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Lecture - 3
Cloud Computing and Virtualization

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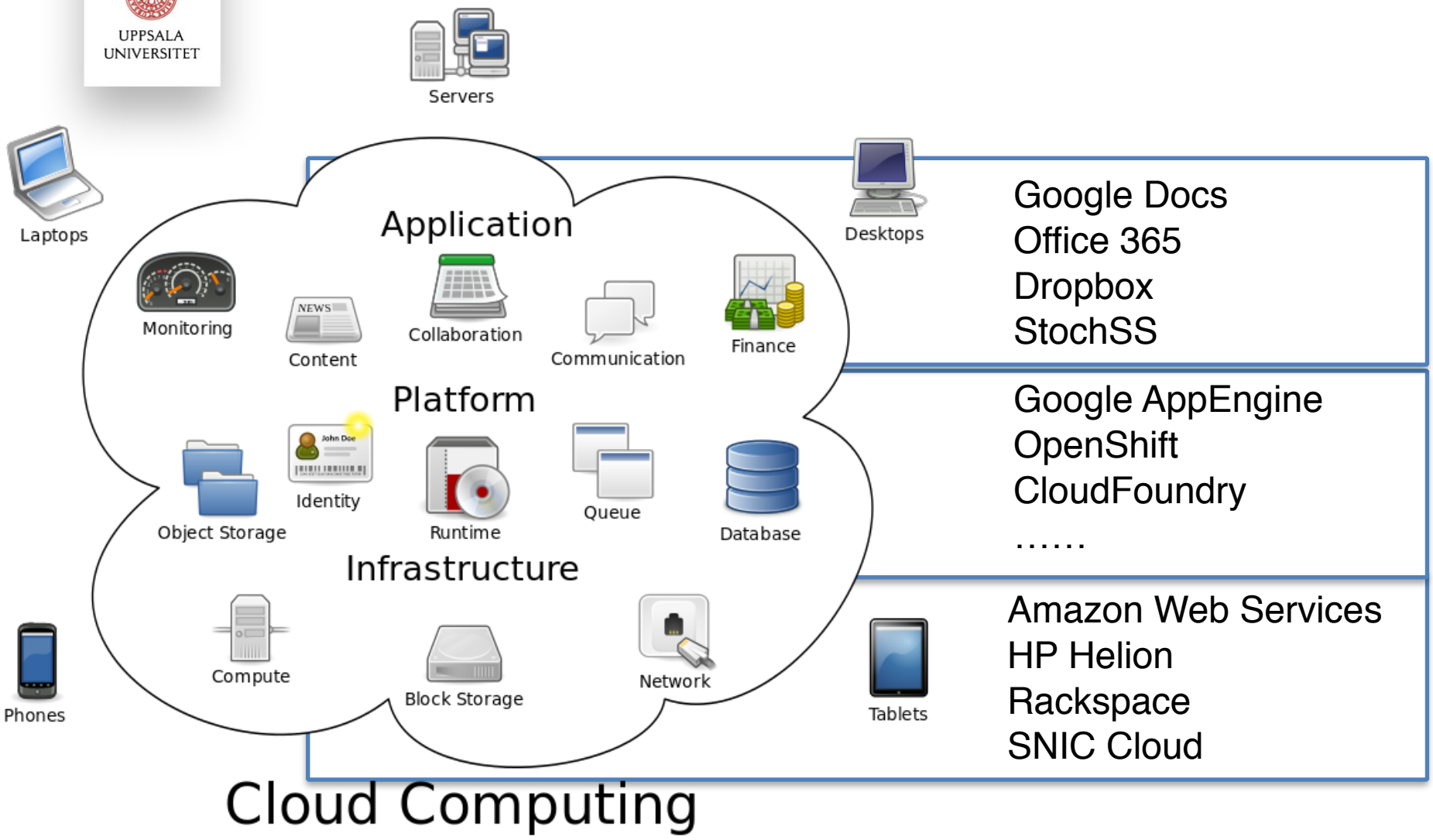

Cloud Computing

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Cloud Computing

"Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model is composed of five essential characteristics, three service models, and four deployment models."

NIST-National Institute of Standards and Technology

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IaaS

- Infrastructure-as-a-Service (IaaS)
- The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications.
- Aims:
  - Transparent access to the **resources**
  - Easy to access
  - Pay-as-you-go model

http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

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PaaS

- Plateform-as-a-Service (PaaS)

- The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider.

- Aims:

  - Transparent access via **IaaS**
  - Easy to manage
  - Pay-as-you-go model

http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

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SaaS

- Software-as-a-Service (SaaS)
- The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through either a thin client interface, such as a web browser (e.g., web-based email), or a program interface.
- Aims:
  - Transparent access via **PaaS**
  - Easy to manage
  - Pay-as-you-go model

http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf

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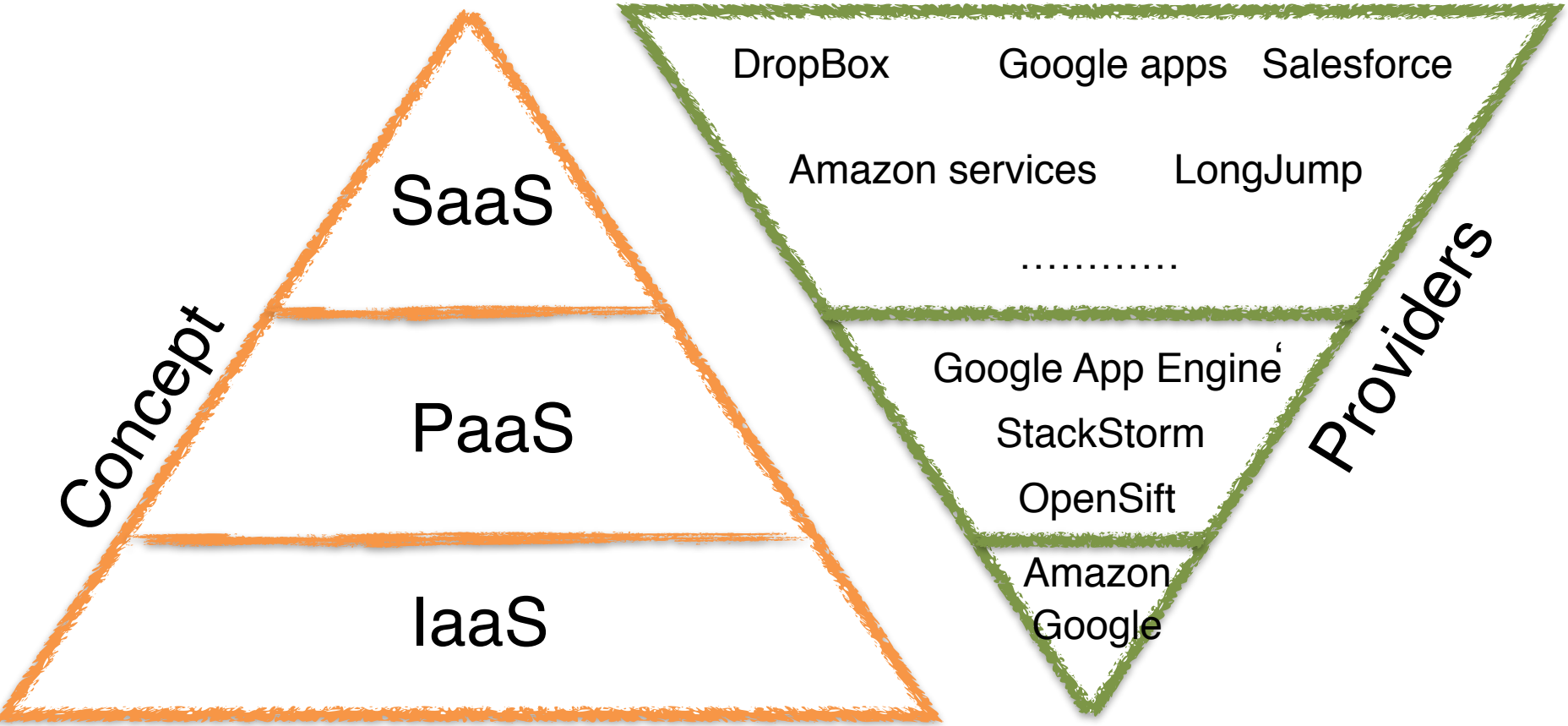
IaaS, PaaS and SaaS



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Virtualization

- Nutshell: The abstraction of available resources

- Definition:

  Virtualization technologies encompass a variety of mechanisms and techniques used to decouple the architecture and user-perceived behavior of hardware and software resources from their physical implementation.

- Whereas, resources can be either compute, storage, network..etc

http://www.computer.org/csdl/mags/co/2005/05/r5028.html

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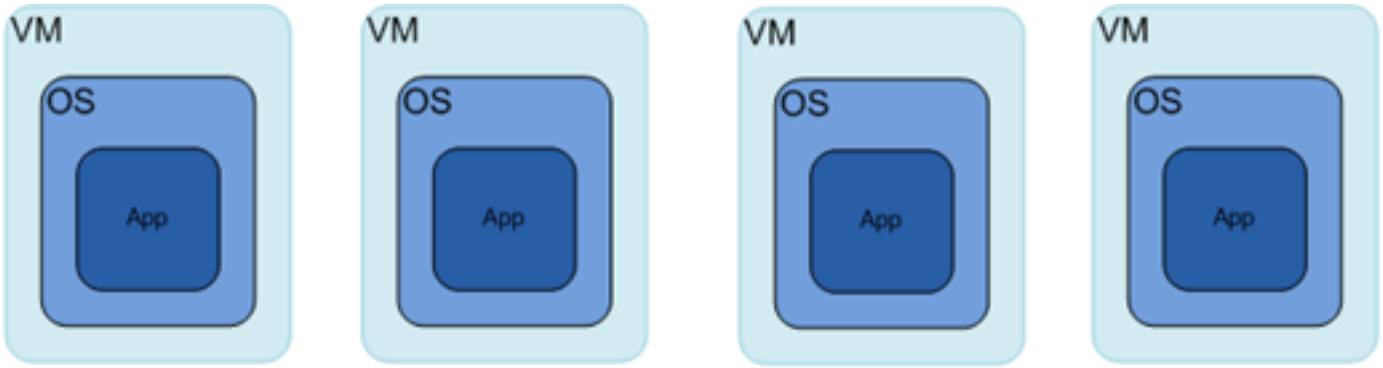
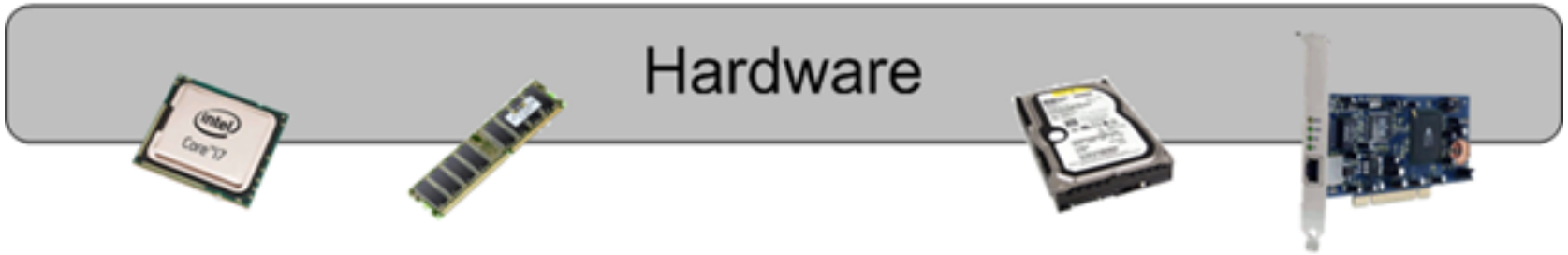
Virtualization
Basic illustration



Virtualization layer



http://blog.cloudpassage.com/2011/07/22/the-difference-between-virtualization-and-cloud-computing/

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Virtualization

- Large verity of platforms:
  https://en.wikipedia.org/wiki/Comparison_of_platform_virtualization_software

- Old concept, relaunched (article from 1974)
  http://cs.nyu.edu/courses/fall14/CSCI-GA.3033-010/popek-goldberg.

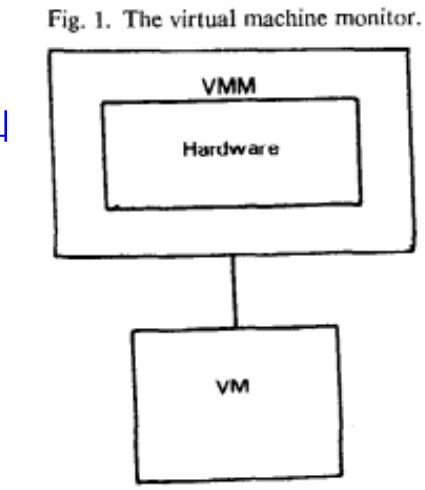

Fig. 1. The virtual machine monitor.

  - Properties of virtual machines (VM)
    - Efficiency
    - Resource control
    - Equivalence

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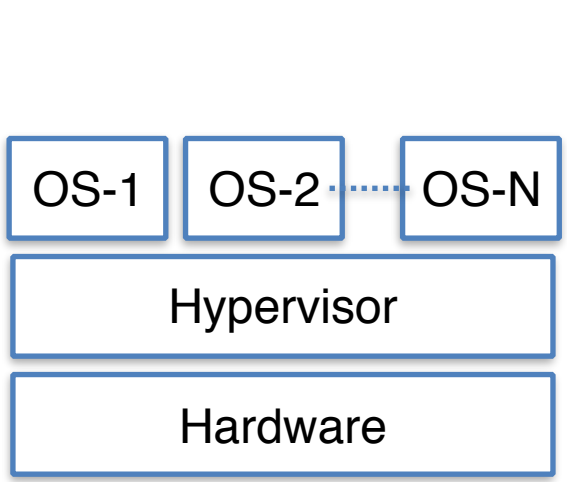
Virtualization

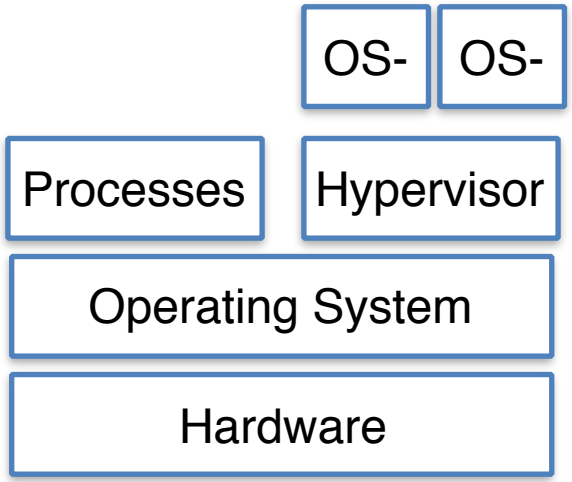
- Virtualization Layer

  Hypervisor or Virtual Machine Monitor (VMM) is a software that provides an interface between hardware and virtual operating systems.

- Types of Hypervisors
  - Bare-Metal
  - Hosted



Bare-Metal



Hosted

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Virtualization

- Virtualization could address following issues:
  - Under-utilized resources
  - Complicated system management
  - Limited access to shared resources
  - Inefficient power consumption
  - Tight coupling with underlying resources
  - …

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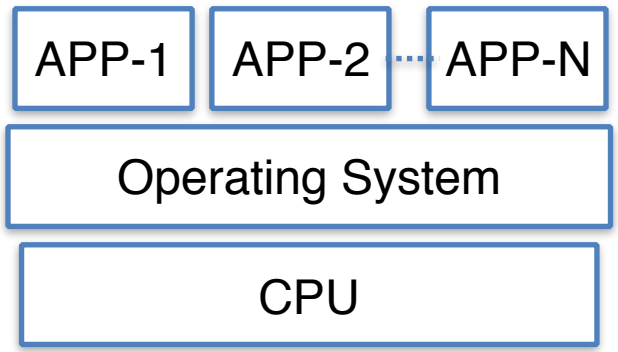
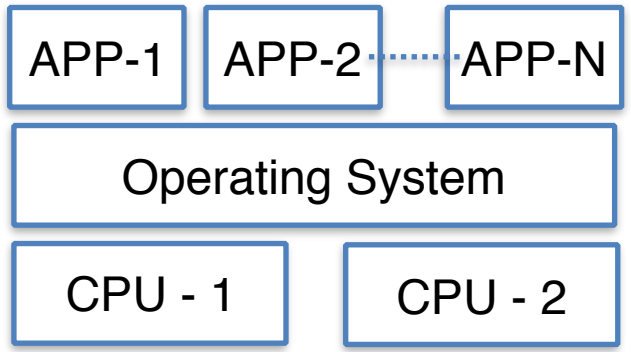
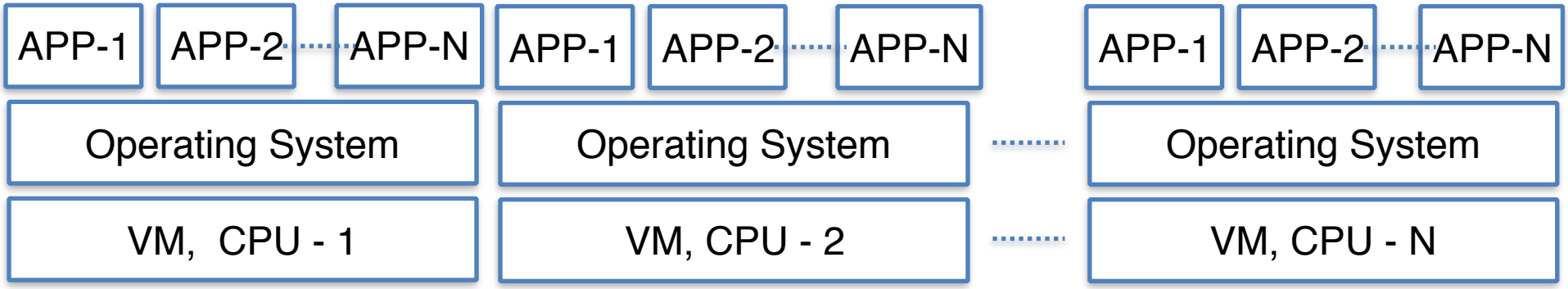
Virtualization



Multi-tasking



Multi-core or Hyper-threading



Virtualization

http://www.hardwaresecrets.com/everything-you-need-to-know-about-the-intel-virtualization-technology/

Virtualization Types

- Platform virtualization
- Memory virtualization
- Desktop virtualization
- Application virtualization
- Network virtualization
- Storage virtualization

Virtualization
Platform virtualization

- Full virtualization
- Para virtualization
- Hardware assisted virtualization
- Operating-System (OS) level virtualization
- Hybrid virtualization

http://www.vmware.com/files/pdf/VMware_paravirtualization.pdf

Virtualization Full

- Guest operating system (VM) is unaware of host OS
- Non-critical instructions run directly on hardware
- Runtime translation of critical non-virtualizable instructions in hypervisor
- Not best in performance

Virtualization Para

- Thin layer interfaces between each guest OS and underlying hardware
- Need Guest kernel modification
- No need of runtime translation for critical instructions
- Superior in performance
- Requires expertise to patch the kernels

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Virtualization Hardware assisted

- Hardware provides support to run instructions independently
- No need to patch the kernels
- Runtime translations not required
- Better performance in comparison to other variants
- Greater stability

Virtualization Hybrid

- Combination of
  - para
  - hardware assisted virtualization
- Address the issues related to security and system stability
- Use patched guest OS along with hardware support

Virtualization OS level

- Same OS for both Host and guest machines
- Userspace is completely isolated
- High performance
- Extremely light-weight
- Recently acquire lots of attention in Cloud world

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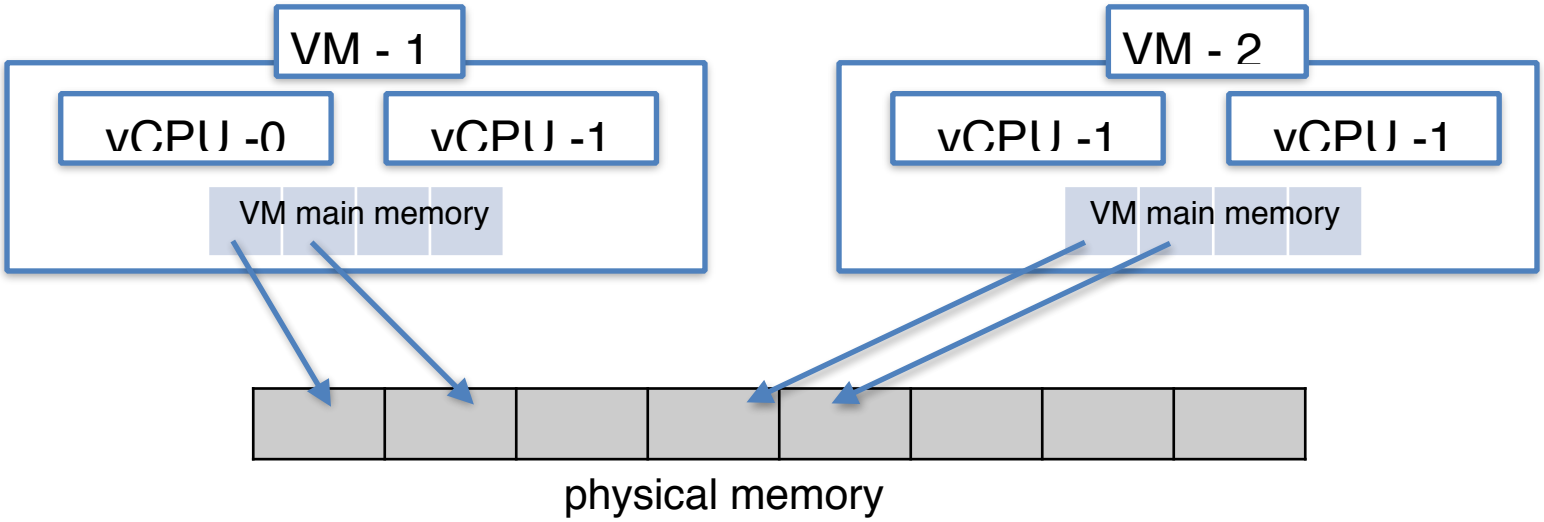
Virtualization Memory

- Brings concepts of consolidation and cost effectiveness

- Managed with virtualizing physical memory by addition of an extra level of address translation



Question: Is the concept of “virtual memory” in a single operating system same as the concept of virtualization in terms of VMs?

Answer: NO

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Virtualization
Desktop and Applications

- Desktop and Applications run on servers
- Stateless thin clients connected to servers
- Efficient system management
- Requires high-end servers for system stability

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Virtualization Network and Storage

- Similar idea of providing an abstraction layer to the physical infrastructures
  - In networks abstraction will be at the level of
    - Routers
    - Switches
    - load balances
    - Gateway
    - Firewalls
    - …
  - Storage abstraction allows single backends to be used for different requirements
    - Ephemeral
    - Persistant
    - Specialize storage backends

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Virtualization Network and Storage

- Aim is to provide:
  - Efficient infrastructure utilization
  - Agility
  - Isolation
  - Security
  - ….

Virtualization Hardware Acceleration

- Aims:
  - enhance the performance
  - reduce the complexity in the hypervisors/VMM
- Intel and AMD chips support VT
  - Intel models

    http://ark.intel.com/Products/VirtualizationTechnology
  - AMD model

http://support.amd.com/en-us/kb-articles/Pages/GPU120AMDRVICPUsHyperVWin8.aspx

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Virtualization
Concept of overcommits

- Process of allocating more than the available physical resources
- Common types:
  - CPU Overcommits
  - Memory Overcommits
  - Storage Overcommits
- Strong requirement from infrastructure providers

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Virtualization
Concept of overcommits

- Pros:
  - Favorable economic model
  - Efficient resources utilization
  - Support green computing
- Cons:
  - Performance loss or unstable system response
  - Complex system understanding
  - VM shutdown by the hypervisor (extreme cases)

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Virtualization CPU overcommit

- Allows more virtual CPUs than physically available
- Example: In case of 8 physical cores

```
8 * overcommit-number = total-number-of-virtual-CPUs
```

- Open stack KVM allows:

```
overcommit-number = 16.0 (max) , 1.0 (no overcommits)
```

http://docs.openstack.org/kilo/config-reference/content/section_compute-scheduler.html

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Virtualization
Memory overcommit

- Allocate more than physical memory
- Open stack KVM allows:

```
overcommit-number = 1.5GB
```

- 1.5 GB is required by the instance
- can run on any physical host having1GB free memory

http://docs.openstack.org/kilo/config-reference/content/section_compute-scheduler.html

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Virtualization Hypervisors

- Contribution from industry and academia
  - Xen
    - Project from Cambridge Computer Laboratory
  - VMware
    - Commercial product
  - KVM (Kernel-based Virtual Machine)
    - A product of Open Virtualization Alliance (OVA)
  - Qemu
    - Opensource machine emulator and virtualizer
  - …..

http://www.xenproject.org/developers/teams/hypervisor.html
http://www.vmware.com/
https://openvirtualizationalliance.org/what-kvm
http://wiki.qemu.org/Main_Page

Virtualization KVM

- Hypervisor for x86 solutions with complete hardware support
- Run multiple guest OSes with private virtualized hardware: network card, memory, disk etc
- Consist of Loadable kernel modules:
  - kvm.ko for core virtualization
  - processor specific kvm-intel.ko or kvm- amd.ko

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Virtualization Tools KVM

- Opensource software
- Support Linux and Windows (limited)
- Peripheral support to the guest OS
- Wide variety of management tools
- Backend for compute resources in many Cloud suites
- Allow resources overcommits

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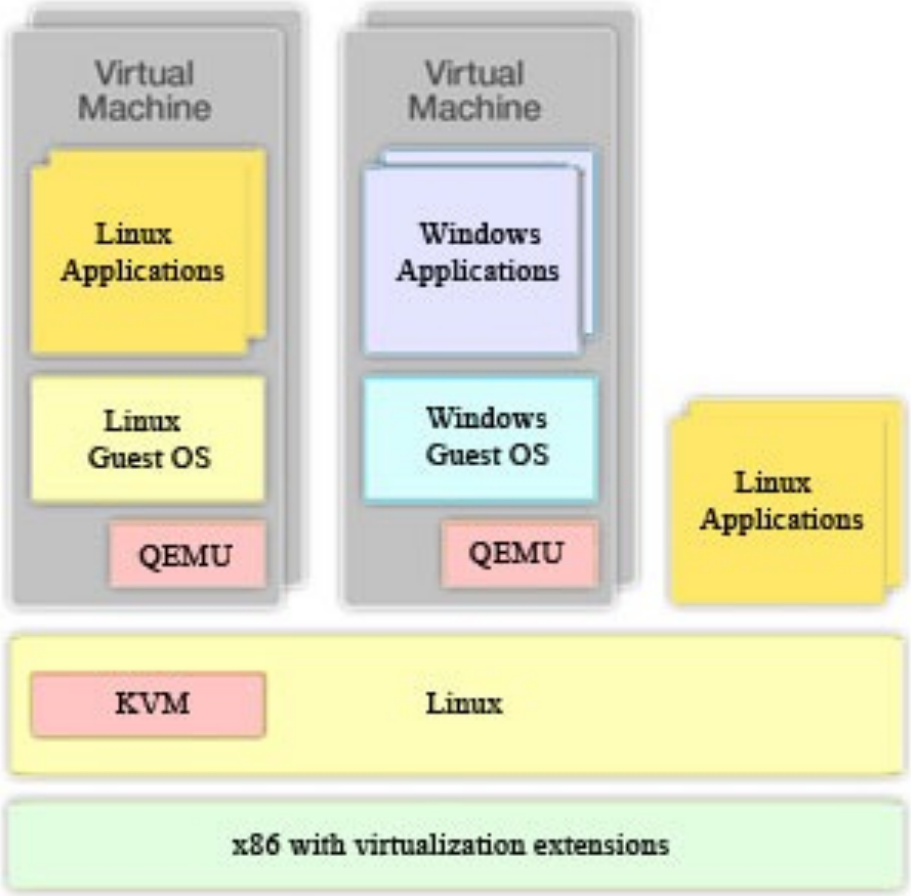
Virtualization Tools KVM



- KVM architecture for x86 system
- support nested virtual machines

http://www-03.ibm.com/systems/kvm/whykvm.html

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Virtualization Tools Qemu

- Qemu runs in following modes:
  - Emulator; hypervisor runs in the user space
  - Hypervisor; Hardware supported virtualization (KQemu)
- Support for multiple OSes
- Based on Xen or KVM, Qemu supports nested virtualization

http://wiki.qemu.org/Main_Page

Virtualization Tools
Qemu

- Opensource software
- Extensive peripheral support
- Diversity of management tools
- Backend for compute resources in many Cloud suites
- Recommended for testing and development environments

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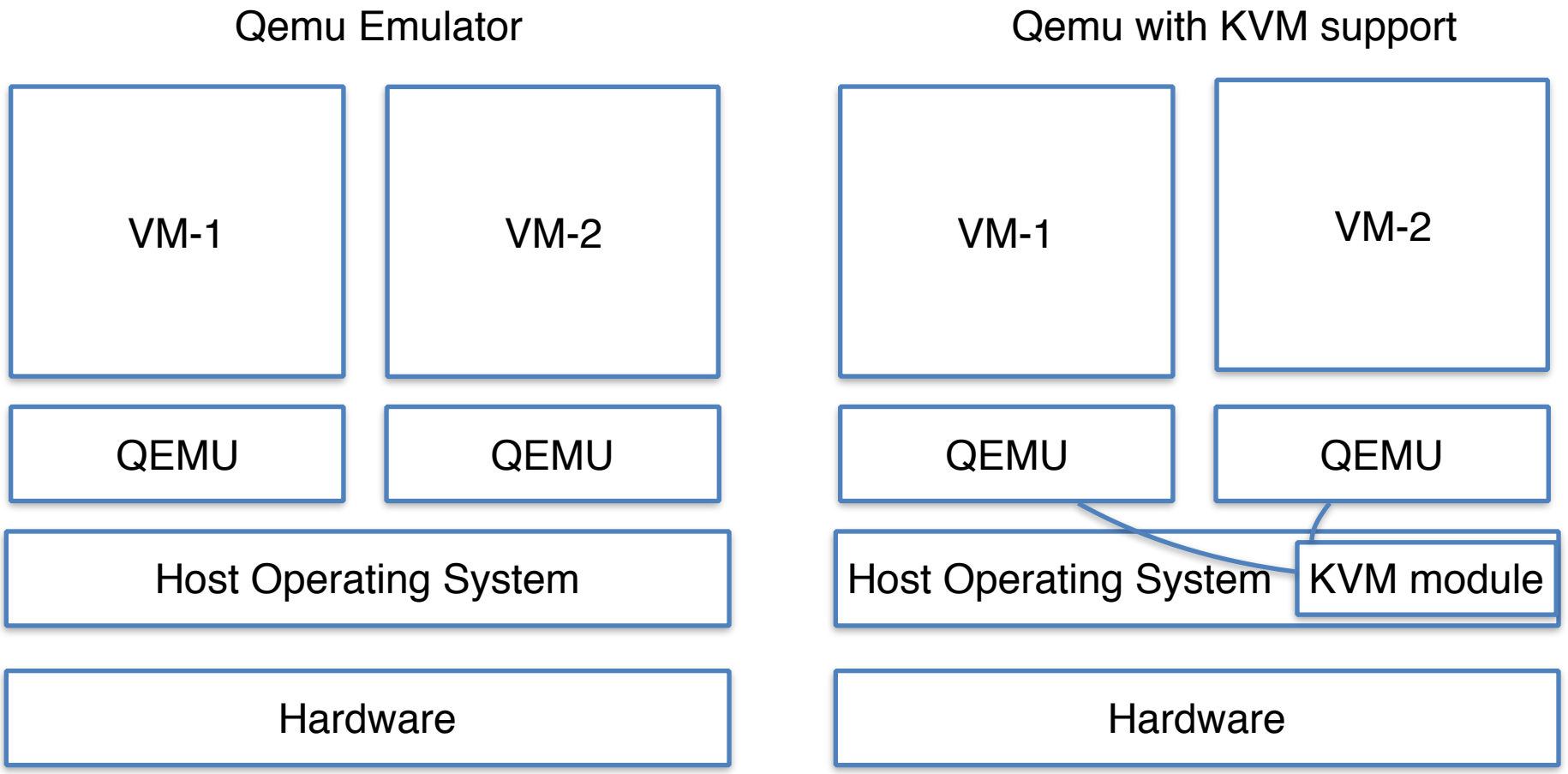
Virtualization Tools Qemu



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Virtualization Tools VMware

- Commercial product by VMware.Inc
- One of the leading server virtualization system
- frontend
- Variety of system management components
- Backend for compute resources in number of Cloud software
-

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Virtualization Tools VMware

- VMware vSphere consists of:
  - VMware ESXi
  - VMware vCenter Server
  - VMware VMFS
  - VMware Virtual SMP
  - VMware Clients (Desktop and Web access)
- ESXi is the virtualization platform
- vCenter Server is a service that act as a administrator to ESXi platform

http://pubs.vmware.com/vsphere-51/topic/com.vmware.vsphere.vcenterhost.doc/GUID-302A4F73-CA2D-49DC-8727-81052727A763.html

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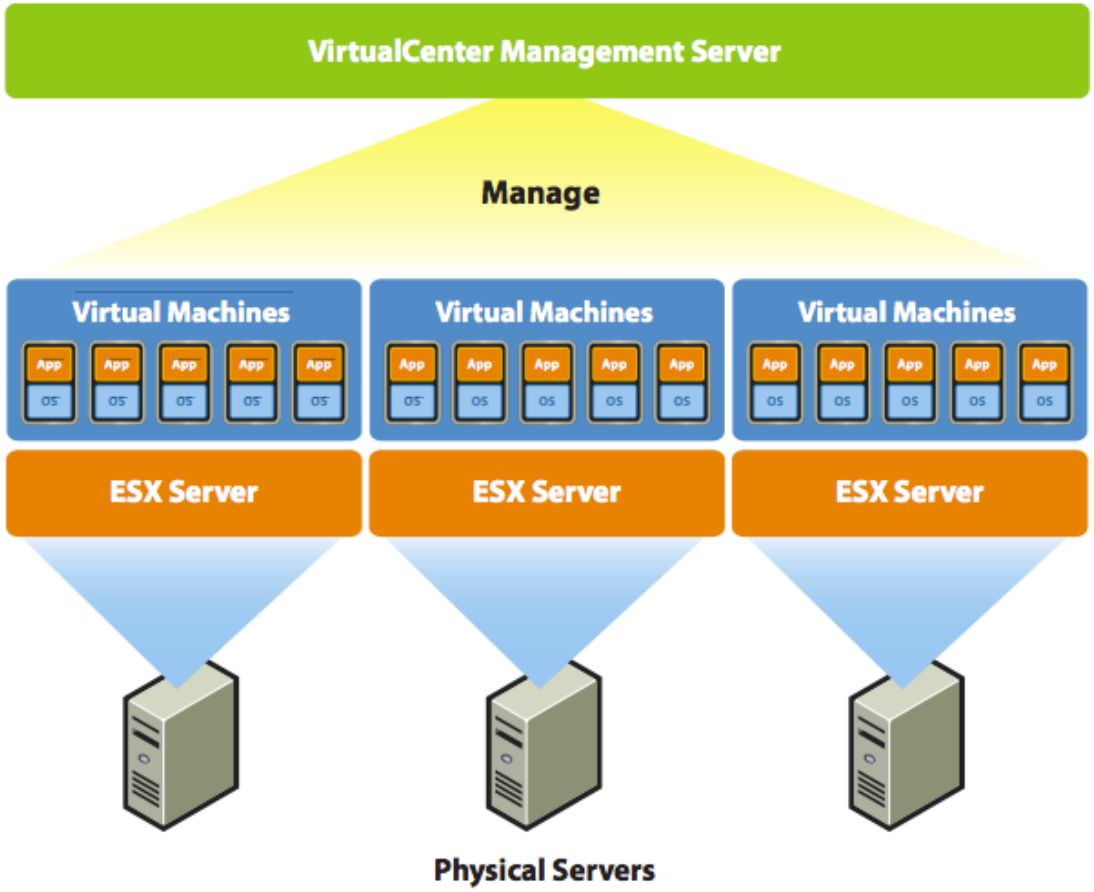
Virtualization Tools VMware

- Overview Architecture



http://www.vmware.com/pdf/vi_architecture_wp.pdf

- Comprehensive solution for data center virtualization
-

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Role of LIBVIRT API

- Virtualization API
- Provide a common and stable layer to securely communicate with guest OS
- Supports all major hypervisors
- Open source project for secure VM management tasks
- Used to build applications based on virtual environment

http://libvirt.org/

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Virtualization Interesting Articles

- A quantitative comparison between xen and kvm (*2010 J. Phys.: Conf. Ser. 219 042005*)
- Performance Measuring and Comparing of Virtual Machine Monitors (*2008 IEEE/IFIP International Conference on Embedded and Ubiquitous Computing*)
- Recommendations for Virtualization Technologies in High Performance Computing (*2nd IEEE International Conference on Cloud Computing Technology and Science*)
- A Comparison of Software and Hardware Techniques for x86 Virtualization (Advance level) (*ASPLOS XII Proceedings of the 12th international conference on Architectural support for programming languages and operating systems*)

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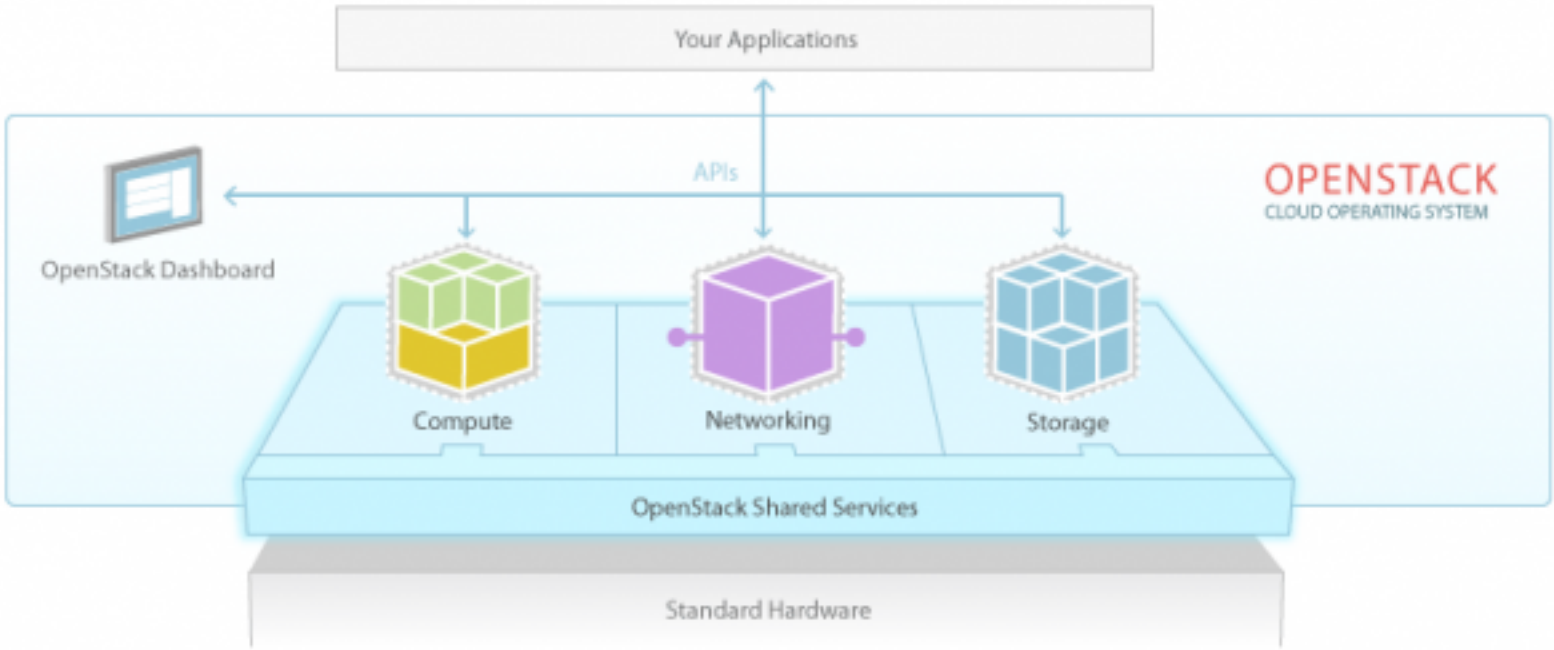
Virtualization and Clouds OpenStack

- Open source platform for build public and private Clouds



http://www.openstack.org/

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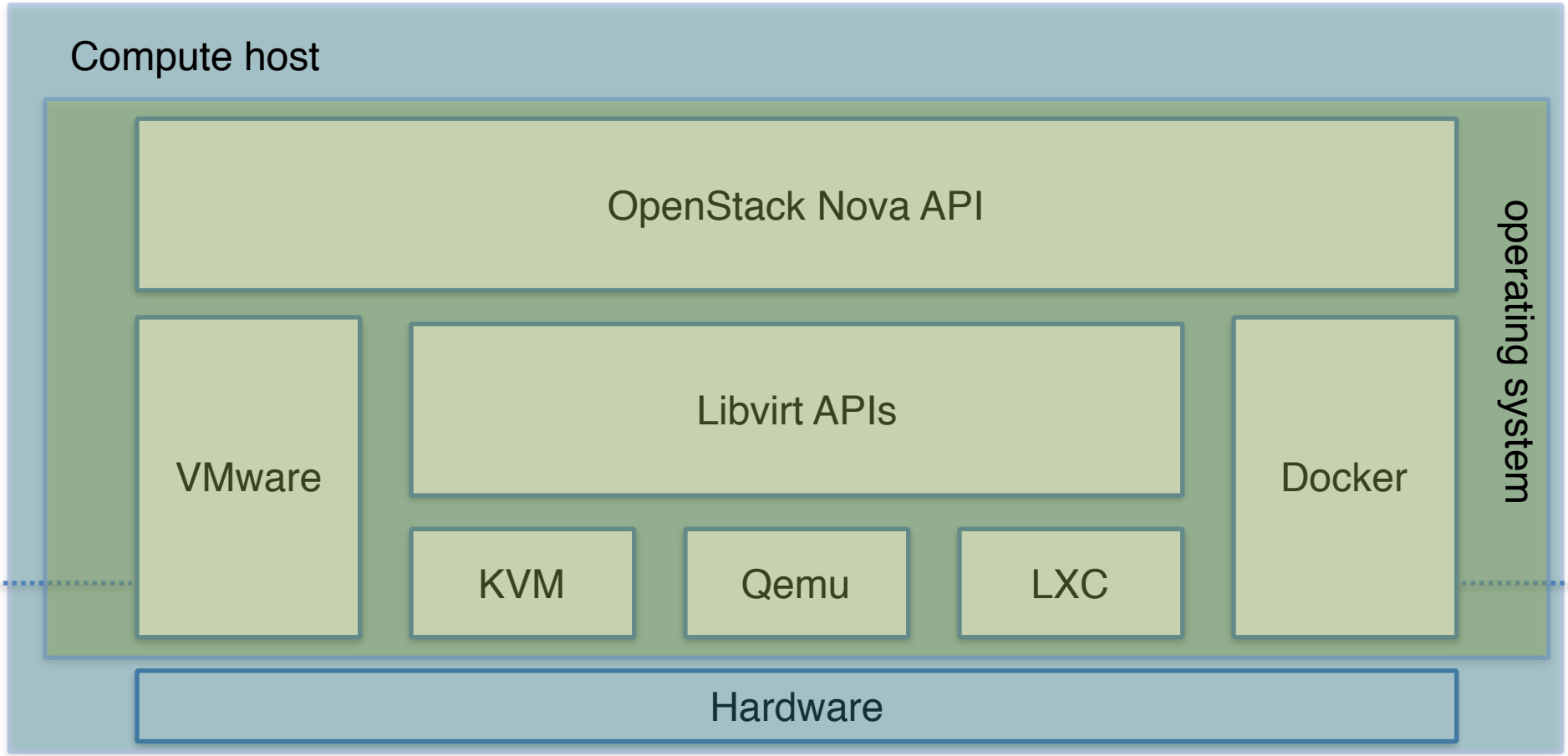
OpenStack Compute

- OpenStack Compute Project (NOVA)



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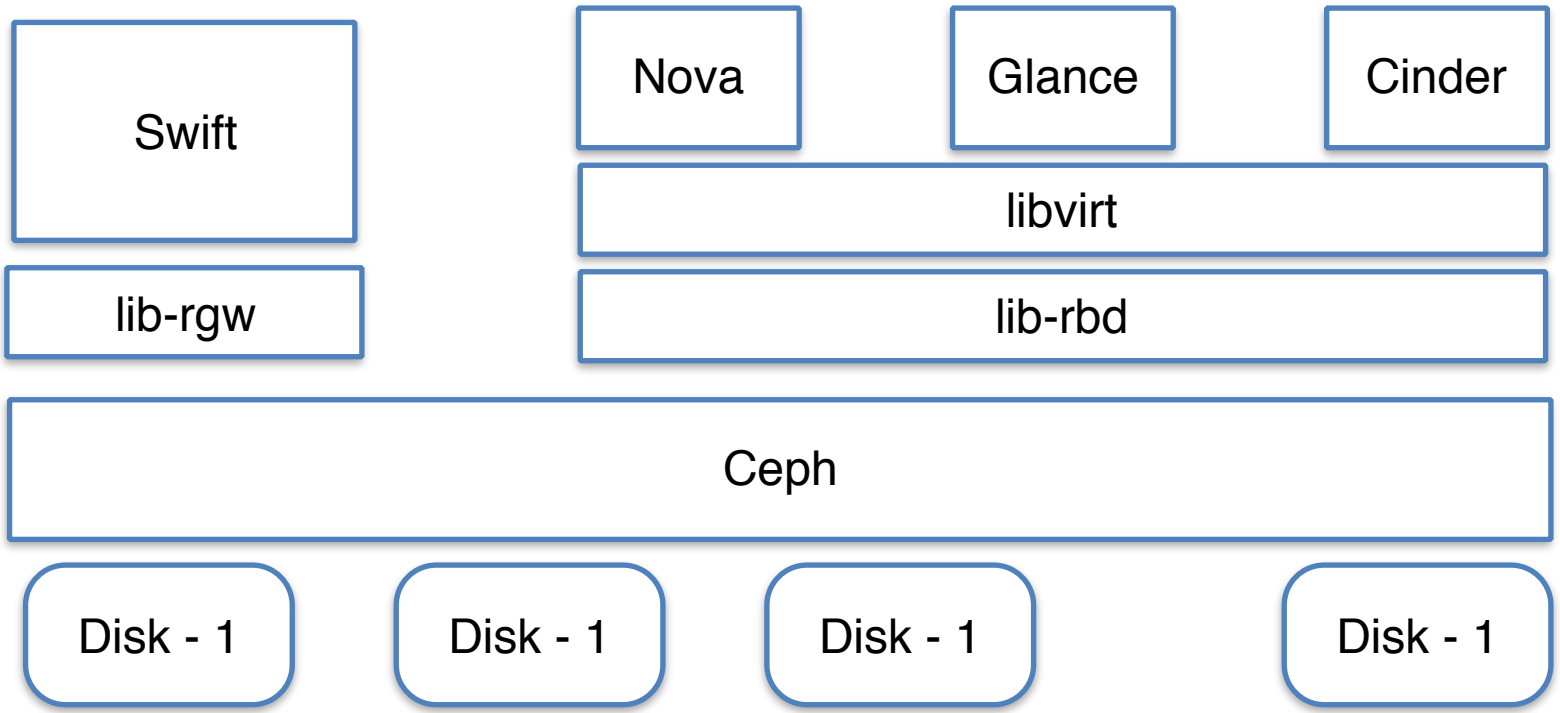
Cloud Virtualization Storage

- OpenStack volume (Cinder)
- OpenStack object store (Swift)

SNIC Cloud Storage backend



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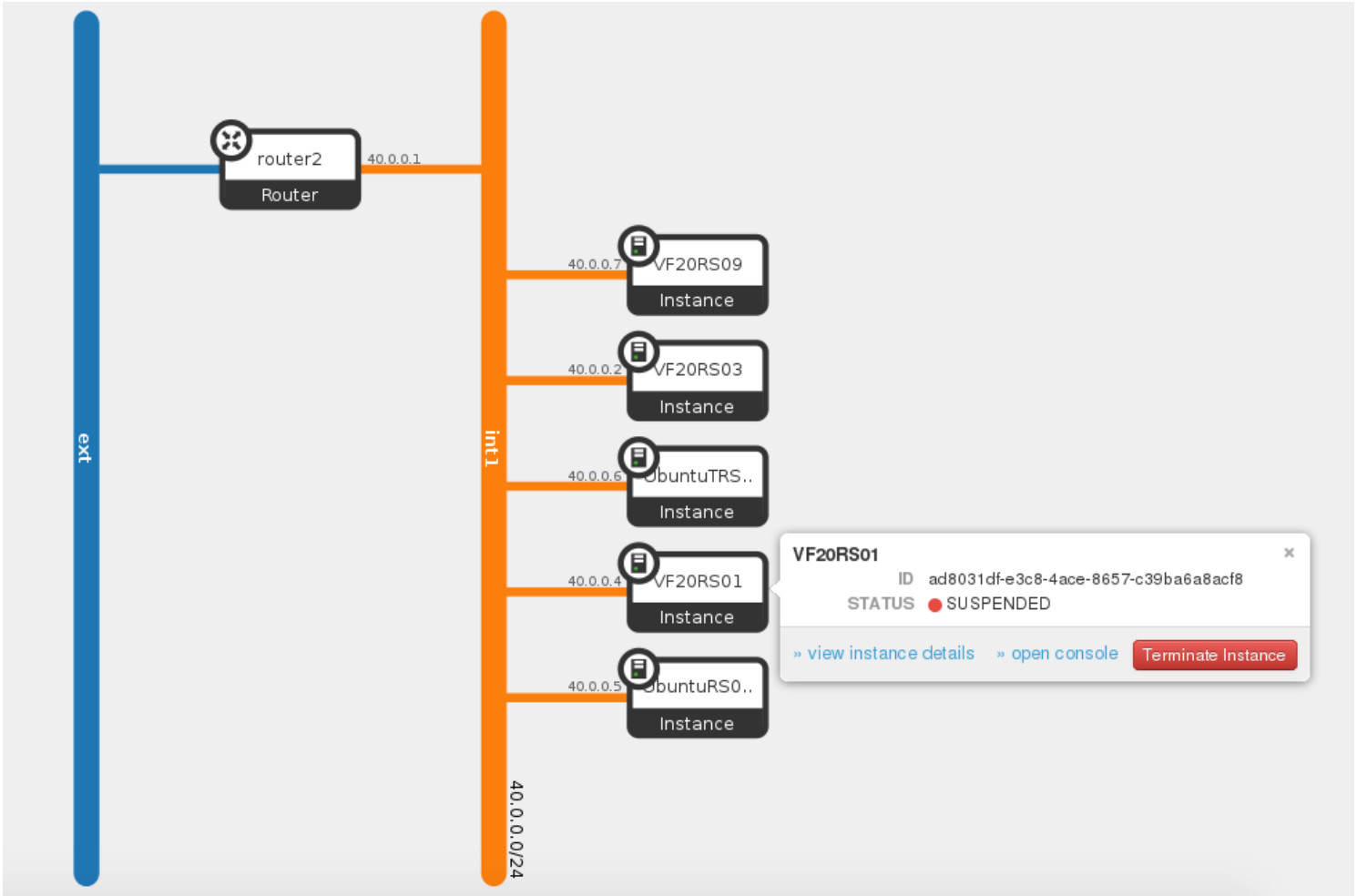
Cloud Virtualization Network

- OpenStack network components (Neutron)



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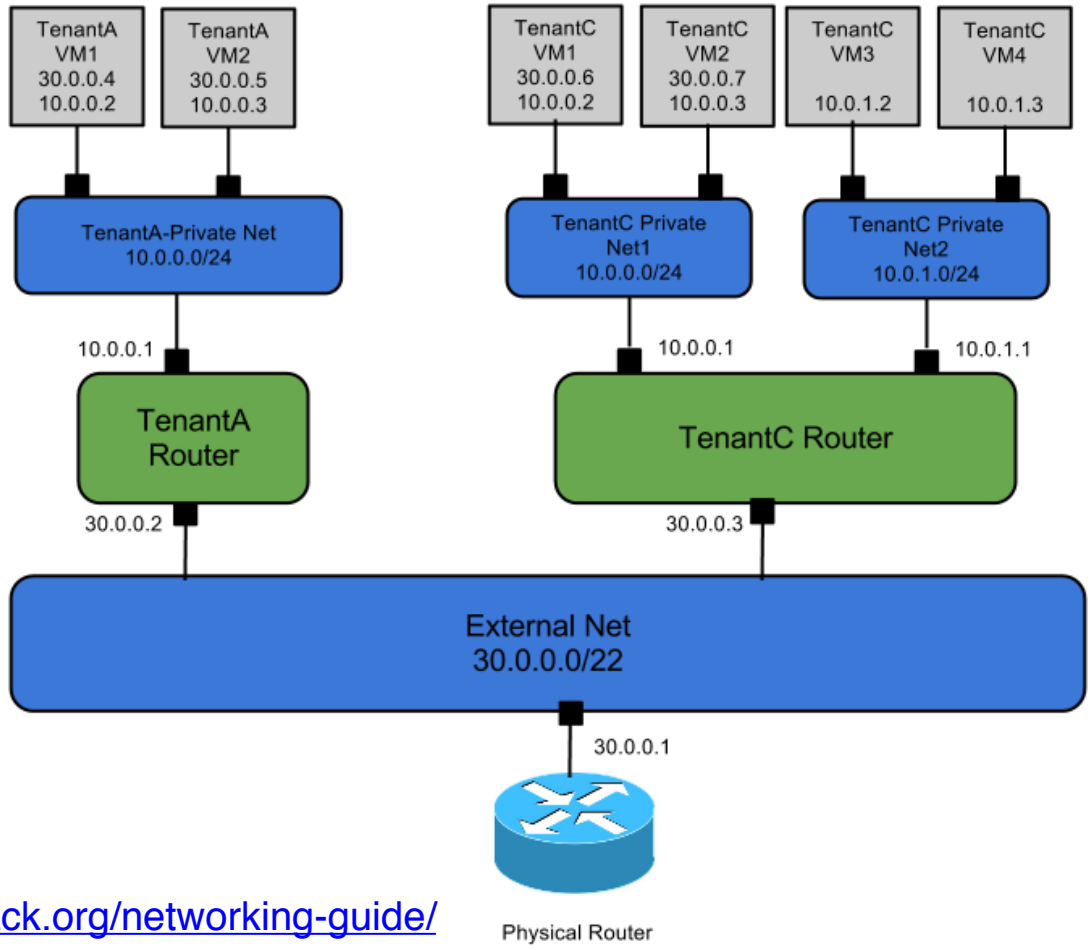
Cloud Virtualization Network

- OpenStack network components (Neutron)



http://docs.openstack.org/networking-guide/

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DEMO

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DOES VIRTUALIZATION EFFECT THE SYSTEM PERFORMANCE?

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Performance

- Yes performance loss may occur but it is highly dependent on
  - Type of virtualization layer (Hypervisor)
  - Use case
- CPU bound application will perform differently than IO bound or network intensive applications

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Performance

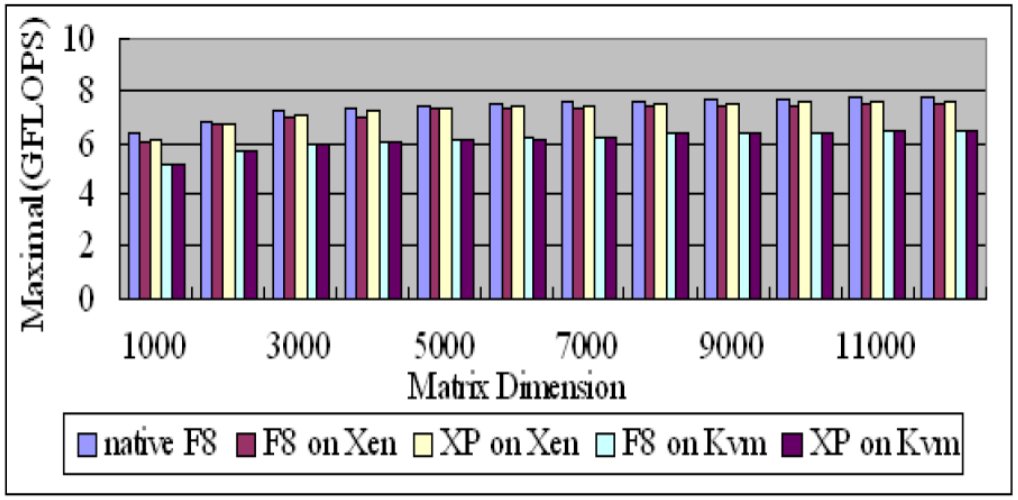

Figure 1. LINPACK results of virtulized Fedora8 and XP in Xen,KVM and native Fedora8

- In comparison with the physical node:
- KVM perform 83.46%
- Xen perform 97.28%

- Reason; Critical instruction test verses para-virtualization

In both cases, There is a performance different compare to physical machine.

Performance Measuring and Comparing of Virtual Machine Monitors (*2008 IEEE/IFIP International Conference on Embedded and Ubiquitous Computing*)

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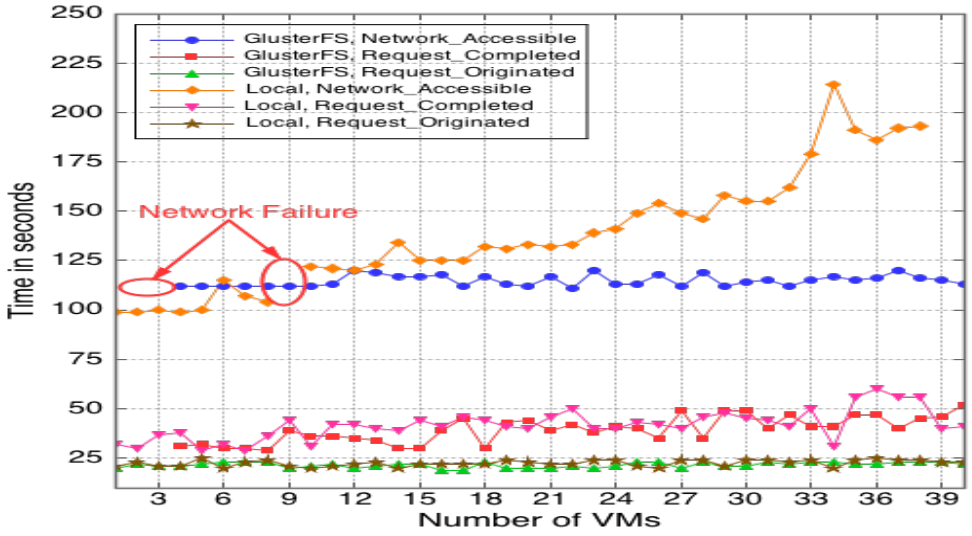
Performance

- Application Level
  - 4% performance loss evaluated with the
  - HEPSPEC-2006 (Thanks to Ulf Tigerstedt, CSC for help with HEPSPEC tests)
- System Level
  - VM boot response both at local vs GlusterFS based setup



Article: A scalable infrastructure for CMS data analysis based on OpenStack Cloud and Gluster file system