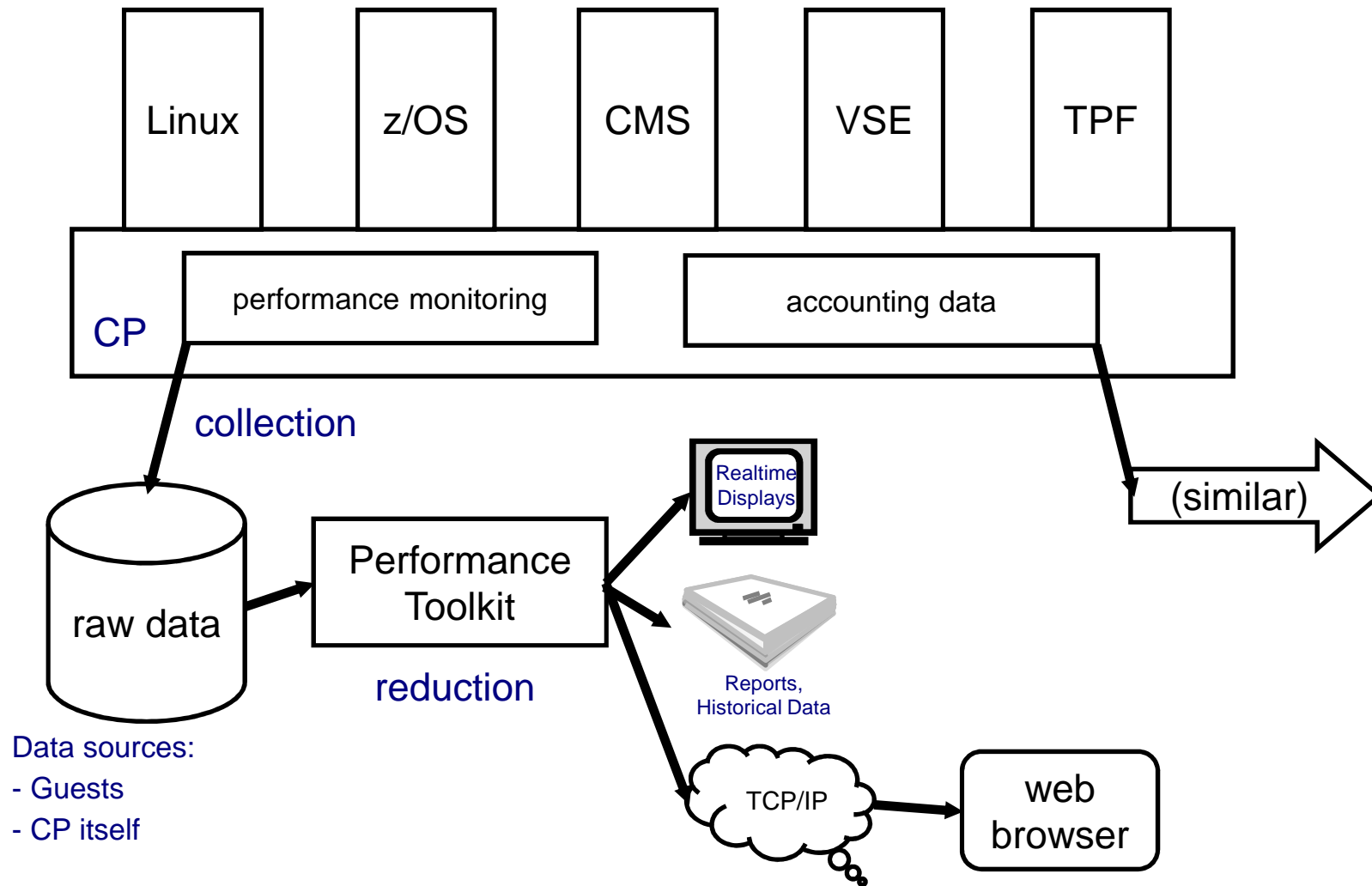
Display or store into virtual machine memory

- Helpful, especially when used with tracing
- Valid for various virtual address spaces
- Options for translation as EBCDIC, ASCII, or System z opcode
- Locate strings in storage
- Store into virtual memory (code, data, etc.)

What: Programmable Operator



What: Performance and Accounting Data



Other Suggested Sessions for New to z/VM

- **Tues 9:30-12:00 10493 Two-Part Intro to REXX (Bring Your Own Computer)**
- **Tues 1:30- 5:30 10189 Three-Part z/VM Installation and Configuration Hands On**
- **Weds 8:00-12:00 10190 Three-Part Linux for Beginners Hands On**

References

- VM web site: www.vm.ibm.com
 - www.vm.ibm.com/events/ for various conferences
 - www.vm.ibm.com/education/ for classes
 - www.vm.ibm.com/techinfo/ for good stuff, plus links to listservs

- Publications on VM Web Site
 - <http://www.vm.ibm.com/pubs/>
 - Follow the links to the latest z/VM library
 - Of particular interest:
 - z/VM CP Command and Utility Reference
 - z/VM CP Planning and Administration
 - z/VM CP Programming Services

- z/Journal article based on this presentation
 - <http://www.mainframezone.com/operating-systems/basics-of-z-vm-virtualization>

- IBM Systems Journal Vol. 30, No. 1, 1991
 - Good article on SIE
 - <http://www.research.ibm.com/journal/sj/301/ibmsj3001E.pdf> (for IBMers)
 - http://ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=5387504 (for customers)

End of Presentation

Question and Answer Time