CLOUD COMPUTING

Virtual Machines Provisioning and Migration Services

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VIRTUAL MACHINES PROVISIONING AND MIGRATION SERVICES

Introduction

In this chapter, we focus on two core services that enable the users to get the best out of the IaaS model in public and private cloud setups, Virtual machine provisioning and migration services:

Analogy for Virtual Machine Provisioning:

- Historically, when there is a need to install a new server for a certain workload to provide a particular service for a client, lots of effort was exerted by the IT administrator, and much time was spent to install and provision a new server. **1) Check the inventory for a new machine, 2) get one, 3) format, install OS required, 4) and install services; a server is needed along with lots of security batches and appliances.**
- Now, with the emergence of virtualization technology and the cloud computing IaaS model:
- It is just a matter of minutes to achieve the same task. All you need is to **provision a virtual server** through a **self-service interface** with small steps to get what you desire with the required specifications. **1) provisioning this machine in a public cloud like Amazon Elastic Compute Cloud (EC2), or 2) using a virtualization management software package or a private cloud management solution installed at your data center in order to provision the virtual machine inside the organization and within the private cloud setup.**

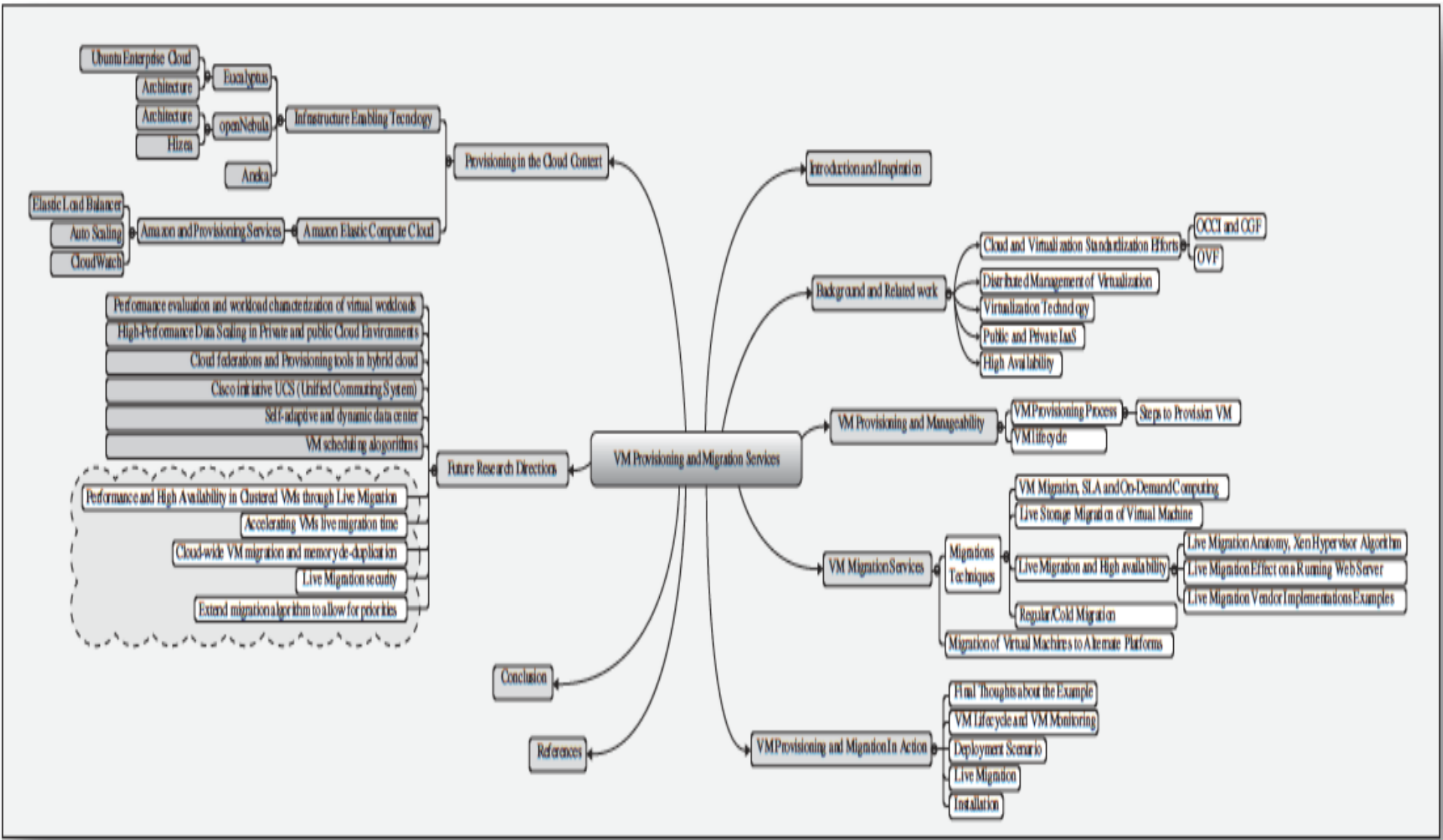
VIRTUAL MACHINES PROVISIONING AND MIGRATION SERVICES
Introduction

- **Analogy for Migration Services:**
- Previously, whenever there was a need for performing a server's upgrade or performing maintenance tasks, you would exert a lot of time and effort, because it is an expensive operation to maintain or upgrade a main server that has lots of applications and users.
- Now, with the advance of the revolutionized virtualization technology and migration services associated with hypervisors' capabilities, these tasks (maintenance, upgrades, patches, etc.) are very easy and need no time to accomplish.
- Provisioning a new virtual machine is a matter of minutes, saving lots of time and effort, Migrations of a virtual machine is a matter of milliseconds:

  1) saving time, 2) effort, 3) making the service alive for customers, and 4) achieving the SLA/SLO agreements and quality-of-service (QoS) specifications required.

VIRTUAL MACHINES PROVISIONING AND MIGRATION SERVICES

VM provisioning and migration mind map



Layered Virtualization Technology

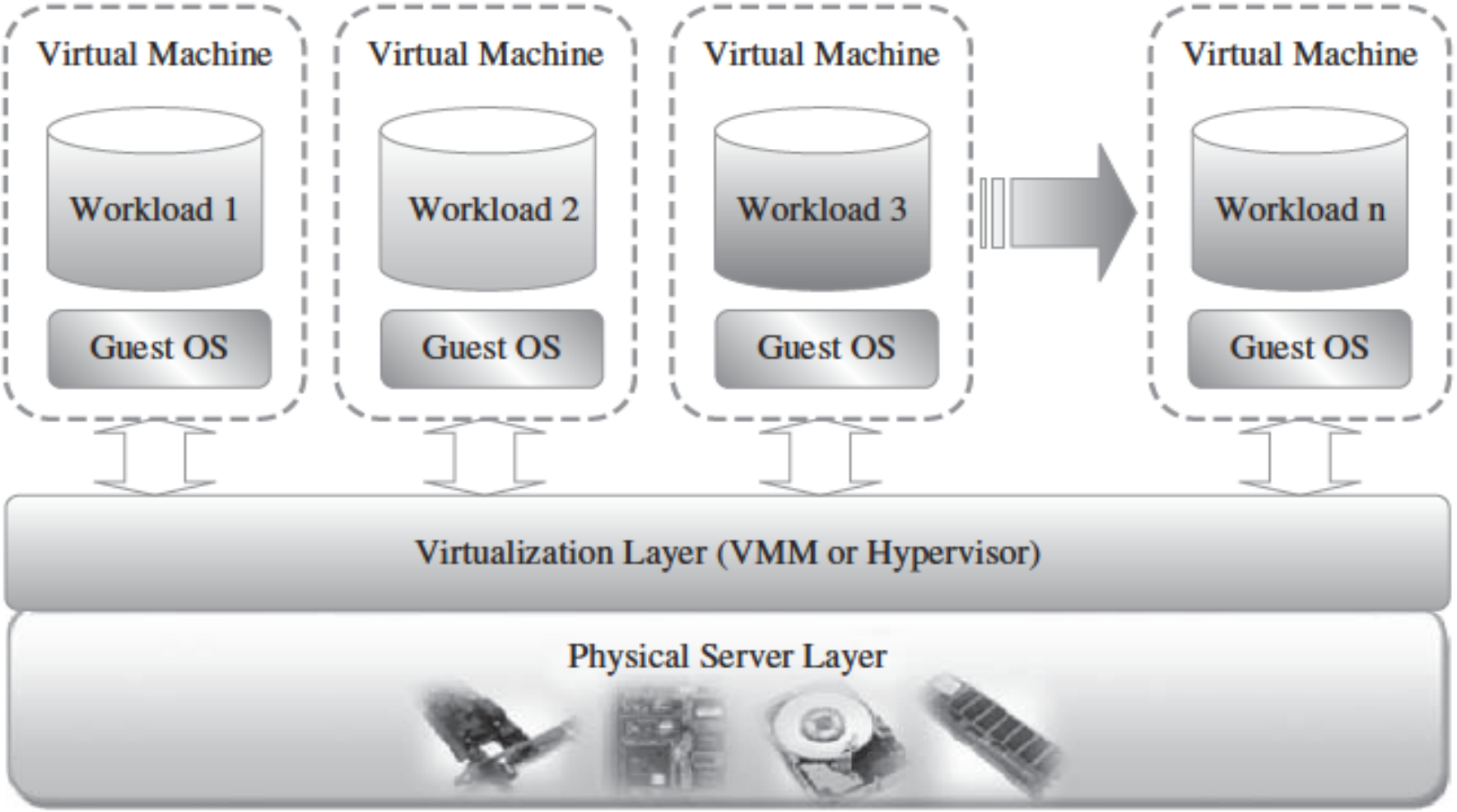


FIGURE 5.2. A layered virtualization technology architecture.

Layered Virtualization Technology

- The virtualization layer partitions the physical resource of the underlying physical server into multiple virtual machines with different workloads. The virtualization layer :
  1) Schedules resources,
  2) Allocates physical resources,
  3) Makes each virtual machine think that it totally owns the whole underlying hardware's physical resource (Preprocessor, disks, etc.)
  4) Makes it flexible and easy to manage resources.
  5) Improve the utilization of resources by multiplexing many virtual machines on one physical host.
  6) The machines can be scale up and down on demand with a high level of resources' abstraction.
  7) Enables High, Reliable, and agile deployment mechanism.
  8) Provides On-demand cloning and live migration.
  9) Having efficient management suite for managing virtual machines.

Public Cloud and Infrastructure Services

- There are many examples for vendors who publicly provide infrastructure as a service. **Amazon Elastic Compute Cloud (EC2)**[4] , but the market now bristles with lots of competition like GoGrid, Joyent Accelerator, Rackspace, AppNexus, FlexiScale, and Manjrasoft Aneka.

- Amazon Elastic Compute Cloud (EC2) services can be leveraged via Web services (SOAP or REST), a Web-based AWS (Amazon Web Service) management console, or the EC2 command line tools.
- The Amazon service provides hundreds of pre-made AMIs (Amazon Machine Images) with a variety of operating systems (i.e., Linux, Open Solaris, or Windows) and pre-loaded software.
- It provides you with complete control of your computing resources and lets you run on Amazon's computing and infrastructure environment easily.
- It also reduces the time required for obtaining and booting a new server's instances to minutes, thereby allowing a quick scalable capacity and resources, up and down, as the computing requirements change.
- Amazon offers different instances' size according to **(a)** the resources' needs (small, large, and extra large), **(b)** the high CPU's needs it provides (medium and extra large high CPU instances), and **(c)** high-memory instances (extra large, double extra large, and quadruple extra large instance).

Private cloud and Infrastructure Services

A private cloud aims at providing public cloud functionality, but on private resources, while maintaining control over an organization's data and resources to meet security and governance's requirements in an organization.

Private cloud exhibits a highly virtualized cloud data center located inside your organization's firewall. It may also be a private space dedicated for your company within a cloud vendor's data center designed to handle the organization's workloads, and in this case it is called **Virtual Private Cloud (VPC)**. Private clouds exhibit the following characteristics:

1) Allow **service provisioning** and **compute capability** for an organization's users in a self-service manner.

2) Automate and provide well-managed virtualized environments.

3) Optimize computing resources, and servers' utilization.

3) Support specific workloads.

There are many examples for vendors and frameworks that provide infrastructure as a service in private setups. The best-known examples are **Eucalyptus** and **OpenNebula** (which will be covered in more detail later on).

4) It is also important to highlight a third type of cloud setup named "hybrid cloud," in which a combination of private/internal and external cloud resources exist together by enabling outsourcing of noncritical services and functions in public cloud and keeping the critical ones internal.

Hybrid cloud's main function is to release resources from a public cloud and to handle sudden demand usage, which is called "cloud bursting."

Cloud and Virtualization Standardization Efforts

Standardization is important to ensure interoperability between virtualization management vendors, the virtual machines produced by each one of them, and cloud computing.

- Distributed Management Task Force (DMTF) have produced standards for almost all the aspects of virtualization technology.
- DMTF initiated the VMAN (Virtualization Management Initiative), which delivers broadly supported interoperability and portability standards for managing the virtual computing lifecycle.
- VMAN's OVF (Open Virtualization Format) in a collaboration between industry key players: Dell, HP, IBM, Microsoft, XenSource, and VMware. OVF specification **provides a common format to package and securely distribute virtual appliances across multiple virtualization platforms.** VMAN profiles define a consistent way of managing a heterogeneous virtualized environment

Cloud and Virtualization Standardization Efforts

- Another standardization effort has been initiated by Open Grid Forum (OGF) through organizing an official new working group to deliver a standard API for cloud IaaS, the Open Cloud Computing Interface Working Group (OCCIWG).
- This group is dedicated for delivering an API specification for the remote management of cloud computing's infrastructure and for allowing the development of interoperable tools for common tasks including deployment, autonomic scaling, and monitoring.
- The new API for interfacing "IaaS" cloud computing facilities will allow:
  - **Consumers** to interact with cloud computing infrastructure on an ad hoc basis.
  - **Integrators** to offer advanced management services.
  - **Aggregators** to offer a single common interface to multiple providers.
  - **Providers** to offer a standard interface that is compatible with the available tools.
  - **Vendors** of grid/clouds to offer standard Interfaces for dynamically scalable service's delivery in their products.

Virtual Machine Provisioning and Manageability

Virtual Machine Life Cycle

- The cycle starts by a request delivered to the IT department, stating the requirement for creating a new server for a particular service.
- This request is being processed by the IT administration to start seeing the servers' resource pool, matching these resources with requirements
- Starting the provision of the needed virtual machine.
- Once it provisioned and started, it is ready to provide the required service according to an SLA.
- Virtual is being released; and free resources.

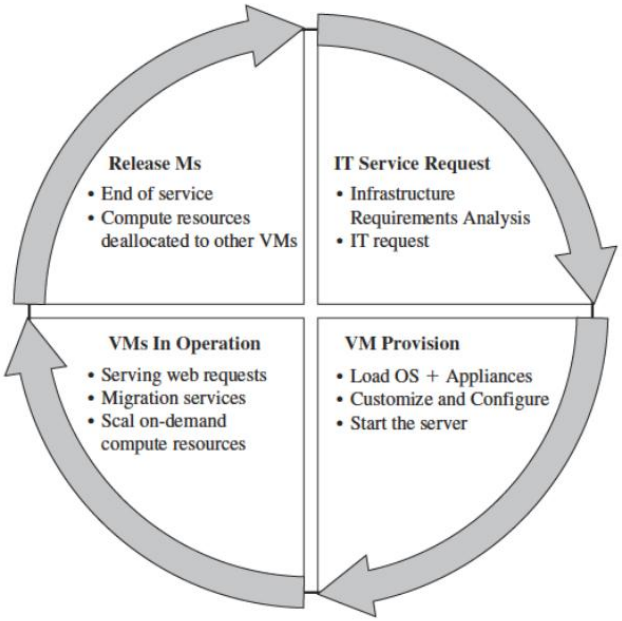


FIGURE 5.3. Virtual machine life cycle.

VM Provisioning Process

- The common and normal steps of provisioning a virtual server are as follows:
- Firstly, you need to select a server from a pool of available servers (physical servers with enough capacity) along with the appropriate OS template you need to provision the virtual machine.
- Secondly, you need to load the appropriate software (operating System you selected in the previous step, device drivers, middleware, and the needed applications for the service required).
- Thirdly, you need to customize and configure the machine (e.g., IP address, Gateway) to configure an associated network and storage resources.
- Finally, the virtual server is ready to start with its newly loaded software.

VM Provisioning Process

To summarize, server provisioning is defining server's configuration based on the organization requirements, a hardware, and software component (processor, RAM, storage, networking, operating system, applications, etc.).

Normally, virtual machines can be provisioned by manually installing an operating system, by using a preconfigured VM template, by cloning an existing VM, or by importing a physical server or a virtual server from another hosting platform. Physical servers can also be virtualized and provisioned using P2V (Physical to Virtual) tools and techniques (e.g., virt-p2v).

After creating a virtual machine by virtualizing a physical server, or by building a new virtual server in the virtual environment, a template can be created out of it.

Most virtualization management vendors (VMware, XenServer, etc.) provide the data center's administration with the ability to do such tasks in an easy way.

VM Provisioning Process

- Provisioning from a template is an invaluable feature, because it reduces the time required to create a new virtual machine.
- Administrators can create different templates for different purposes. For example, you can create a Windows 2003 Server template for the finance department, or a Red Hat Linux template for the engineering department. This enables the administrator to quickly provision a correctly configured virtual server on demand.

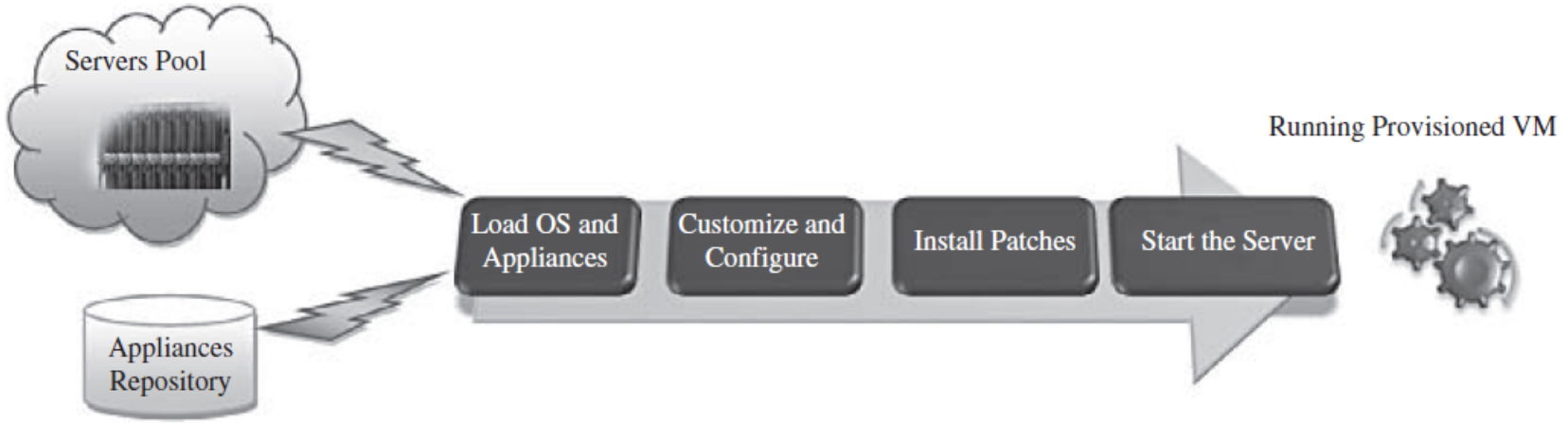


FIGURE 5.4. Virtual machine provision process.

VIRTUAL MACHINE MIGRATION SERVICES
Live Migration and High Availability

Live migration (which is also called **hot or real-time migration**) can be defined as the movement of a virtual machine from one physical host to another while being powered on.

When it is properly carried out, this process takes place without any noticeable effect from the end user's point of view **(a matter of milliseconds)**.

One of the most significant advantages of live migration is the fact that **it facilitates proactive maintenance in case of failure**, because the potential problem can be resolved before the disruption of service occurs.

Live migration can also be used for **load balancing** in which work is shared among computers in order to optimize the utilization of available CPU resources.

VIRTUAL MACHINE MIGRATION SERVICES

Live Migration Anatomy, Xen Hypervisor Algorithm.

- How to live migration's mechanism and memory and virtual machine states are being transferred, through the network, from one host A to another host B:
- the Xen hypervisor is an example for this mechanism. The logical steps that are executed when migrating an OS.
- In this research, the migration process has been viewed as a transactional interaction between the two hosts involved:

Live Migration Timeline

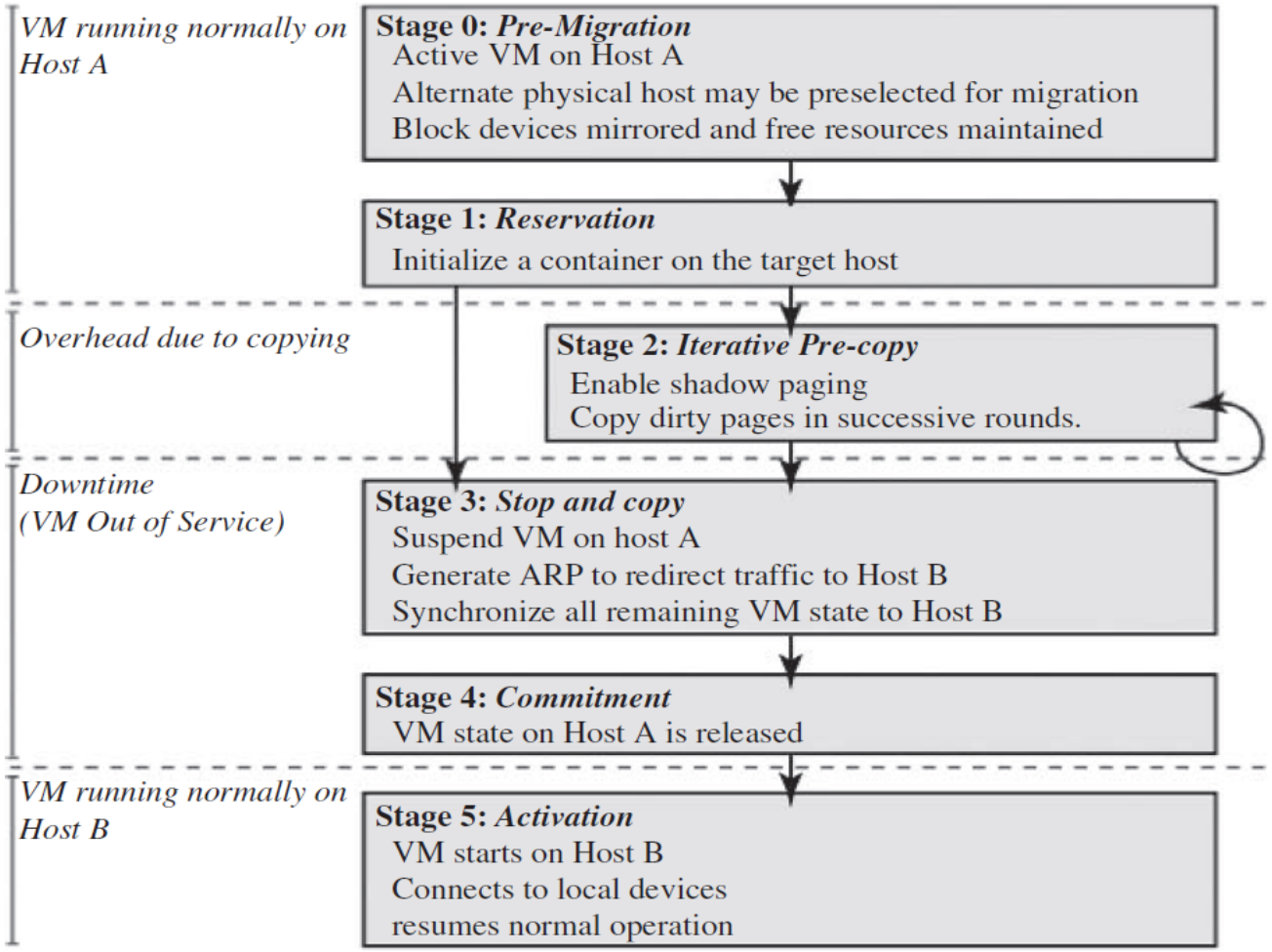


FIGURE 5.5. Live migration timeline [21].

Live Migration Stages

Stage-0: Pre-Migration. An active virtual machine exists on the physical host A.

Stage-1: Reservation. A request is issued to migrate an OS from host A to host B (a precondition is that the necessary resources exist on B and a VM container of that size)

Stage-3: Stop-and-Copy. Running OS instance at A is suspended, and its network traffic is redirected to **B**. As described in reference 21, CPU state and remaining inconsistent memory pages are then transferred. At the end of this stage, there is a consistent suspended copy of the VM at both A and B. The copy at A is considered primary and is resumed in case of failure.

Stage-4: Commitment. Host B indicates to A that is has successfully received a consistent OS image. Host A acknowledges this message as a commitment of migration transaction.

Stage-5: Activation. The migrated VM on B is now activated. Post-migration code runs to reattach the device's drivers to the new machine and advertise moved IP addresses.

This approach to failure management ensures that at least on host has a consistent VM image at all times during migration:

1) Original host remains stable until migration commits and that the VM may be suspended and resumed on that host with no risk of failure.
2) A migration request essentially attempts to move the VM to a new host and on any sort of failure, execution is resumed locally, aborting the migration.

Live Migration

Live migration Effect on a Running Web Server

- Clark et al. evaluated the mentioned migration on Apache 1.3 Web Server; this served a static content at a high rate. The throughput is achieved when continuously serving a single 512-KB file to a set of 100 concurrent clients.

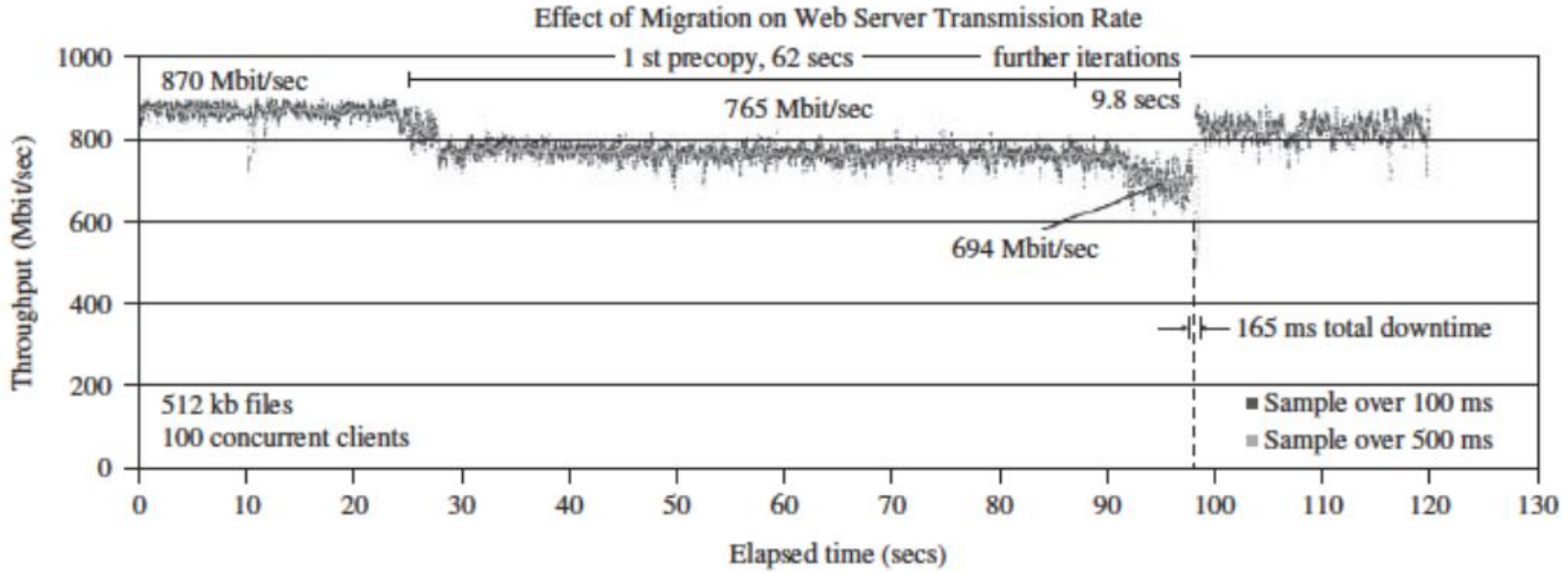


FIGURE 5.6. Results of migrating a running Web server VM [21].

Live Migration

Live Migration Vendor Implementations Example

There are lots of VM management and provisioning tools that provide the live migration of VM facility, two of which are VMware VMotion and Citrix XenServer “XenMotion”.

VMware VMotion:

a) Automatically optimize and allocate an entire pool of resources for maximum hardware utilization, flexibility, and availability.

b) Perform hardware’s maintenance without scheduled downtime along with migrating virtual machines away from failing or underperforming servers.

Citrix XenServer “XenMotion”:

Based on Xen live migrate utility, it provides the IT Administrator the facility to move a running VM from one XenServer to another in the same pool without interrupting the service (hypothetically zero – downtime server maintenance), making it a highly available service and also good feature to balance workloads on the virtualized environments.

Regular/Cold Migration

Cold migration is the migration of a powered-off virtual machine. With cold migration:

- You have options of moving the associated disks from one data store to another.
- The virtual machines are not required to be on a shared storage. 1) Live migrations needs to a shared storage for virtual machines in the server's pool, but cold migration does not. 2) In live migration for a virtual machine between two hosts, there should be certain CPU compatibility checks, but in cold migration this checks do not apply.
- Cold migration (VMware product) is easy to implement and is summarized as follows:
  - The configuration files, including NVRAM file (BIOS Setting), log files, and the disks of the virtual machines, are moved from the source host to the destination host's associated storage area.
  - The virtual machine is registered with the new host.
  - After the migration is completed, the old version of the virtual machine is deleted from the source host.

Live Storage Migration of Virtual Machines

- This kind of migration constitutes moving the virtual disks or configuration file of a running virtual machine to a new data store without any interruption in the availability of the virtual machine’s service.

VM Provisioning and Migration in Action

- Now we will have a look at a real example of how to manage the life cycle, provision, and migrate a virtual machine by the help of one of ConVirt (Open-source framework for the management of open-source virtualization like Xen and KVM).
- Please refer to the text book for more information in this regards.

Provisioning in the Cloud Context

- In the cloud context, we shall discuss systems that provide the virtual machine provisioning and migration services;
- Amazon EC2 is a widely known example for vendors that provide public cloud services.
- Also, **Eucalyptus and Open-Nebula** are two complementary and enabling technologies for open-source cloud **tools in building private, public, and hybrid cloud architecture**.
- Eucalyptus is a system for implementing on-premise private and hybrid clouds using the hardware and software's infrastructure, which is in place without modification.
- The current interface to Eucalyptus is compatible with Amazon's EC2, S3, and EBS interfaces, but the infrastructure is designed to support multiple client-side interfaces.
- Eucalyptus is implemented using commonly available Linux tools and basic Web service's technologies.
- Eucalyptus adds capabilities, such as end-user customization, self-service provisioning, and legacy application support to data center's virtualization's features, making the IT customer's service easier.

Provisioning in the Cloud Context

- OpenNebula is a virtual infrastructure manager that orchestrates storage, network, and virtualization technologies to enable the dynamic placement of multi-tier services on distributed infrastructures, combining both data center's resources and remote cloud's resources according to allocation's policies.
- OpenNebula provides internal cloud administration and user's interfaces for the full management of the cloud's platform.

Amazon Elastic Compute Cloud

Infrastructure Enabling Technology

Eucalyptus, OpenNebula, and Aneka.

- some of the Eucalyptus (elastic utility computing architecture for linking your programs to useful systems.) features are:
  - Interface compatibility with EC2, and S3 (both Web service and Query/REST interfaces).
  - Simple installation and deployment.
  - Support for most Linux distributions (source and binary packages).
  - Support for running VMs that run atop the Xen hypervisor or KVM.
  - Support for other kinds of VMs, such as VMware, is targeted for future releases.
  - Secure internal communication using SOAP with WS security.
  - Cloud administrator's tool for system's management and user's accounting.
  - The ability to configure multiple clusters each with private internal network addresses into a single cloud.

Eucalyptus aims at fostering the research in models for service's provisioning, scheduling, SLA formulation, and hypervisors' portability.

Eucalyptus Architecture.

- Eucalyptus architecture, constitutes each high-level system's component as a stand-alone Web service with the following high-level components.

- **Node controller** (NC) controls the execution, inspection, and termination of VM instances on the host where it runs.
- **Cluster controller** (CC) gathers information about and schedules VM execution on specific node controllers, as well as manages virtual instance network.
- **Storage controller** (SC) is a put/get storage service that implements Amazon's S3 interface and provides a way for storing and accessing VM images and user data.
- **Cloud controller** (CLC) is the entry point into the cloud for users and administrators. It queries node managers for information about resources, makes high-level scheduling decisions, and implements them by making requests to cluster controllers.
- **Walrus** (W) is the controller component that manages access to the storage services within Eucalyptus. Requests are communicated to Walrus using the SOAP or REST-based interface.

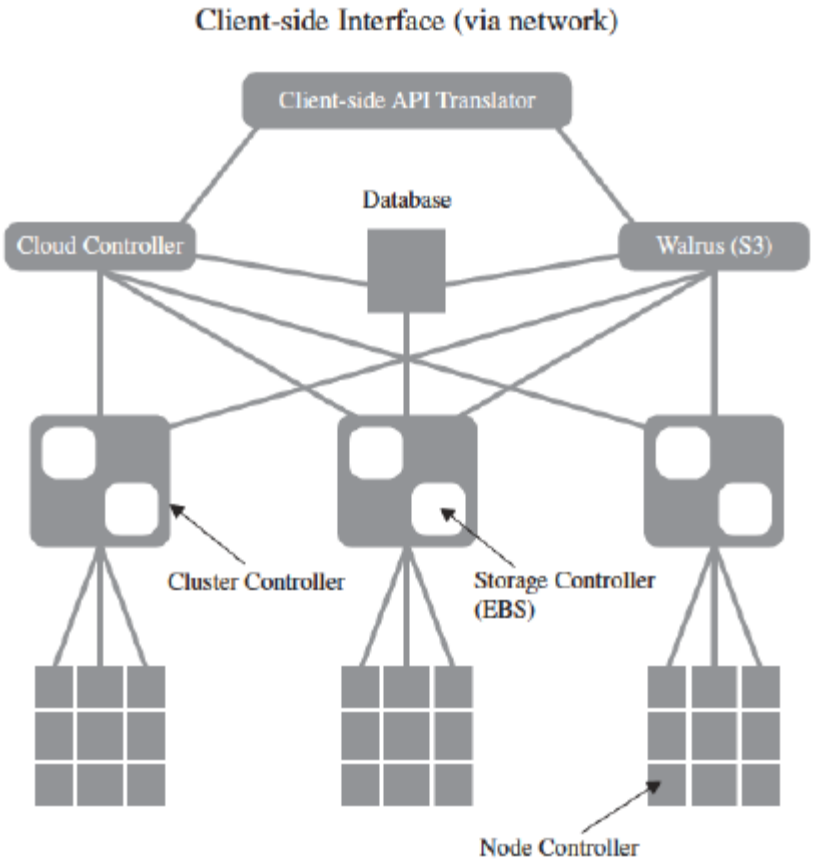


FIGURE 5.20. Eucalyptus high level architecture.

VM Dynamic Management Using OpenNebula

- **OpenNebula** is an open and flexible tool that fits into existing data center's environments to build any type of cloud deployment.
- OpenNebula can be primarily used as a virtualization tool to manage your virtual infrastructure, which is usually referred to as private cloud.
- **OpenNebula** supports a hybrid cloud to combine local infrastructure with public cloud-based infrastructure, enabling highly scalable hosting environments.
- **OpenNebula** also supports public clouds by providing cloud's interfaces to expose its functionality for virtual machine, storage, and network management.
- **OpenNebula** is an open-source alternative to these commercial tools for the dynamic management of VMs on distributed resources. This tool is supporting several research lines in advance reservation of capacity, probabilistic admission control, placement optimization, resource models for the efficient management of groups of virtual machines, elasticity support, and so on.
- **Haizea** is an open-source virtual machine-based **lease management** architecture developed by Sotomayor et al. It can be used as a scheduling backend for OpenNebula. Haizea uses leases as a fundamental resource provisioning

OpenNebula, High level architecture

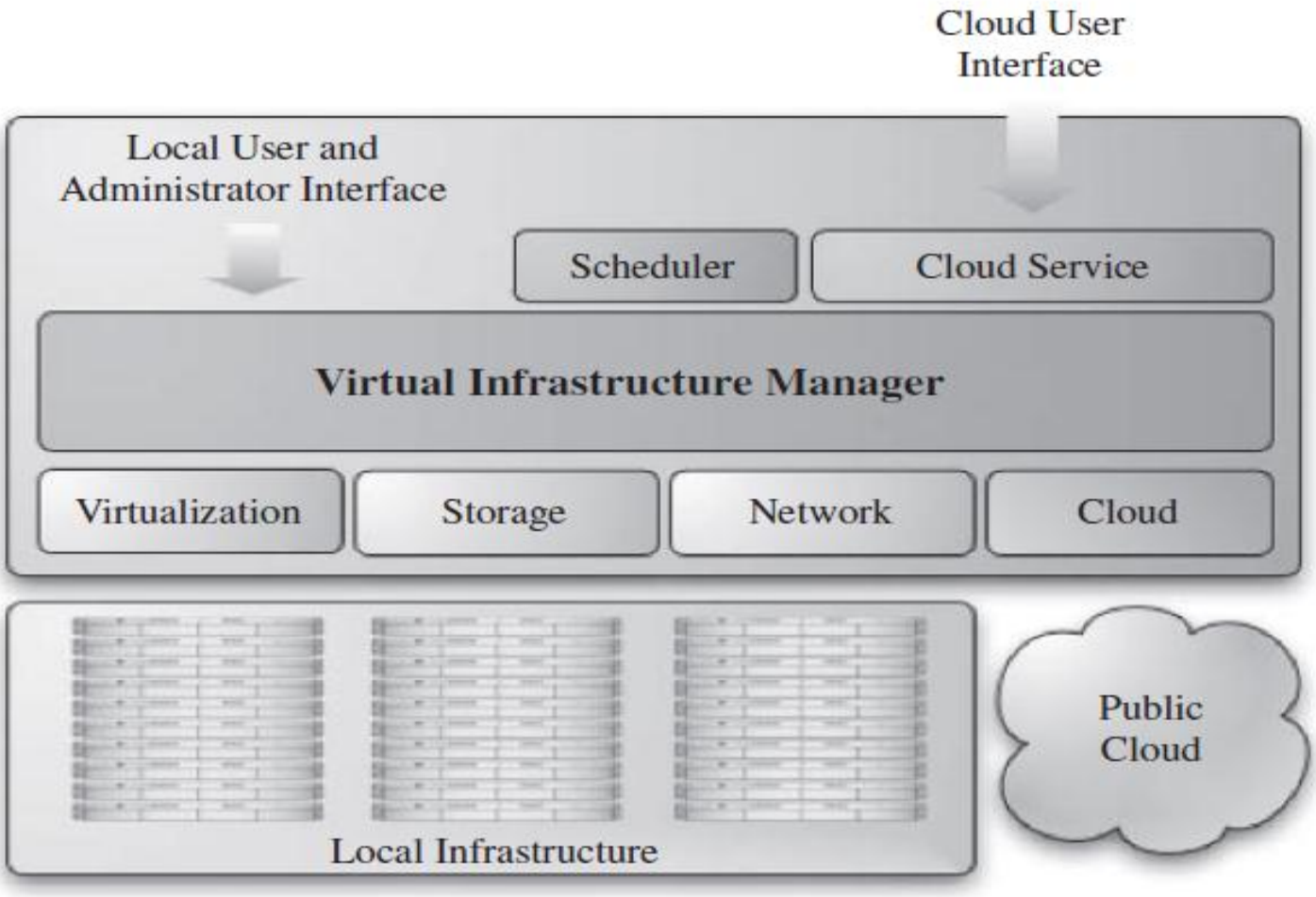


FIGURE 5.21. OpenNebula high level architecture [14].

OpenNebula and Haizea

- **Haizea** is an open-source virtual machine-based **lease management** architecture developed by Sotomayor et al.
- It can be used as a **scheduling backend for OpenNebula**. Haizea uses leases as a fundamental resource provisioning abstraction and implements those leases as virtual machines, taking into account the overhead of using virtual machines when scheduling leases. Haizea also provides advanced functionality such as:

  - Advance reservation of capacity.
  - Best-effort scheduling with backfilling.
  - Resource preemption (using VM suspend/resume/migrate).
  - Policy engine, allowing developers to write pluggable scheduling policies in Python.

FUTURE RESEARCH DIRECTIONS

Virtual machine provision and migration services take their place in research to achieve the best out of its objectives, and here is a list of potential areas' candidates for research:

- **Self-* (Self-adaptive) and dynamic data center:** Data centers exist in the premises of any hosting or ISPs that host different Web sites and applications. These sites are being accessed at different timing pattern (morning hours, afternoon, etc.). Thus, workloads against these sites need to be tracked because they vary dynamically over time. The sizing of host machines (the number of virtual machines that host these applications) represents a challenge, and there is a potential research area over here to study the performance impact and overhead due to this dynamic creation of virtual machines hosted in these self-adaptive data centers, in order to manage Web sites properly.
- **Study of the performance in this dynamic environment** will also tackle the balance that should be exist between a rapid response time of individual applications, the overall performance of the data, and the high availability of the applications and its services.

FUTURE RESEARCH DIRECTIONS

- **Performance evaluation and workload characterization of virtual workloads:** It is very invaluable in any virtualized infrastructure to have
  - **a notion about the workload in each VM,**
  - **the performance's impacts due to the hypervisors layer, and**
  - **the overhead due to consolidated workloads for such systems.**

Single-workload benchmark is useful in quantifying the virtualization overhead within a single VM, but not useful in a whole virtualized environment with multiple isolated VMs with varying workloads. So, **there is a big need for a common workload model and methodology** for virtualized systems.

- One of the potential areas is the development of fundamental tools and techniques that facilitate the integration and provisioning of distributed and hybrid clouds in federated way.
- High-performance data scaling in private and public cloud environments.

FUTURE RESEARCH DIRECTIONS

- Organizations and enterprises that adopt the cloud computing architectures can face lots of challenges related to:
- (a) the elastic provisioning of compute clouds on their existing data center's infrastructure,
- (b) the inability of the data layer to scale at the same rate as the compute layer.

So, there is a persisting need for implementing systems that are capable of **scaling data with the same pace as scaling the infrastructure**, or **to integrate current infrastructure elastic provisioning systems with existing systems** that are designed to scale out the applications and data layers.

FUTURE RESEARCH DIRECTIONS

- **Performance and high availability in clustered VMs through live migration:**
- Clusters are very common in research centers, enterprises, and accordingly in the cloud. There are two aspects of great importance:
  - **high availability,**
  - **high performance service.**

This can be achieved through clusters of virtual machines in which **high available applications** can be achieved **through the live migration of the virtual machine to different locations in the cluster or in the cloud**.

So, the need exists to **(a)** study the performance, **(b)** study the performance's improvement opportunities with regard to the migrations of these virtual machines, and **(c)** decide to which location the machine should be migrated.

- **VM scheduling algorithms.**
- **Accelerating VMs live migration time.**
- **Cloud-wide VM migration and memory de-duplication.**

FUTURE RESEARCH DIRECTIONS

- Normal VM migration is being done within the same physical site location (campus, data center, lab, etc.). However, migrating virtual machines between different locations is an invaluable feature to be added to any virtualization management's tools.
- For more details on memory status, storage relocation, and so on; check the patent pending technology about this topic. Considering such setup can enable faster and longer-distance VM migrations, cross-site load balancing, power management, and de-duplicating memory throughout multiple sites. It is a rich area for research.

Live migration security:

Live migration security is a very important area of research, because several security's vulnerabilities exist; check **reference 38** for an empirical exploitation of live migration:

- Extend migration algorithm to allow for priorities.
- Cisco initiative UCS (Unified Commuting System) and its role in dynamic just-in-time provisioning of virtual machines and increase of business agility.