Cloud technologies

ACTS, CDAC Bangalore.

Topics for the day

- Cloud Computing
- Virtualization
- Containerization
- Cloud Service models
- Cloud Deployment models
- Services provided by Cloud
- Cloud development best practices
- Introduction to AWS and Services

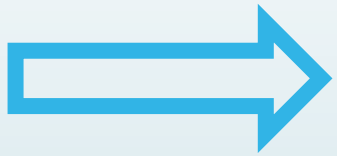
Introduction to cloud

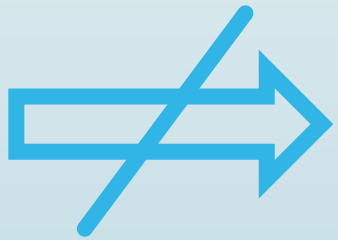
- Cloud computing is the on-demand availability of computer system resources, especially data storage and computing power, without direct active management by the user.
- The availability of **high-capacity networks**, **low-cost computers** and **elastic-storage** as well as the widespread adoption of **hardware virtualization**, service-oriented architecture and autonomic and utility computing has led to growth in cloud computing.
- cloud computing allows companies to avoid or minimize up-front IT infrastructure costs
- The main enabling technology for cloud computing is **virtualization**.

What is it ?

- Act of creating a virtual (rather than actual) version of something including :
- Virtual computer hardware platforms
- Operating systems
- Storage devices
- Computer network resources.

Key Technology in Cloud Computing

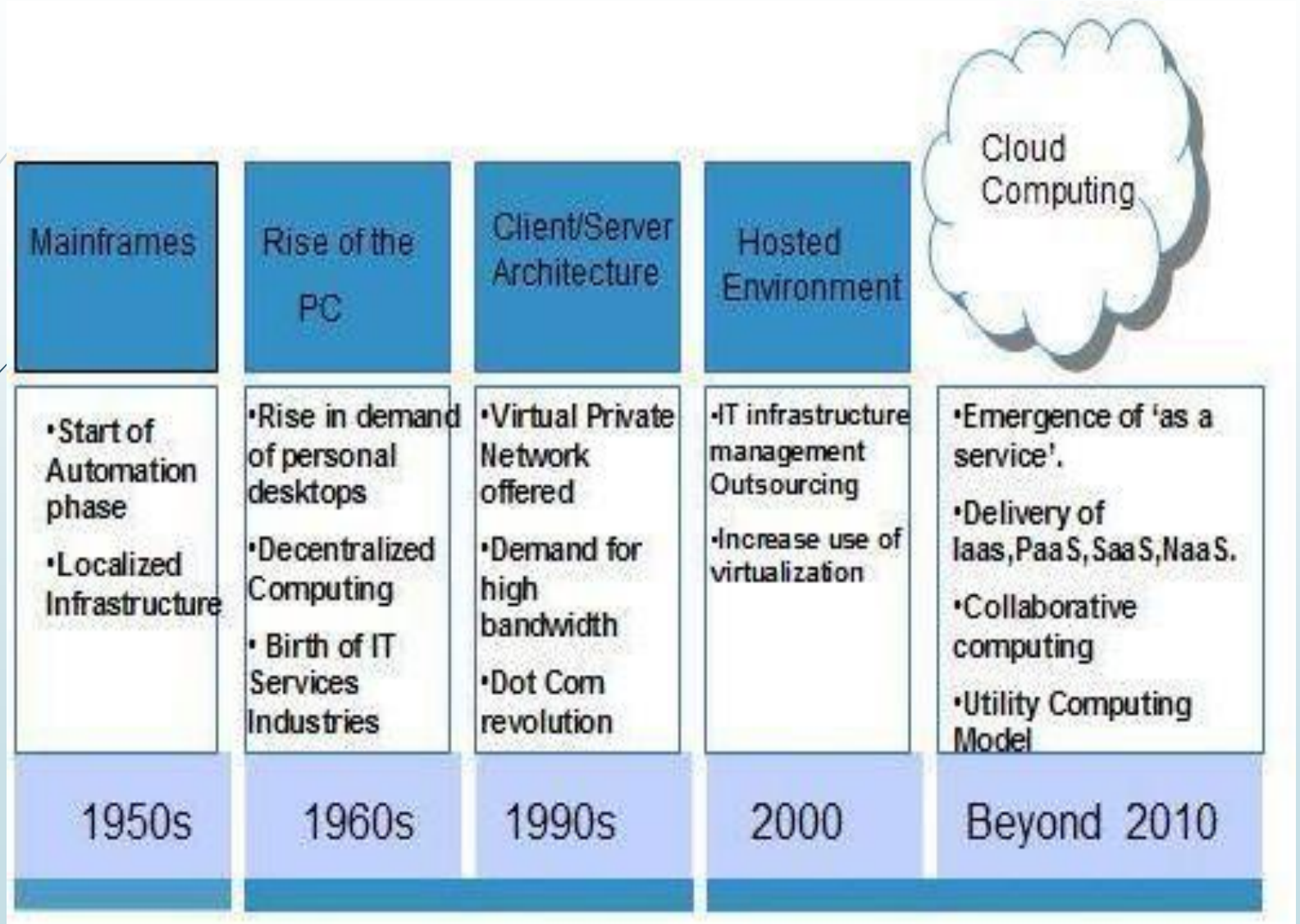
Cloud Computing  Virtualization

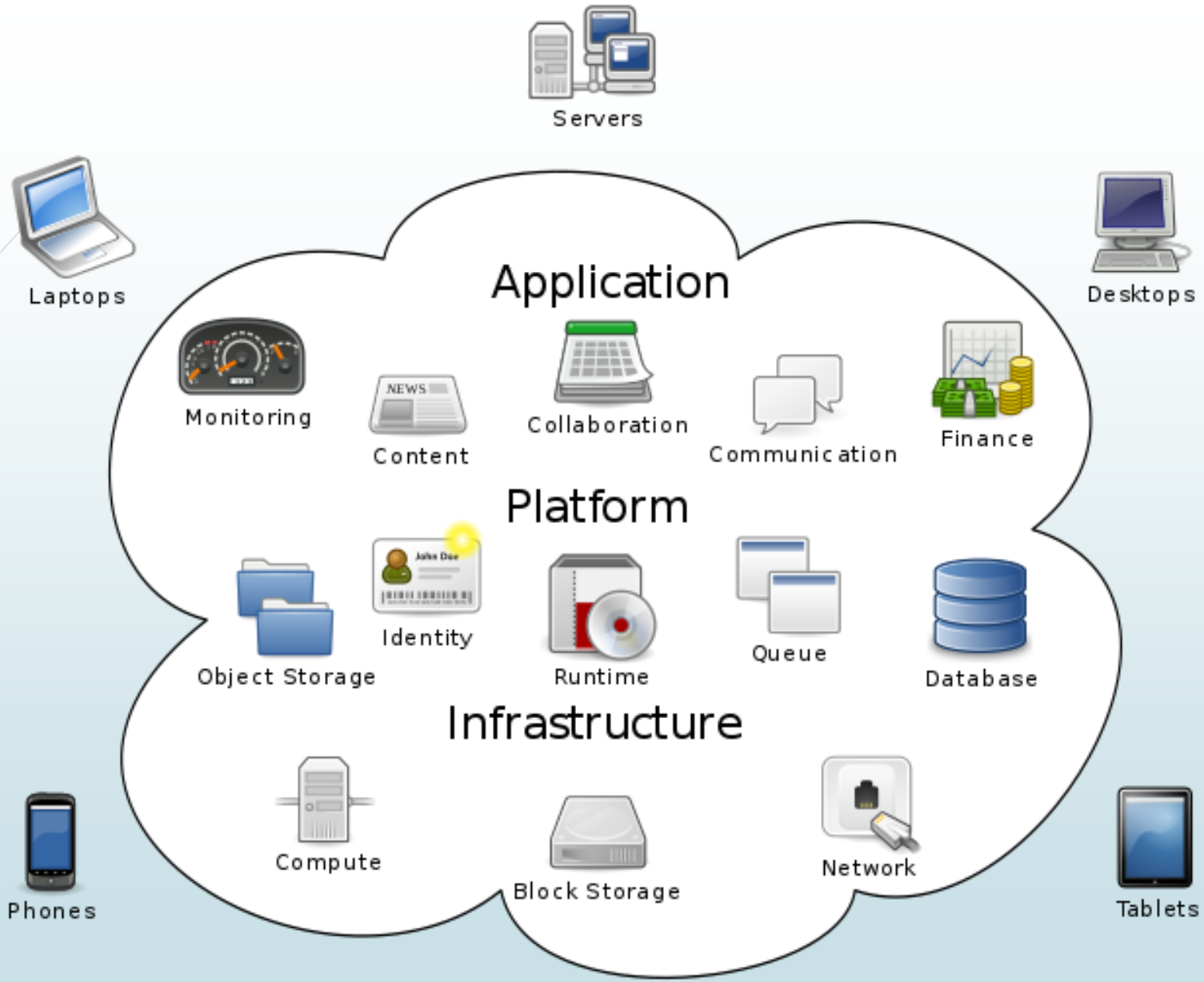
Virtualization  Cloud Computing

How does it work?

- Virtualization transforms hardware into software.
- It is the creation of a fully functional virtual computer that can run its own applications and operating system.
- Creates virtual elements of the CPU, RAM, and hard disk.

History


Mainframes
Rise of the PC
Client/Server Architecture
Hosted Environment
Cloud Computing
•Start of Automation phase
•Localized Infrastructure
•Rise in demand of personal desktops
•Decentralized Computing
• Birth of IT Services Industries
•Virtual Private Network offered
•Demand for high bandwidth
•Dot Com revolution
•IT infrastructure management Outsourcing
•Increase use of virtualization
•Emergence of 'as a service'.
•Delivery of Iaas,PaaS,SaaS,NaaS.
•Collaborative computing
•Utility Computing Model
1950s
1960s
1990s
2000
Beyond 2010



Cloud computing

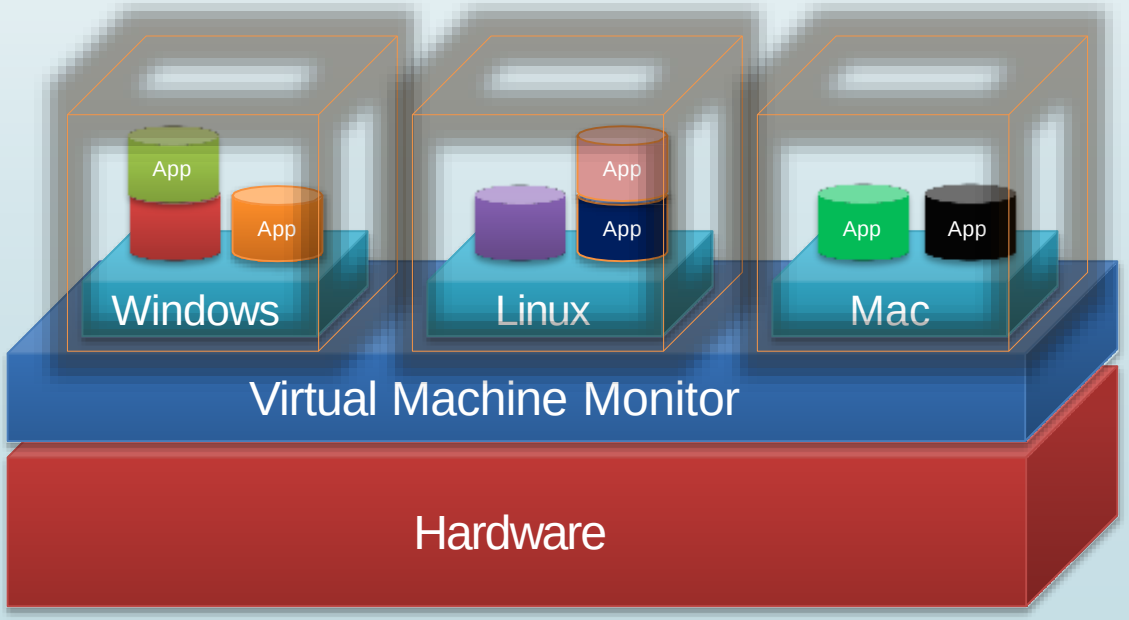
Introduction to Virtualization

Outline

- Goals
  - Understanding the benefits of virtualization in IT industry and how to virtualize HW resources
- Schedule
  - Introduction to virtualization
  - OS vs. VMM
  - CPU virtualization and scheduling
  - Memory virtualization and management
  - I/O virtualization
  - Live VM migration
  - Introduction to Systemtap

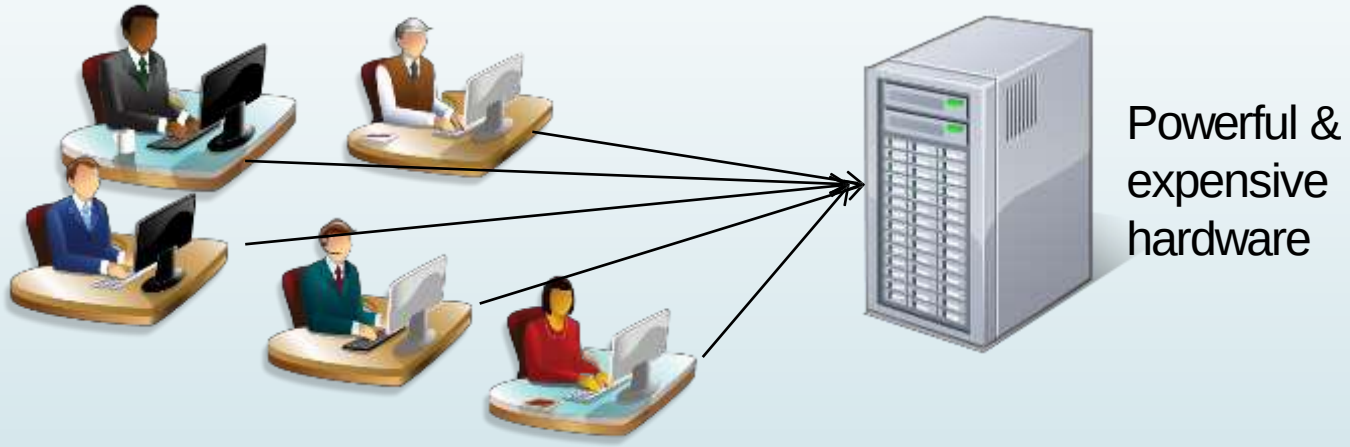
What is Virtualization?

- Multiple OSes on a single machine
  - Giving an illusion that each OS is running on real HW
  - **Virtual Machine Monitor (VMM)**
    - Another layer of kernel to virtualize multiple OSes
    - Also called "**hypervisor**"
      - An OS as a supervisor is no more HW-dictator!



History – Born and Died (1/4)

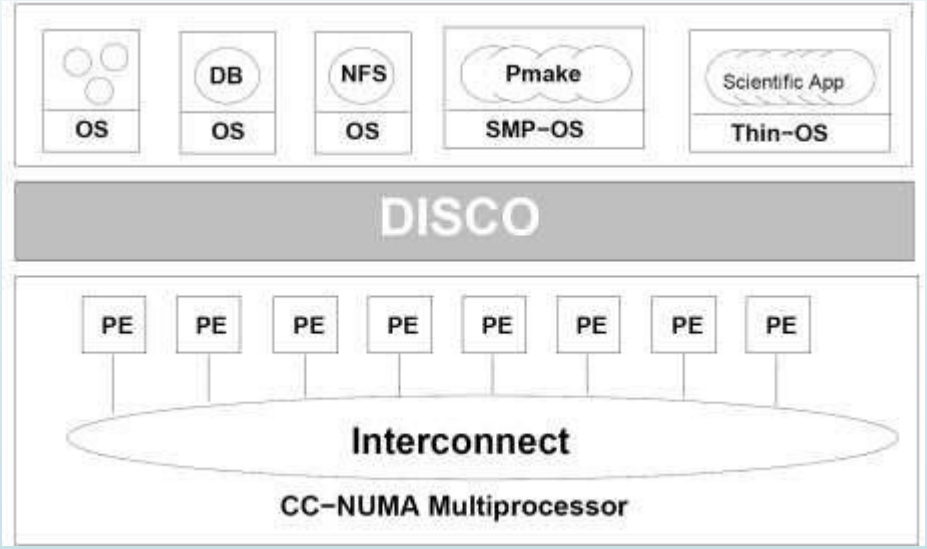
- 1960s-1970s
  - High cost of computing machines
  - IBM VM/370: A VMM for IBM mainframe



- 1980s-1990s
  - But, lost attentions since PC era (1980s)
  - Cheap HW → No need to share hardware
  - CPU did not support virtualization well
    - High engineering cost and overhead

History - Reborn (2/4)

- The late 1990s
  - Regain attention for "**server consolidation**"
    - Toward cost-effective large-scale computing
  - Stanford's research project: Disco



Disco: Running Commodity Operating Systems on Scalable Multiprocessors [SOSP'97]

- They founded VMware in 1998

History - Renaissance (3/4)

- 1998-2002
  - VMware
    - **“Full-virtualization”**
      - Running unmodified OS
        - Starting with SW-based binary translation
    - Success in industry and academia
      - VMware‘s state-of-the-art techniques in SOSP and OSDI
- 2003
  - Xen
    - University of Cambridge’s project: **Open source!!!**
    - “Xen and Art of Virtualization” [SOSP’03]
    - **“Para-virtualization”**
      - Modified OS for near-native performance: Linux on x86
    - 2003-
      - Virtualization research renaissance based on Xen
    - 2007: Acquired by Citrix

History - Ubiquitous (4/4)

- 2005-2006
  - HW-assisted virtualization
  - x86 virtualization
    - Intel VT-x & AMD-V
    - Running unmodified OS with near-native performance
    - Default functionality now
- 2006-now
  - Cloud computing
    - Infrastructure-as-a-Service (IaaS)
  - Virtual desktop infrastructure (VDI)
  - Mobile virtualization
    - ARM virtualization technology (Cortex-A15)

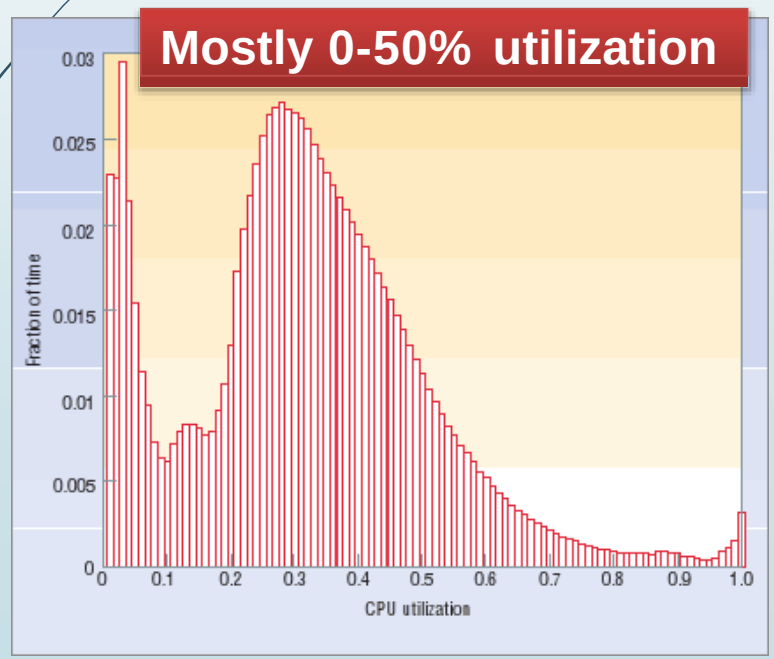
Microsoft VDI

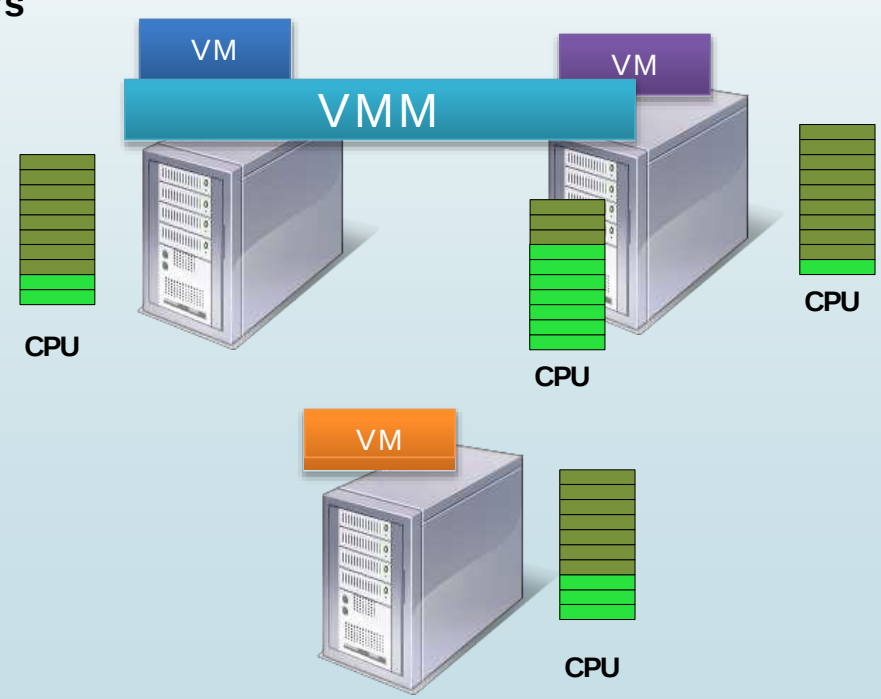
HP Virtual Desktop Infrastructure

Why Virtualization? (1/6)

- Efficient resource utilization
  - Low resource utilization of each server machine
  - Low total cost of ownership (TCO)
    - Low cost of infrastructure and energy

Average CPU utilization of 5000+ Google's servers

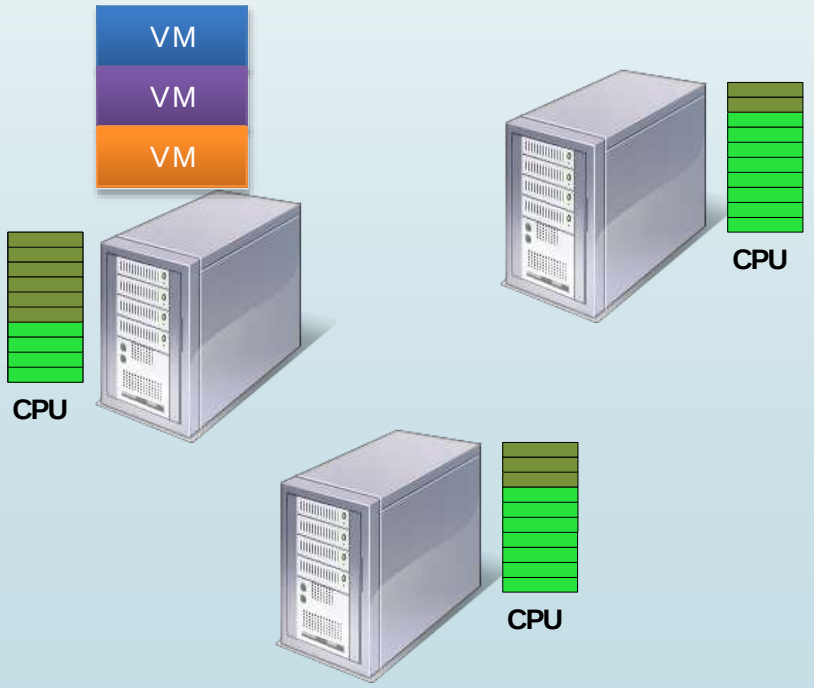




The Case for Energy-Proportional Computing [IEEE Computer'07]

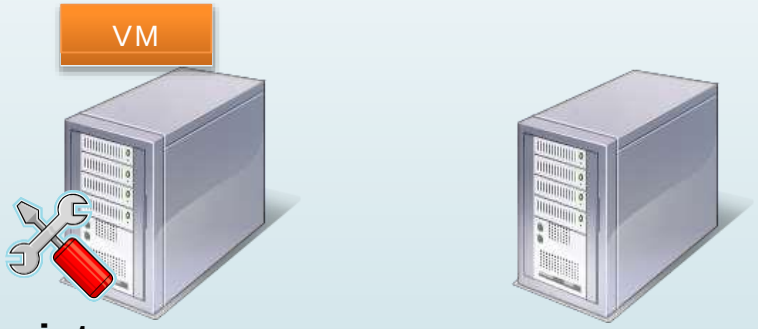
Why Virtualization? (2/6)

- Flexible VM relocation
  - **"Live VM migration"**
    - Flexible VM relocation with near-zero downtime
  - **Flexible load balancing**
    - Relieving resource bottleneck



Why Virtualization? (3/6)

- Flexible VM relocation
  - **“Live VM migration”**
    - Flexible VM relocation with near-zero downtime
  - **<u>High availability</u>**

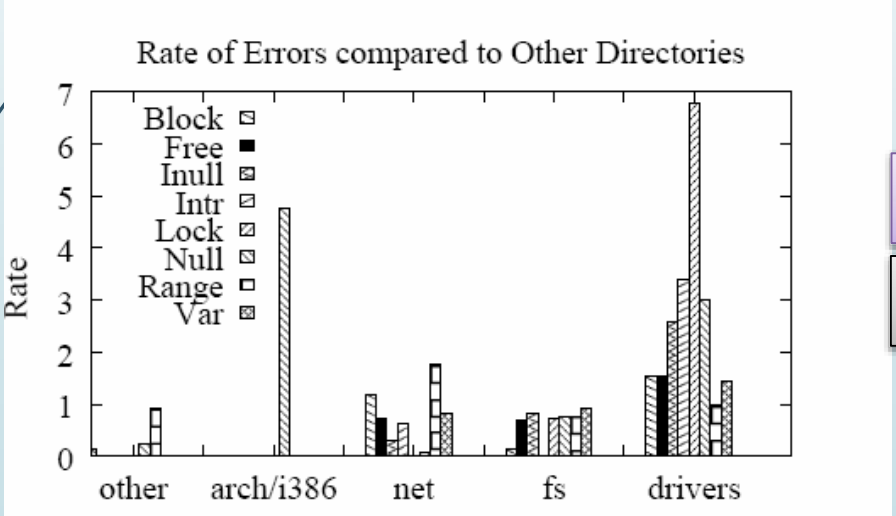


SW or HW maintenance
(upgrade or fix)

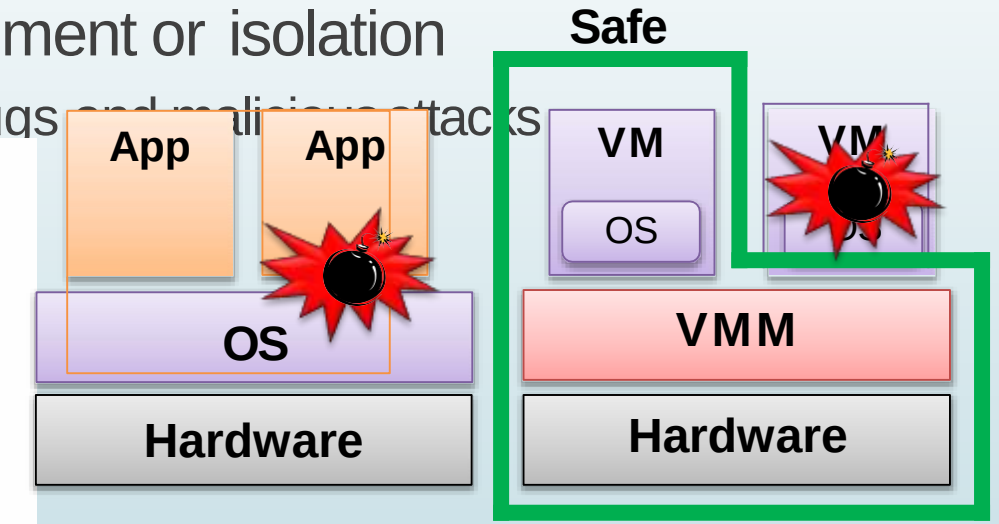
Why Virtualization? (4/6)

- Strong isolation
  - Strong isolation between co-located VMs
  - Fault containment or isolation
  - Safe from bugs and malicious attacks

OSes, especially drivers, are error-prone



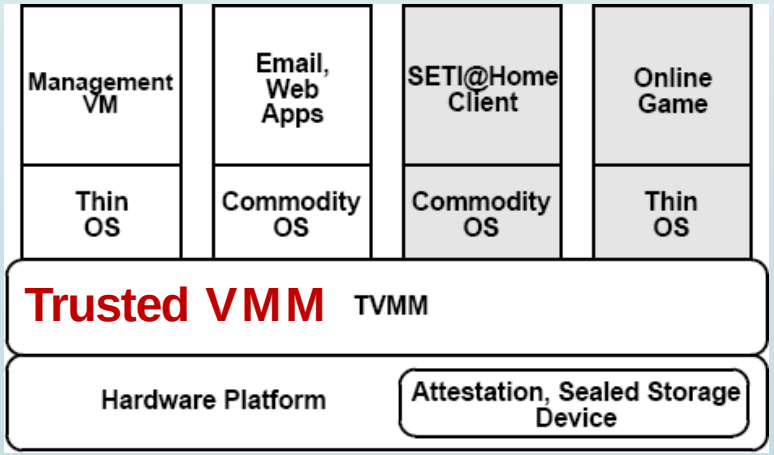
An empirical study of operating systems errors [SOSP'01]



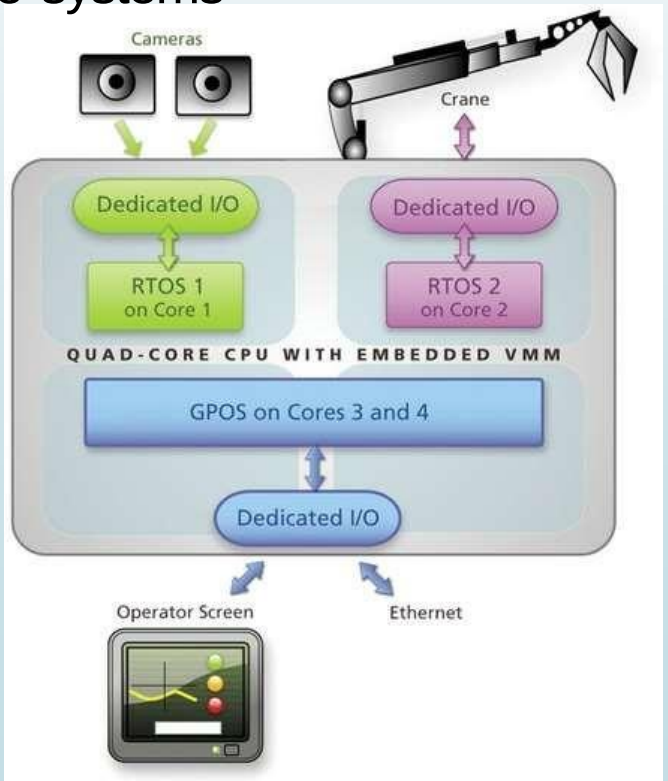
VMM is much smaller than OS
→ Low trusted computing base (TCB)

Why Virtualization? (5/6)

- Multiple OSes on a single device
  - OS dependency of legacy SW
    - Linux + Windows, Android + iOS
  - Different requirements of SW
    - Virtualization for embedded or mobile systems
      - RTOS + GPOS
    - Building secure systems
      - Security-enhanced OS + GPOS



Terra: A Virtual Machine-Based Platform for Trusted Computing [SOSP'03]



Why Virtualization? (6/6)

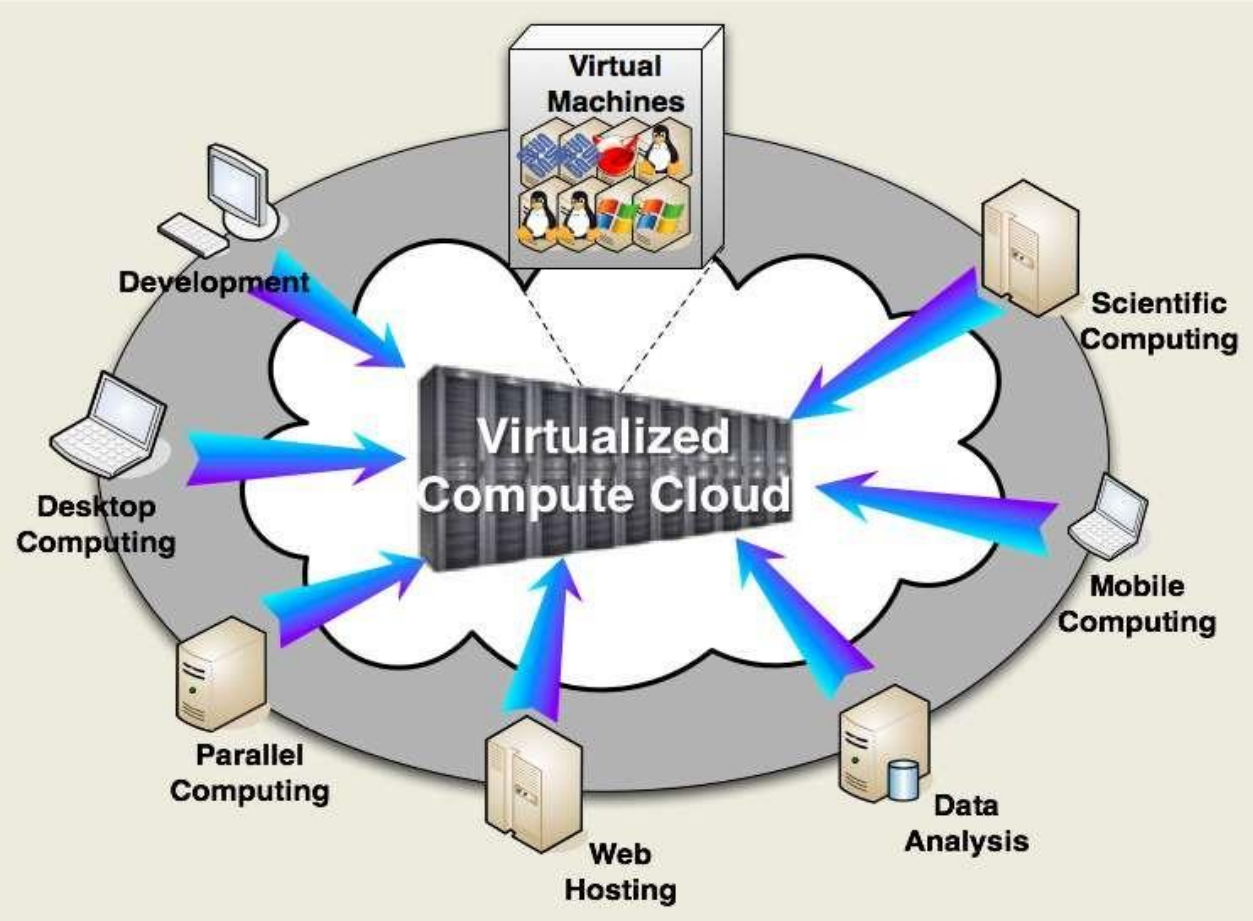
- Other benefits
  - Strong security monitoring
    - Security monitoring outside OSes
  - Ease of deployment
    - Virtual appliance
      - A bundle of OS and applications
  - Flexible testing and debugging
    - Building distributed environments on a single machine
    - Kernel development and debugging
    - VM-based recording and replaying

Use Cases

- Cloud computing
- Virtual desktop infrastructure
- Mobile virtualization

Virtualization & Cloud Computing

- VM-based resource pool for various demands
  - Infrastructure-as-a-Service (IaaS)



Virtualization & Cloud Computing

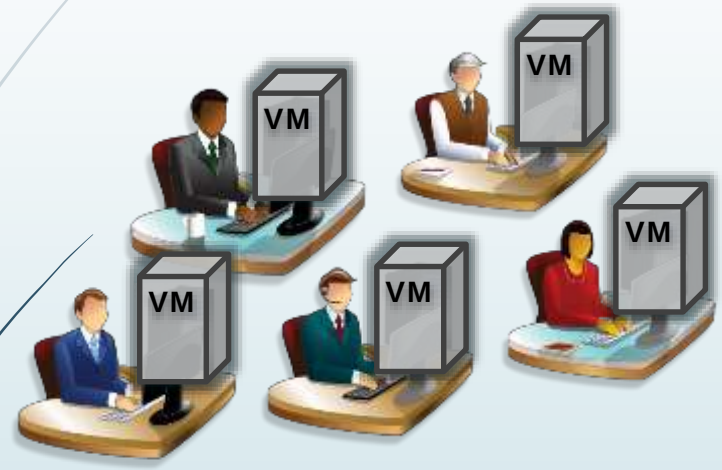
- Many providers use commercial & open-source VMMs

Virtualization Solutions	Cloud Providers
vmware	terremark, CONTEGIX, bluemile, TIER 3, bluelock., DATAPIPE
Xen	amazon web services, rackspace HOSTING, SOFTLAYER, CARPATHIA, GOGRID
KVM	IBM, DATAPIPE, Joyent, ElasticHosts Flexible servers in the cloud

Virtual Desktop Infrastructure (VDI)

- Desktop provisioning

Dedicated workstations



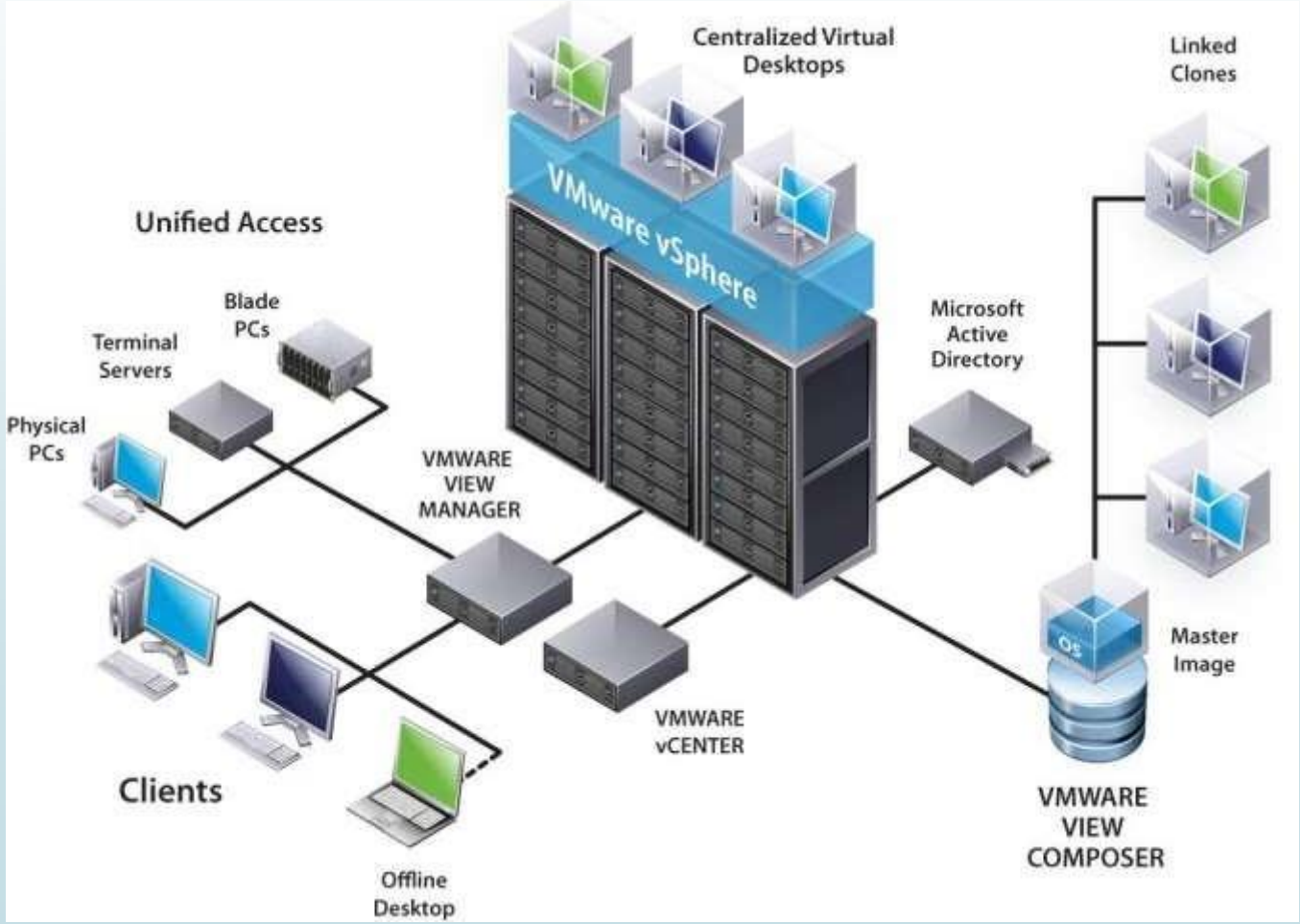
- Energy wastage by idle desktops
- Resource underutilization
- High management cost
- High maintenance cost
- Low level of security

VM-based shared environments

+ **Energy savings by consolidation**
+ **High resource utilization**
+ **Low management cost**
  (flexible HW/SW provisioning)
+ **Low maintenance cost**
  (dynamic HW/SW upgrade)
+ **High level of security**
  (centralized data containment)

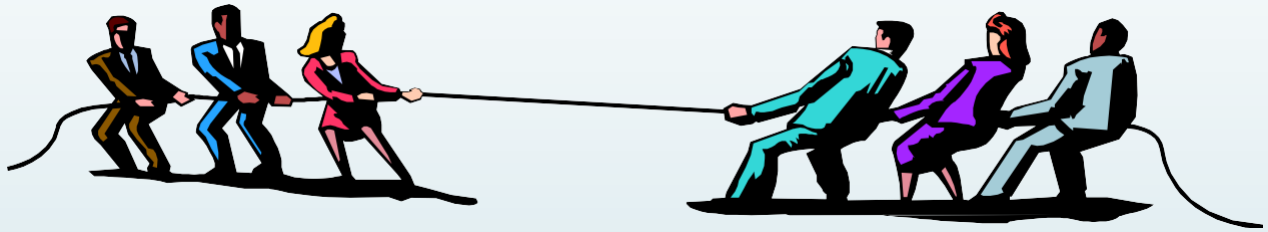
Virtual Desktop Infrastructure (VDI)

- VMware VDI
  - Pioneer of VDI



Mobile Virtualization

- Trends of consumer electronics
  - Digital convergence
    - What do consumer electronics(CE) devices want to achieve?



Reliability

Trustworthiness for primary functions

Extensibility

Flexibility for adding features as needed

Business Phone

Personal Phone

Mobile Virtualization

- Embracing all apps in a unified market
  - iOS + Android + Windows
  - Technically possible, but not yet by industry
  - Currently, not much attractive.
    - Multiple Androids
    - Android + RTOS
  - Issues
    - Performance, performance, performance…
      - Graphics acceleration → **Challenging**
      - CPU, memory limitation
        - High-end smartphones can resolve this limitation

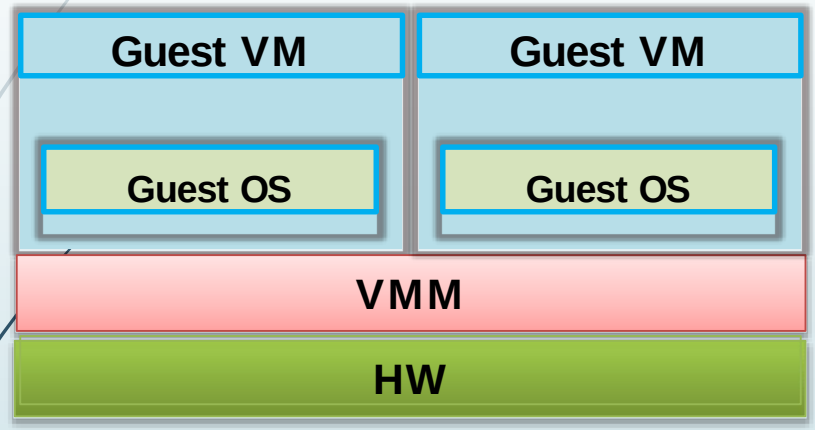
Basic Terminologies

- Types of VMMs
  - Type-1 vs. Type-2
- Virtualization methods
  - Full-virtualization vs. Para-virtualization

Type-1 vs. Type-2

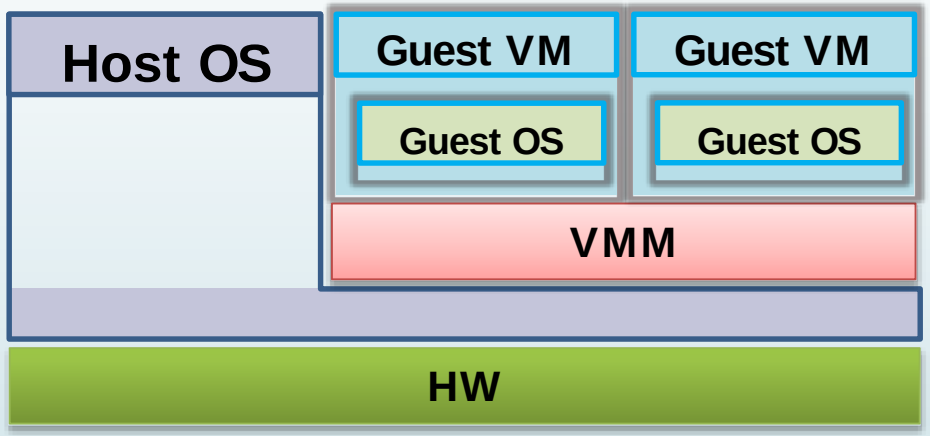
- Depending on what sits right on HW

Type-1: VMM on HW



- Xen, VMware ESX server, Hyper-V
- Mostly for server, but not limited
- VMM by default
- OS-independent VMM

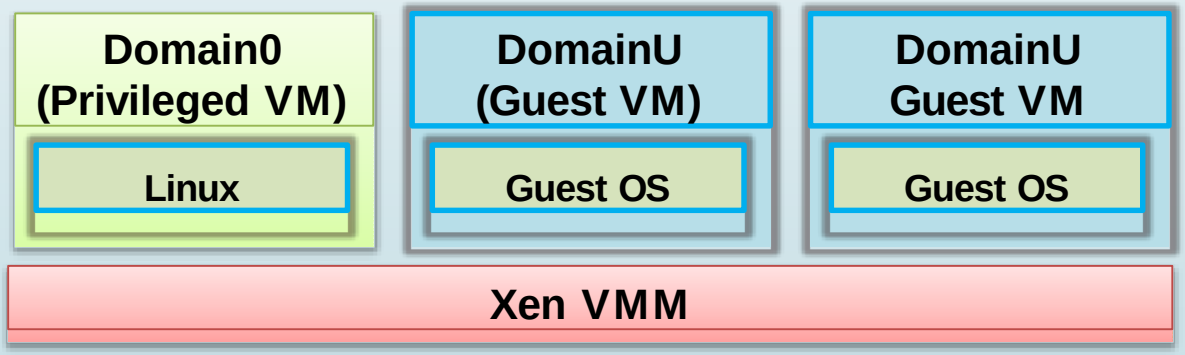
Type-2: Host OS on HW



- KVM, VMware Workstation, VirtualBox
- Mostly for client devices, but not limited
- VMM on demand
- OS-dependent VMM

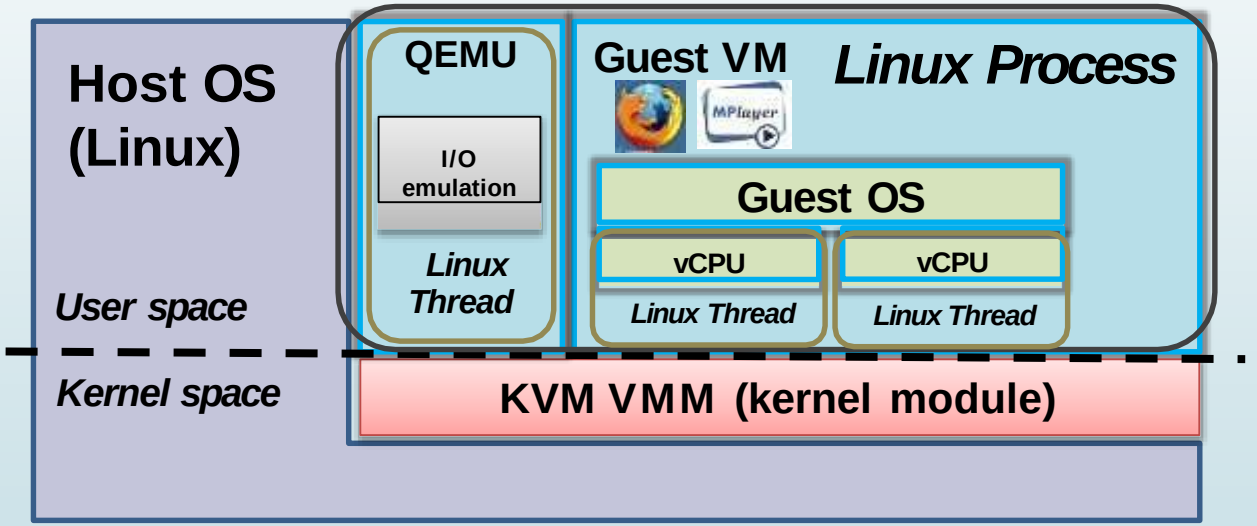
Xen: Type-1 VMM

- Type-1 VMM
  - Para-virtualization and full-virtualization
  - Domain0
    - Privileged VM for guest VM (domainU) management
    - Handling I/O operations requested from domainUs
      - Including native device drivers to directly access HW



KVM: Type-2 VMM

- Type-2 VMM for Linux as a host OS
  - Based on HW-assisted virtualization
  - Linux kernel mainline (2.6.20~)



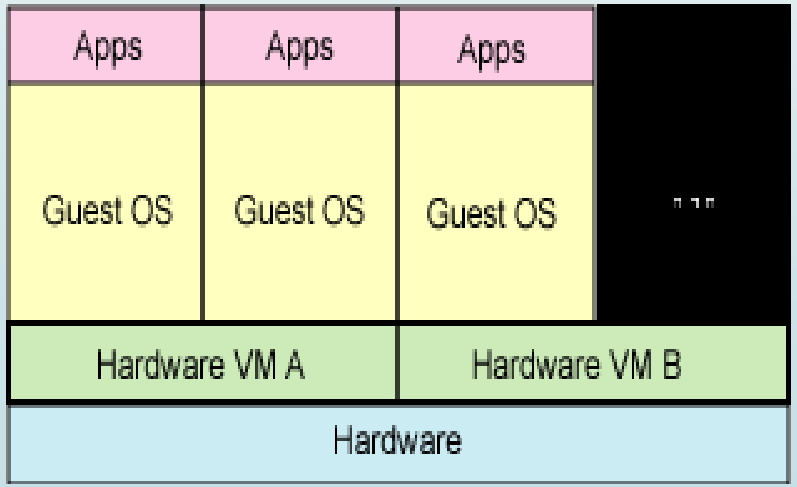
Full- vs. Para-virtualization

- Depending on whether OS source is modified
  - Full-virtualization = No OS source modification
    - SW-based full virtualization
      - Emulation
    - HW-based full virtualization
      - HW-assisted virtualization
  - Para-virtualization = OS source modification
    - Virtualization-aware OS
    - Bridging semantic gap between VMM and OS
    - Mostly for performance

Today's virtualization solutions adopt both approaches for optimized performance

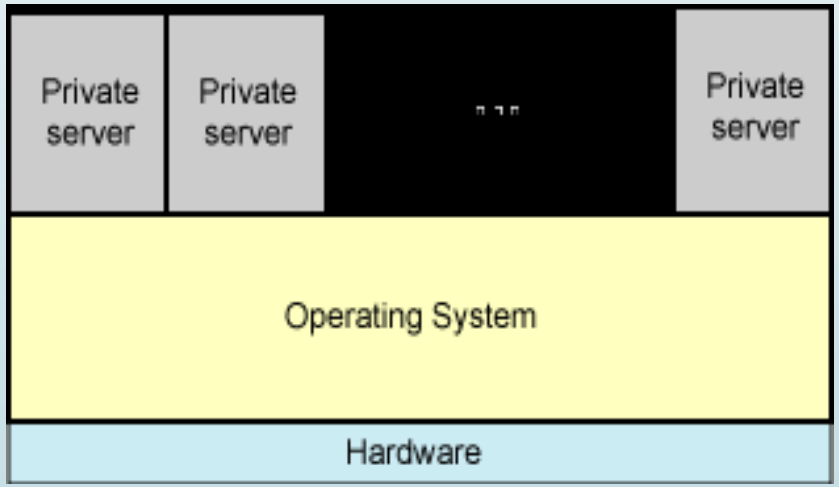
Hardware enabled virtualization

- the virtual machine has its own hardware and allows a guest OS to be run in isolation.
- Intel VT (IVT)
- AMD virtualization (AMD-V)
- Examples:
  - VMware Fusion
  - Parallels Desktop for Mac
  - Parallels Workstation



Operating system-level virtualization

- virtualizing a physical server at the operating system level, enabling multiple isolated and secure virtualized servers to run on a single physical server.
- Examples:
  - Parallels Workstation
  - Linux-VServer, Virtuozzo
  - OpenVZ, Solaris Containers
  - FreeBSD Jails
  - Chroot ?



Application Virtualization

- typically for the purpose allowing application binaries to be portably run on many different computer architectures and operating systems.
- http://en.wikipedia.org/wiki/Comparison_of_Application_Virtual_Machines
- Examples:
  - .NET CLR
  - JVM
  - Script Languages:Python,Ruby,Javascript...

Resource Virtualization

- ✓ LVM
- ✓ SAN
- ✓ VPN/NAT
- ✓ Multiprocessor and multi-core
- ✓ Cluster and Grid computing
- ✓ Partitioning

Virtualization Under Linux(1)

- UML (User Mode Linux)
  - http://user-mode-linux.sourceforge.net/
- KVM (Kernal-based Virtual Machine)

  - From Linux-2.6.20
  - http://kvm.qumranet.com/kvmwiki
- XEN

  - http://xen.xensource.com/

Virtualization Under Linux(2)

- QEMU
  - http://fabrice.bellard.free.fr/qemu/
- QEMU Accelerators
  - KQEMU
  - QVM86
  - VirtualBox (released in January 2007)
  - KVM with QEMU

Virtualization Under Linux(3)

- Bochs (GPLed, very slow)
  - A portable x86 and AMD64 PCs emulator mostly written in C++ and distributed as free software under GPL.
  - http://bochs.sourceforge.net/
- VirtualBox(commercial&open source, fast)
  - http://www.virtualbox.org/
- VMWare (Workstation,Server,Player)

Virtualization Under Linux(4)

- SWSOFT Virtualizations
  - http://www.swsoft.com 

  - http://www.parallels.com/ 

  - http://openvz.org/ 

- Linux-VServer
  - http://linux-vserver.org/ 

- Compare with:
  - FreeBSD Jail
  - Solaris Containers (Zones)

Linux Virtualization in Windows(1)

- ✓ VMWare
- ✓ Virtual PC
- ✓ VirtualBox
- ✓ Bochs
- ✓ QEMU