IBM Systems & Technology Group

Introduction to Virtualization: z/VM Basic Concepts and Terminology

Kevin Adams
z/VM Development
kadams1@us.ibm.com

06/26/12

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People who contributed ideas and charts:

- ☒Kevin Adams
- ☒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

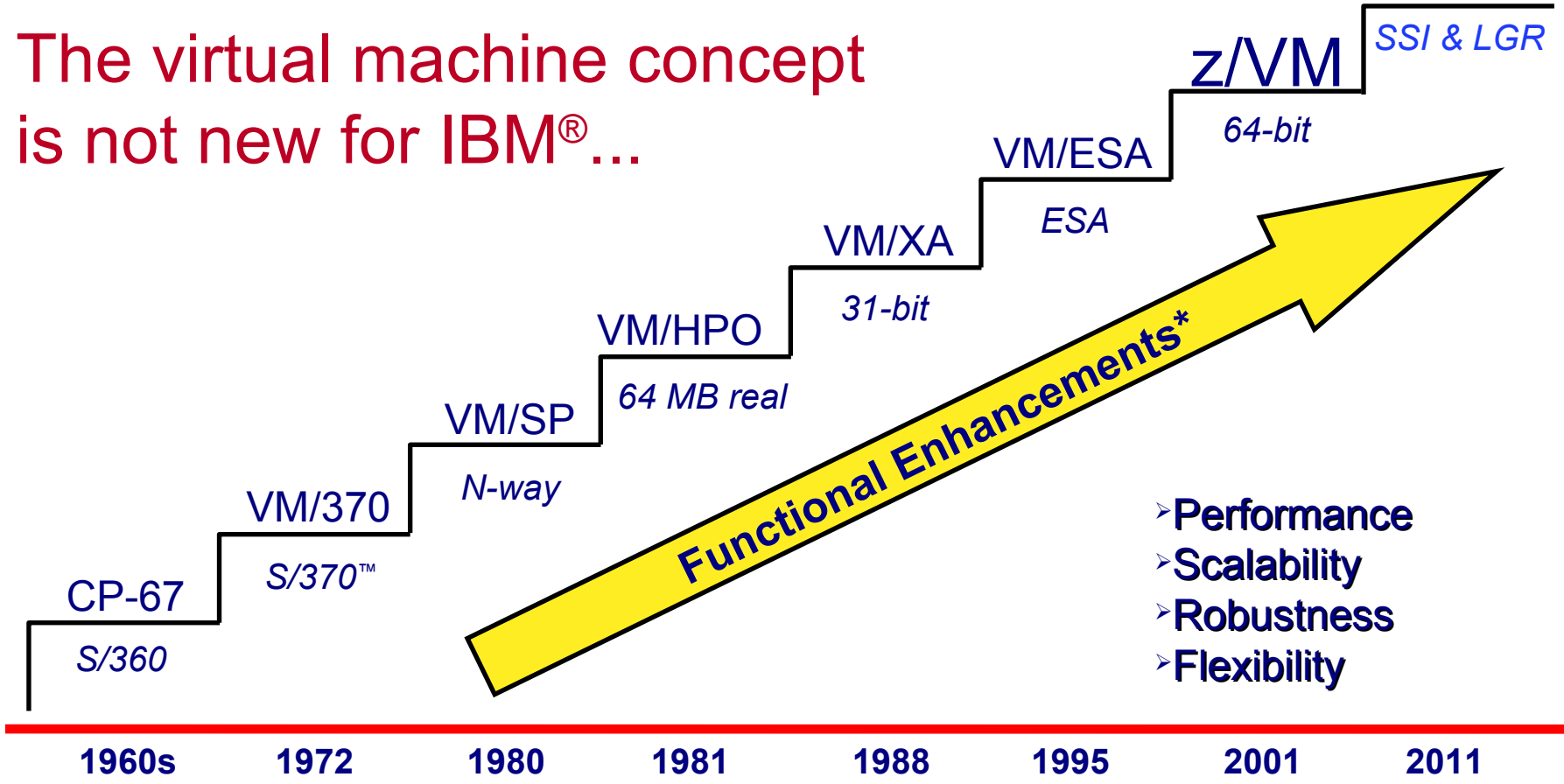
Different *models* implement the architecture in different ways.

- 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®...



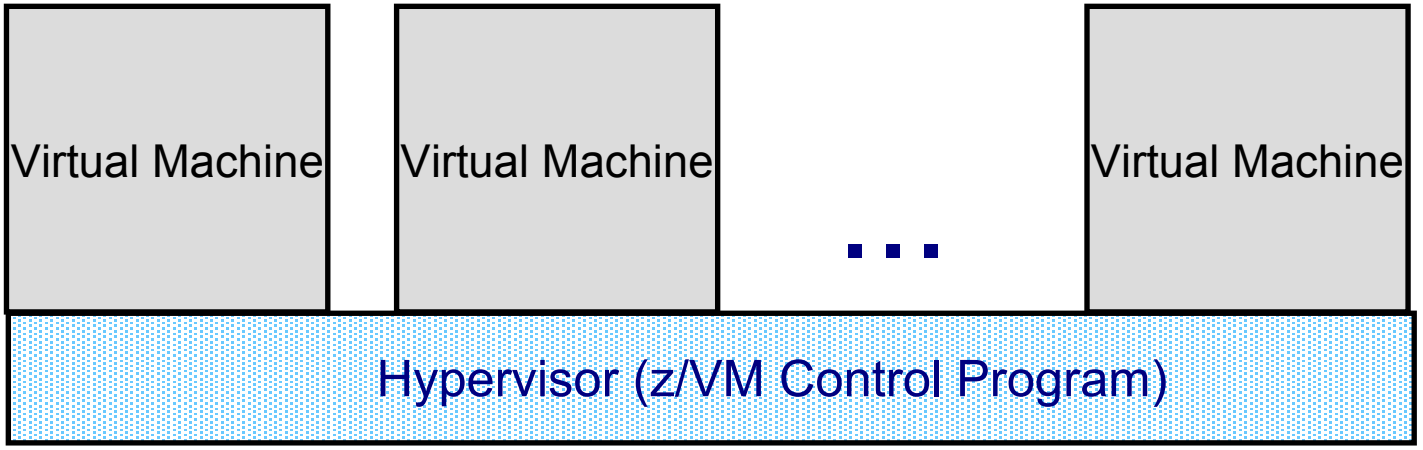
* Investments made in hardware, architecture, microcode, software

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



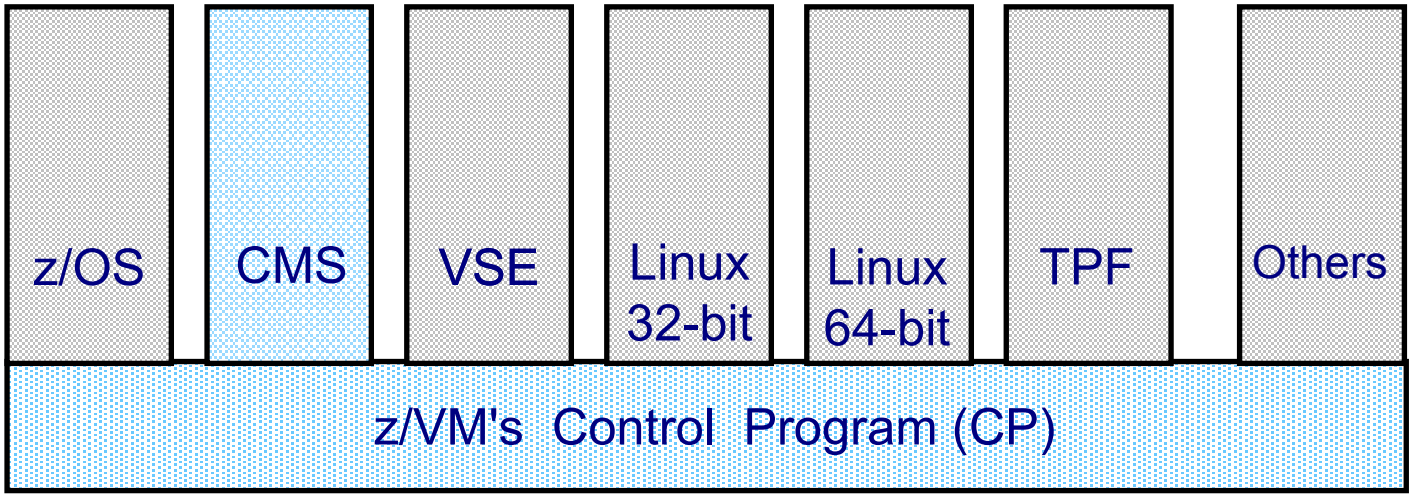
A **virtual machine** is an execution context that obeys the architecture.

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 overcommittment 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

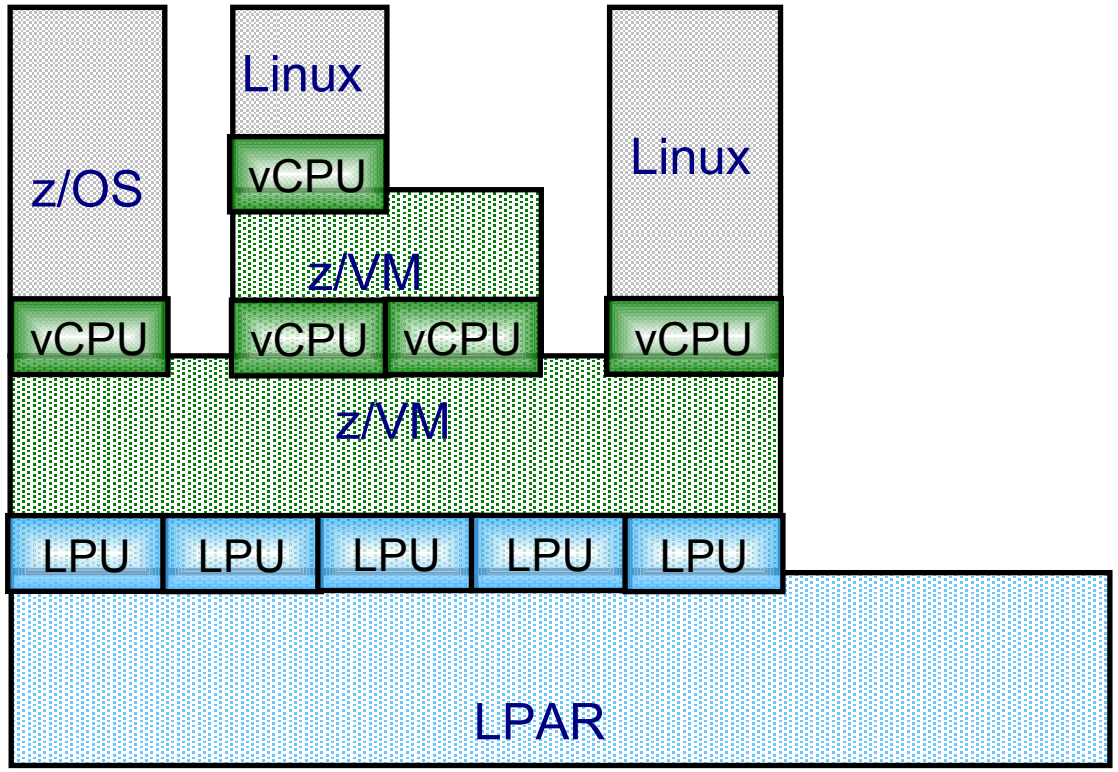
In VM...

- *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.

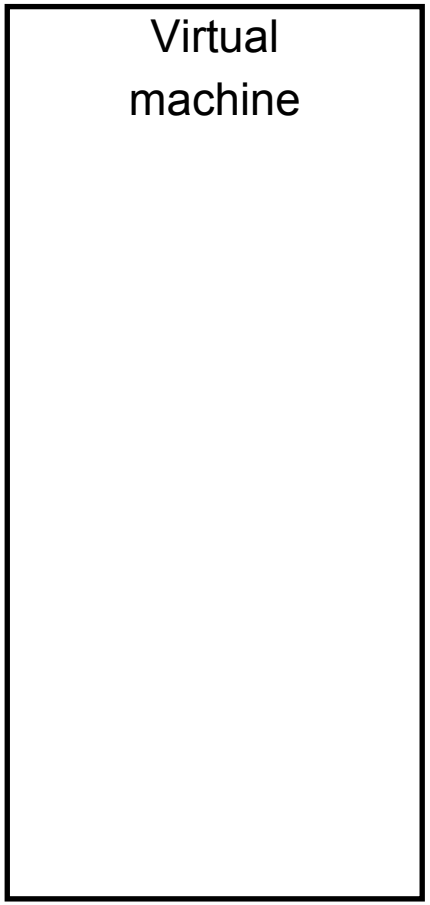
In relationship to LPAR (partitioning)...

- *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:

- memory
- architecture
- processors
- spool devices
- network device
- disk devices
- other attributes

```
USER LINUX01 MYPASS 512M 1024M  G

MACHINE ESA 2

IPL 190 PARM AUTOCR

CONSOLE 01F 3270 A

SPOOL   00C 2540 READER *

SPOOL   00D 2540 PUNCH  A

SPOOL   00E 1403 A

SPECIAL 500 QDIO 3 SYSTEM MYLAN
LINK    MAINT 190 190 RR

LINK    MAINT 19D 19D RR
```

How: CP Commands

CP DEFINE

- Adds to the virtual configuration somehow
- CP DEFINE STORAGE
- CP DEFINE CPU
- 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 (logical) processor can be dedicated to a virtual processor

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

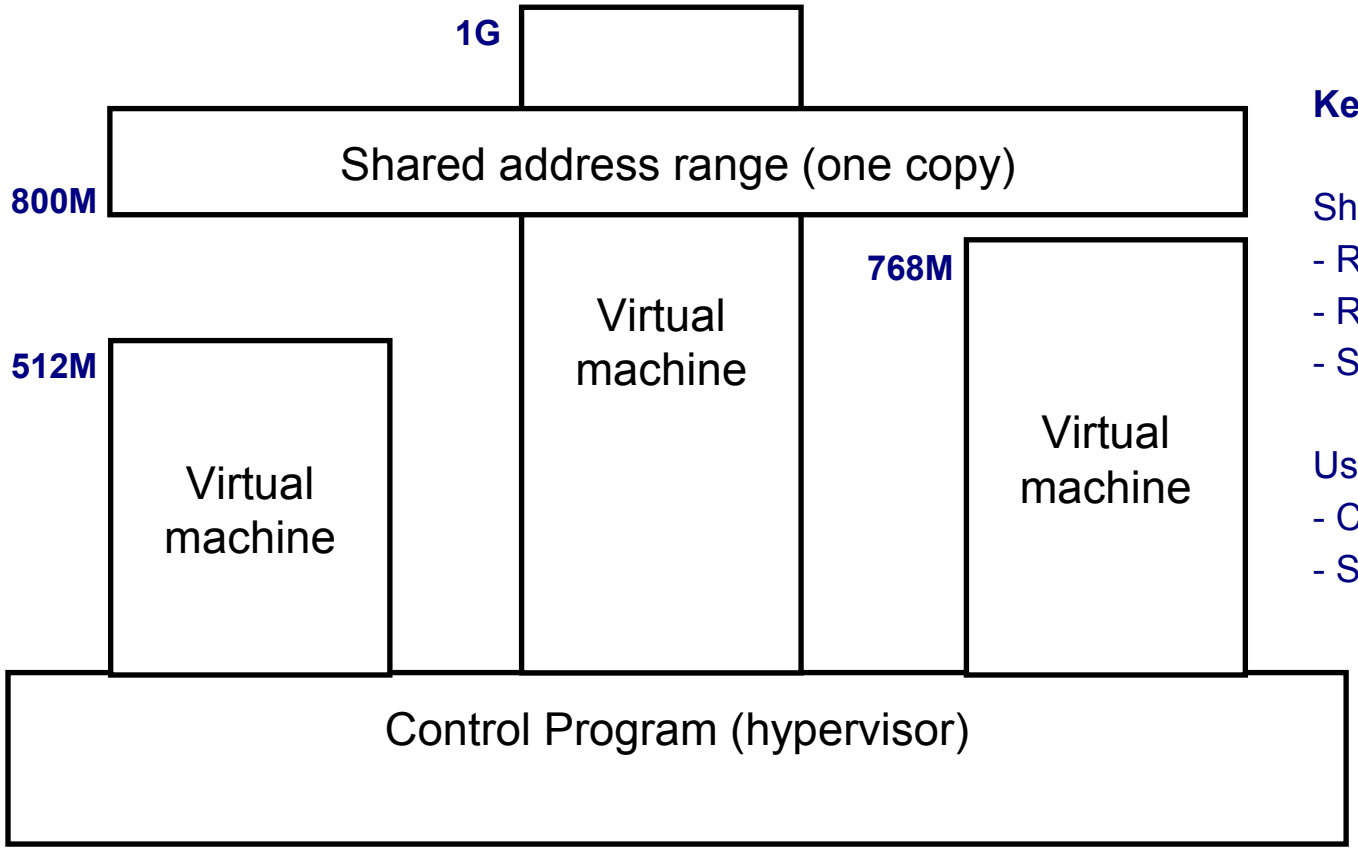
Configuration

- 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 (using CP SET RESERVED)

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

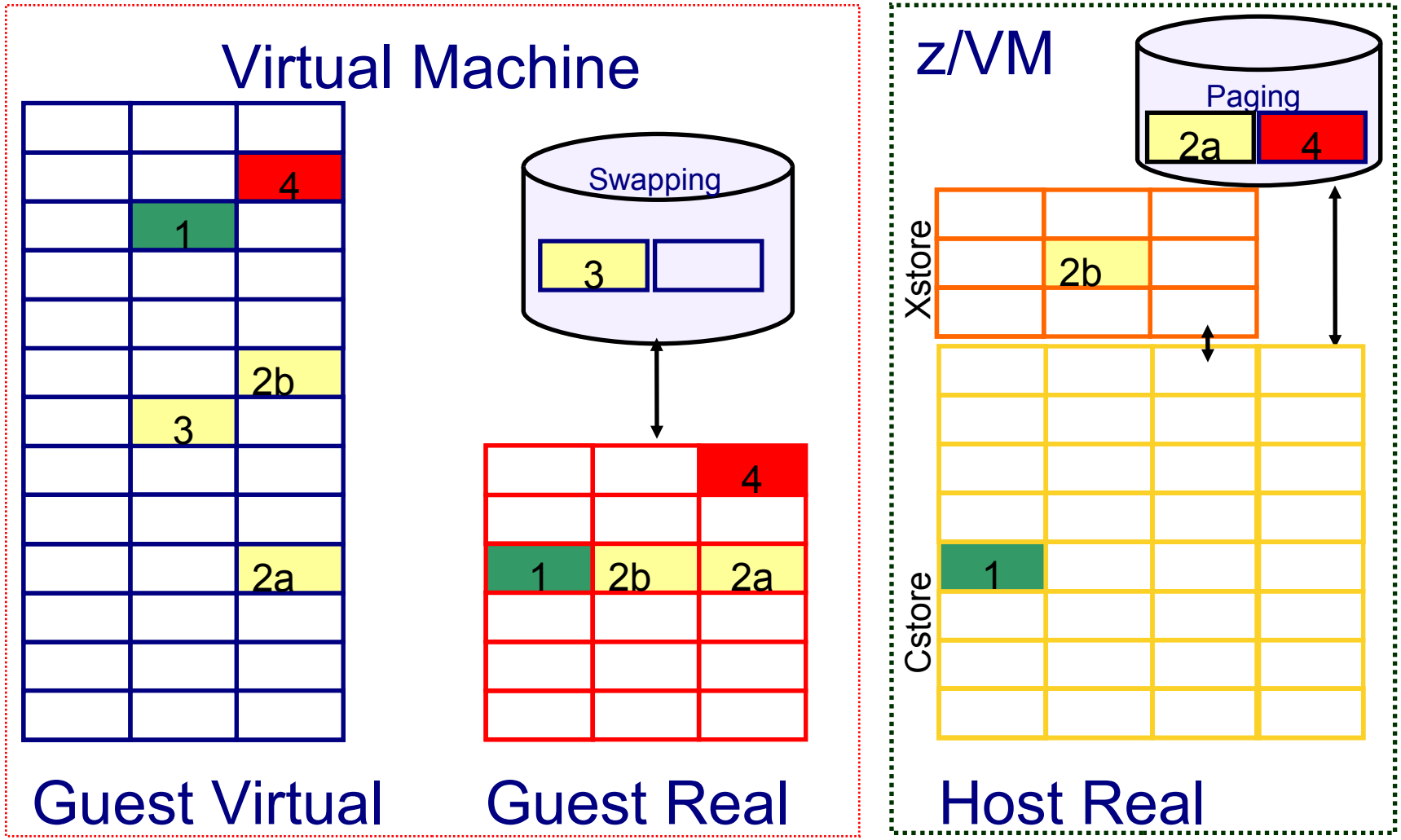
LPAR

- ☒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

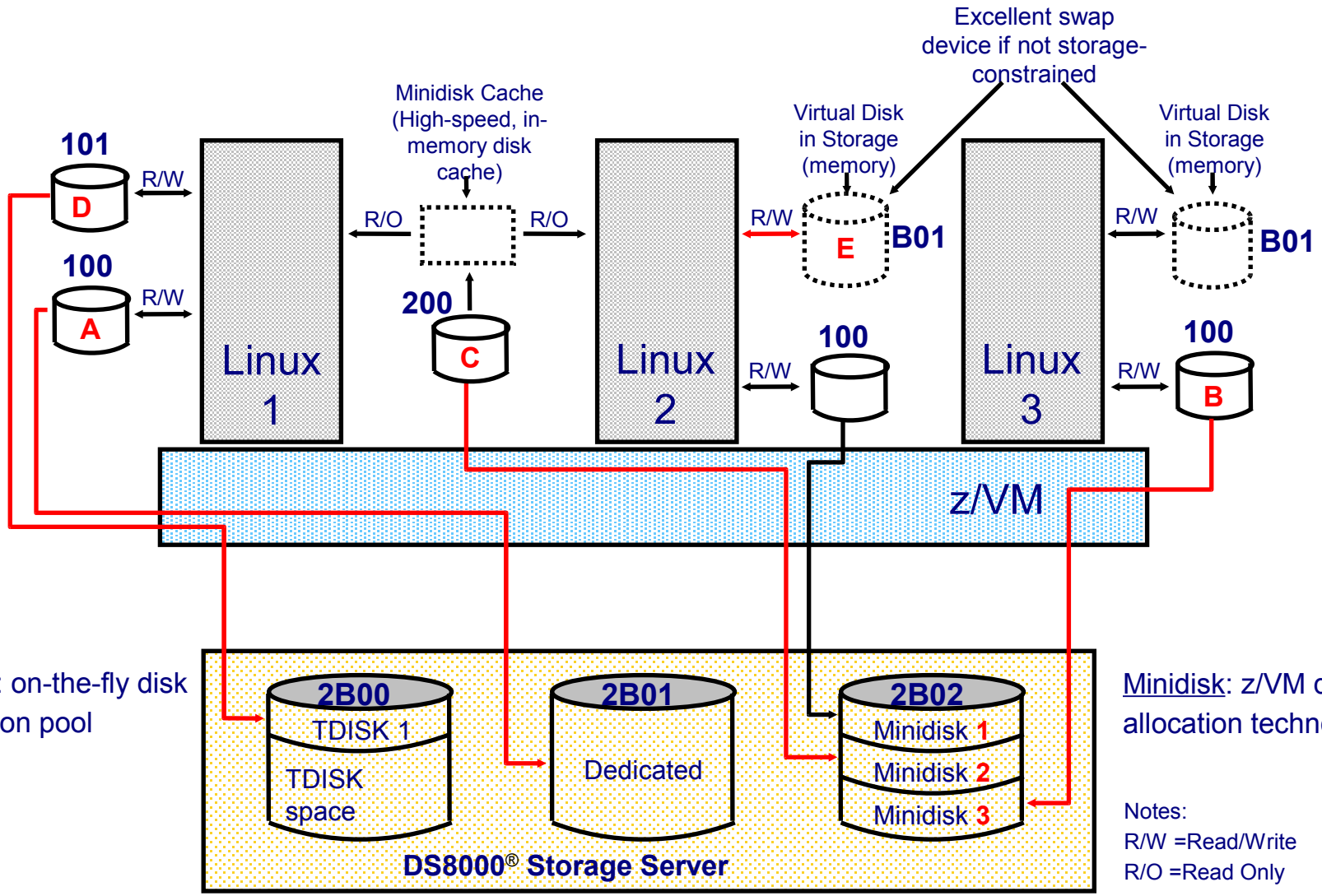
- Dedicated or Attached
  - The guest has exclusive use of the entire real device.
- Virtualized
  - Present a slice of a real device to multiple virtual machines
  - Slice in time or slice in space
  - E.g., DASD, crypto devices
- Simulated
  - Provide a device to a virtual machine without the help 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

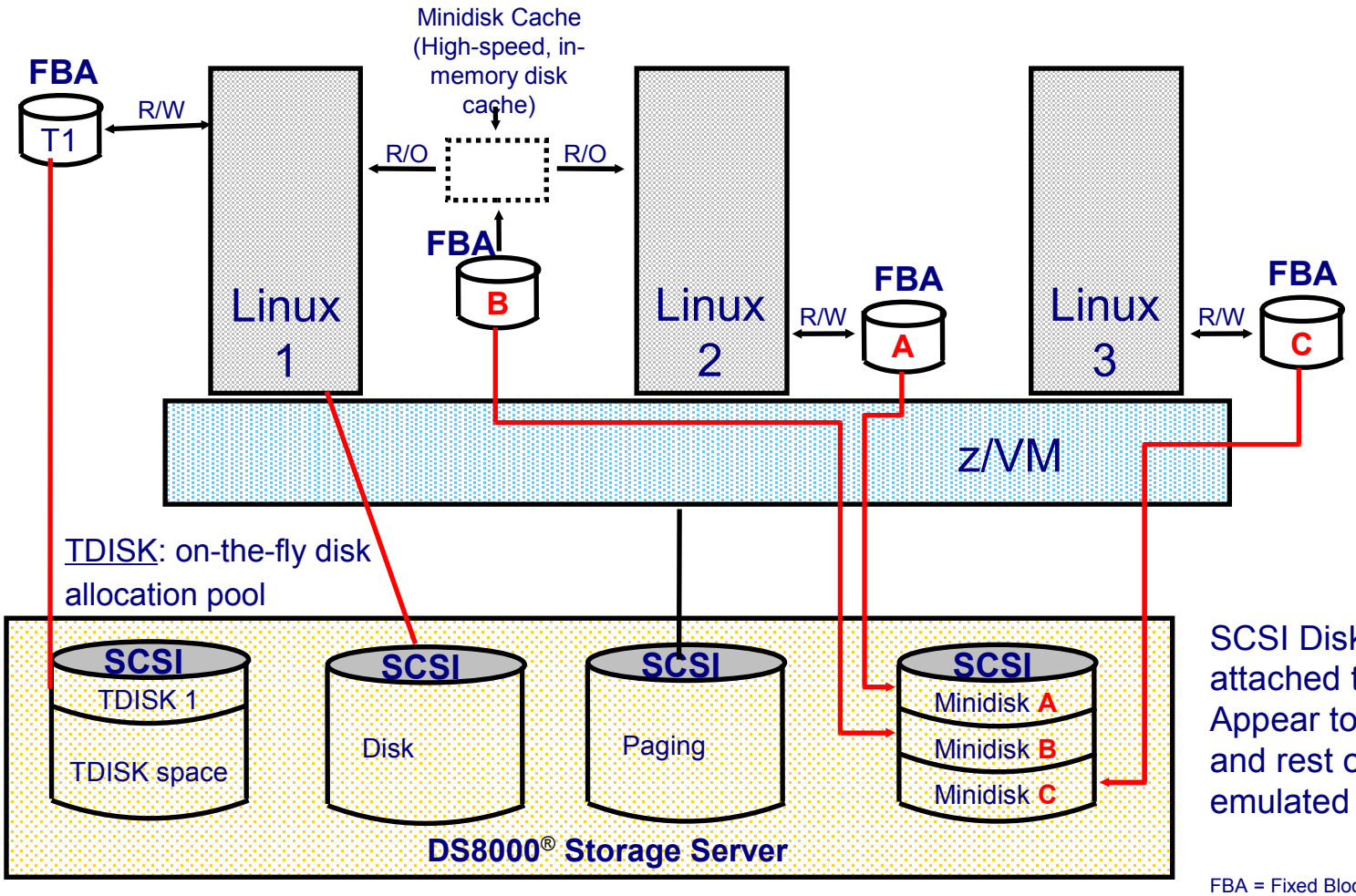


TDISK: on-the-fly disk allocation pool

Minidisk: z/VM disk allocation technology

Notes:
R/W =Read/Write
R/O =Read Only

z/VM Disk Technology - SCSI



SCSI Disks attached to z/VM. Appear to guests and rest of VM as emulated FBA.

FBA = Fixed Block Architecture

What: Data-in-Memory

Minidisk Cache

- ☒Write-through cache for non-dedicated disks
- ☒Cached in central and/or expanded storage
- ☒Psuedo-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)

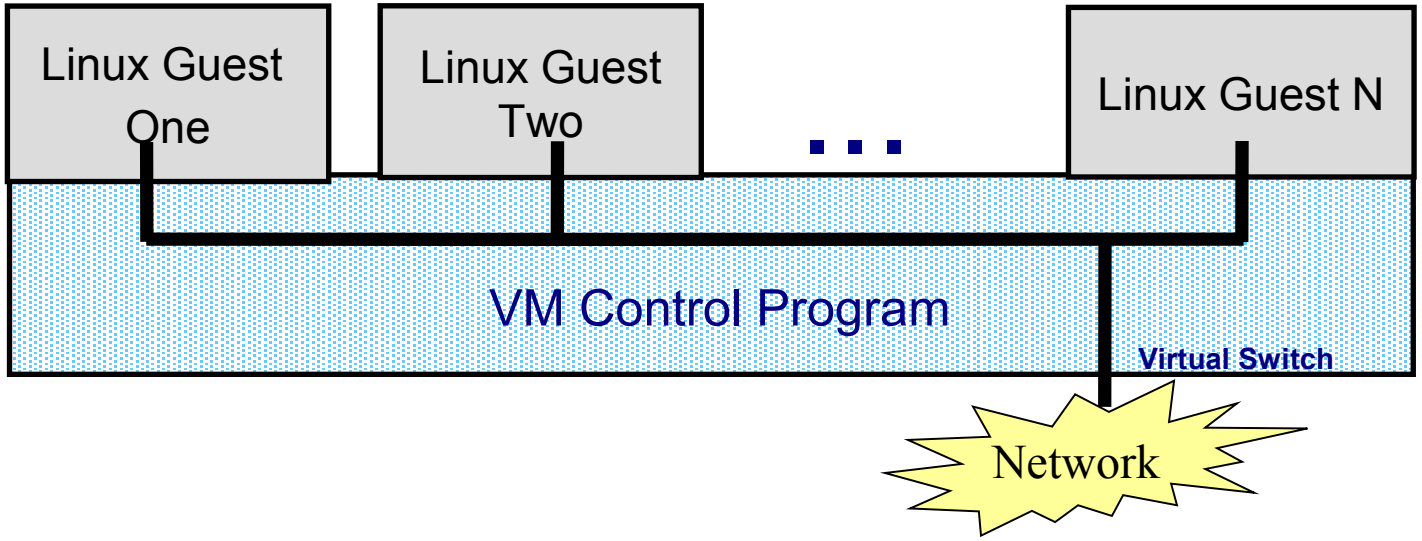
Connecting virtual machines to another LPAR

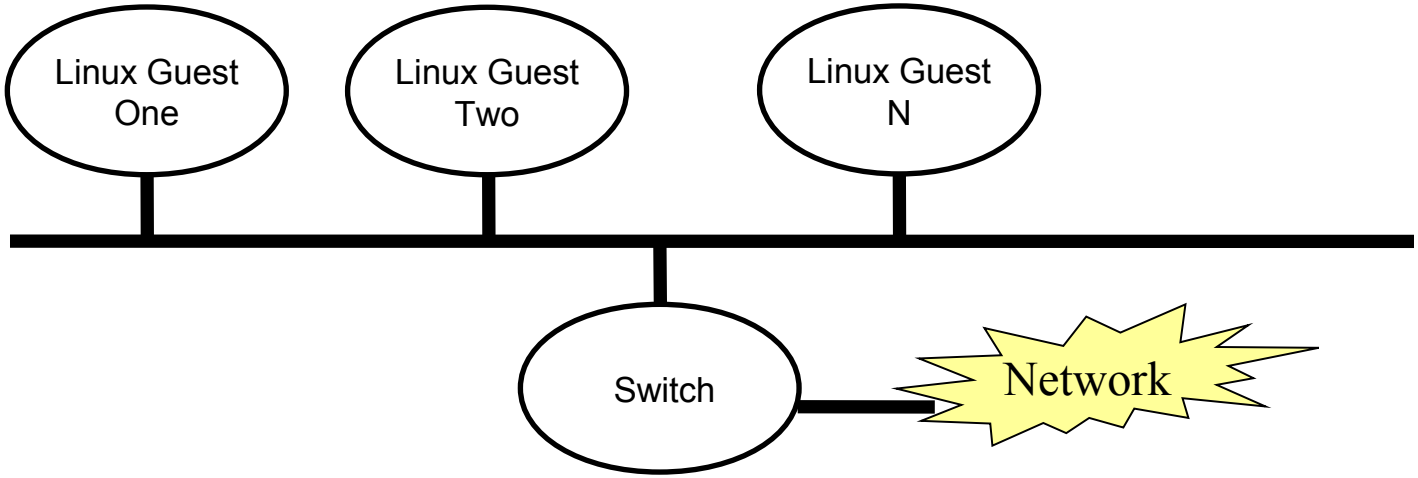
- HiperSockets
- Shared OSA

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

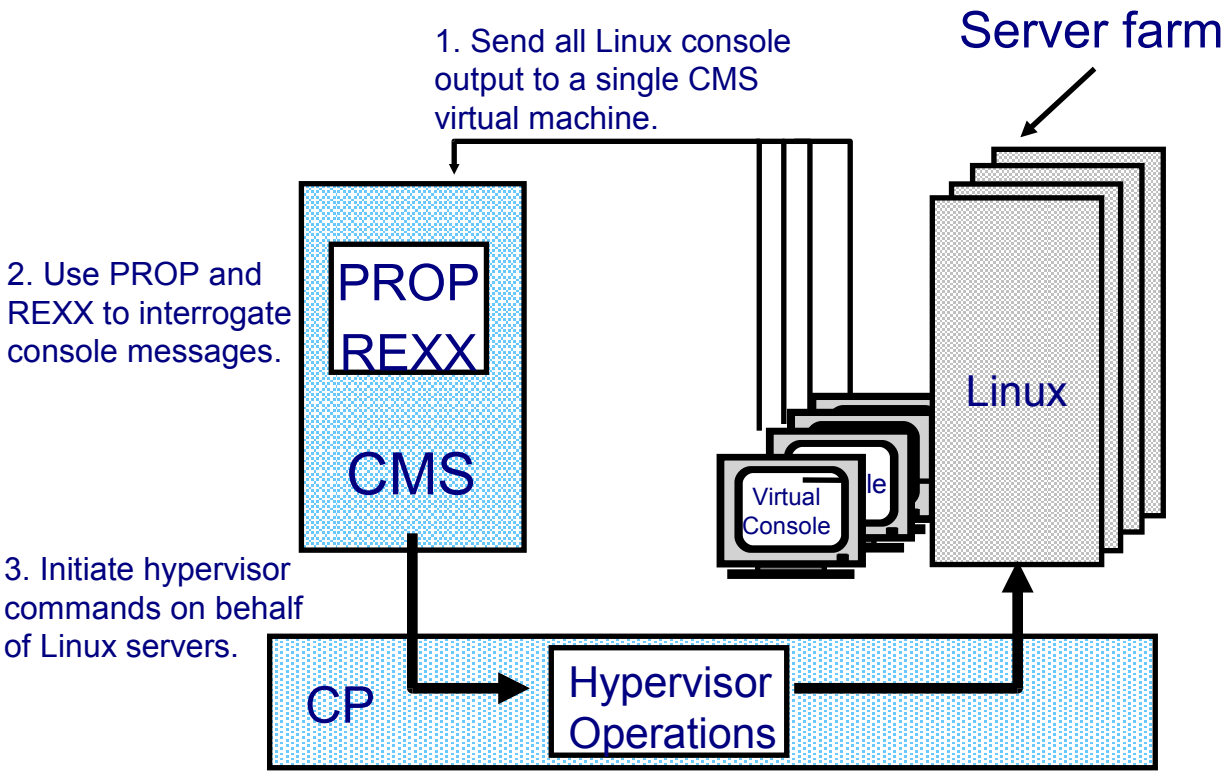
Tracing of virtual machine

- 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

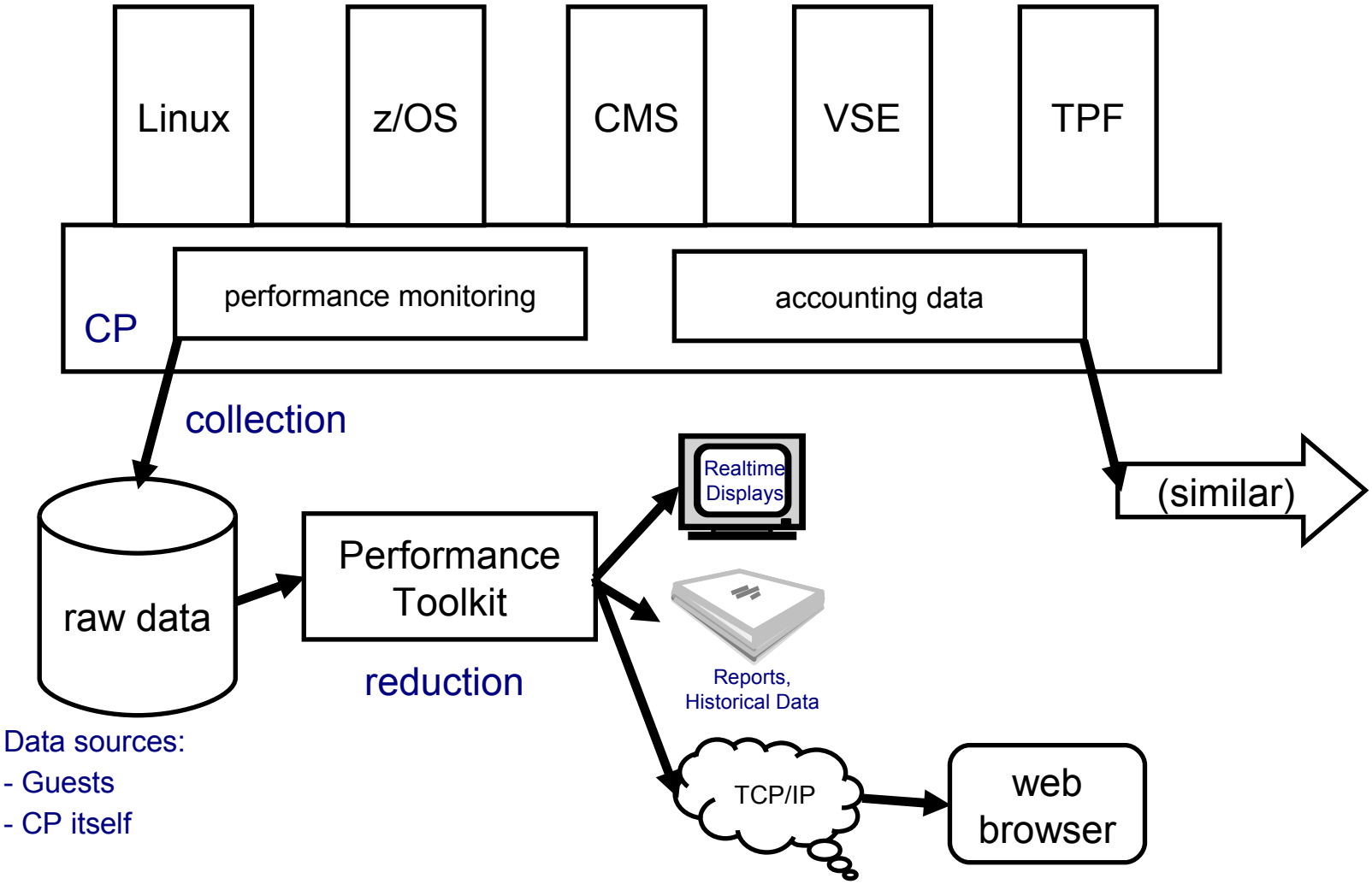
Display or store into virtual machine memory

- 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



References

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  - 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
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End of Presentation

Question and Answer Time