BITS Pilani

Cloud Computing

VM Capacity & Provisioning

Agenda

- IaaS Recap
- VM Management
  - Why VM Management?
  - VM management Tools
  - VM Provisioning
  - VM Migration Techniques
  - Live Migration Example

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Recap

What is AWS

Amazon Web Services (AWS) is the world's most comprehensive and broadly adopted cloud platform, offering over 200 fully featured services from data centers globally. Millions of customers—including the fastest-growing startups, largest enterprises, and leading government agencies—are using AWS to lower costs, become more agile, and innovate faster.

Global Infrastructure: AWS serves over one million active customers in more than 190 countries, and it continues to expand its global infrastructure

Security: All AWS customers benefit from data center and network architectures built to satisfy the requirements of the most security-sensitive organizations.

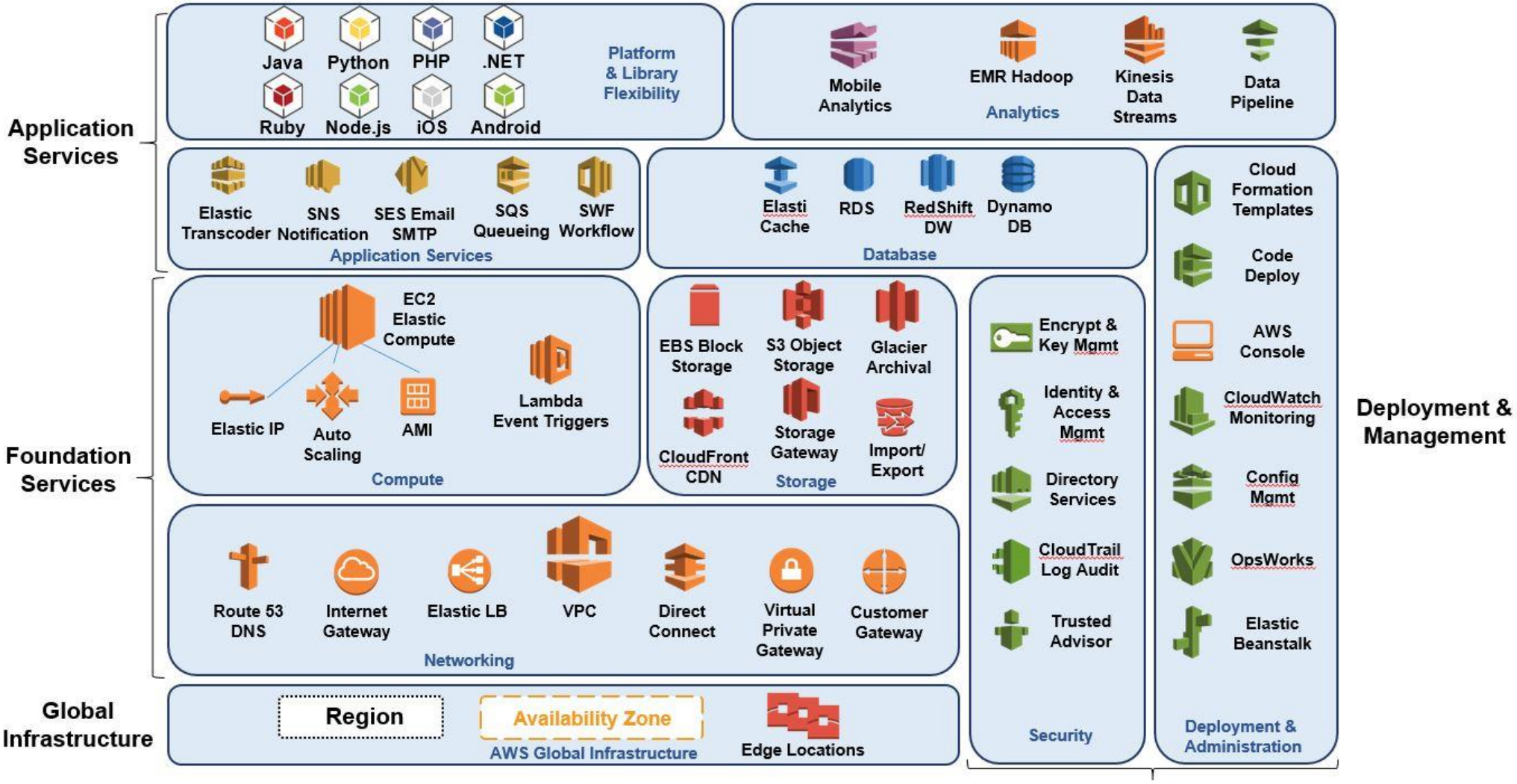
- Application building blocks
- Stable APIs
- Proven Amazon infrastructure
- Focus on innovation and creativity
- Long-term investment

AWS Regions & Availability Zones

- AWS provides a **highly available technology infrastructure platform** with multiple locations worldwide. These locations are composed of **regions** and **Availability Zones**. Each **region** is a **separate geographic area**.
- Each **region** has **multiple, isolated locations** known as **Availability Zones**. AWS enables the **placement of resources** and data in multiple **locations**. Resources **aren't replicated** across regions **unless organizations** choose to do so.
- Additionally, for faster delivery of content, AWS has **EDGE locations** concentrated in major cities. (Used with CloudFront & Route53)

Availability Zones located in AWS Regions consist of one or more discrete data centers, each of which has redundant power, networking, and connectivity, and is housed in separate facilities. Each AZ has multiple internet connections and power connections to multiple grids.

AWS Reference Model



What is OpenStack?

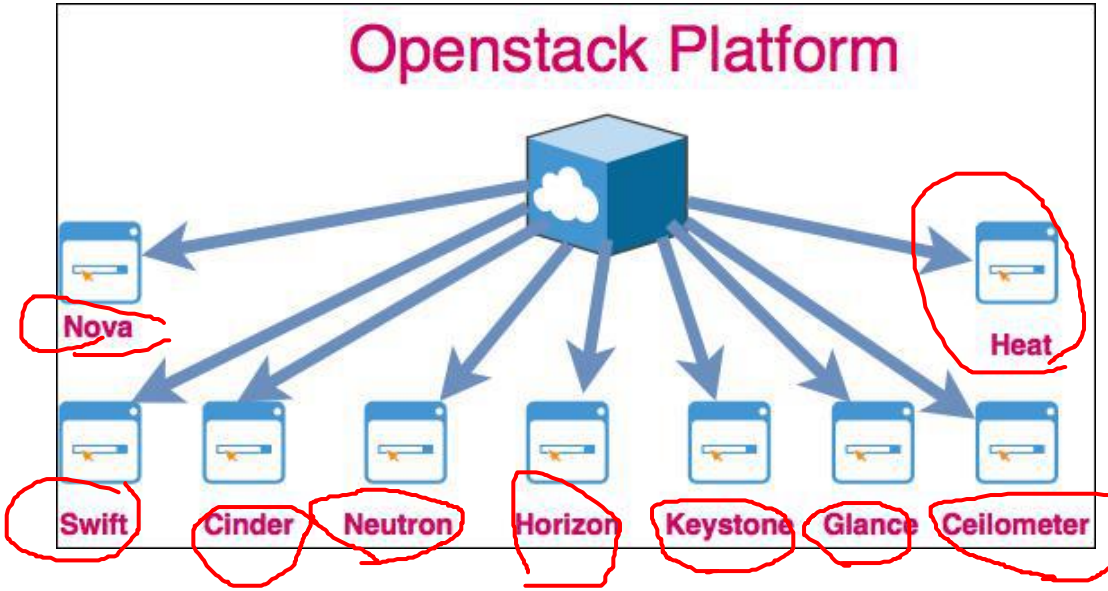
OpenStack is a **cloud operating system** that controls **large pools of compute, storage, and networking resources**.

Managed through **a dashboard** that gives administrators control while empowering their users to provision resources through a web interface.

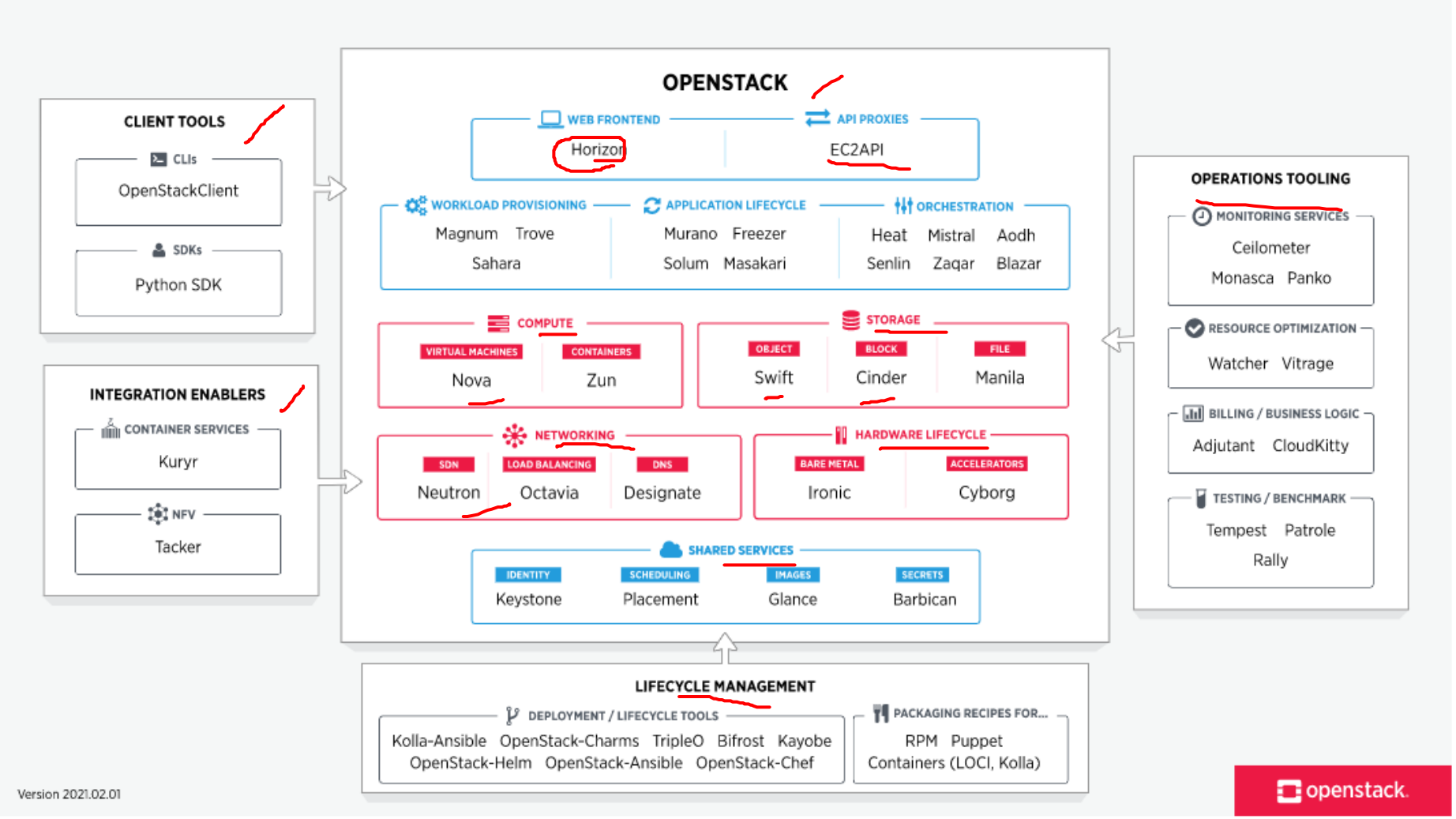
OpenStack is a set of software tools for building and managing cloud computing platforms for public and private clouds.

Backed by some of the biggest companies in software development and hosting, as well as thousands of individual community members, many think that OpenStack is the future of cloud computing.

Managed by **OpenStack Foundation a non profit organization**.



OpenStack Reference Model



Differences

In principle, the main difference between AWS and OpenStack is that the former already exists, while the latter one you have to build yourself.

Since building cloud infrastructure from scratch entails significant upfront investments (setting up a data centre, hardware purchase, cloud deployment consulting fee, etc.), AWS is usually a more compelling option at the beginning of the cloud migration journey.

At the end of the day, all you need to do is to create an account on AWS and attach a credit card, and you can start using cloud resources right away.

AWS will charge you based on the actual resource consumption.

Differences

On the other hand, those costs(AWS) can quickly become significant as the number of workloads continues to increase.

Over time, it may turn out that the aggregated recurring cost of using AWS will exceed the cost of OpenStack deployment.

Of course, running cloud infrastructure on-premises also comes with some recurring costs (hosting facilities, power consumption, staff salary, etc.), but these are lower when running workloads in the long-term and at scale, according to Canonical's Cloud Pricing Report from 2021.

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VM Management

Anatomy of Cloud

Virtual Infrastructure (VI) management—the management of virtual machines distributed across a pool of physical resources—becomes a key concern when building an IaaS cloud and **poses a number of challenges**.

In traditional physical resources, machines require a fair amount of configuration, including preparation of the machine's software environment and network configuration.

In a **virtual infrastructure**, this configuration must be done **on-the-fly**, with as little time between the time the VMs are requested and the time they are available to the users.

This is further complicated by the need to configure groups of VMs that will provide a specific service (e.g., an application requiring a Web server and a database server).

Additionally, a **virtual infrastructure manager** must be capable of **allocating resources efficiently**, taking into **account an organization's goals** (such as minimizing power consumption and other operational costs) and **reacting to changes in the physical infrastructure**.

Anatomy of Cloud

Virtual infrastructure management in **private clouds** has to deal with an additional problem:

Unlike large IaaS cloud providers such as Amazon, **private clouds typically do not have enough** resources to provide the illusion of "infinite capacity."

The **immediate provisioning scheme used in public clouds**, where resources are provisioned at the moment they are requested, is **ineffective in private clouds**.

Support for additional provisioning schemes is required for applications that require resources at specific times, such as **best-effort provisioning** and **advance reservations** to guarantee quality of service (QoS).

Thus, **efficient resource allocation algorithms** and **policies** and the ability to combine both **private and public cloud resources**, resulting in a hybrid approach, become even more important.

What do we manage in Public Cloud?

When we talk about RM, we are referring to the pillars of IaaS

- Compute Resource
- Storage Resource
- Memory
- Network

Other ancillary services can be added as required. The challenge is that most cloud ecosystems are hybrid consisting of several VM's

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).

What do we manage in Private Cloud?

When we talk about RM, we are referring to the pillars of IaaS

- Compute Resource
- Storage Resource
- Memory
- Network

Other ancillary services can be added as required. The challenge is that most cloud ecosystems are hybrid consisting of several VM's

Private cloud exhibits a highly virtualized cloud data centre located inside your organization's firewall.

It may also be a private space dedicated for your company within a cloud vendor's data centre 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.

The best-known examples are Eucalyptus and OpenNebula

Why Resource Management

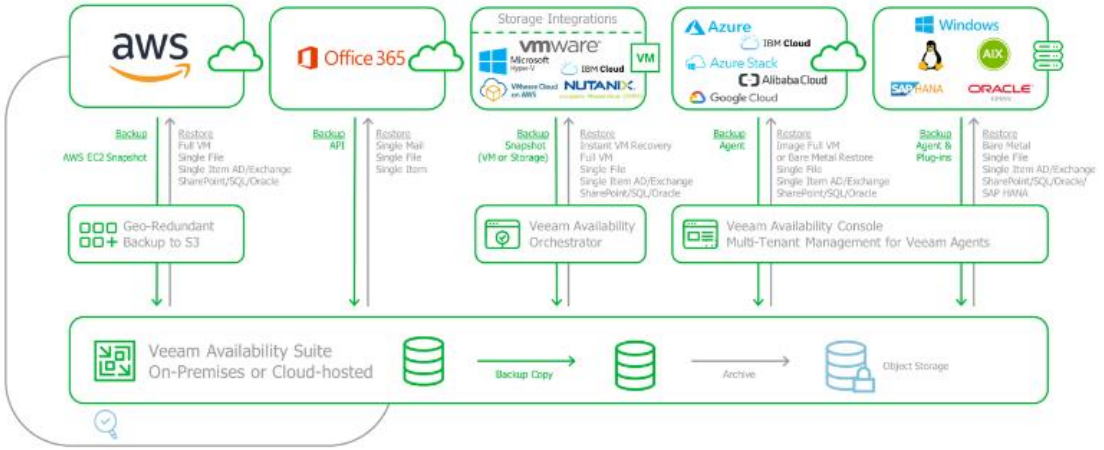
With the infrastructure world in constant flux, more and more businesses are adopting a multi-cloud deployment model.

Consider the impact on the data alone. 10 years ago, all anyone worried about was if the SAN would stay up, and if it didn't, would their data be protected.

Fast forward to today, even a small business can have data scattered across the globe.

Maybe they have a few vSphere hosts in an HQ, with branch offices using workloads running in the cloud or Software as a Service-based applications.

Maybe backups are stored in an object storage repository (somewhere — but only one guy knows where). This is happening in the smallest of businesses, so as a business grows and scales, the challenges become even more complex.



Key Considerations

- **How to Protect my VM Instance**
- **How to Recover VM in case of Failure**
- **How to achieve smooth scaling**

What is Resource Management

RM is a process that deals with the procurement and release of resources.

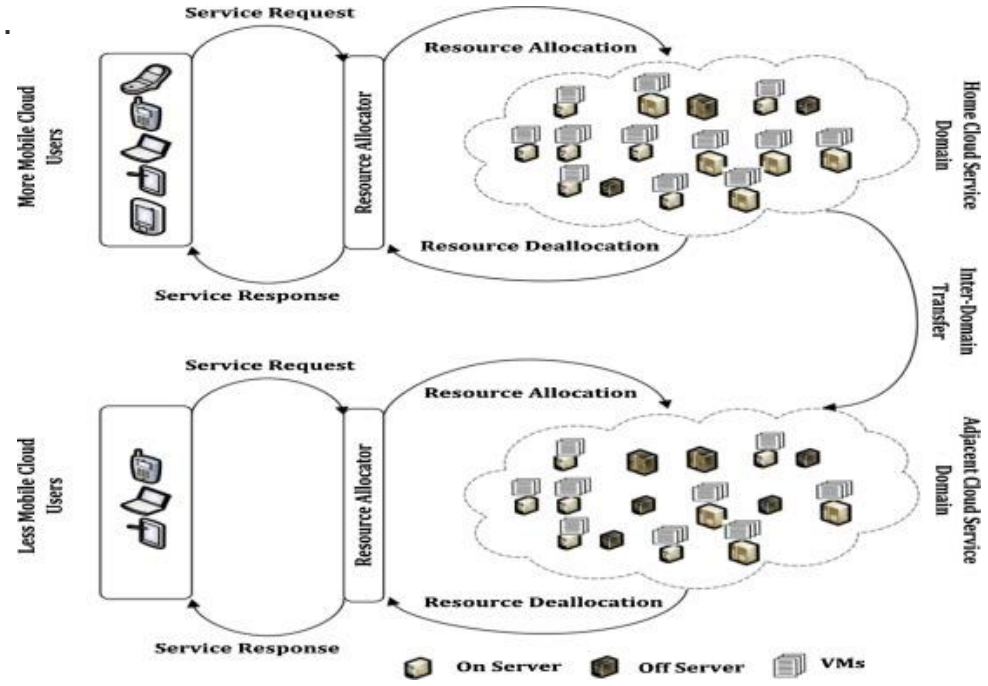
Virtualization techniques are used for flexible and on-demand resource provisioning.

To do so, for each received task, either a new VM is created or it is placed on the existing VM of the same user.

Once the task is completed, all the acquired resources are released which become parts of the free resource pool.

Resource assignment is performed on the basis of Service Level Agreement (SLA) that is agreed between the service provider and the customer.

SLA contains details of the service level that is required by a tenant. Moreover, it contains information about the payment process and SLA violation penalty.

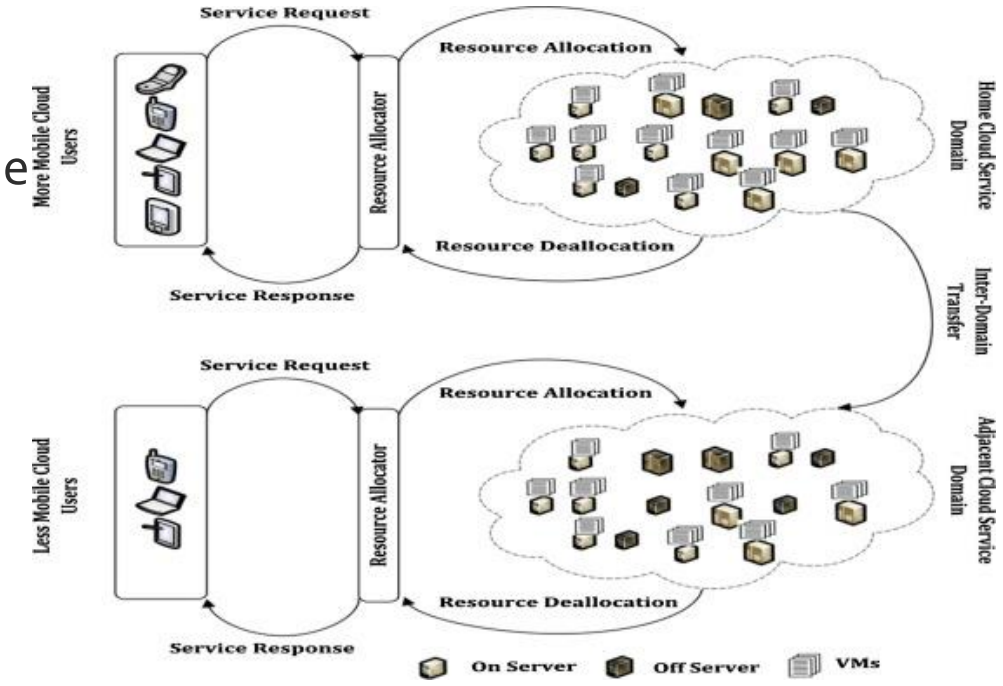


What is Resource Management

Cloud resource management requires complex policies and decisions for multi-objective optimization.

Effective resource management is extremely challenging due to the scale of the cloud infrastructure and to the unpredictable interactions of the system with a large population of users.

The scale makes it impossible to have accurate global state information and the large user population makes it nearly impossible to predict the type and the intensity of the system workload.



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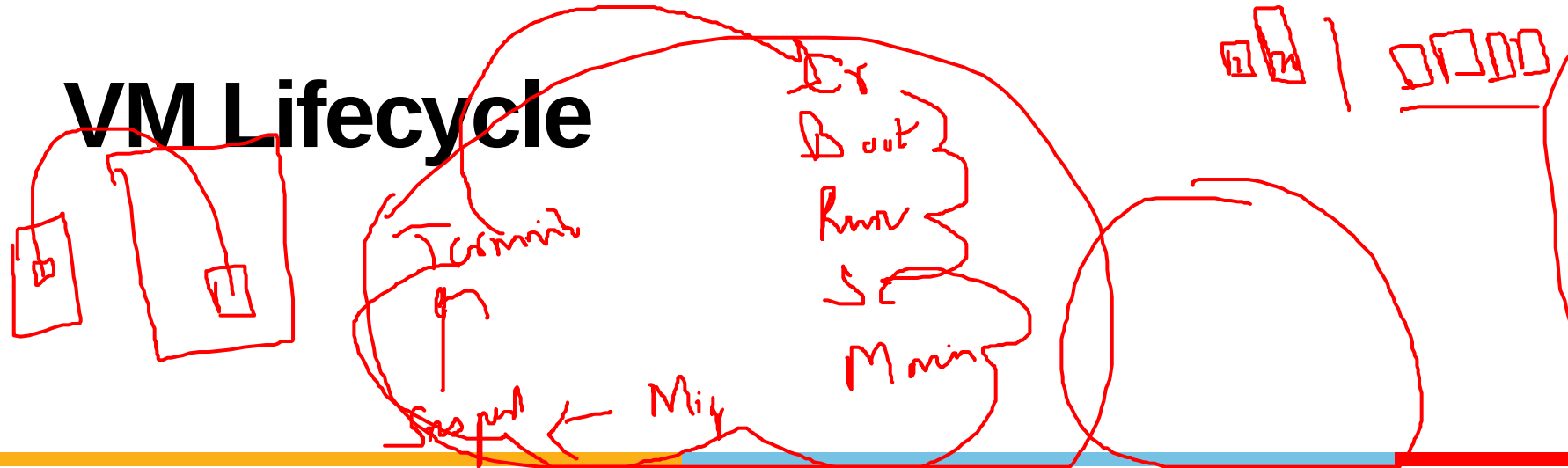
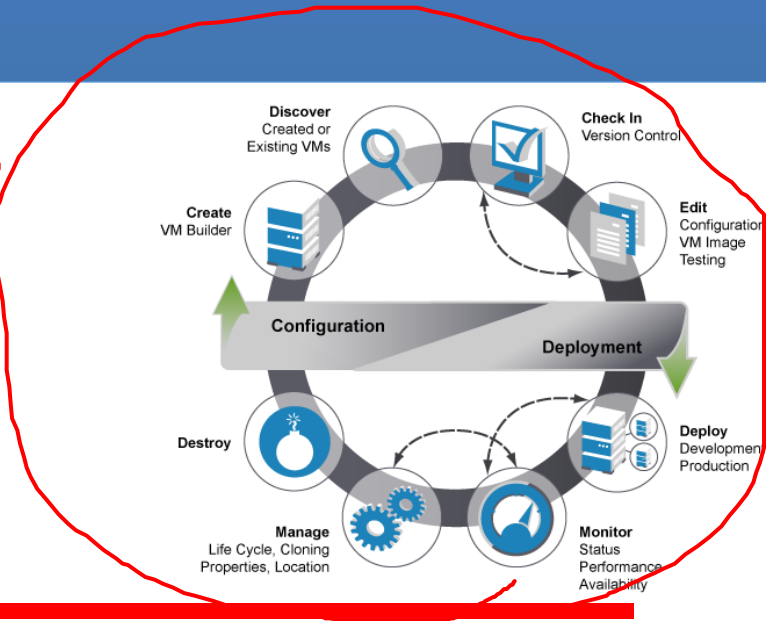
VM Lifecycle





VM Life Cycle

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(Service Level agreement).**
- **Virtual is being released; and free resources.**

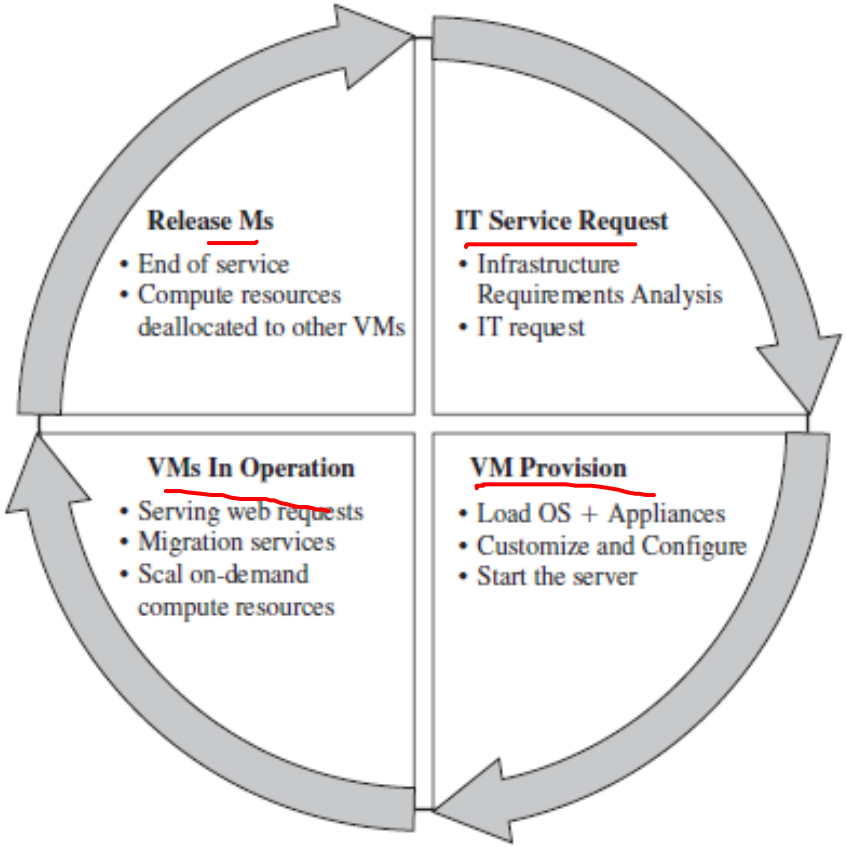


FIGURE 5.3. Virtual machine life cycle.

VM Provisioning process

- Server provisioning is defining server's configuration based on the organization requirements, a H/W, and S/W component (processor, RAM, storage, networking, operating system, applications, etc.).

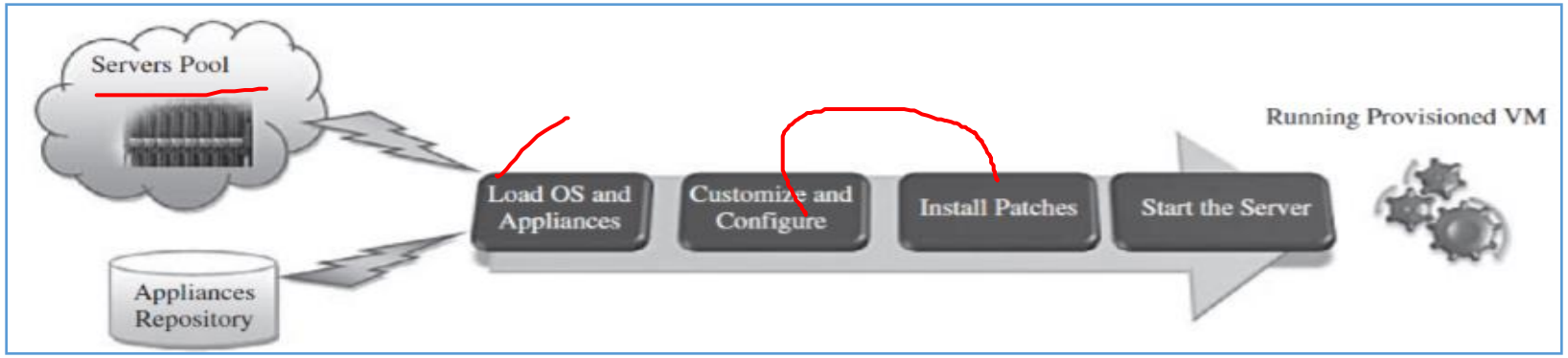
VMs can be provisioned by

- Manually installing an OS,
- Using a preconfigured VM template,
- Cloning an existing VM, or importing a physical server or a
- Server from another hosting platform.
- Physical servers can also be virtualized and provisioned using P2V (Physical to Virtual)

VM Provisioning process

Steps to Provision VM -

- Select a server from a pool of available servers along with the appropriate OS template you need to provision the virtual machine.
- Load the appropriate software.
- Customize and configure the machine (e.g., IP address, Gateway) to an associated network and storage resources.
- Finally, the virtual server is ready to start with its newly loaded S/W.



VM Provisioning using templates

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

Provisioning from a template reduces the time required to create a new virtual machine.

- Administrators can create different templates for different purposes.

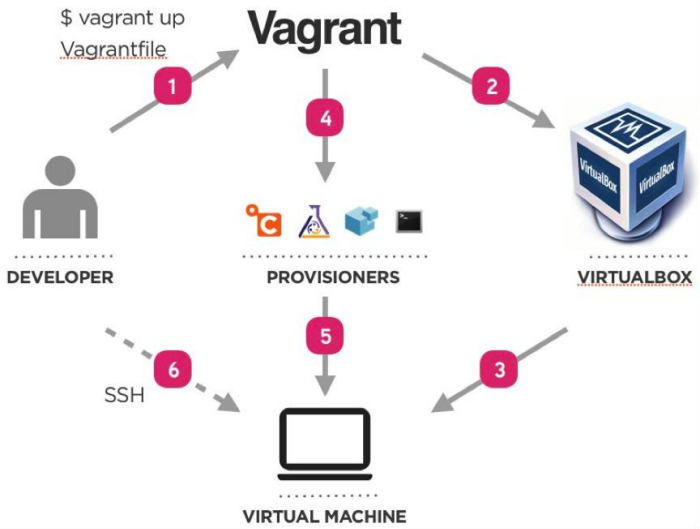
For example –

- Vagrant provision tool using VagrantFile (template file) - Demo
- Heat – Orchestration Tool of openstack (Heat template in YAML format) - Demo

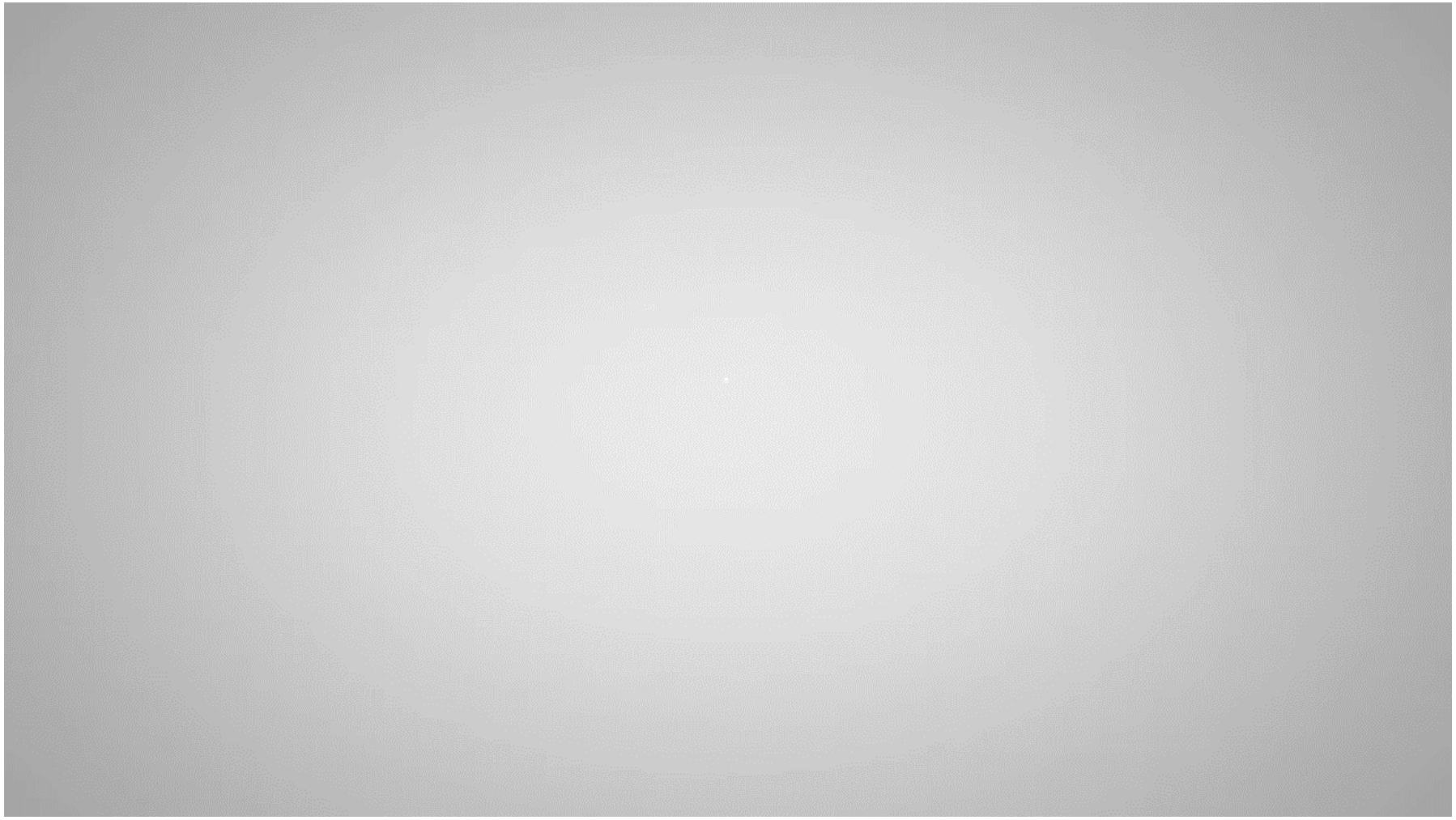
This enables the administrator to quickly provision a correctly configured virtual server on demand.

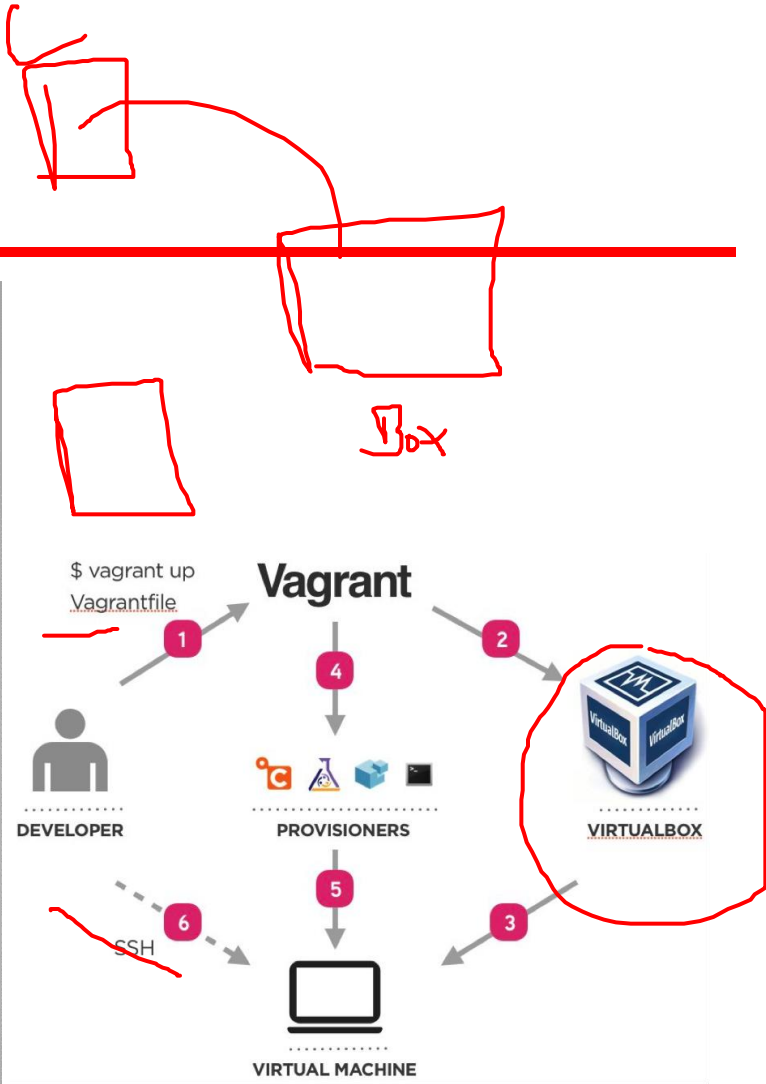
Provisioning from a template is an invaluable feature, because it reduces the time required to create a new virtual machine.

Understanding Vagrant

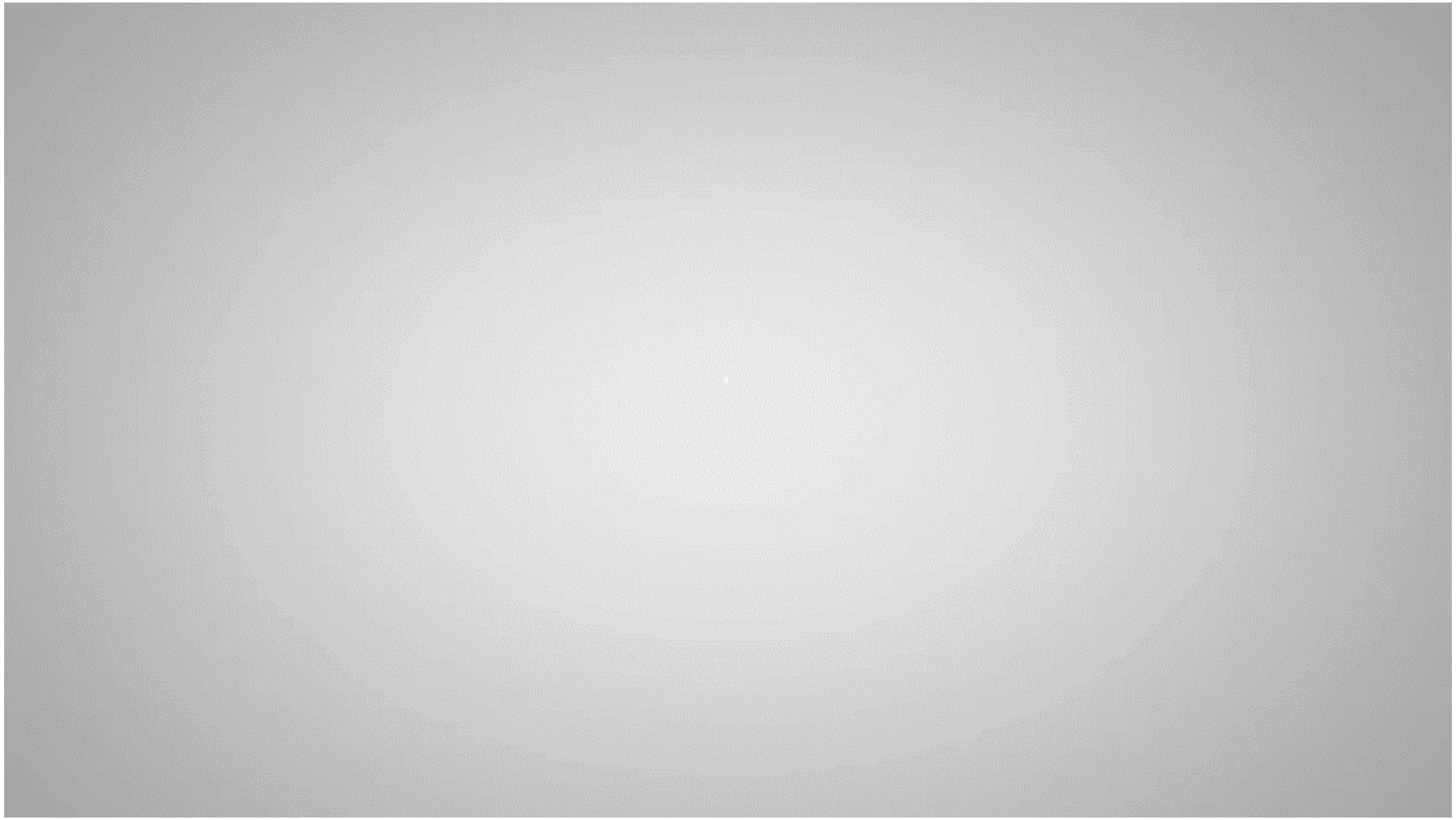


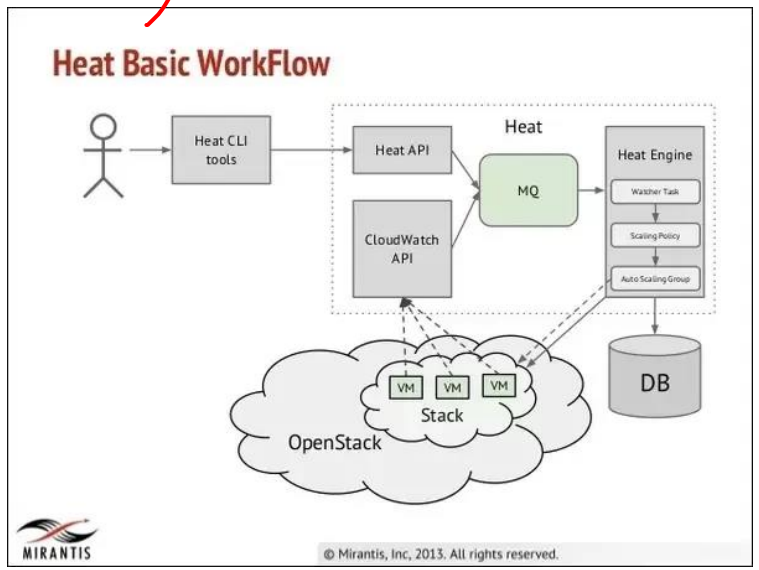
Demo – Vagrant Provisioning



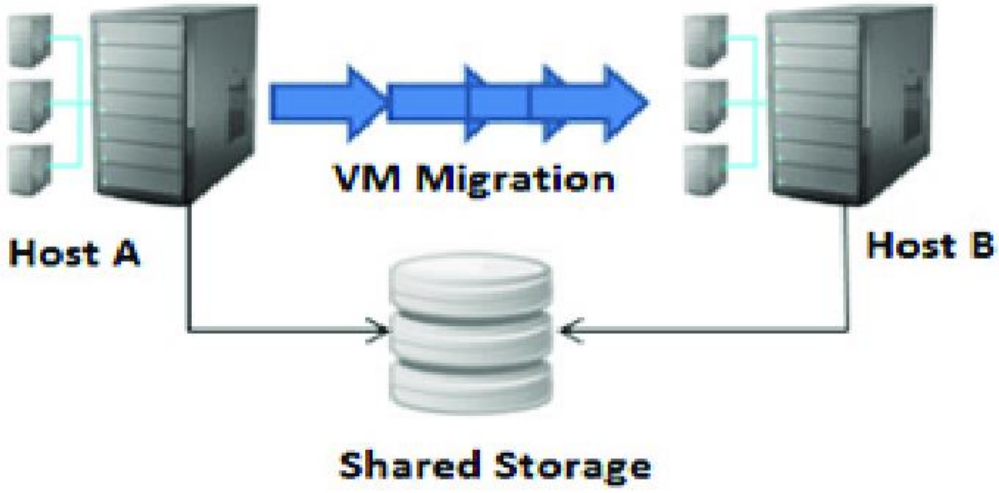


Demo – HEAT Provisioning





VM Migration



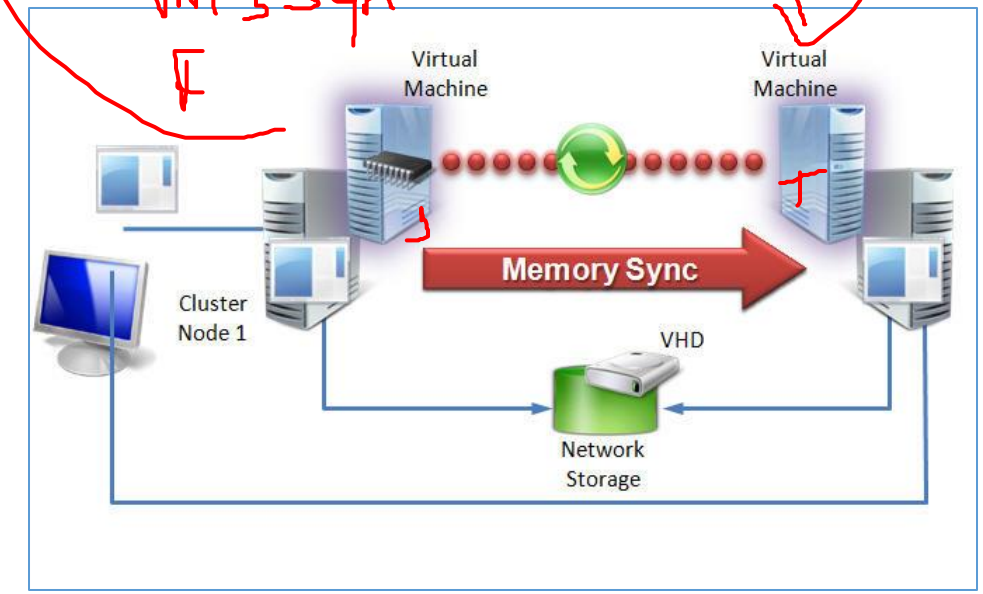
What is VM Migration

The process of moving a virtual machine from one host server or storage location to another;

There are different techniques of VM migration-

- - Hot/live migration,
- - Cold/regular migration, and
- - Live storage migration of a virtual machine.

In this process, all key machines' components, such as CPU, storage disks, networking, and memory, are completely virtualized, thereby facilitating the entire state of a virtual machine to be captured by a set of easily moved data files.



What is VM Migration

- Migration can be categorized as cold or non-live migration and live migration.
- Based on granularity, the migration can be divided into single and multiple migrations.
- The design and continuous optimization and improvement of live migration mechanisms are striving to minimize downtime and live migration time.
- The downtime is the time interval during the migration service is unavailable due to the need for synchronization.
- For a single migration, the migration time refers to the time interval between the start of the pre-migration phase to the finish of post-migration phases that instance is running at the destination host.
- On the other hand, the total migration time of multiple migrations is the time interval between the start of the first migration and the completion of the last migration.

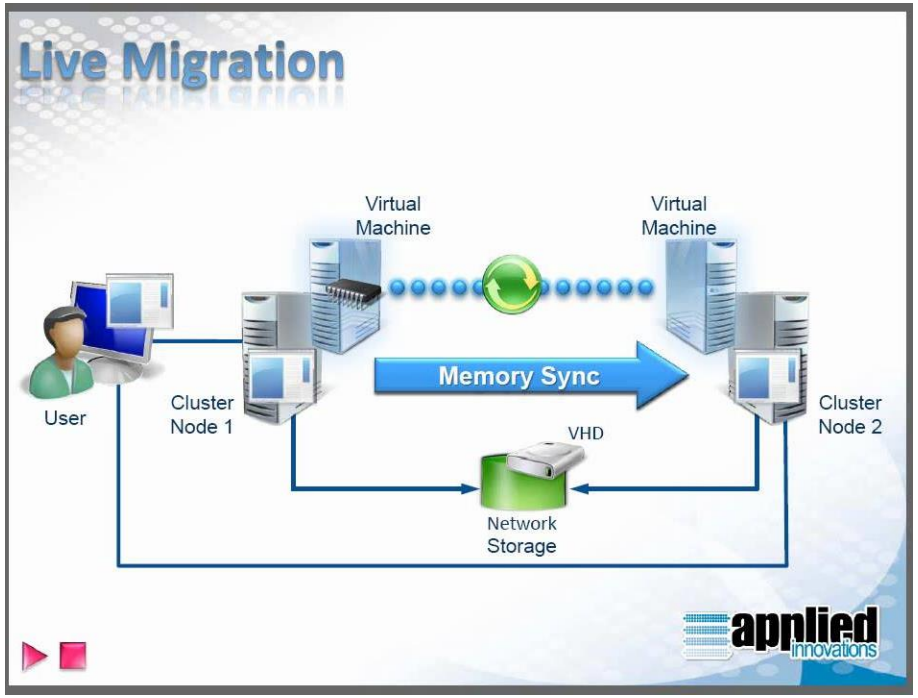
What is VM Live Migration

Live 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.

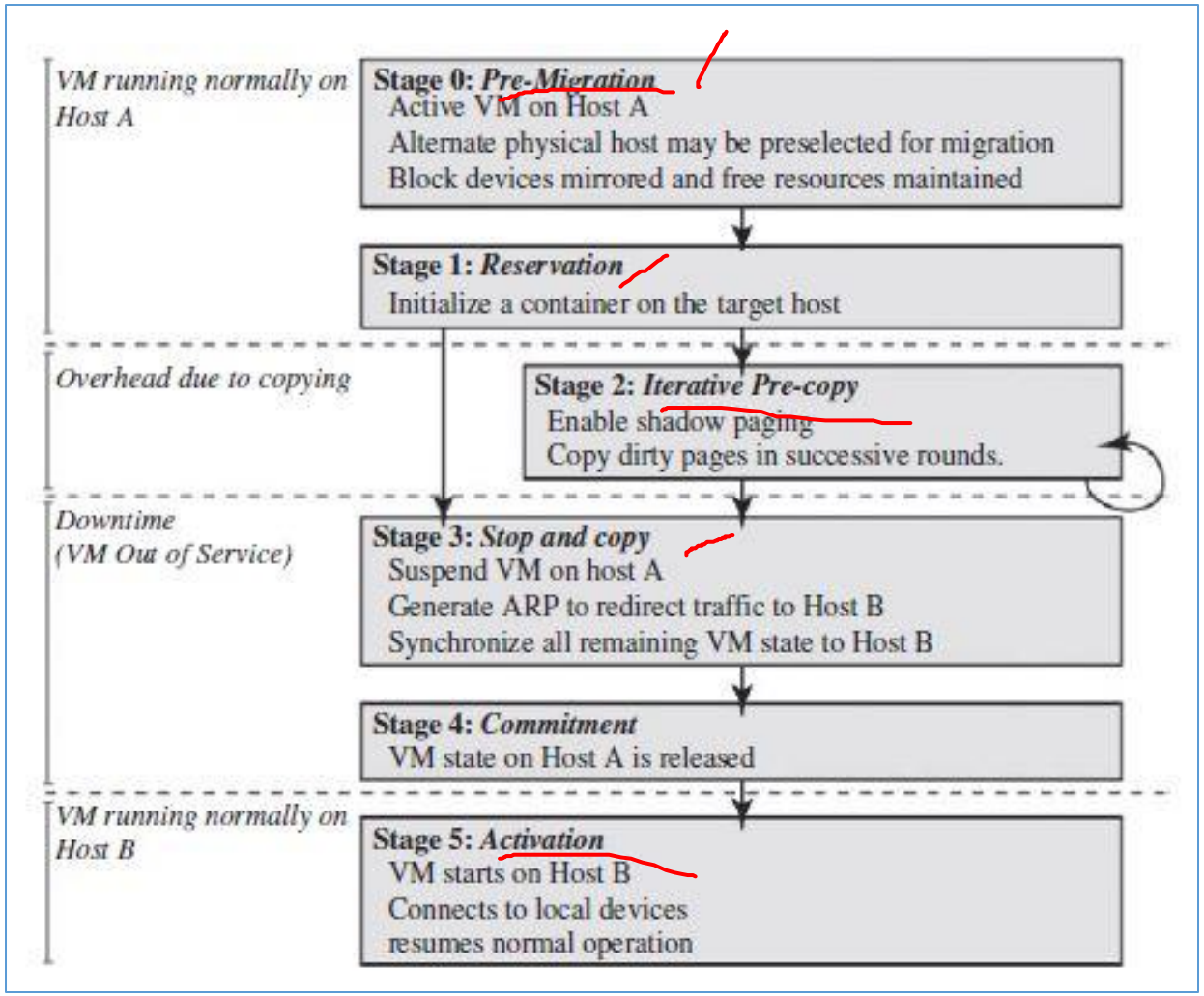


Live Migration Xen Hypervisor

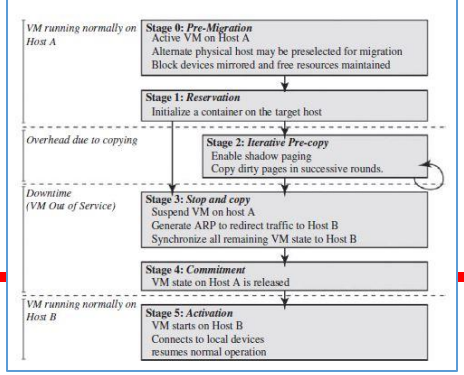
The steps of live migration's mechanism and how memory and virtual machine states are being transferred, through the network, from one host A to another host B: •

The Xen hypervisor is an example for this mechanism.

The migration process has been viewed as a transactional interaction between the two hosts involved:



Live Migration Xen Hypervisor



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 on a VM container of that size).

Stage 2: Iterative Pre-Copy. During the first iteration, all pages are transferred from A to B. Subsequent iterations copy only those pages dirtied during the previous transfer phase.

Stage 3: Stop-and-Copy. Running OS instance at A is suspended, and its network traffic is redirected to B. CPU state and any 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 it has successfully received a consistent OS image. Host A acknowledges this message as a commitment of the migration transaction. Host A may now discard the original VM, and host B becomes the primary host.

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.

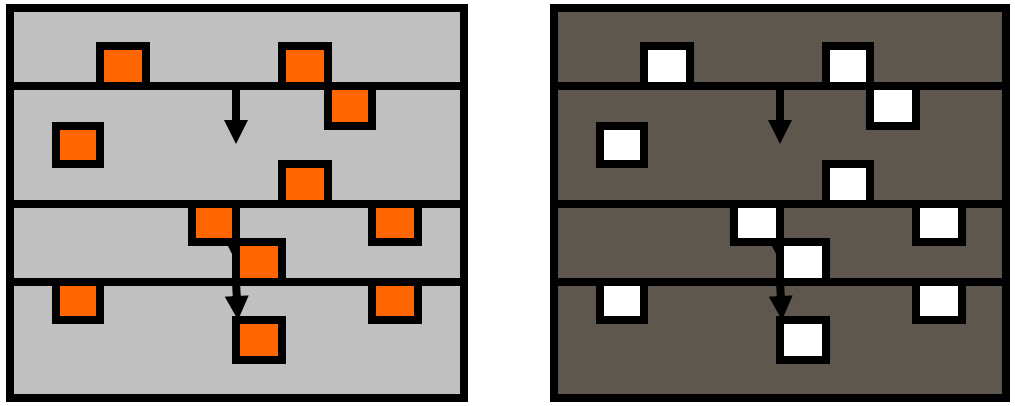
Live Migration Xen Hypervisor

Memory and storage transmission can be categorized into three phases:

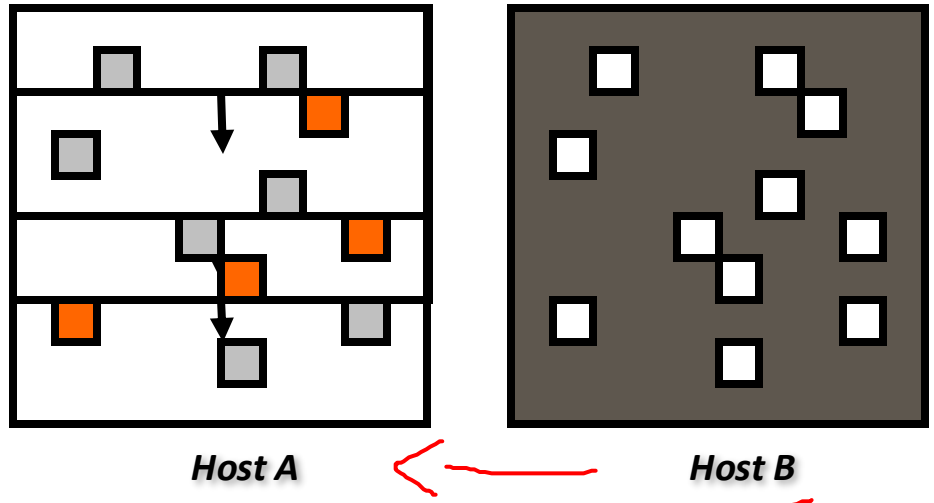
- Push phase where the instance is still running in the source host while memory pages and disk block or writing data are pushed through the network to the destination host.
- Stop-and-Copy phase where the instance is stopped, and the memory pages or disk data is copied to the destination across the network. At the end of the phase, the instance will resume at the destination.
- Pull phase where the new instance executes while pulling faulted memory pages when it is unavailable in the source from the source host across the network.

Live Migration Process

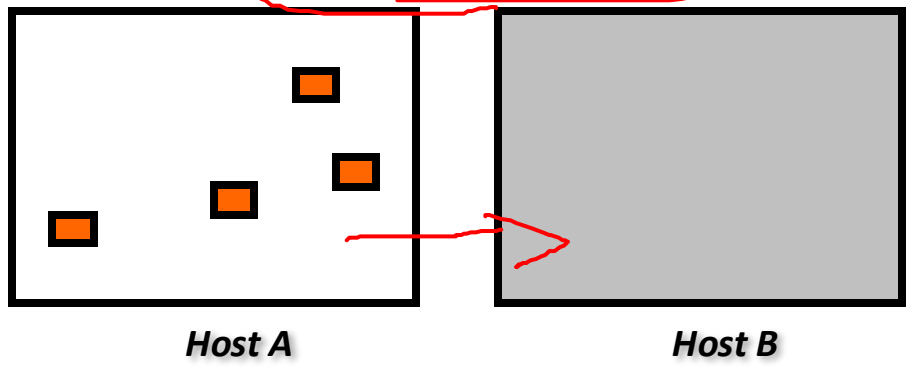
Pre-copy migration : Round 1, Enable Shadow Paging



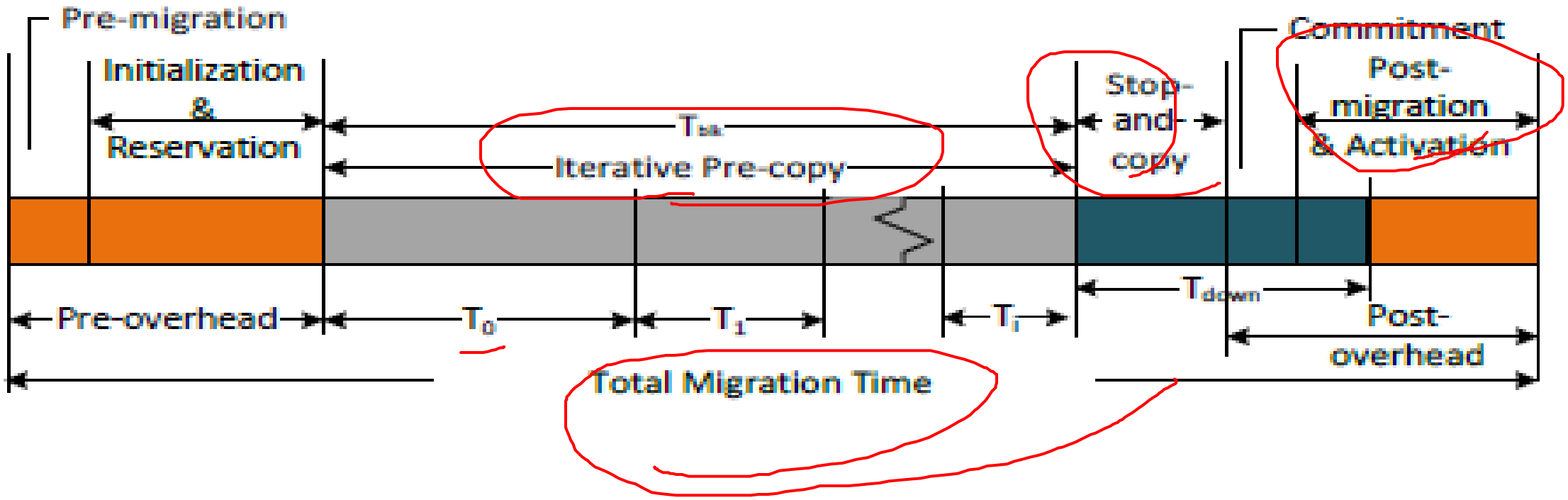
Pre-copy migration : Round 2



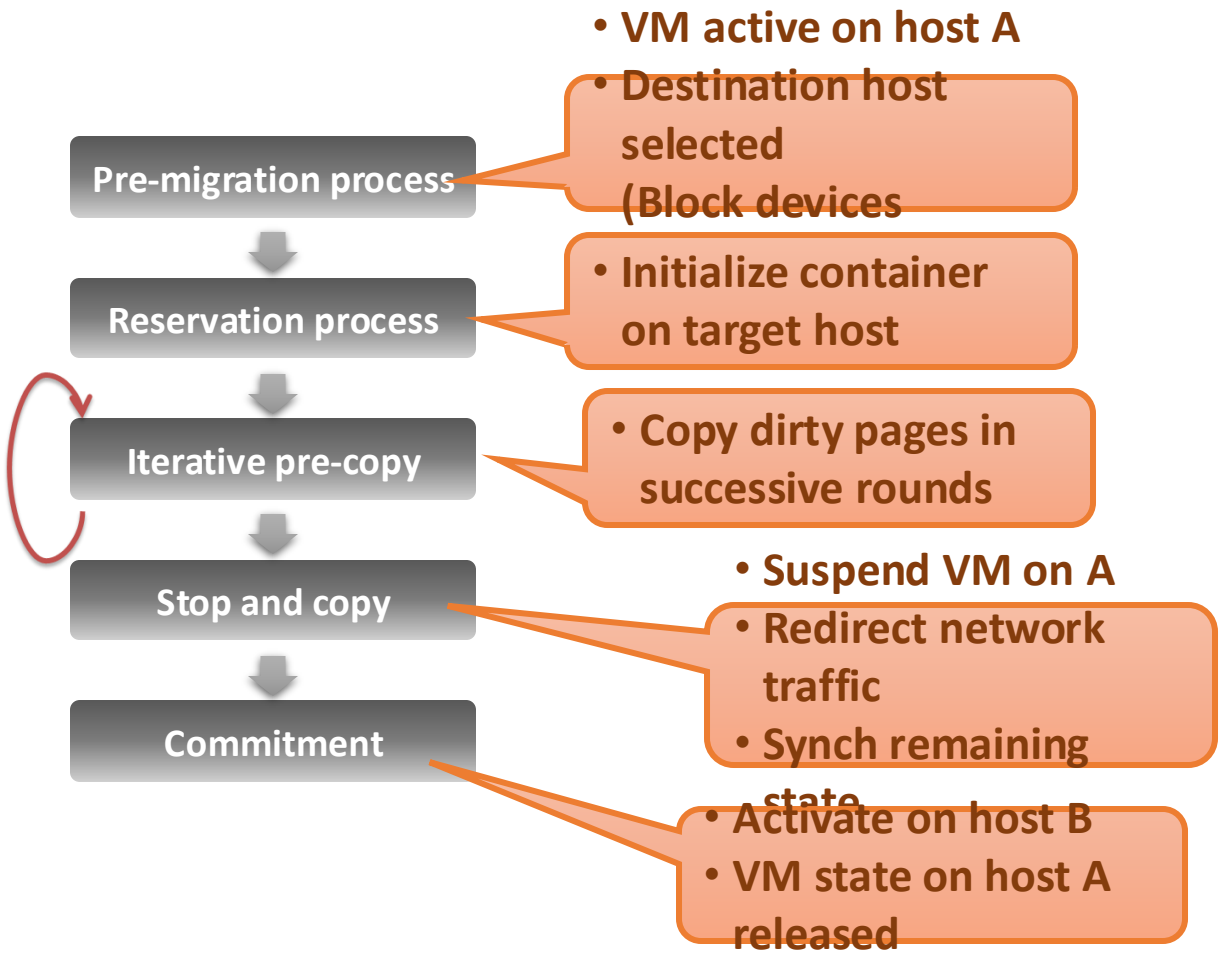
Stop & Copy – Final Round



Live Migration Process



Live Migration Technique



Pre-migration and Post-migration phases are handling the computing and network configuration.

During the pre-migration phase, migration management software creates instance's virtual interfaces (VIFs) on the destination host, updates interface or ports binding, and networking management software, such as OpenStack Neutron server, configures the logical router.

During the post-migration phase, migration management software updates port or interface states and rebinds the port with networking management software and the VIF driver unplugs the instance's virtual ports on the source host.

Live Migration Technique

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 one 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.

Challenges of live migration :

- VMs have lots of state in memory
- Some VMs have soft real-time requirements

Live Migration Effect on a Running Web Server

Clark et al. evaluated the mentioned migration on Apache 1.3 Web Server; that 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.

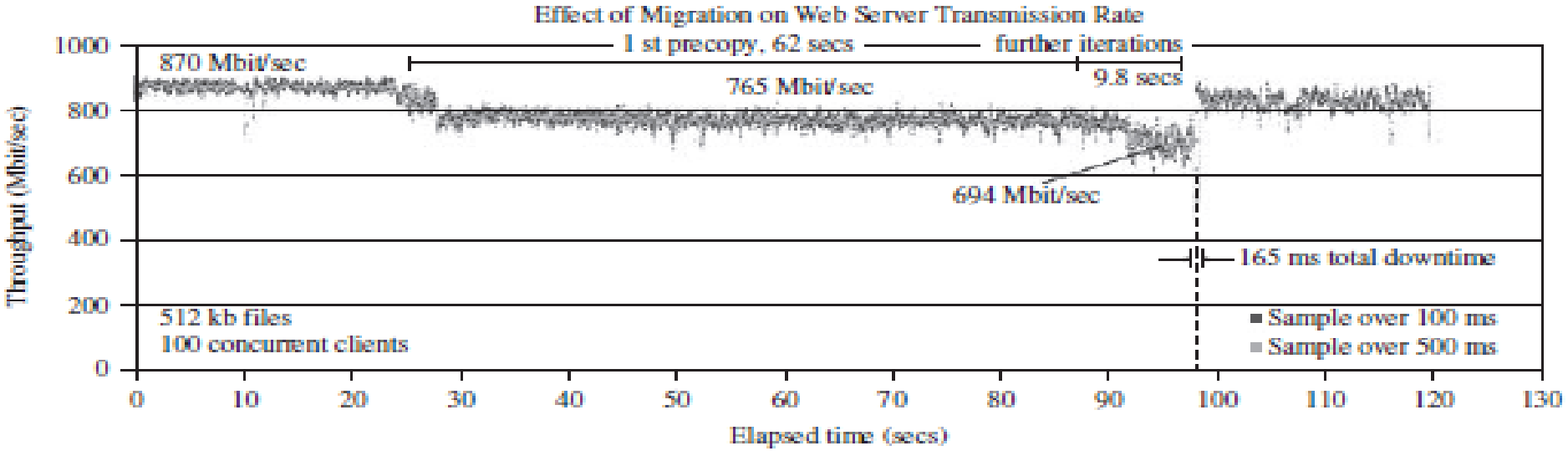


FIGURE 5.6. Results of migrating a running Web server VM [21].

Live Migration Vendor Implementations Example

There are lots of VM management and provisioning tools that provide the live migration of VM facility

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.

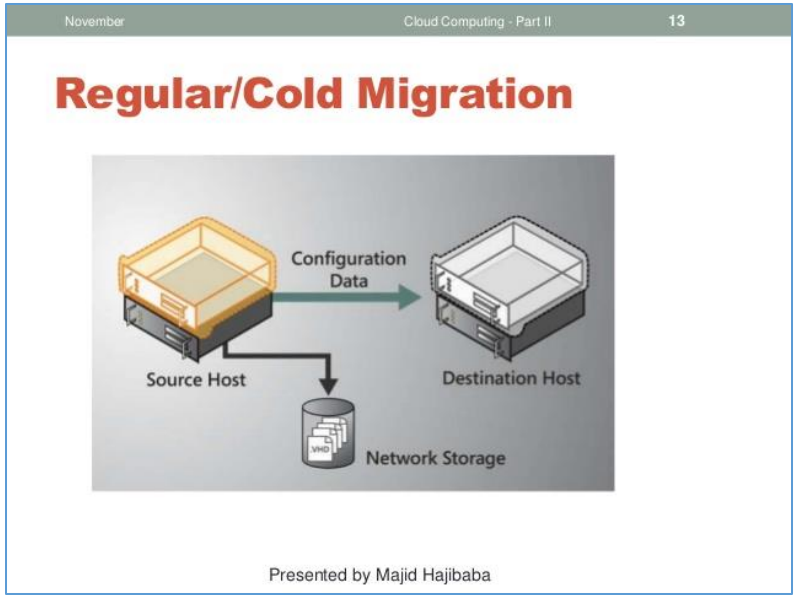
Citrix XenServer "XenMotion":

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.

Live Migration Demo – Hyper V

Cold Migration

- **Cold migration** is the migration of a powered-off virtual machine.
- With cold migration, you have the option of moving the associated disks from one data store to another. The virtual machines are not required to be on a shared storage.
- It's important to highlight that the **two main differences between live migration and cold migration** are that live migration **needs a shared storage** for virtual machines in the server's pool, but cold migration does not;
- Also, in live migration for a virtual machine between two hosts, there would be **certain CPU compatibility checks** to be applied; while in cold migration this checks do not apply.

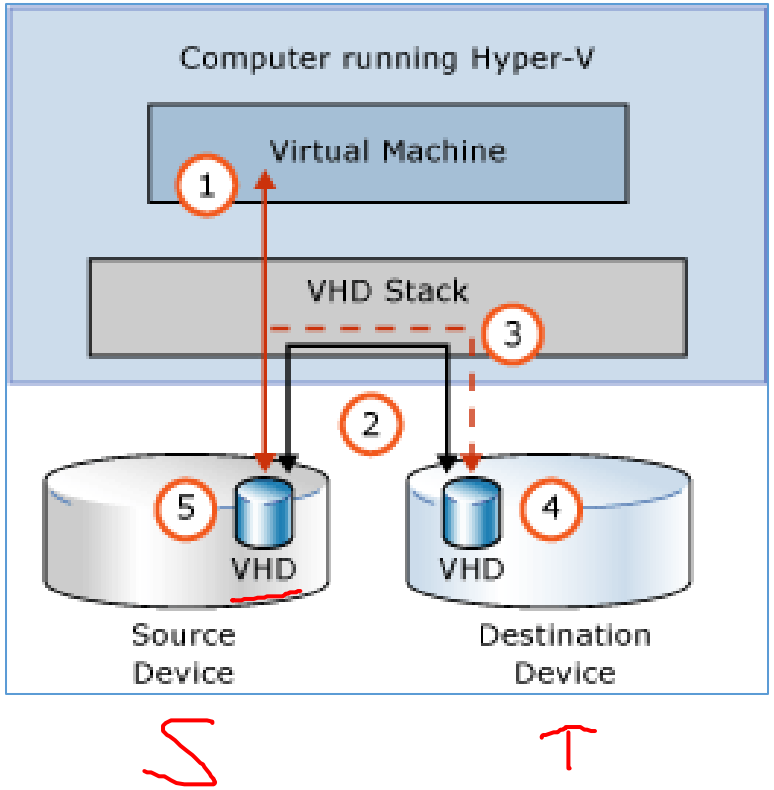


Note:

- The configuration files, including the NVRAM file (BIOS settings), log files, as well as the disks of the virtual machine, 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

Storage Migration

- 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
- 1. Throughout most of the move operation, disk reads and writes go to the source virtual hard disk.
- 2. While reads and writes occur on the source virtual hard disk, the disk contents are copied to the new destination virtual hard disk.
- 3. After the initial disk copy is complete, disk writes are mirrored to both the source and destination virtual hard disks while outstanding disk changes are replicated.
- 4. After the source and destination virtual hard disks are completely synchronized, the virtual machine switches over to using the destination virtual hard disk.
- 5 The source virtual hard disk is deleted.



FUTURE DIRECTIONS

- Self-adaptive and dynamic data center.
- Performance evaluation and workload characterization of virtual workloads.
- High-performance data scaling in private and public cloud environments.
- Performance and high availability in clustered VMs through live migration.
  - VM scheduling algorithms.
  - Accelerating VMs live migration time.
  - Cloud-wide VM migration and memory de-duplication.
- Live migration security.

Q & A……..

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Credits

•Hwang, Kai; Dongarra, Jack; Fox, Geoffrey C.. Distributed and Cloud Computing: From Parallel Processing to the Internet of Things (Kindle Locations 3532-3533). Elsevier Science. Kindle Edition.