Cloud Computing

Master MABIDA

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Structure

- Elements of cloud Computing
- Virtualization
- Cloud Computing
- High Availability
- vSphere Infrastructure
- Security on the Cloud
- Conversions among VM and physical machines
- vCenter, datacenters and cluster management
- How to work with Virtual Machines

Datacenter, definition

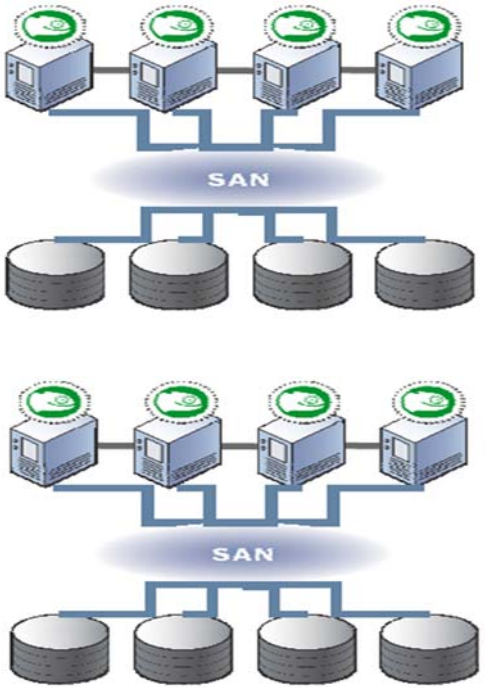
Datacenter

- A computer factory/farm in which servers/computers are called HOSTS and are hosted and organized:
  - power, net maintenance, etc.
  - As: industrial computers, blades
- They can be exploited for private purposes, grid, cloud computing, renting/hosting, etc.

Server

Infrastructure, definition

- A set of datacenter and clusters
- A set of
  - NAS: Network Area Storage
  - SAN: Storage Area Network
- Etc..



Motivations for Cloud computing and Virtualization

- **Computer Based Physical Systems (servers)** are
  - not flexible:
    - The HW/SW has to be dimensioned for the workload worst case and not for the real/typical one
    - HW/SW can be hardly reused for different purposes since specific allocation is performed
  - subjected to HW failure, and thus:
    - Software has to be installed again when changing hardware
    - OS has to be reinstalled in most cases
  - Subjected to high costs of setup, installation and use:
    - Power, conditioning, network connection, etc.
  - not scalable, to scale up frequently implies hardware change/re-eng.
    - Data duplication, migration, distribution of activities among HW
    - Balancing or workload, add more HW, sharing databases, etc.

Final Motivations

- Reduction of costs for HW and operating system SW maintenance.
  - High costs to guarantee high availability: 99,999% of up time
  - High costs to guarantee high reliability
  - High costs to follow the HW/SW technological trends for performances, computational needs
  - Critical mass is needed to justify HW costs
- Sharing resources
  - Among for multiple applications and solutions
- Needs of High flexibility in terms of features
  - Most of the SW is becoming a services (licensing per year/month or users) and not anymore a product.
  - Many vendors provide complex SW systems in terms of services, on the basis of their consumption via network connection

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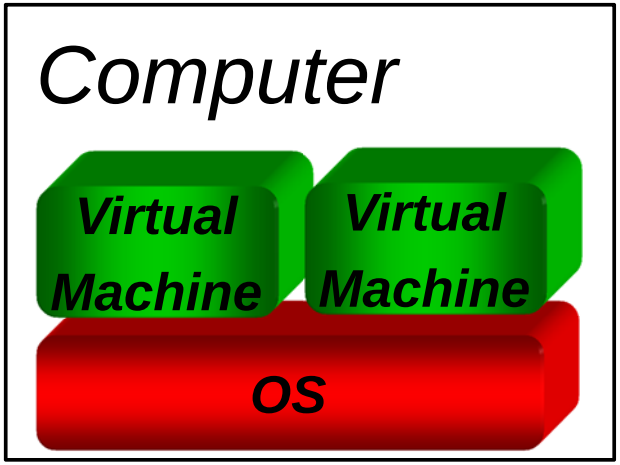
Concept of Virtual Server

- Hyp:
  - you can make the image (in a file) of the HD of a Physical Server (with its Operating System and files) and
  - put in execution the OS from the HD (file) by a program of "emulation“
- Thus we have:
  - a computer with an operating system OS
  - that hosts a program of "emulation“,
  - which in turn, it is capable to run in separate processes the images of the correspondign OS VM

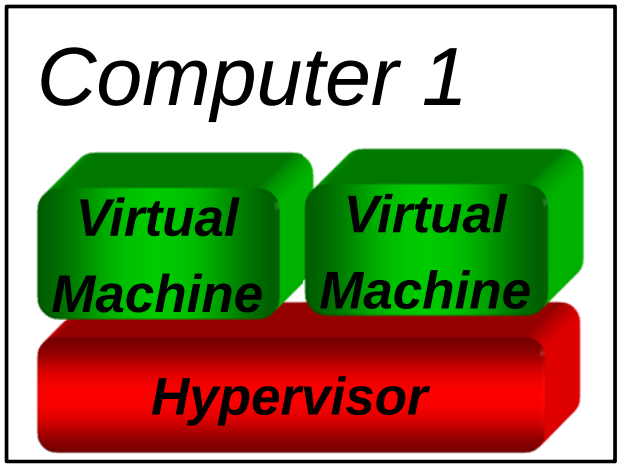


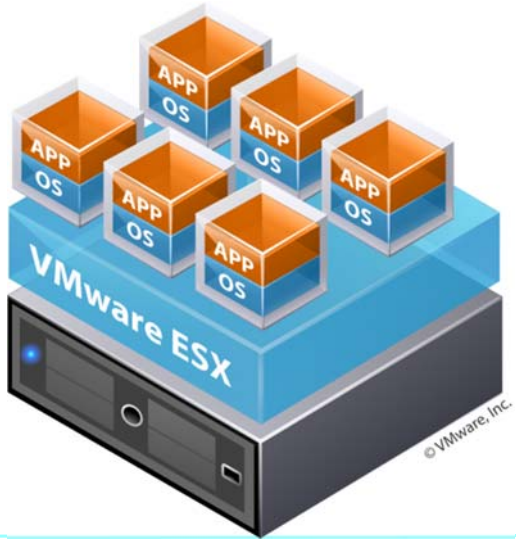
Typical Features for renting a Computer or a Virtual Machine into a Datacenter

- **Requesting** to have one or more Computers/Hosts and/or VMs
- **Hardware**:
  - CPU: 32/64 bit, number of cores/CPU, frequency of work, intel/amd, etc.
  - RAM memory: size and frequency of work
  - Power supply: fault-tolerant or not; with UPS or not, etc..
  - HD: space, speed (7.2, 15Kgiri), security level/RAID, type SAS/SATA, SCSI
  - Network features:
    - Number of connections/cards, number of IP addresses, static/DHCP
    - Transfer rate: minimum guaranteed, maximum possible, down/upload
    - Maximum transferred bytes: per day, per month, etc.
  - NAS/SAN, Network area storage/SAN, fiber/internet: size, RAID, etc.
- **Software**:
  - Operating systems
  - Software preinstalled into the Computer/VM, see in the following
- **Services**:
  - Periodic back up: details on HD space
  - Access to VM/Computer: remote desktop or KVM tool
  - Reboot or not of the Server, for example via Plesk.

Virtual Machine, Virtualization

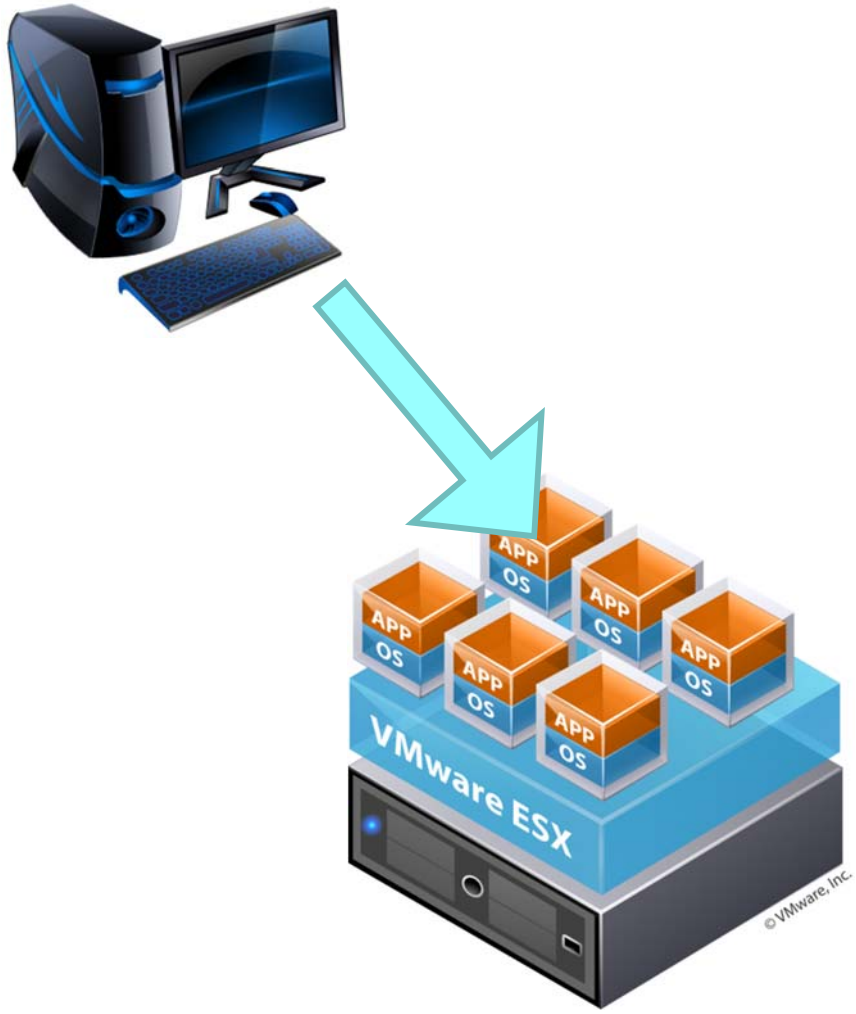
- **Virtual Machine:**
  - An image of an operating system that can be put in execution into a real host/computer creating a virtual computer that exploits a part of all of the host resources
    - E.g.: Host may be Linux-like while the VM may be Window, Mac, Linux, …
- **Virtualization**
  - Transforming a physical computer into a VM, virtual machine, hosted on some Host computer
- **Hypervisor** (VM Monitor) to manage the several VMs on the host





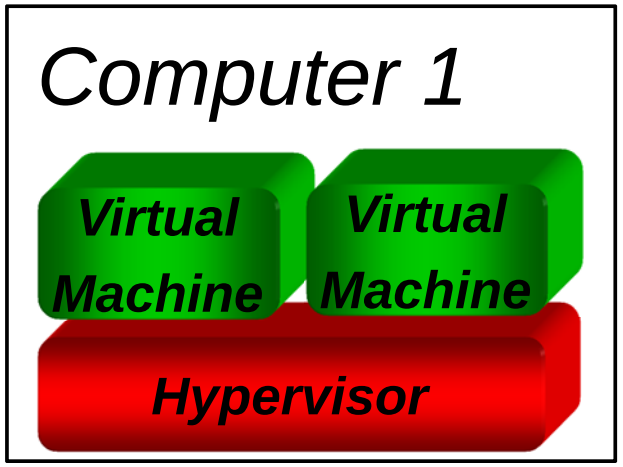
The Virtualization

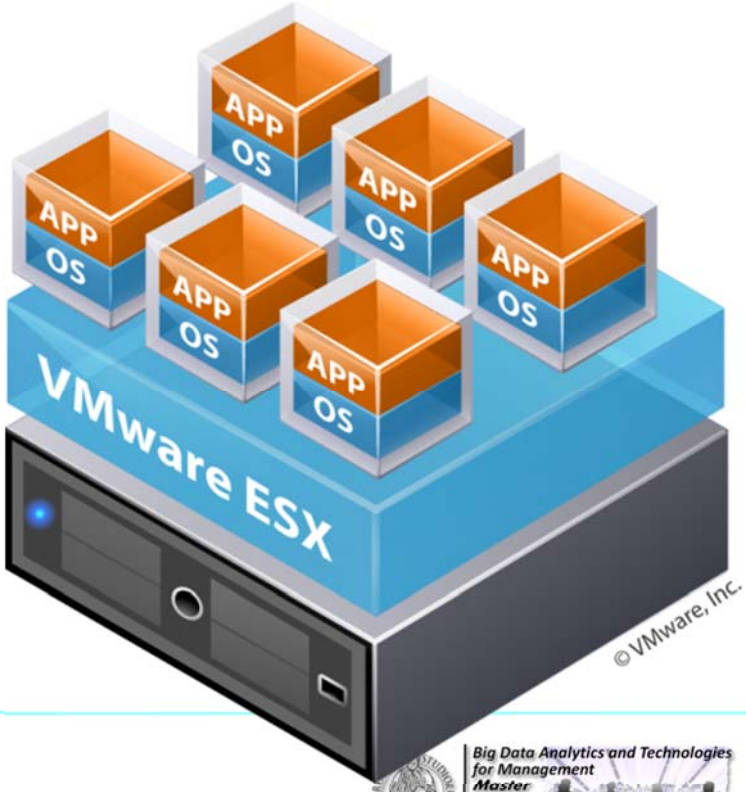
- Process by which it is possible to create a virtual machine, VM,
- For example by:
  - An installation DVD
  - Cloning a physical machine (P2V)



The Hypervisor

- It is the essential OS, that can be installed in a Host and canput in execution and manage one or more VM
- The Host is a server HW that host the Hypervisor
- ESX of Vmware is an Hypervisor.





Motivations for Cloud computing and Virtualization

- **Most of the Host/datacenter capabilities** are not exploited at 100% in every time instant
  - They are typically present in large industries/institutions or in large services: google, amazon, tiscali, Dada, ibm, cnr, etc
  - Their size is typically defined on the basis of the workload worst case
- ***If they are big***: the exploitation of the remaining resources for cloud/hosting is a solution to recover money, since a non working machine (like a caw) is a costs without any return.
- ***If they are small:*** it could be a solution to host machines on a professional infrastructure to reduce annual costs for HW/SW
  - Delegating to cluster owners the costs for *maintenance, renovating hardware, renovating software, network costs, back up costs, power supply, etc.*

Benefits of Virtual Machine

- **Main benefits:**
  - Separation of OS+SW with respect to the needed HW
  - Exploiting legacy solutions which can be wrapped into a VM and protected with a physical firewall without reinstalling and recompiling old applications.
  - The simple upgrade can be obtained by giving more CPU instead of changing HW and reinstalling all SW elements.
- **For example:**
  - An old Linux Server hosting several web portals with a old versions of: MySQL, PHP, etc.. and many configuration aspects: users, mailing lists, etc. very time consuming to port on a new server
  - An old Cobol application running only on an old Windows 2000 Server, which cannot be recompiled into a new Windows Server 2008 at 64 bits without spending months of work.
  - A Cobol application running on machine based on an IBM system 36….
  - Etc.

VM on PC workstations

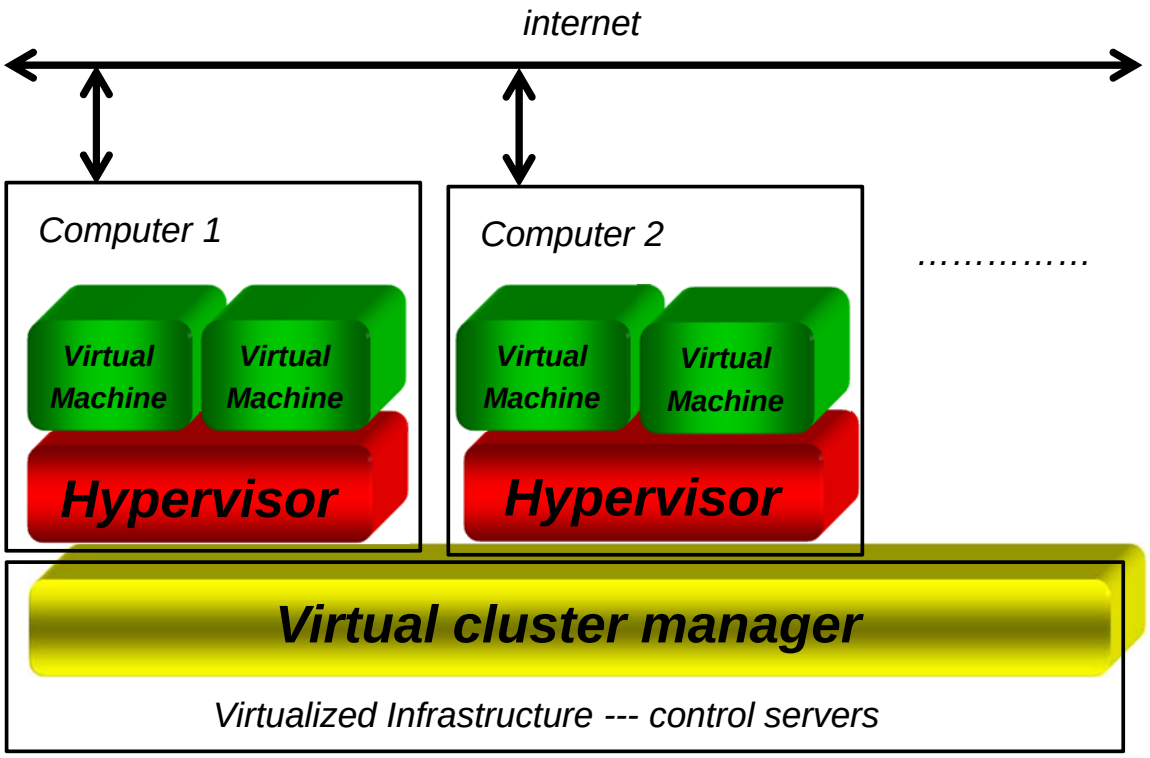
- On a single Computer it is possible to put in execution a VM by using a standalone Hypervisor
- **VMware Workstation** can play on Windows:
  - VMware Virtual Machines with: MS Win, Linux, Mac, ChromeOS, etc.
- **VMware Player** can play on Windows or Linux
  - Free of charge
  - VMware Virtual Machines with: MS Win, Linux, Mac, ChromeOS, etc
- **VMware Fusion** can play on MAC:
  - VMware Virtual Machines with: MS Win, Win 7, ChromeOS, etc.
- **Microsoft Virtual PC** on Windows 7:
  - Free of charge
  - Create VM with Win XP, Linux Ubuntu,

Software/Components preinstalled into rented Computers/VMs

- **Several kinds of software components/tools** that can be accessible on rented VM and/or Computers.
- **Availability of HW/SW**: for example at 98% or 99.999%
- **Typical components** that could be requested:
  - DB: MySQL
  - FTP: server and client
  - Web Server: Apache, IIS
    - Add-on: PHP, Perl, Python, cache tools on several levels
  - SMTP address, antispam
  - Web Application Server: TomCat, ….
  - And: Antivirus, backup, email, Drupal, Joomla, etc…
- **A full server can be customized, so that any other tool can be installed as well from the user**

Cloud Computing with VMs

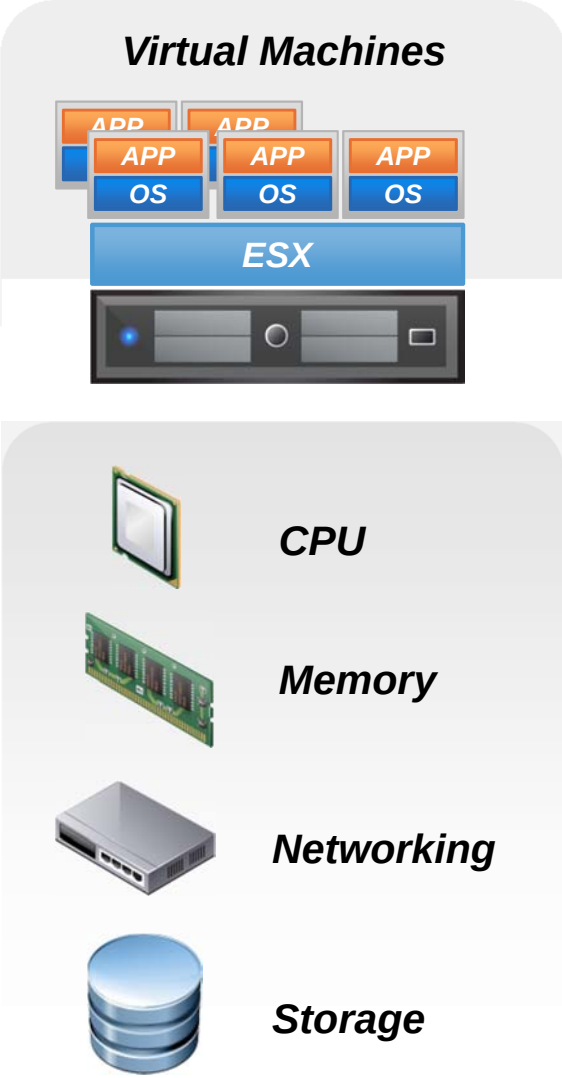
Several Hypervisors on a Clusters



Host: risorse primarie

- Host Profile

- Memory Reservation
- Storage
- Networking
- Date and Time
- Firewall
- Security
- Services
- Users and User Groups
- Security



Limiting VM Resources

- **VM Resources** (CPU, Mem, HD, net.) consists also in providing support for:

  - Dynamically providing resources over the reserved values that can be negotiation into the SLA/ contract.

- **Controlling and limiting** access and the exploitation of HW resources:
  - A limit on the number of CPUs
    - ➔A limit on the number of Clocks, over of a reserved number of clocks
  - A limit on the maximum size of the RAM, over of the reserved number of Mbytes
  - A limit on the size of the HD, SAN/NAS access
  - A limit on the number of network cards, number of Mbps, etc.

VM: Memory Definitions

- **Reserved: not available for the other VM on the same host!!**

- **Active**: memory actually used
- **Ballon**: Memory requested by the VM to the host
  - This memory is shared among several hosts
- **Shared**: memory available for sharing
- **Swapped**: amount of memory that has been swapped into the HD by the VMKernel of the host
  - This parameter has to be low as much as possible
  - Increse the reserved to make it low or reduce the number of VM on the host

Virtual Resources, 1/2

- The idea of Virtual Resources (CPU, Mem, HD, net.) consists in providing a number of resources larger than those that physically available and manage them virtually and/or dynamically
- **For example, one Host may have 2 VM and HW resources:**
  - **2 cores at 1300 Mhz**
  - **1.8 Gbyte RAM**
  - **2 network cards**
  - Best case:
    - CPU=400+800 Mhz
    - RAM=400+400 Mbyte
    - 2 Network cards shared
  - Worst case → no resources enough:
    - CPU=3 cores at 1300 Mhz
    - RAM=2 Gbyte
    - 2 Network cards shared

VM1:

- *1 CPU 1300 Mhz, 400 Mhz reserved*
- *1 Gbyte RAM max, 400 Mbyte reserved*
- *2 network cards, 2 IPs*

VM2:

- *2 CPU 1300 Mhz, 800 Mhz reserved*
- *1 Gbyte RAM max, 400 Mbyte reserved*
- *2 network cards, 2 IPs*

Virtual Resources, 2/2

- The server hosting the VMs
  - Min Mhz:
    - 400Mhz + 800Mhz
  - Max Mhz:
    - 1300Mhz + 2*1300Mhz
  - Min RAM:
    - 400Mbyte + 400Mbye
  - Max RAM:
    - 1000Mbyte + 1000Mbye
  - Network:
    - No limits on the number of virtual IP addresses/cards

VM1:

- *1 CPU 1300 Mhz, 400 Mhz reserved*
- *1 Gbyte RAM max, 400 Mbyte reserved*
- *2 network cards, 2 IPs*

VM2:

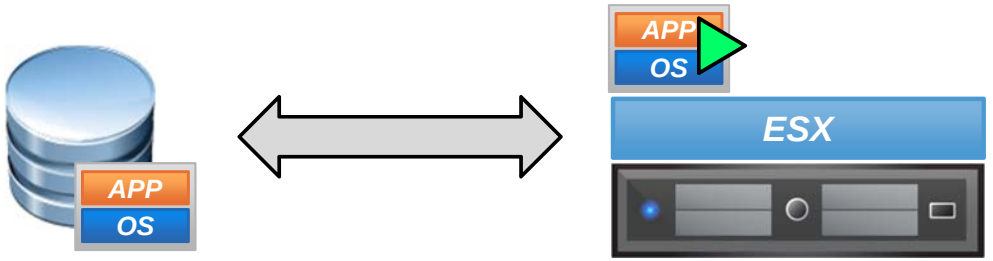
- *2 CPU 1300 Mhz, 800 Mhz reserved*
- *1 Gbyte RAM max, 400 Mbyte reserved*
- *2 network cards, 2 IPs*

Model for HD, Storage

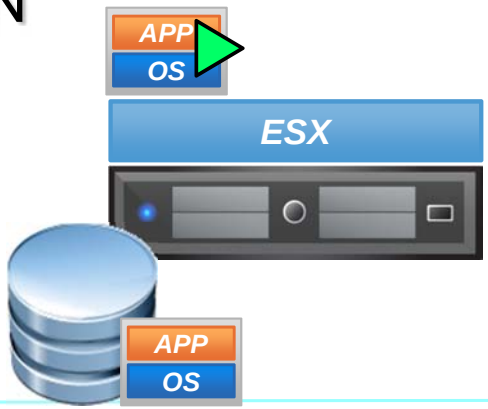
- Storage:
  - HD contained into VM
  - SAN: External to VM and mounted for their usage
  - In any case connected with some Operating Systems (may be dedicated)
- HD with fault tolerant solution:
  - Redundancy: replications into the Storage
  - Distributed/federate/replicated: replications into multiple storage

Simple configuration

- VM stored on a storage and executed on a remote hypervisor host
  - At the start is uploaded on ESX memory and RUN
  - Each write is passed back to the storage
  - All via network



- VM stored and executed on the same hypervisor host
  - At the start is uploaded on ESX memory and RUN
  - Each write is passed back to the storage
  - All via internal communication
  - → higher performances
  - → lower flexibility

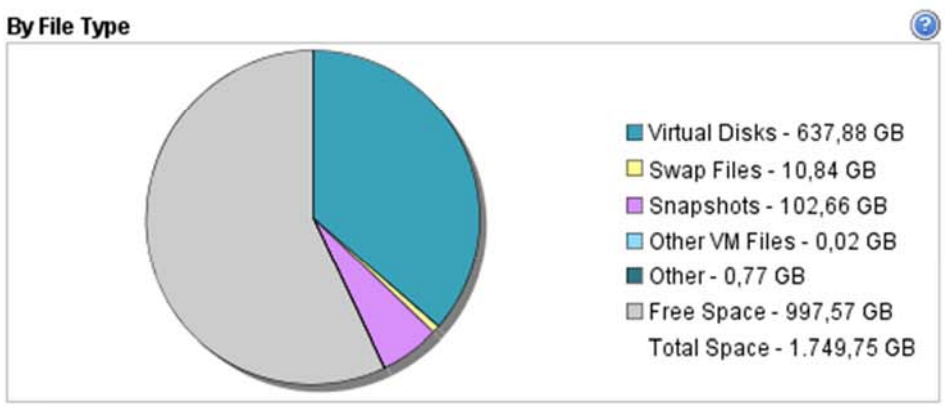


Examples

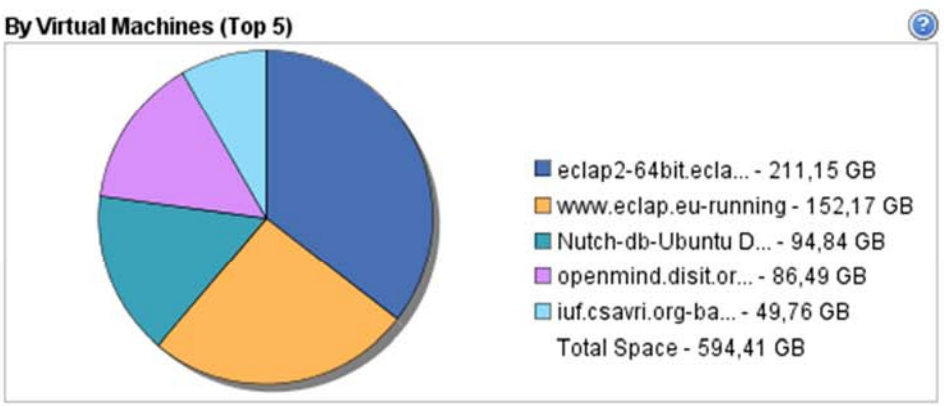
Host

Space Utilization for 145-Storage-A-4

By File Type

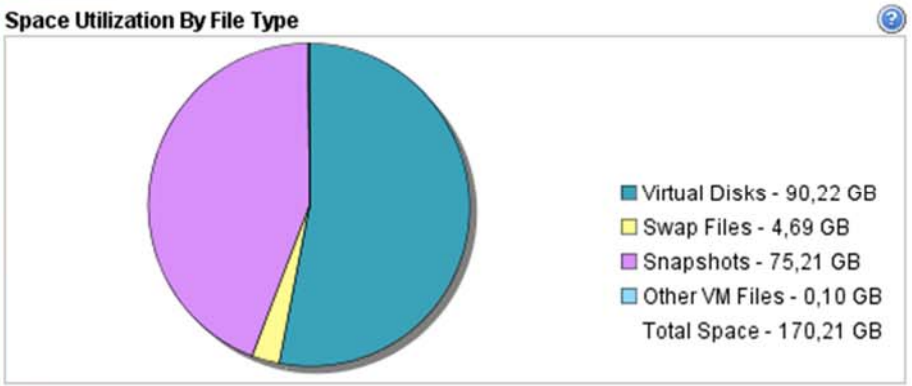


By Virtual Machines (Top 5)

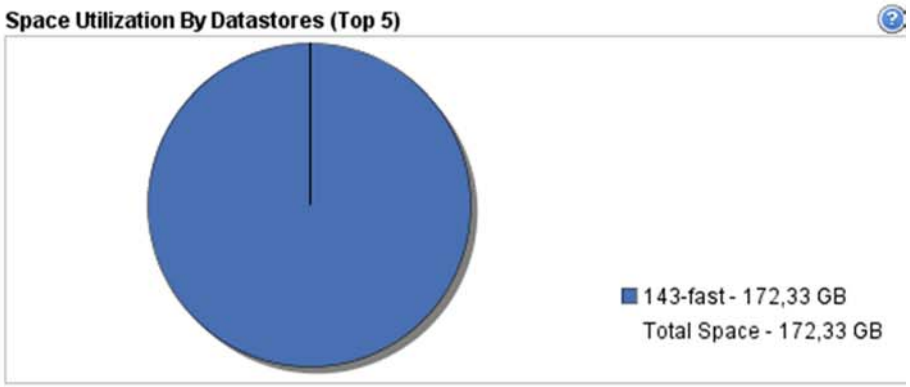


Virtual Machine

Space Utilization By File Type



Space Utilization By Datastores (Top 5)



Virtual Machine: Snapshots

- **Working on VM Snapshots**
  - Creating a Snapshot:
    - A point from which it is possible to reboot, restart
    - Consuming HD space
    - Making back up since the core image of the VM is not changed, changes are confined in the files representing the last status “you are here” and not the previous conditions
  - Restarting from a past snapshot
    - Losing current point: “you are here”, to avoid this do another snapshot!!
  - Deleting a past snapshot
    - Recovering HD space, removing a past restarting point
  - Removing all snapshots
- **Defragmenting images of the HDs** into the VM

VM Snapshots

- **VM Snapshots can be at VM Off or ON**
  - Snapshots of running VM have implications…
- **Removing Snapshots**
  - **Defragmenting images of the HDs** into the VM
  - Consolidating the changes in the previous version
- VMware WS has an automated Snapshot model to plan the periodic snapshotting of the VM, for example:
  - every hour, day, week, …
- A way to make back up
  - A different way can be to clone the VM on different host or NAS. In most cases, the cloning implies the lost of performed snapshots

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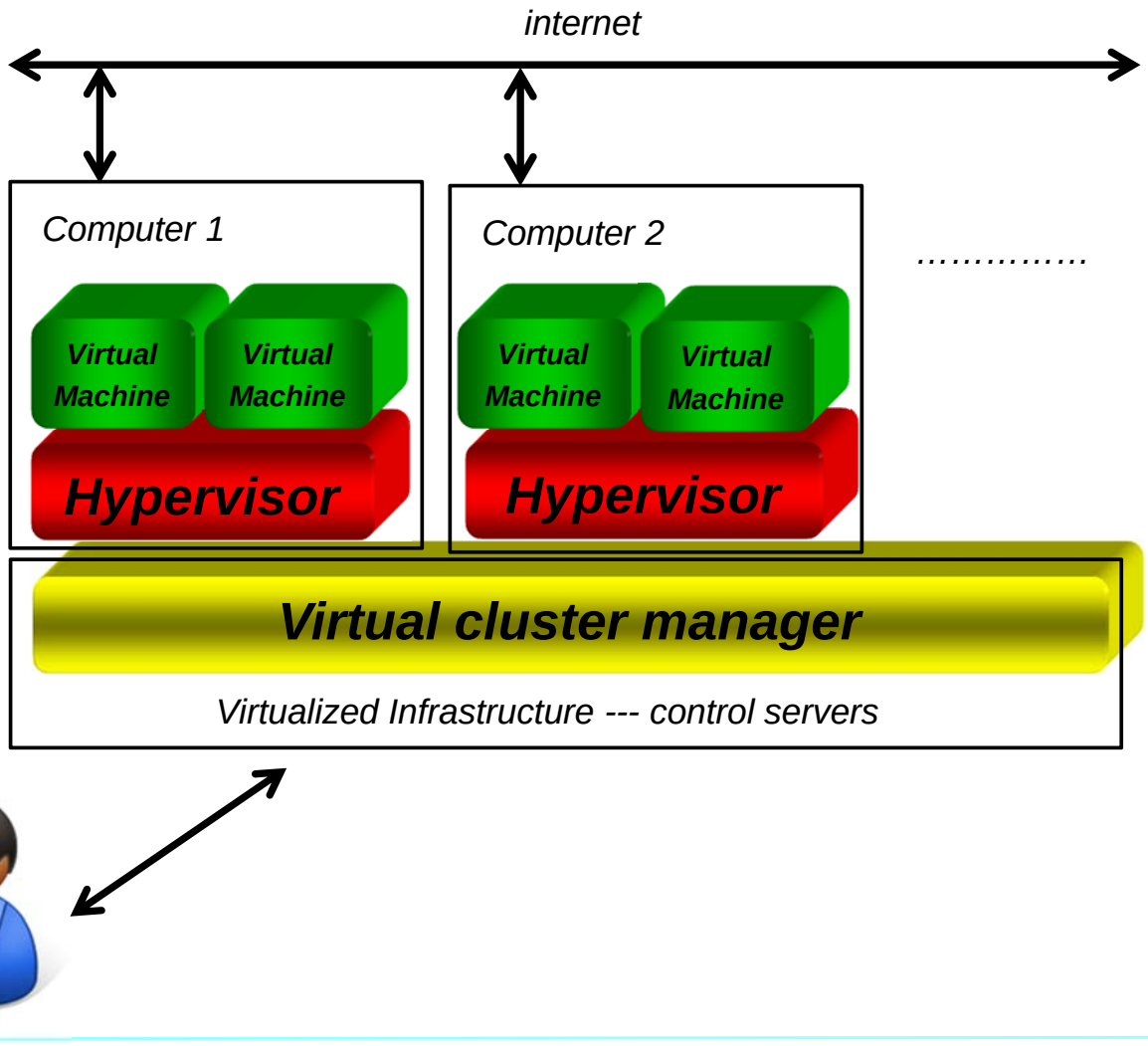


Cloud Computing

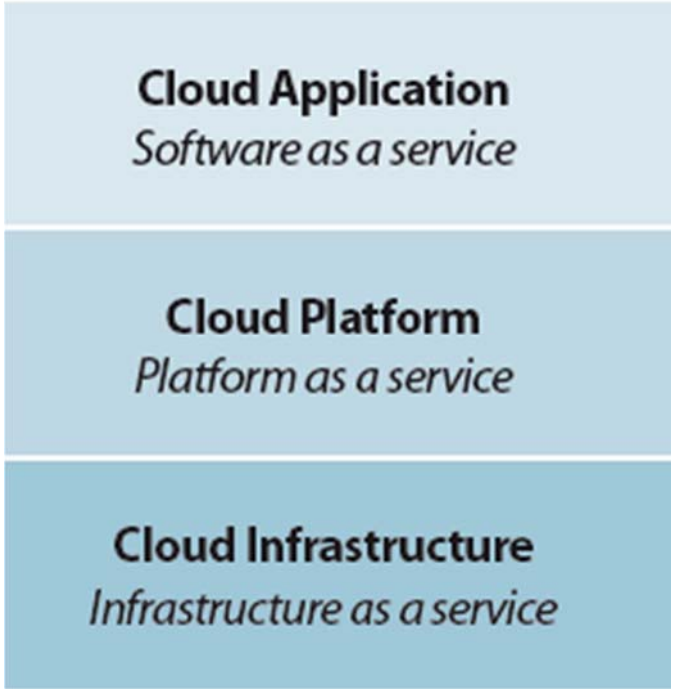
- **A Cloud:** a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers, VMs
  - They are dynamically provisioned and presented as one or more unified computing resources
  - based on service-level agreements, SLA, established through negotiation between the service provider and consumers
- Subset of grid computing where the allocated process are virtual computers
- **Implies**
  - An alternative way to have local servers or GRIDs
  - Outsourcing: HW and SW tools, they may be grid elements
  - Outsourcing: network, CPU, memory, HD, etc.
  - Definition of some service agreement, monthly rate, minimum network capability, kind of HW, mem space, minimum level of CPU/mem, etc.

Goals of Cloud Computing

- ***Scalability***.
  - ♣ scaling with workload demands so that performance and compliance with service levels remain on target
- ***Availability***.
  - ♣ users of Internet applications expect them to be up and running every minute of every day, i.e.: h24, 24/7
- ***Reliability***
  - ♣ physical system components rarely fail, but it happen. So that, they can be replaced without disruption.
  - ♣ Today, reliability means that applications do not fail and most importantly they do not lose data, and the service is not stopped.
- ***Security***.
  - ♣ Applications need to provide access only to authorized, authenticated users, that need to be able to trust that their data is secure.

Definizioni

- **Classificazione NIST**
  - **Software as a Service (SaaS)**
  - **Platform as a Service (PaaS)**
  - **Infrastructure as a Service (IaaS)**
- **Business Process as a Service (BPaaS)**
  - **Aggiunto in seguito**
- **Everything as a Service (XaaS)**
  - Middleware as a Service !!!!



Infrastructure as a Service (IaaS)

- erogazione di servizi infrastrutturali relativi a capacità elaborativa, storage, rete e altri elementi di base assolutamente indipendenti da servizi applicativi di qualunque tipo.
- Si utilizza quindi l'infrastruttura messa a disposizione dal provider per eseguire la propria applicazione,
  - pagamento in base al consumo dell'infrastruttura
  - lasciando sotto la responsabilità dell'utente la gestione del sistema operativo, dell'eventuale middleware e della parte di runtime, oltre che dell'applicazione stessa.
- Amazon EC2 è un esempio di servizio IaaS.

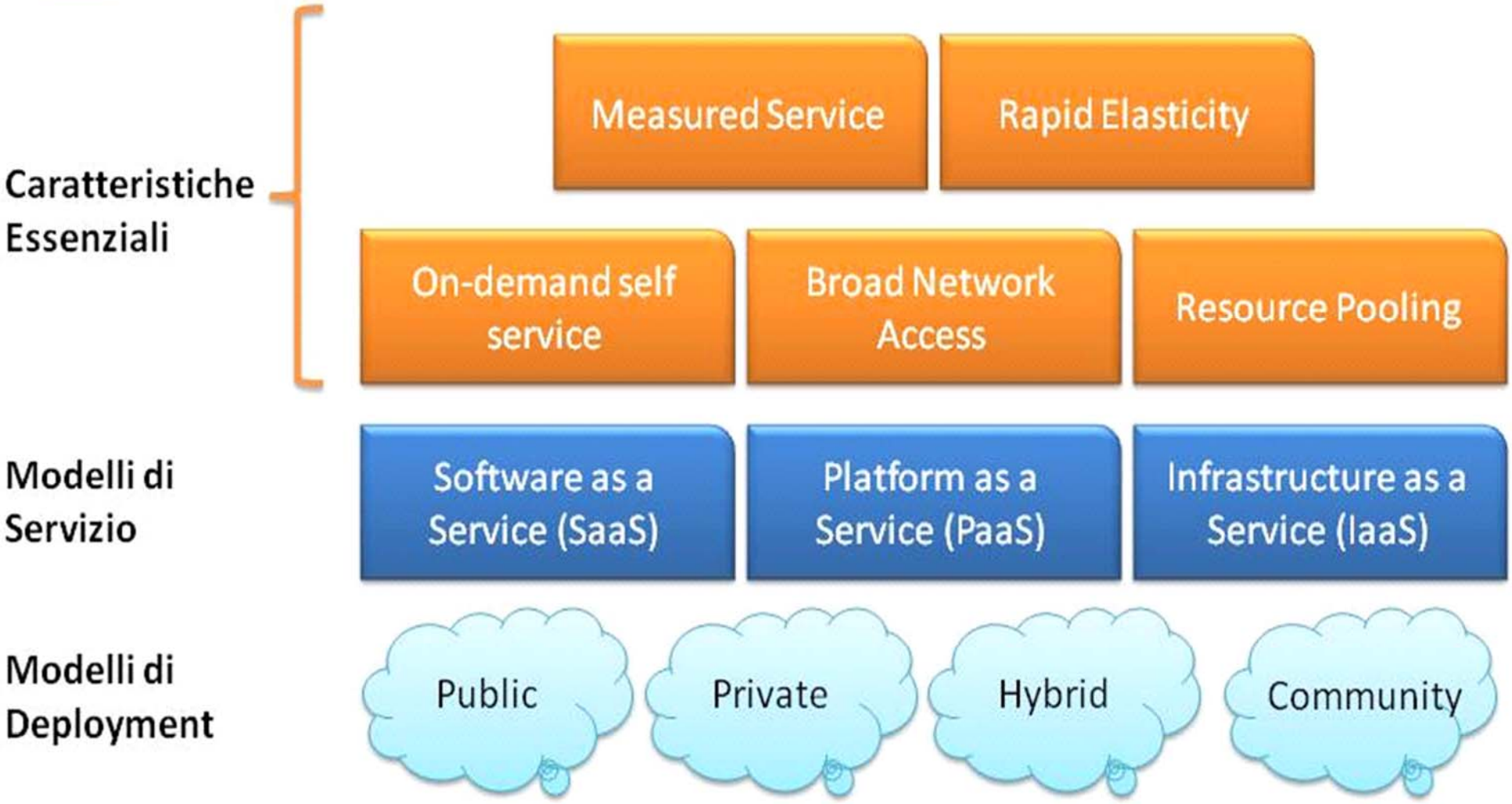
Platform as a Service (PaaS)

- erogazione di servizi applicativi di base come sistemi operativi, middleware, linguaggi, tecnologie di base dati e l'ambiente runtime necessari per eseguire l'applicazione,
- L'applicazione rimane l'unica cosa sotto la responsabilità dell'utente, oltre alla definizione del modello (e.g., numero e dimensione dei server, datacenter, caratteristiche del networking) da utilizzare per l'esecuzione dell'applicazione.
- Google AppEngine è un esempio di Platform as a Service.
- A livello PaaS viene anche collocato l'insieme dei servizi MaaS, Middleware as a Service.

Software as a Service (SaaS)

- erogazione di servizi applicativi di qualunque tipo, accessibili indipendentemente dalla collocazione e dal tipo di device utilizzato.
- Non è eseguita un'applicazione proprietaria del cliente, ma il cliente stesso paga il diritto (mediante licenza o canone di affitto) di utilizzo di un'applicazione messa a disposizione dal provider, senza preoccuparsi di come essa venga realizzata e gestita nel cloud.
- L'unica preoccupazione del cliente in questo caso, oltre ovviamente alla scelta della corretta applicazione che soddisfi le sue necessità, è gestire il numero di licenze richieste in funzione del numero di utenti.
- SalesForce.com Customer Relationship Management (CRM) è un esempio di soluzione in cui il software è venduto in modalità as a service.

Modello Generale



Definizioni

- ***Private Cloud.*** abilitata per operare soltanto per un'organizzazione. può essere gestita dalla stessa organizzazione o da parte di terzi.
- ***Community Cloud.*** **co**ndivisa da più organizzazioni a supporto di una singola community che ha interessi e obbiettivi comuni. Questa può essere gestita dalle stesse organizzazioni o da terzi in modalità on-premise e off-premise.
- ***Public Cloud****.* resa disponibile in maniera pubblica ed è di proprietà di un organizzazione che vi gestisce la vendita di servizi cloud.
- ***Hybrid Cloud.*** Infrastruttura composizione di due o più cloud (siano essi private, community o pubblici), rimangono entità separate, ma comunque accomunate da standard o tecnologie proprietarie che abilitano un certo livello di portabilità di dati e/o applicazioni di migrazione e/o bursting.

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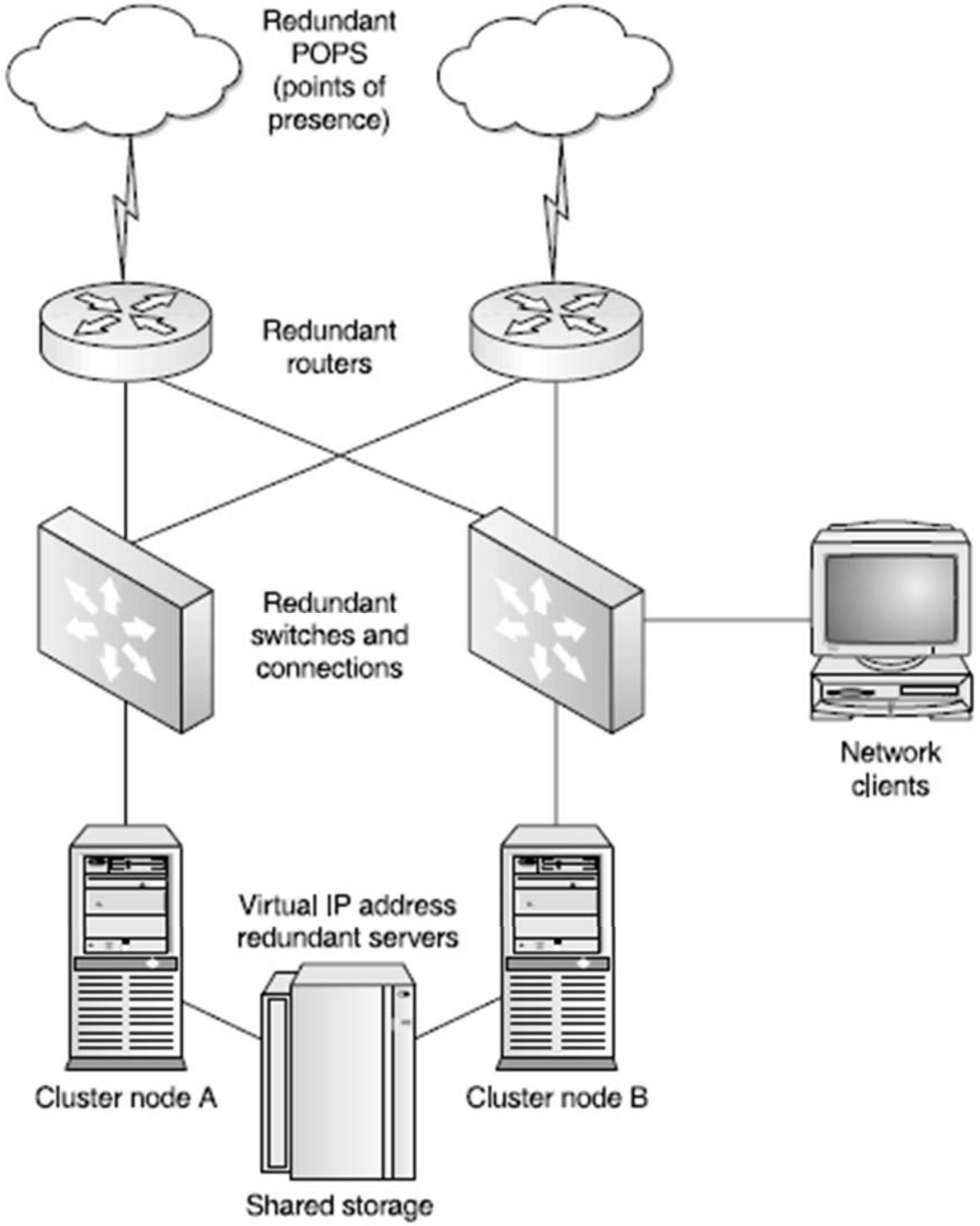
High Availability

The high availability has to be guaranteed only by the integration of features of:

- ***High Reliability***
- ***High Serviceability***
- ***Fault tolerance***
- ***Migration of VM to different HW***
- ***Disaster recovering***

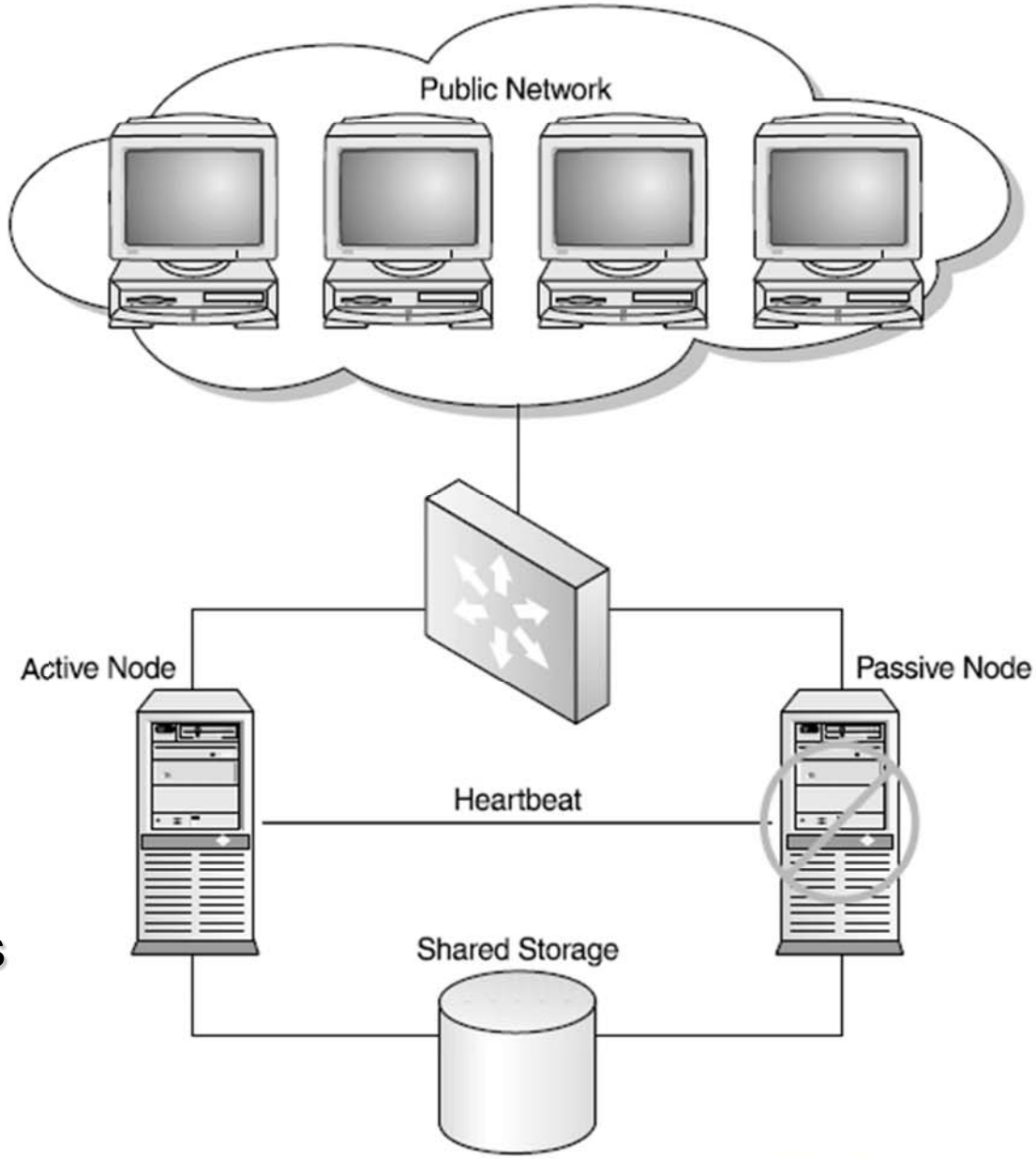
High Availability

- ***High Availability***, available 99.999 % (called “Five Nines”) percent of the time.
- ***Five Nines*** *is the term for saying a service or system will be up almost 100 percent of the* time.
- In case of failure:
  - the path changes to guarantee the service



High Availability: Hot spare

- **Fully cloned** servers to be alternatively used when the running one fails
- **Internal Network**
  - *Heartbeat* to detect the server availability and thus failover.
  - *[To keep servers aligned on context and data]*
- **Shared data** storage is a simplification and optional.
  - A different solution may be to have a cloned storage to keep aligned among the two servers



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  - Vmotion
  - Power Management
  - Resource Scheduling
  - Fault Tolerance
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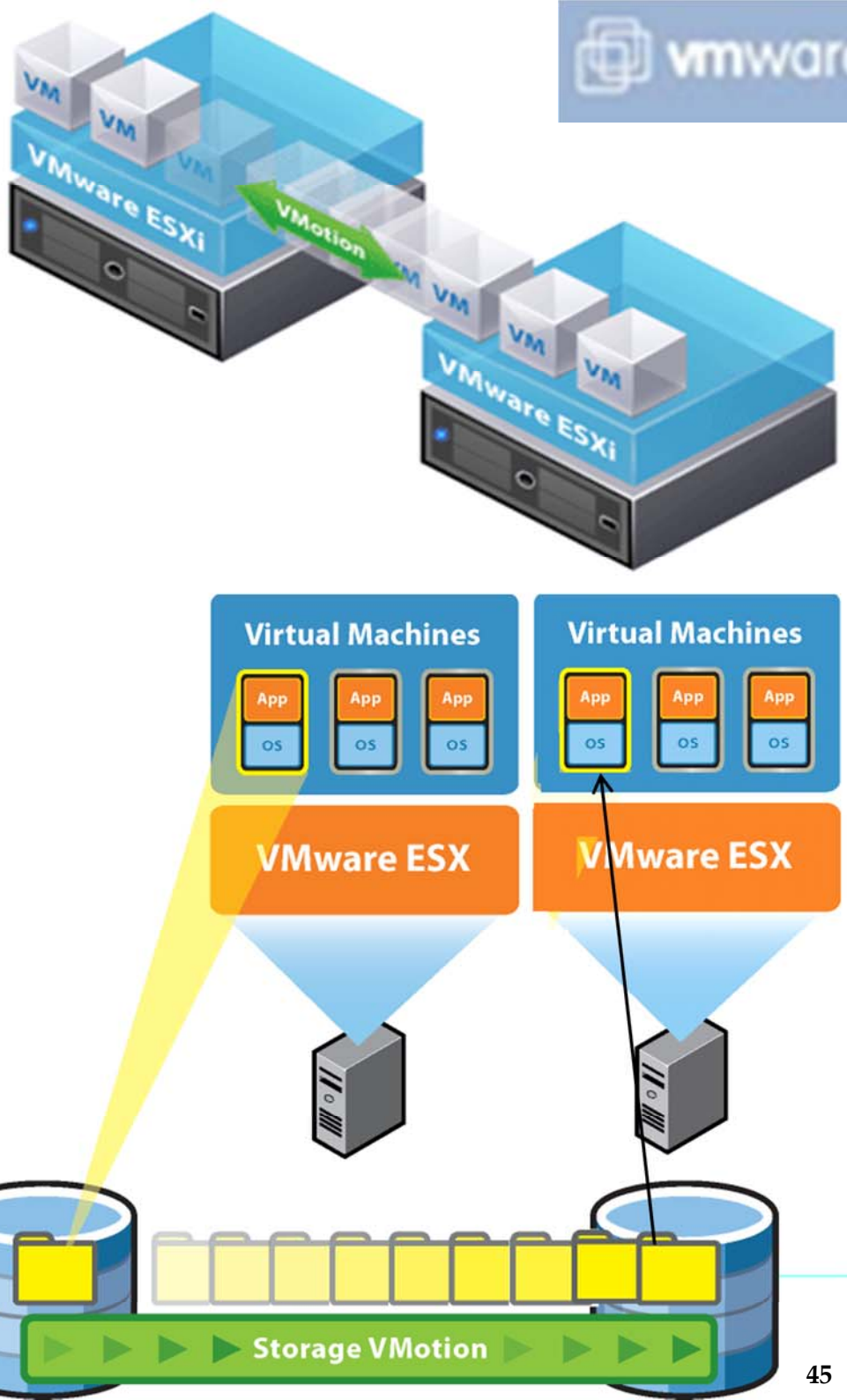
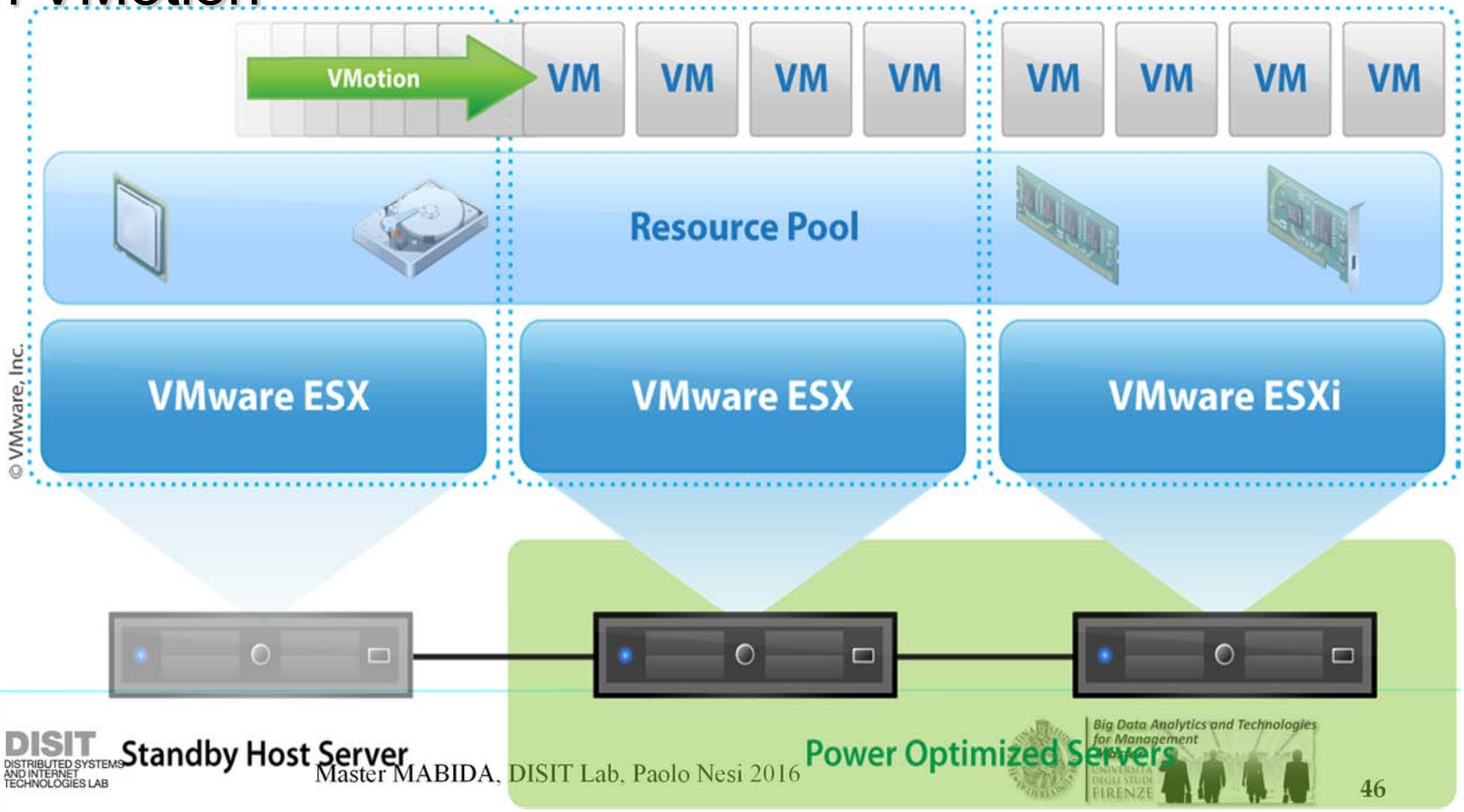
VMotion of VMware vSphere

- **you need**:
  - VM without snapshots
  - VM must be powered off to simultaneously migrate both host and datastore
  - Compatibility among host CPU and VMs
  - Dedicated virtual network
  - **The VMs** can be ON
- Steps:
  1. moving HD images
  2. aligning OS and CPU status
  3. off-the old and then on-new



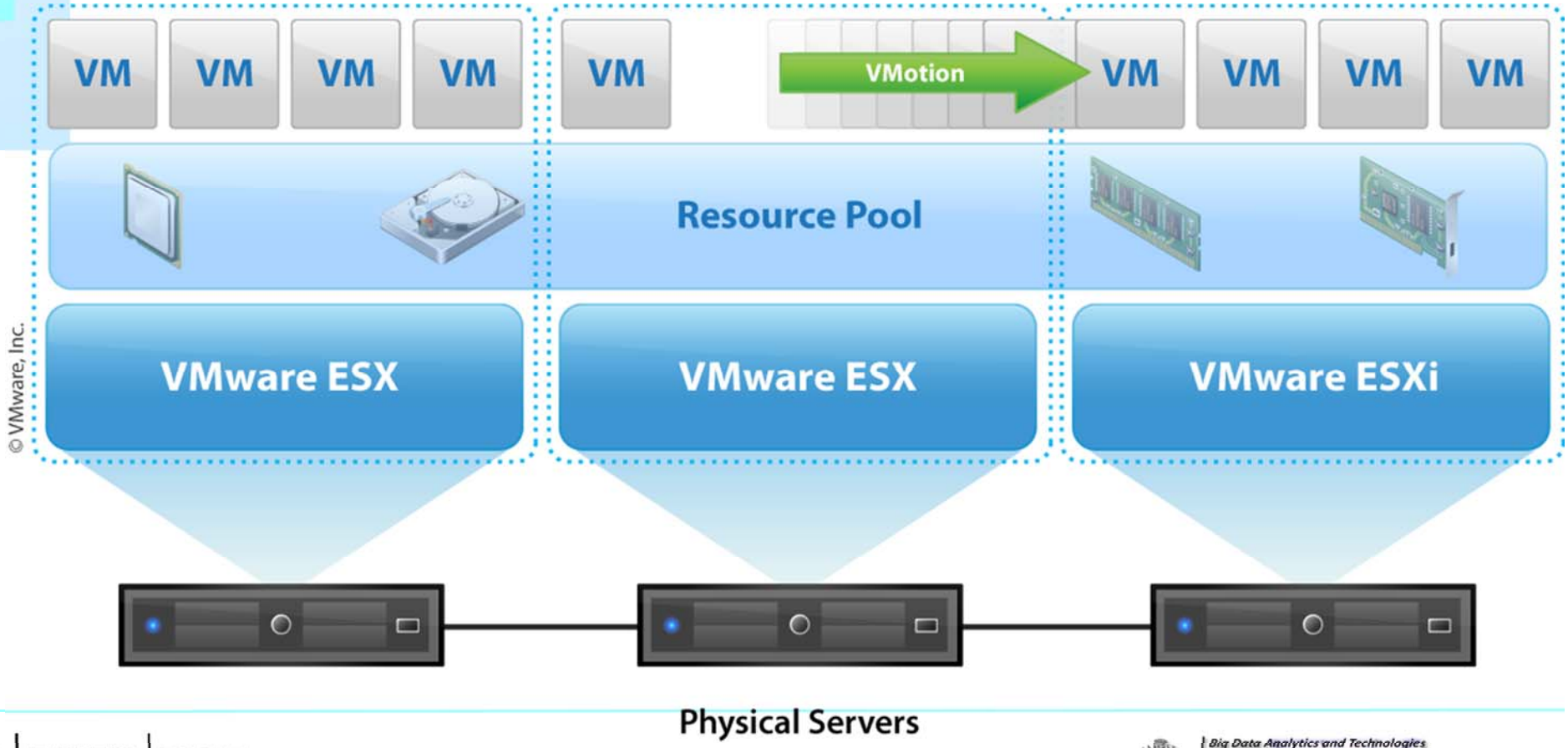
VMware DPM, Power Management

- DPM consolidates workloads to reduce power consumption
  - Cuts power and cooling costs
  - Automates management of energy efficiency
  - optimizing host resources
- Based on VMotion



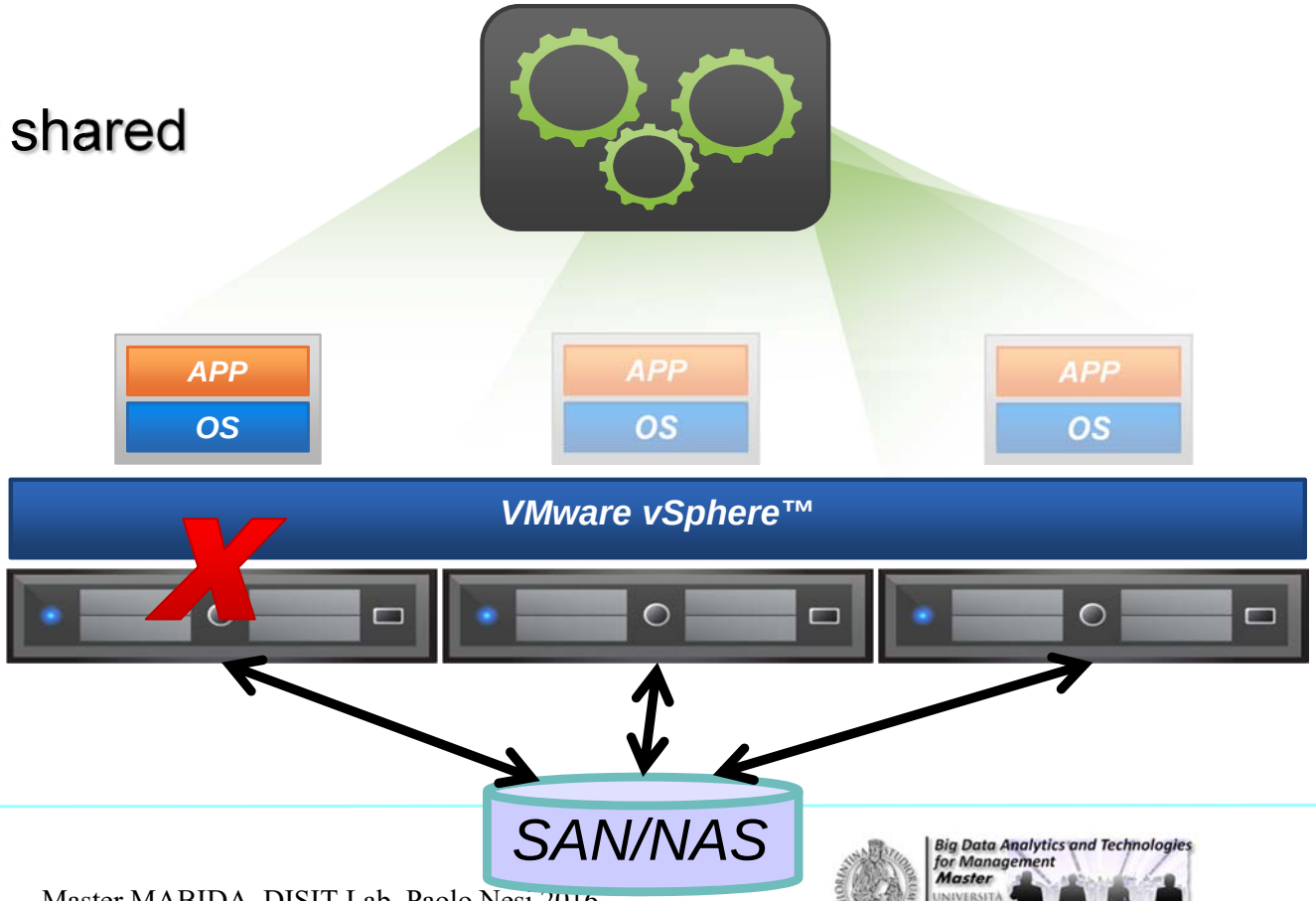
VMware DRS, Distrib. Res. Scheduling

- DRS is used to balance the workload among Hosts
- Moving VMs is a tools for balancing the workload on Hosts
- ..



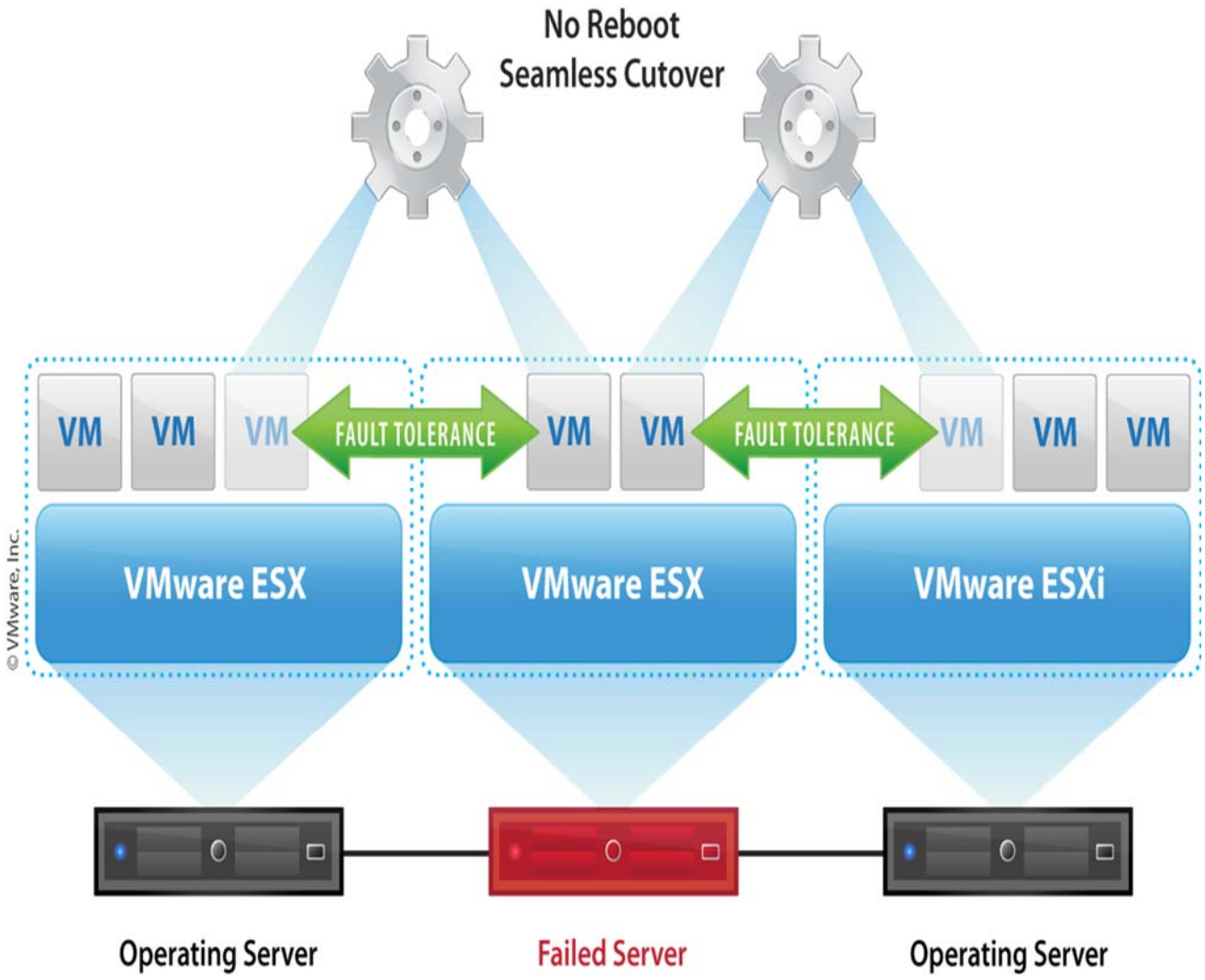
VMware Fault Tolerance, FT

- Single identical VMs running in lockstep on separate hosts
- Zero downtime, zero data loss failover for all virtual machines in case of hardware failures
- Single common mechanism for all applications and Operating systems
- Need to have a storage shared by the same VM
- The VM itself can be stored in the SAN



HA: High Availability of vSphere

- **When a host fails**, the running VM on the host may be turned ON on another hosts
  - Just the time to turn on again the host
- **HOT Spare** solution:
  - It is also possible to keep aligned 2 distinct hosts to make a faster switch OFF→ON of the VM on the faulty host
  - implies to have duplicated resources: Host, CPU etc.



Structure

- Elements of cloud Computing
- Virtualization
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- Security on the Cloud
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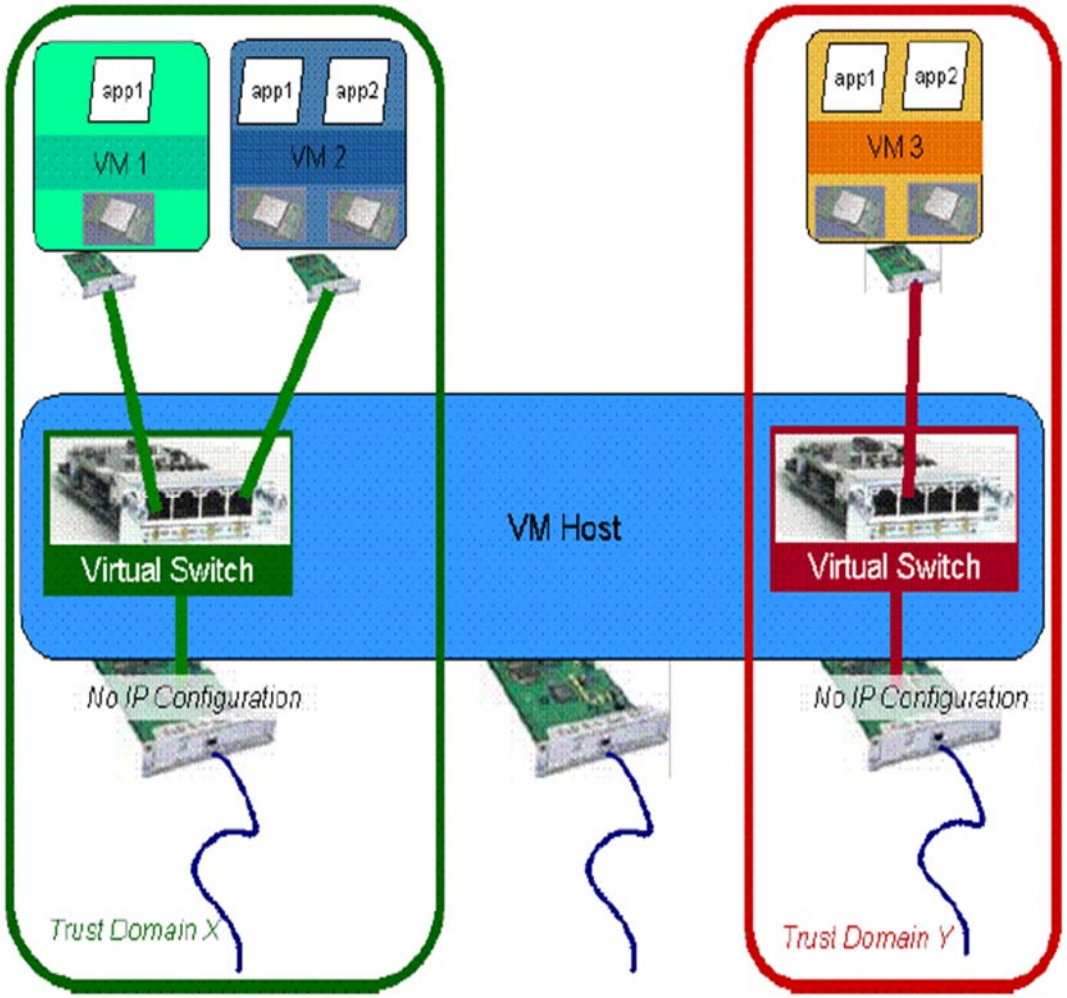
Security on the cloud

- Protecting VMs from external access
- Protecting VMs each other in the cloud
- Technologies:
  - Accessing to other VM via dedicated virtual networks, using Virtual Networking, Virtual Switch
  - Avoiding shared disk, at least using authenticated connections
  - Using Firewall
  - Communicating with other VMs via protected connections: protected WS, HTTPs, SSL, SFTP, etc.

Virtual Networking

- Per isolare meglio dei guest OS da altri che non sono nello stesso trust domain
- isolare i virtual switch dei singoli trust domain.
- Solo i guest che condividono lo stesso domain hanno schede di rete virtuali sullo stesso virtual switch.
- virtual switch su porte logiche del sistema host che non hanno indirizzo ip configurato.

Figure 1 - Isolating virtual machines to separate network trust domains



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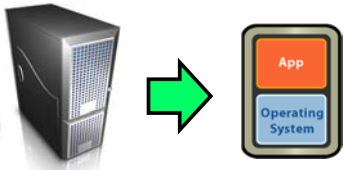
VM Converter, the migration

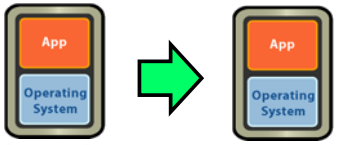
- **Conversion possibilities, migration possibilities**

- **P2V, from Physical → Virtual machine**



  - Reusing legacy servers into stronger and new HW machines
  - From ISO CD of an OS → VM

- **V2V, from Virtual → to Virtual**



  - Import/export a VM from/to different standards
  - From VM Workstation → Infrastructure VM
  - From Infrastructure VM → template for VM with some parameters
  - From Infrastructure VM →VM Workstation
  - From Infrastructure VM → Infrastructure VM changing parameters
  - …..

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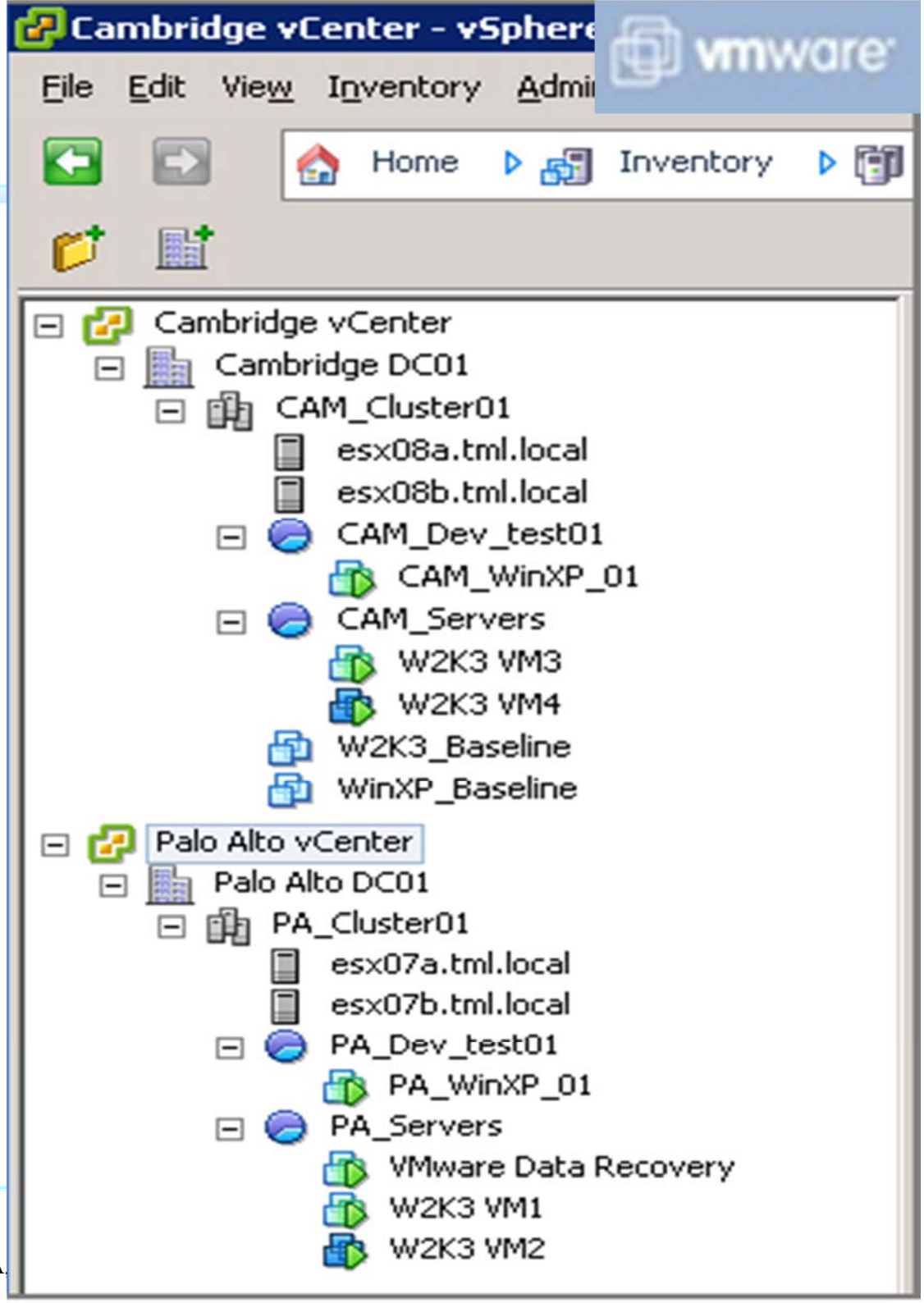
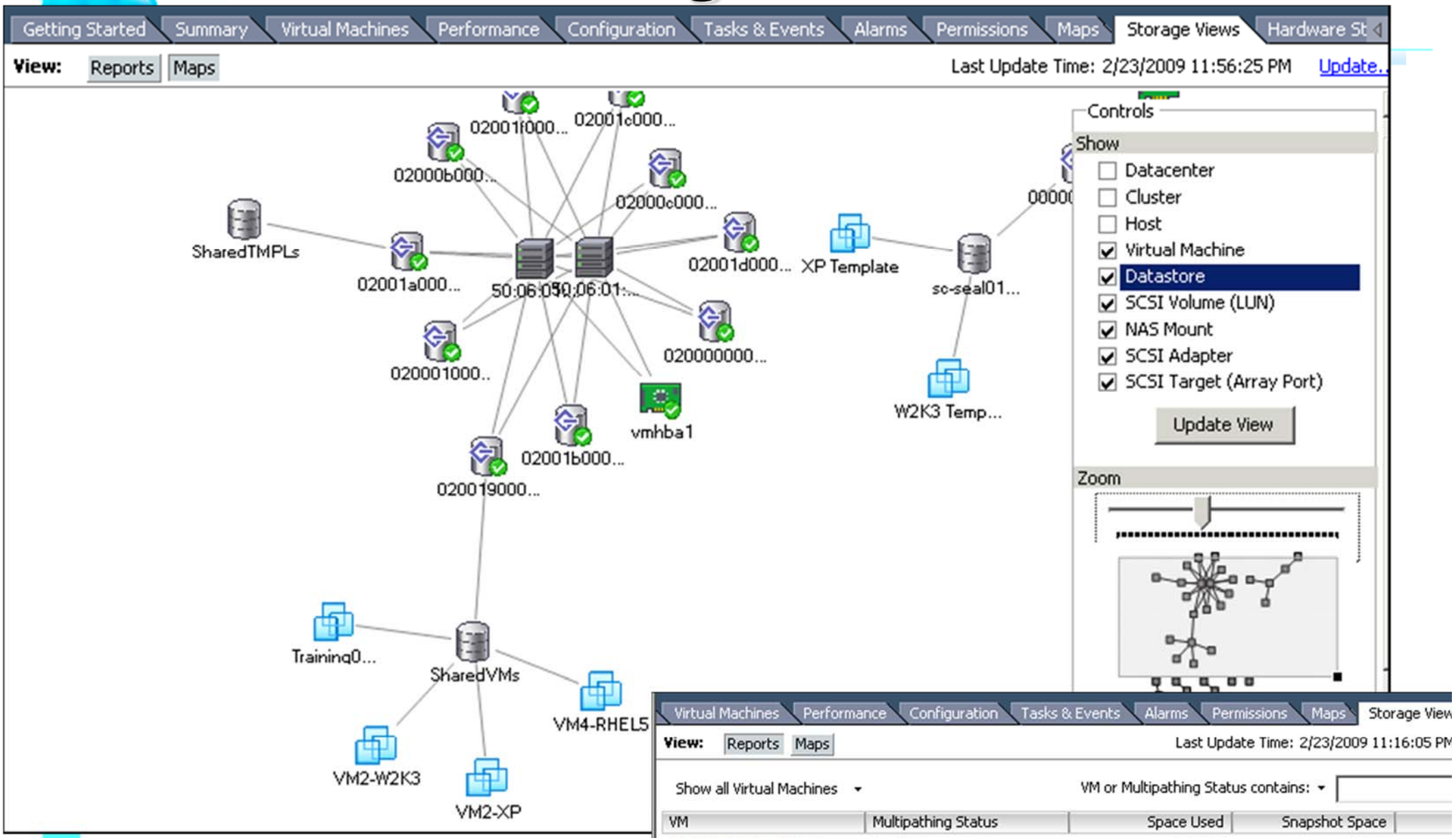
vCenter vSphere

- The so called Inventory
- Datacenter
  - Cluster00
    - Host….
    - Host….
    - Application:
      - VM1
      - VM2
    - VM3
    - VM4
  - Cluster01
    - H2..
    - …



Storage View

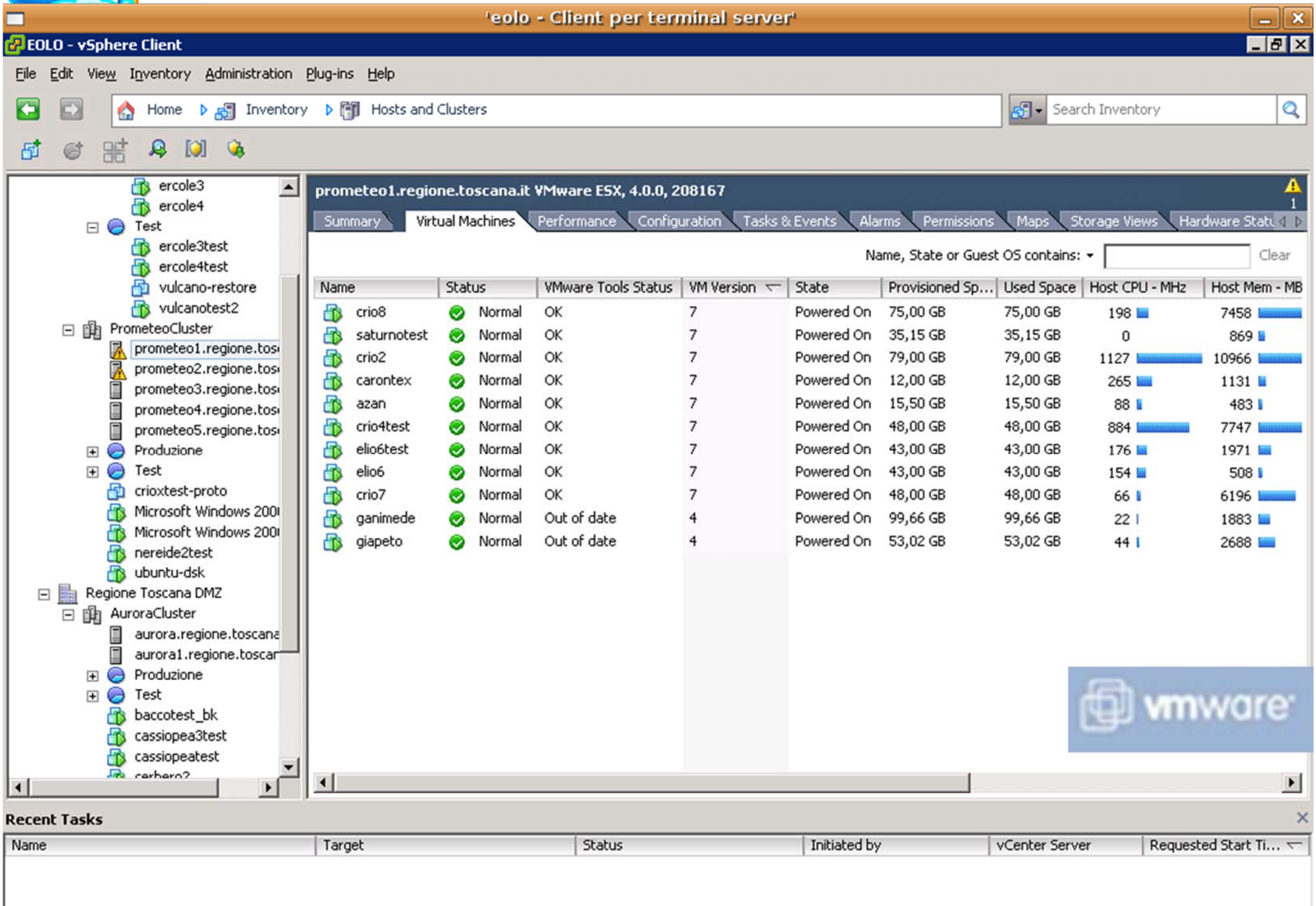


VM	Multipathing Status	Space Used	Snapshot Space
Train01_WindowsXP_01	Partial/No Redundancy	1.94 GB	0.00 B
VM2-XP	Partial/No Redundancy	3.38 GB	0.00 B
VM4-RHEL5	Partial/No Redundancy	8.10 MB	0.00 B
VM2-W2K3	Partial/No Redundancy	4.50 GB	256.07 MB
W2K3 Template	Partial/No Redundancy	4.00 GB	0.00 B
XP Template	Partial/No Redundancy	3.00 GB	0.00 B

Monitoring the Solution

- Monitoring and assessing performance at level of:
  - ♣ Datacenter, Cluster, Host
  - ♣ Virtual Machine from outside
  - ♣ Virtual Machine inside:
    - ➔ this has to be performed by using tools inside the VM operating system
    - ➔ Windows:
      - System monitoring hosts, detailed performances
    - ➔ Linux:
      - Top or other tools

Performance Analysis, Cluster/DC



Performance Analysis, Single VM

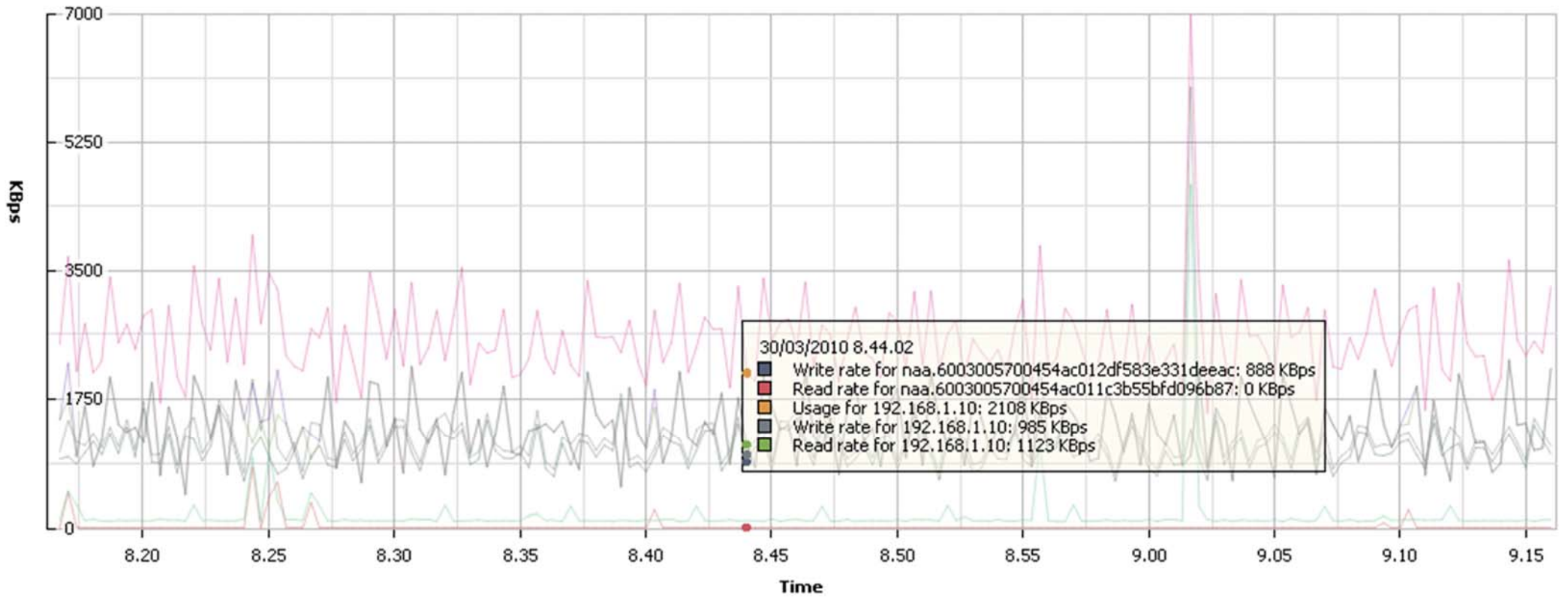
Getting Started | Summary | Virtual Machines | Resource Allocation | Performance | Configuration | Tasks & Events | Alarms | Permissions | Maps | Storage Views | Hardware Status

Overview | Advanced

Disk/Real-time, 30/03/2010 8.16.12 - 30/03/2010 9.16.12 Chart Options...

Graph refreshes every 20 seconds

Switch to: Disk

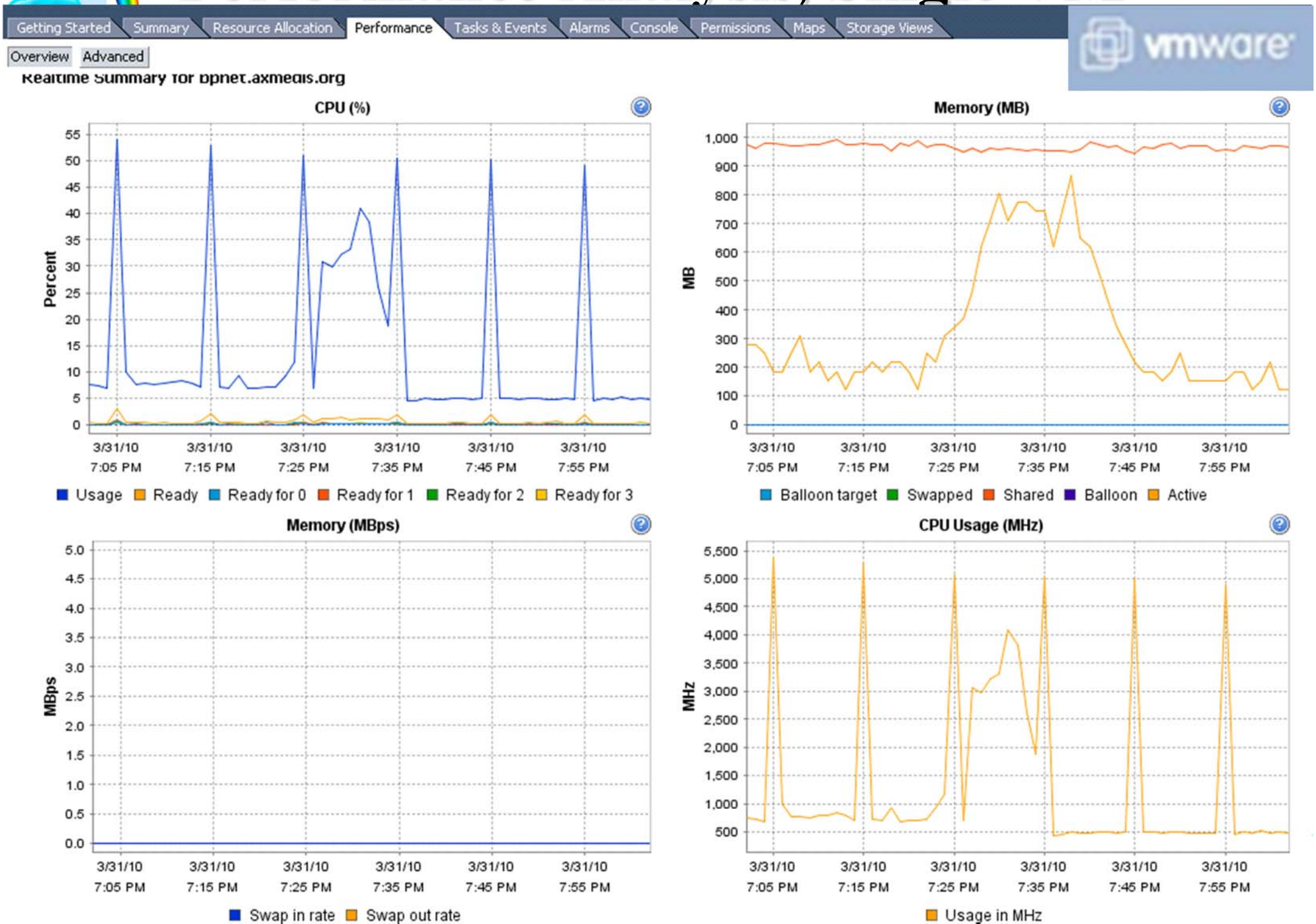


Performance Chart Legend

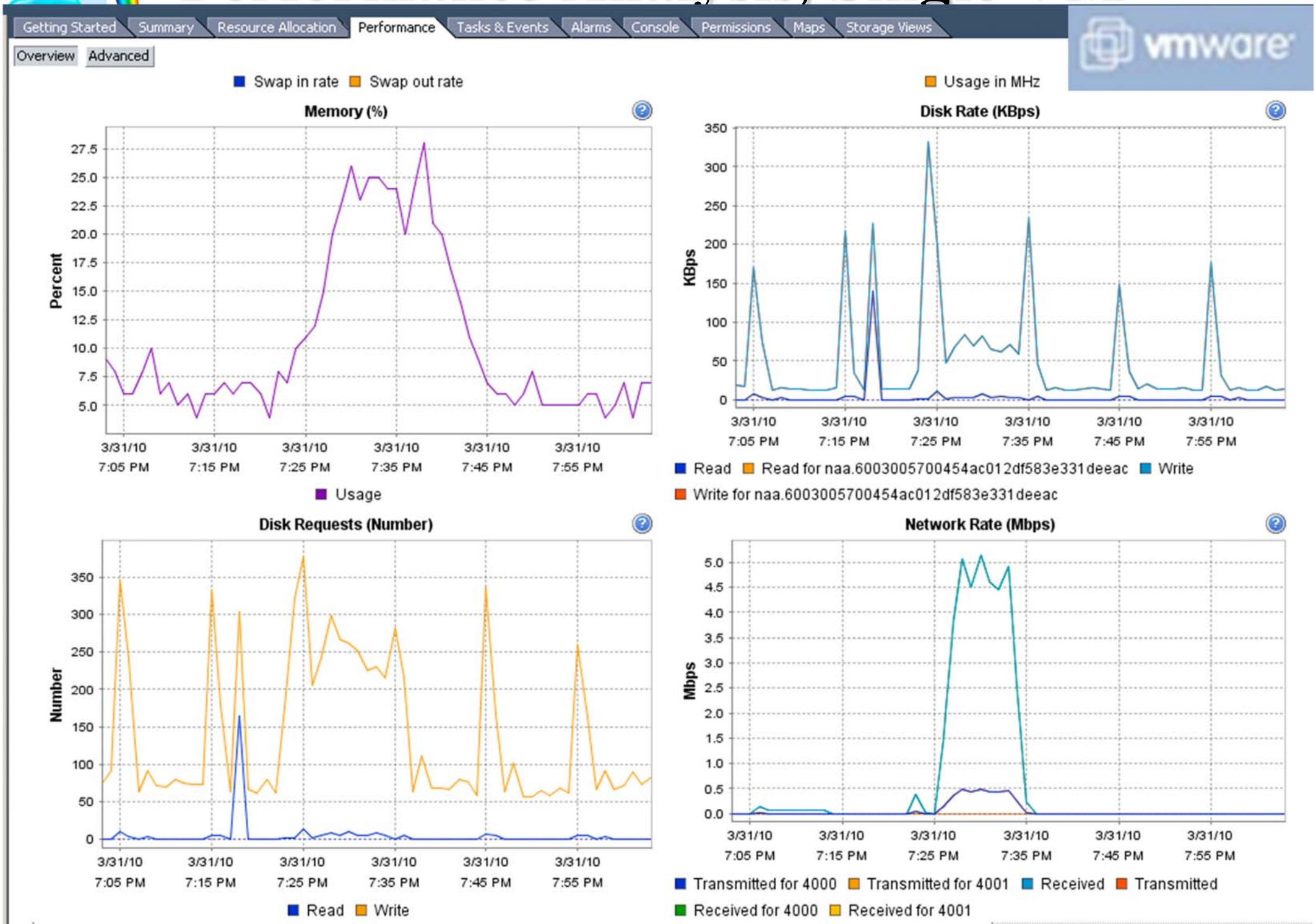
Key	Object	Measurement	Rollup	Units	Latest	Maximum	Minimum	Average
	naa.600300570...	Write rate	Average	KBps	1001	1727	626	1058,693
	naa.600300570...	Read rate	Average	KBps	0	820	0	18,045
	192.168.1.10	Usage	Average	KBps	3281	6992	1564	2594,006
	192.168.1.10	Write rate	Average	KBps	1110	6019	716	1218,615
	192.168.1.10	Read rate	Average	KBps	2170	2279	446	1374,872
	naa.600300570...	Read rate	Average	KBps	2170	2279	446	1356,693

vmware

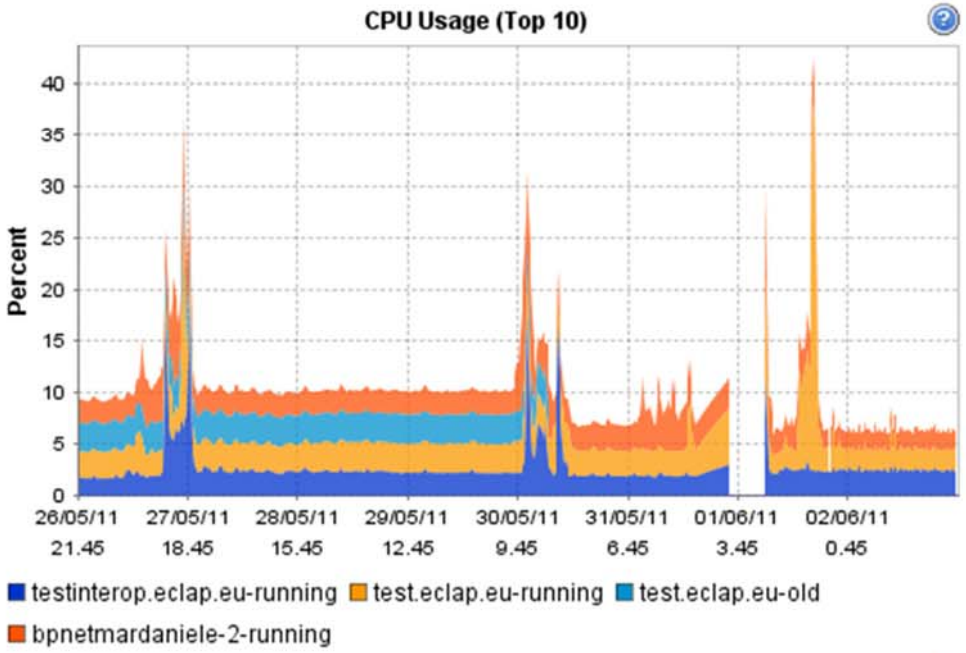
Performance Analysis, Single VM

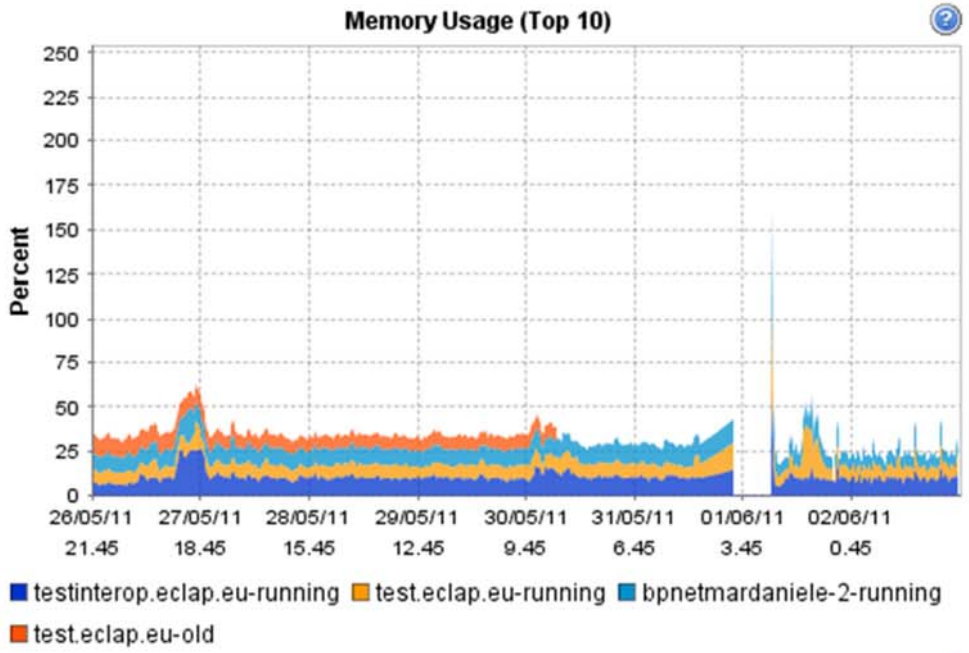


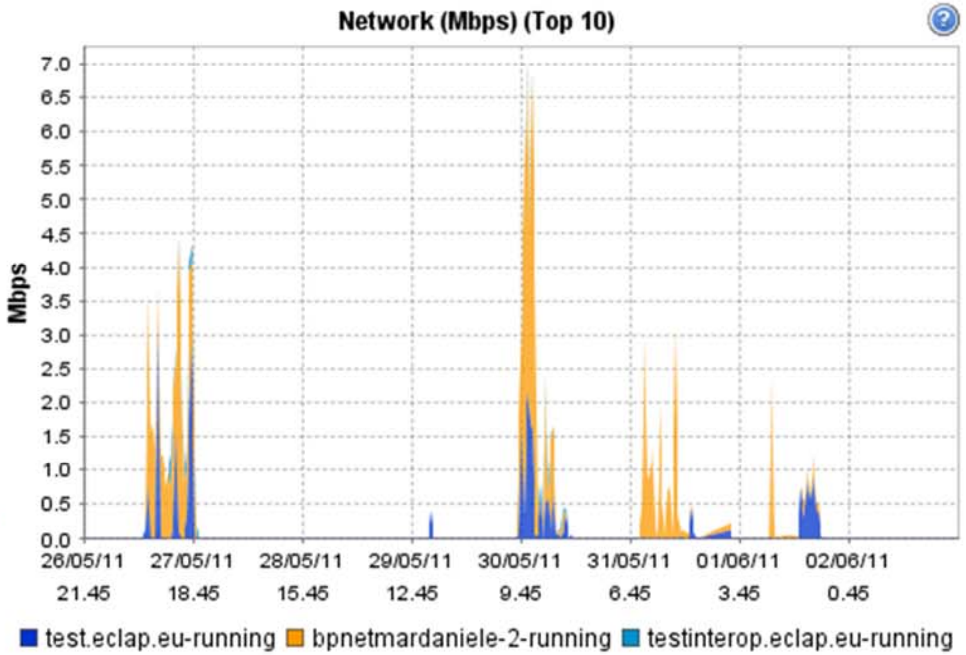
Performance Analysis, Single VM

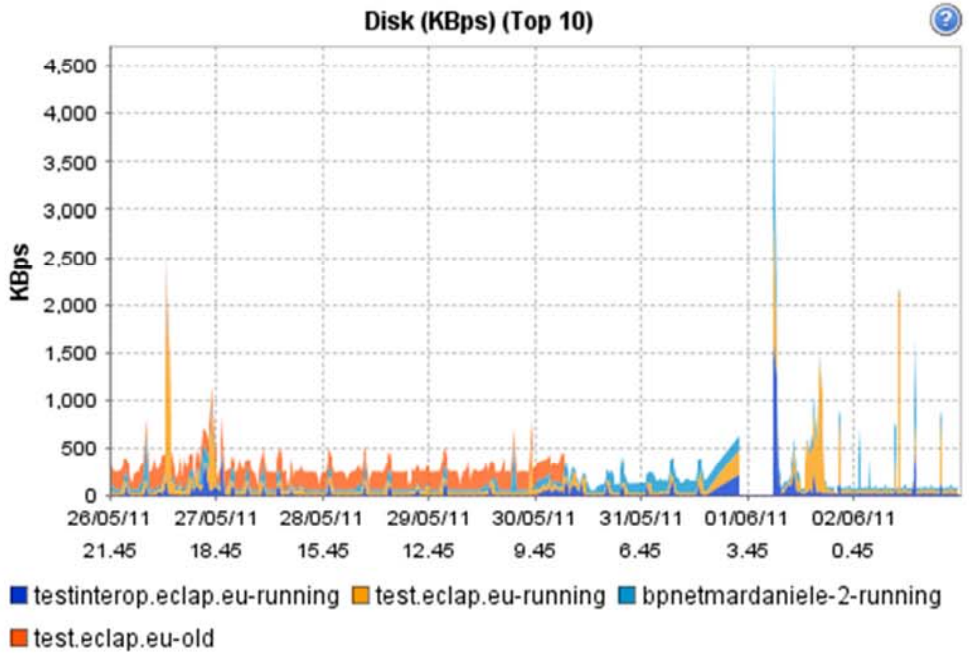


Performance Analysis of VM on the Host









Problematiche del Monitoraggio

- Parametri da monitorare: IaaS, PaaS, e SaaS:
  - Condizioni e parametri di stato degli HOST
  - Parametri di consumo degli HOST
    - Spazio storage, snapshots, etc.
  - Condizioni e parametri di stato delle VM e del sistema operativo
  - Parametri di consumo delle VM
    - Spazio disco, memoria, connessione
  - Condizioni e parametri di stato delle applicazioni e dei servizi dentro le VM
  - Parametri di consumo delle applicazioni e dei servizi dentro le VM:
    - E.g.: Numero di fatture, numero di utenti

Monitorare perche’

- Actions:
  - Allarmi gialli/rossi (75%/90%) se si superano soglie definite
  - Invio di: email, sms, etc.
  - Attivazione di riconfigurazioni, cambi di configurazione, estensioni di risorse
  - Attivazione di moving
  - Shutdown di emergenza
  - Network off/on
  - Cambio di billing in base alla SLA
  - Etc. etc.

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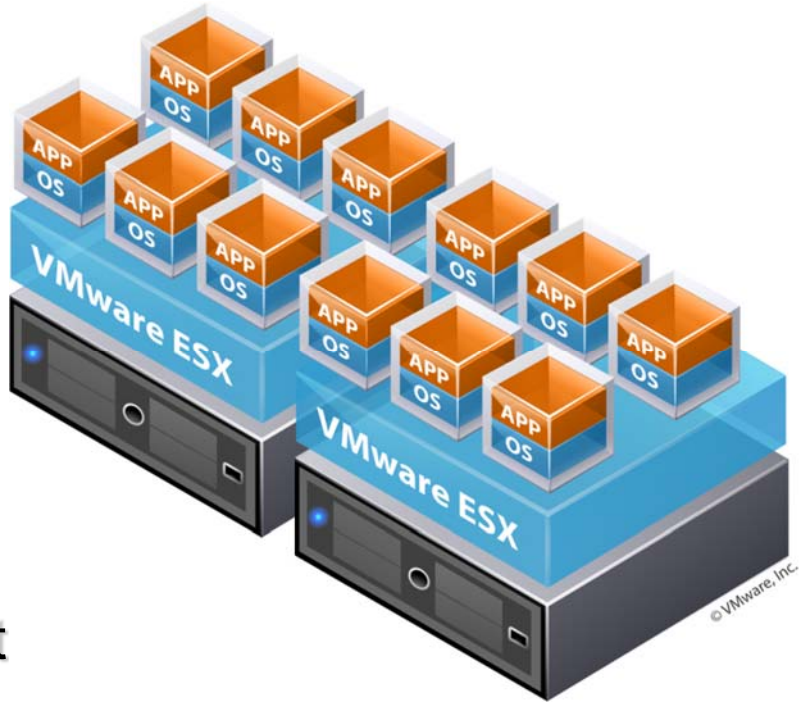
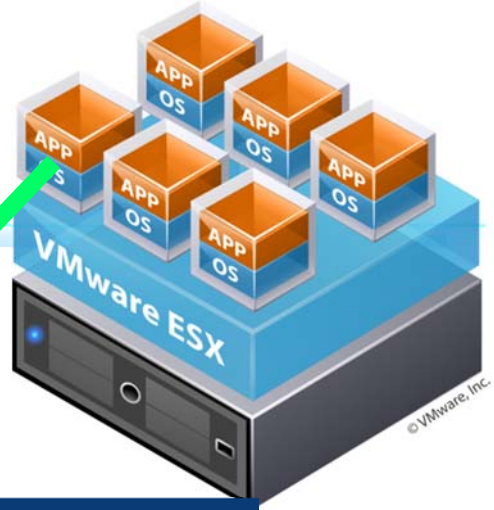
How to WORK with VMs in the Cloud

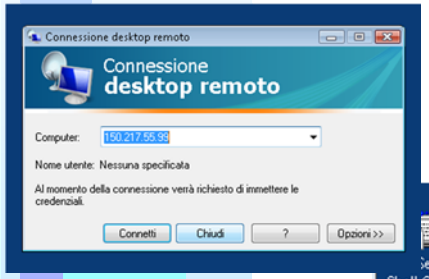
- **KVM solutions**
  - Local access via local KVM
  - Local server access via HTTP
- **Windowing Terminal**
  - MS Windows Remote Desktop
  - X Terminal to linux
- **Remote Solutions**:
  - VNC, Radmin, etc.
  - VNC: Also possible via HTTP port
- **Telnet, char based consol, SSH**
  - VT100 terminal for example



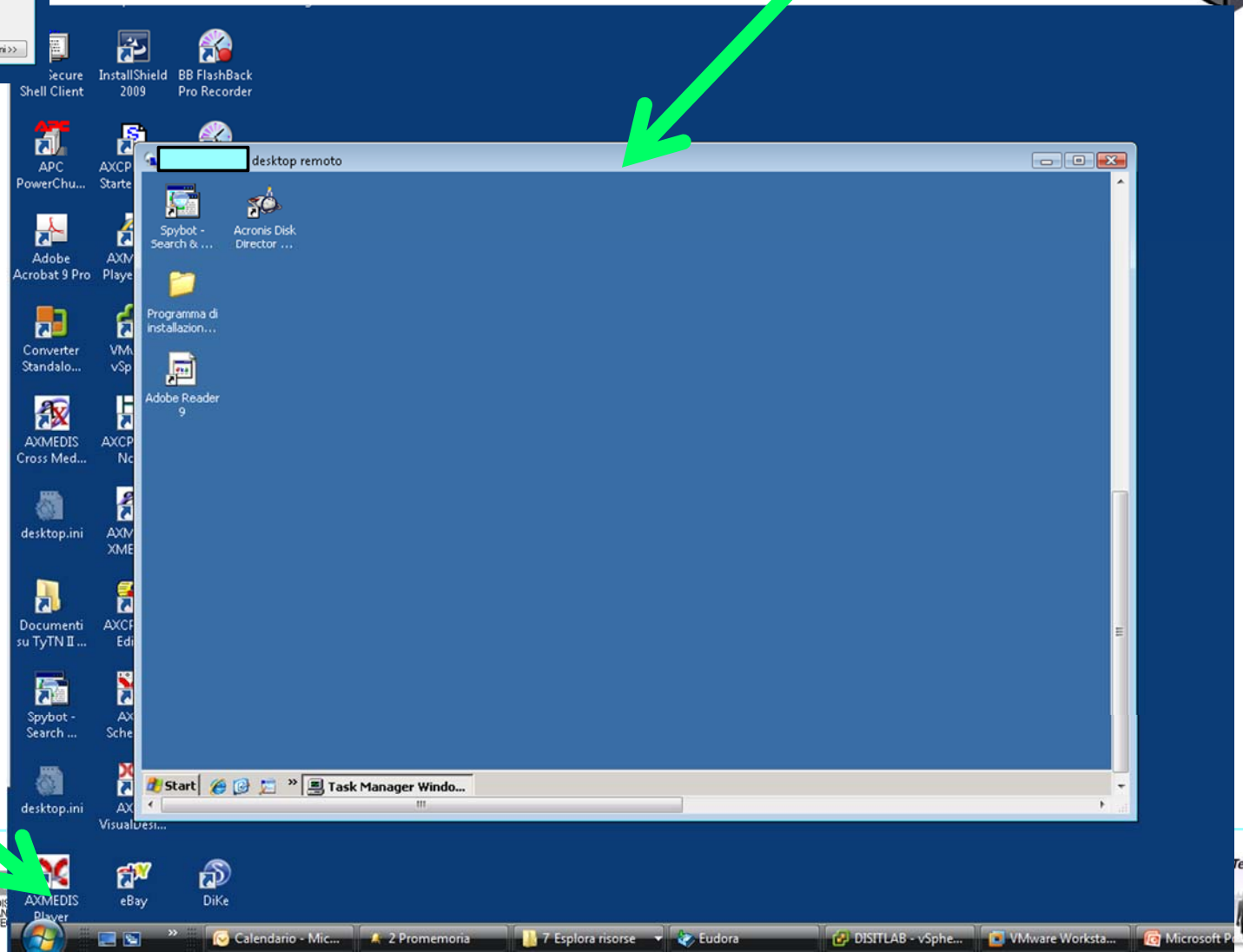
Windows Remote Desktop



- *Remote machine*
- *Windows 2003*

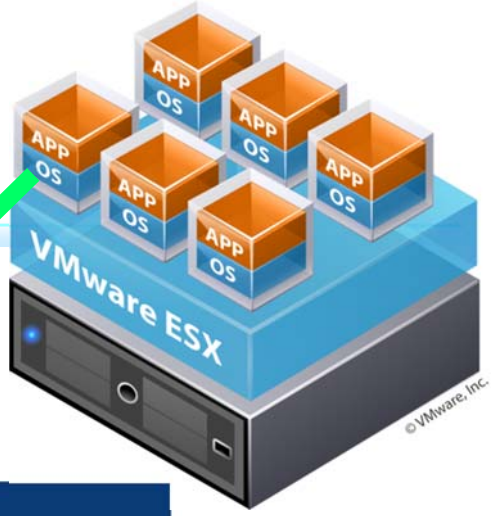


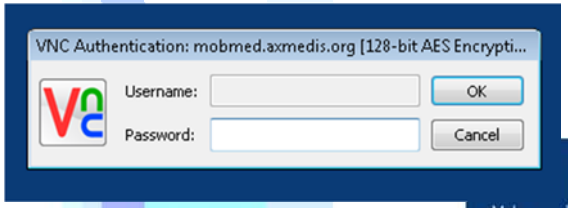
- *Local machine*
- *Windows Vista*



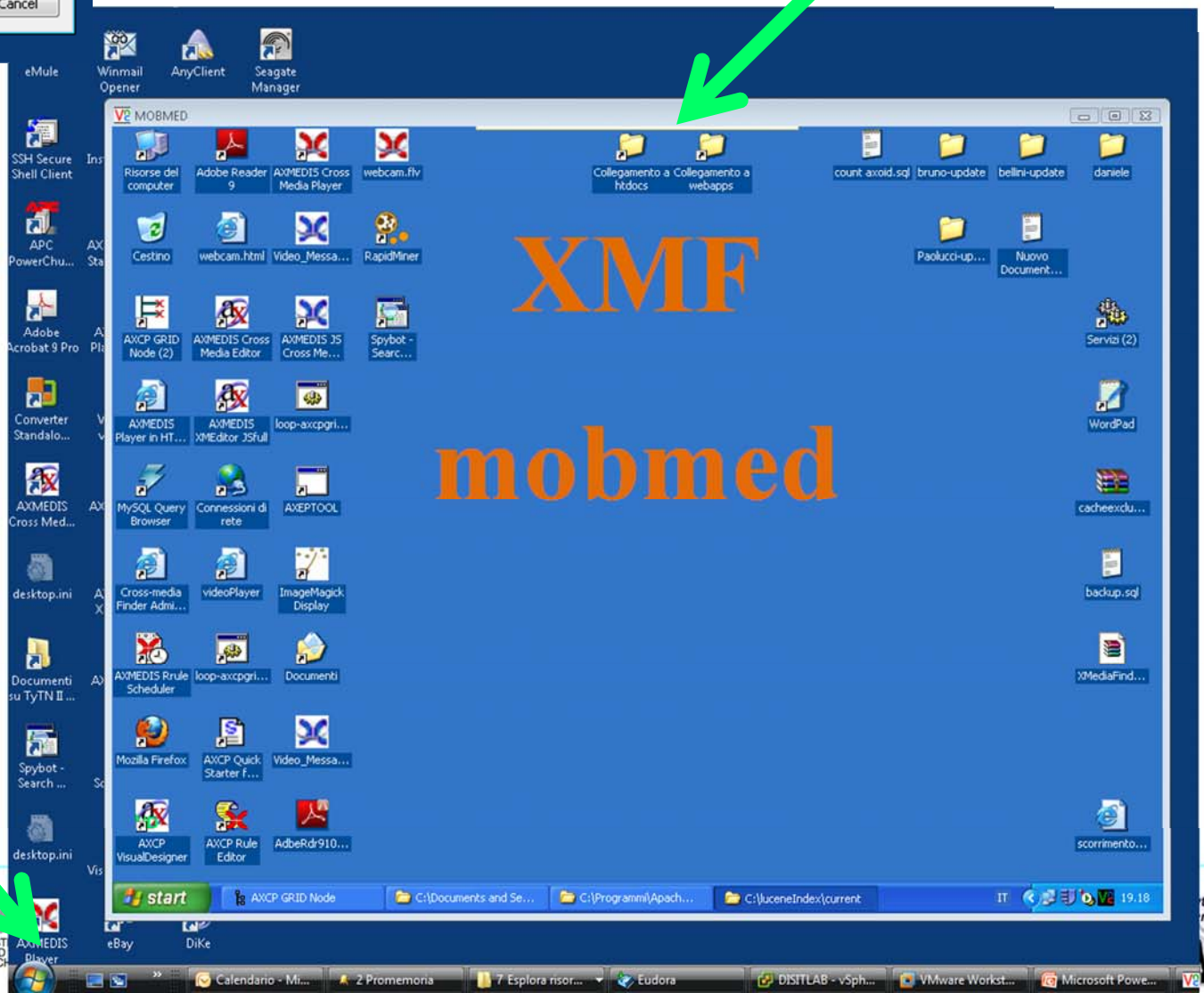
VNC remote connection

- *Remote machine*
- *Windows XP*





- *Local machine*
- *Windows Vista*



Riferimenti per approfondimenti

- Versione completa della slide: http://www.disit.org/6587
- ICARO project official web page dove in documenti vi sono documenti accessibili e video: http://www.cloudicaro.it/
- Altra documentazione accessibile su
  - Video overview: http://www.disit.org/6558
  - Page with Smart Cloud Videos: http://www.disit.org/6544
  - ICARO page at DISIT http://www.disit.org/5482

References

- **VMware**: http://www.vmware.com
- **HP**: www.hp.com/go/integrityvm
- **Microsoft Hyper-V**: http://www.microsoft.com/hyper-v-server/en/us/default.aspx
- **"Windows Server 2008 Hyper-V Technical Overview"-** http://download.microsoft.com/download/4/2/b/42bea8d6-9c77-4db8-b405-6bffce59b157/Hyper-V%20Technical%20Overview.docx
- **Comparison of Hypervisors by VMware -** http://www.vmware.com/technology/whyvmware/architectures.html#c132894
- **"VMware vSphere 4" Datasheet -** http://www.vmware.com/products/vsphere/
- ICARO project: http://www.disit.org/5482, http://www.cloudicaro.it/en/

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