MODULE-I

INTRODUCTION

Ashwini Janagal

Cloud Computing at a Glance

Computing is being transformed into a model consisting of services that are commoditized and delivered.

Cloud Computing at a Glance

- Dynamic Provisioning
  - Services
  - Compute Capab
  - Storage
  - Network

Let Me store my Music Files Here

STORAGE CLOUD

I just Have Dual Core!!!!! Let me use Quad core from cloud

COMPUTING RESOURCES

I don't have MS-word. Let me use Google Cloud

SOFTWARES

Cloud Computing at a Glance

- Dynamic Provisioning
  - Services
  - Compute Capabilities
  - Storage
  - Network

Well, when you use services from cloud you have to pay

Pay-Per-Usage

Cloud Computing at a Glance

1969

ARPANET

As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of 'computer utilities' which like present electric and telephone utilities, will service individual homes and offices across the country.

Cloud Computing at a Glance

1969

ARPANET

As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of 'computer utilities' which like present electric and telephone utilities, will service individual homes and offices across the country.

UTILITY COMPUTING

2007 Onwards

CLOUD COMPUTING

Cloud Computing at a Glance

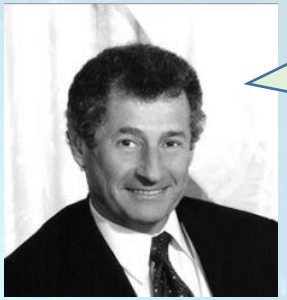
1969

ARPANET

As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of 'computer utilities' which like present electric and telephone utilities, will service individual homes and offices across the country.

cloud computing can be classified as a new paradigm for the dynamic provisioning of computing services supported by state-of-the-art data centers employing virtualization technologies for consolidation and effective utilization of resources

Cloud Computing at a Glance



1969

ARPANET

As of now, computer networks are still in their infancy, but as they grow up and become sophisticated, we will probably see the spread of 'computer utilities' which like present electric and telephone utilities, will service individual homes and offices across the country.

cloud computing can be classified as a new paradigm for the dynamic provisioning of computing services supported by state-of-the-art data centers employing virtualization technologies for consolidation and effective utilization of resources

Cloud Computing at a Glance

DIfferent People have different views for CLOUD COMPUTING

Chief IT Officer

Student

Researcher

Oh I can increase and Decrease the Infrastructure as needed....

Oh... now I have more space to store my music, movies, notes....

Oh... how easily I can work in IISc Data center sitting at Shivamogga

Cloud Computing at a Glance

DIfferent People have different views for CLOUD COMPUTING

- Chief IT Officer
- Student
- Researcher

I don't care where my servers are, who manages them, where my documents are stored, or where my applications are hosted. I just want them always available and access them from any device connected through Internet. And I am willing to pay for this service for as a long as I need it.

Cloud Computing at a Glance

Technologies for CLOUD COMPUTING ARE

Web 2.0: Application and Service Delivery Platform

Service Orientation: Deliver Capabilities with proper abstraction

Virtualization: Provides customization, control and Flexibility.

Cloud Computing at a Glance

Advantage of CLOUD COMPUTING ARE

Easily build new systems and software.

Dynamic Provisioning easy compared to buying new infrastructure and software.

Especially if you don't know

- How much is required?
- What to do after its job is done?

Cloud Computing at a Glance: The Vision of Cloud Computing

Cloud Computing at a Glance: The Vision of Cloud COmputing

The Increase in Cloud COmputing Demand, has led

- Fastracked Technical Development.
- Enriched Set of Services
- More Sophesticated Services
- Less Costly Services

Cloud Computing at a Glance: The Vision of Cloud COmputing

Restriction

- Single or Limited Services Offered By Same Vendor At a Time
- To move fm one vendor to another for hosted services is difficult

Vision

- IT services are traded as utilities in an open market, without technological and legal barriers.
- In this cloud marketplace, cloud service providers and consumers, trading cloud services as utilities, play a central role

Cloud Computing at a Glance

How does SERVICE DISCOVERY HAPPENS?

Ans in Current Scenario:
When a person searches for services using any search egine.

Ans which we hope for Future:

A digital Market that trades cloud computing services based on our request.

Cloud Computing at a Glance

How does SERVICE DISCOVERY HAPPENS?

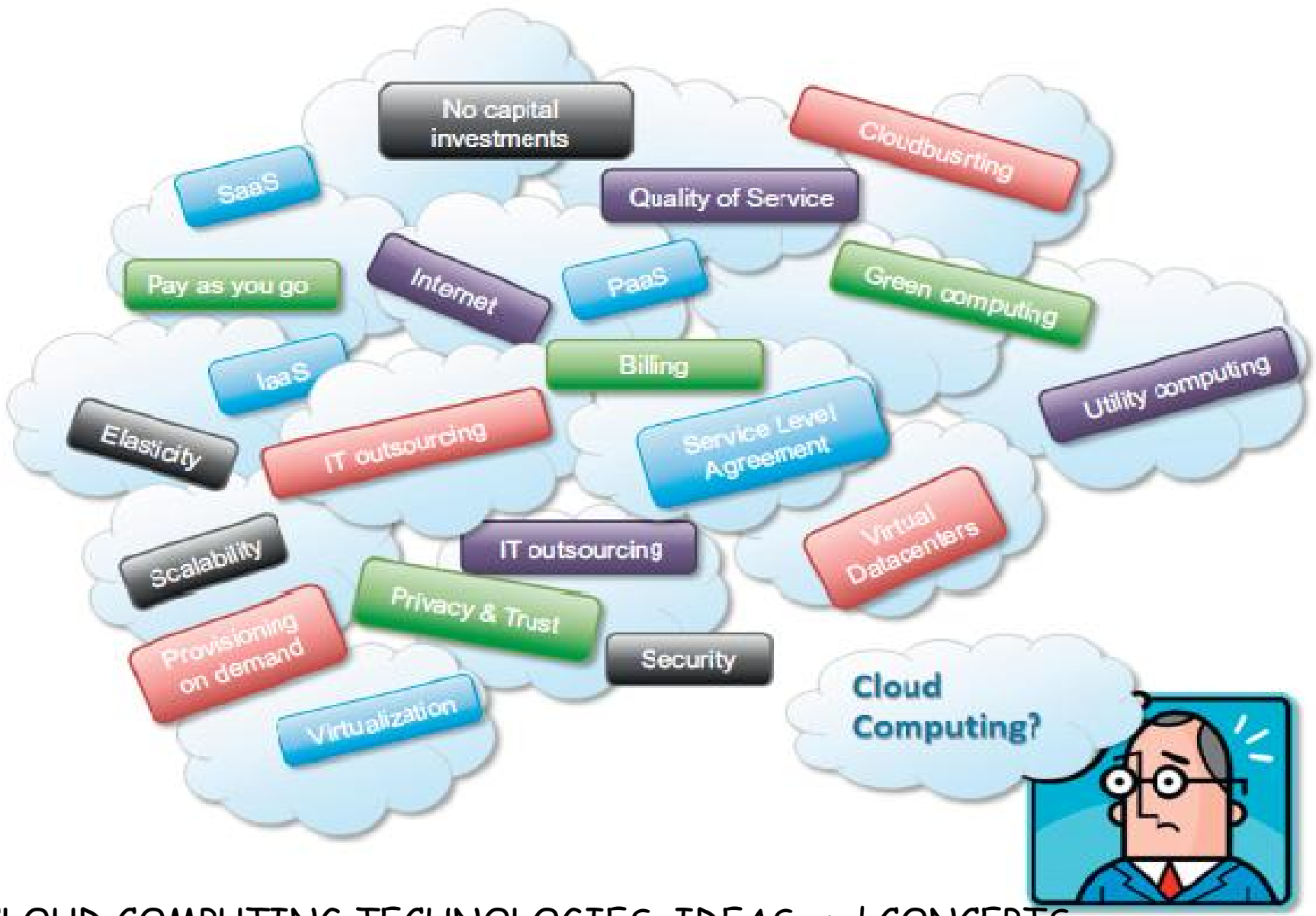
Ans which we hope for Future:

A digital Market that trades cloud computing services based on our request.

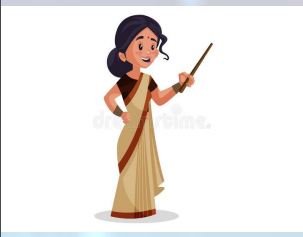
↓ ADVANTAGES

1. Automation of Discovery Process and its Integration to existing System.
2. Increase the revenue of Service traders.
3. Reduces the gap between providers and consumers.

Cloud Computing: Defining Cloud



Cloud Computing: Defining Cloud



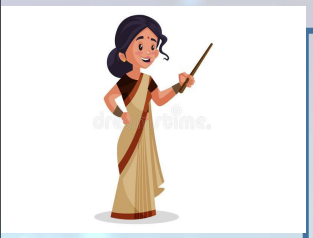
What is the PROPER Definition for Cloud Computing?

Cloud computing refers to both the applications delivered as services over the Internet and the hardware and system software in the datacenters that provide those services.

XaaS --> Everything As A Service

- IT Infrastructure
- Development Platforms
- Databases

Cloud Computing: Defining Cloud



Definition of cloud by U.S. National Institute of Standards and Technology (NIST):

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

Means:
Found
Everywhere

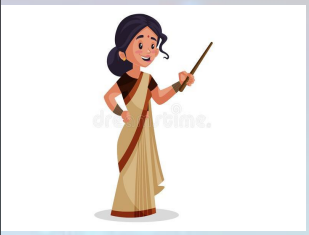
Cloud Computing: Defining Cloud

Definition According to George Reese.
Author of book:
"Cloud Application Architectures: Building Applications and Infrastructure in the Cloud (Theory in Practice (O'Reilly))"

we can define three criteria to discriminate whether a service is delivered in the cloud computing style:

- The service is accessible via a Web browser (nonproprietary) or a Web services application programming interface (API).
- Zero capital expenditure is necessary to get started.
- You pay only for what you use as you use it. (Pay-Per-Usage)

Cloud Computing: Defining Cloud



What is the PAY_PER_USAGE?

It makes it possible to

- Access online storage
- rent virtual hardware
- use development platforms

and pay only for their effective usage, with no or minimal up-front costs.

Just pay some minimum amount using your credit card/debit card/UPI/Net Banking etc. and start using S/W

No need to buy new hardware, software etc...

Cloud Computing: Defining Cloud

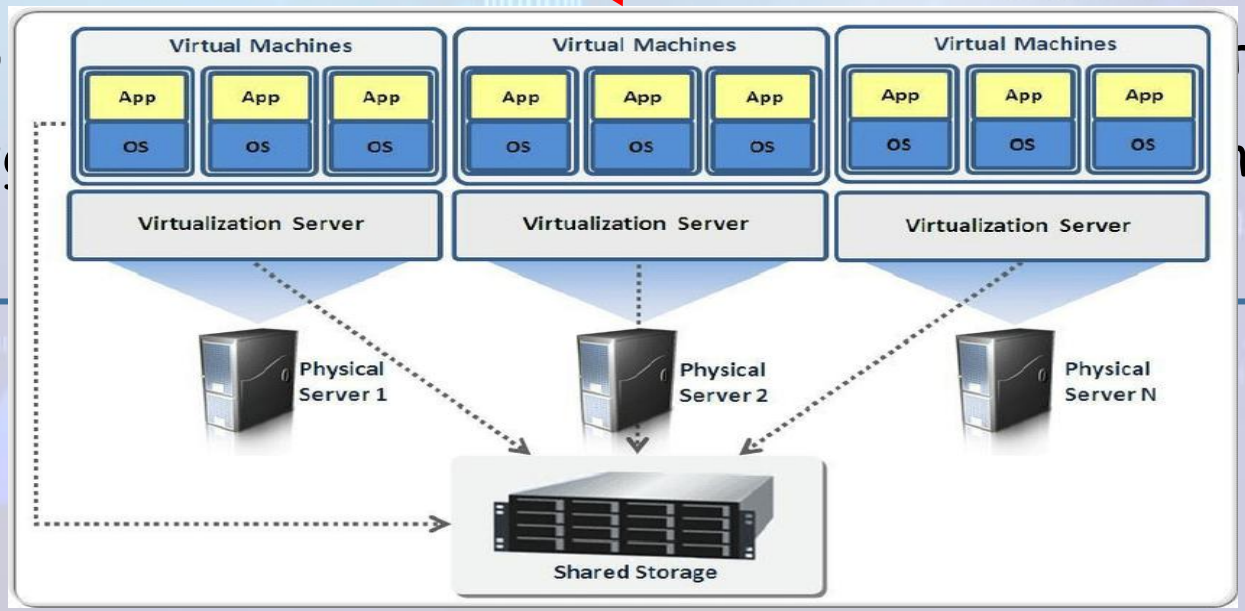
Definition According to Prof. Rajkumar Buyya, University of Melbourne

A cloud is a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources based on service-level agreements established through negotiation between the service provider and consumers.

Cloud Computing: Defining Cloud

Definition According to Prof. Rajkumar Buyya, University of Melbourne

A cloud is a type of parallel and distributed system consisting of a collection of interconnected and **virtualized computers** that are dynamically provisioned and presented as one or more unified computing reso rs established throu nd consumers.



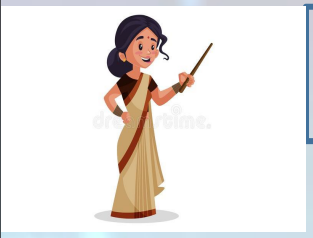
Cloud Computing: Defining Cloud

Definition According to Prof. Rajkumar Buyya, University of Melbourne

A cloud is a type of parallel and distributed system consisting of a collection of interconnected and virtualized computers that 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.

- An agreement between cloud vendor and user
- Defines Quality of Service (Qos) parameters under which service is delivered.

Cloud Computing: A Closure Look



Can we have a look at some practicle examples?

Application-1

Large enterprises can offload some of their activities to cloud based systems.

Example : The New York Times (1851)

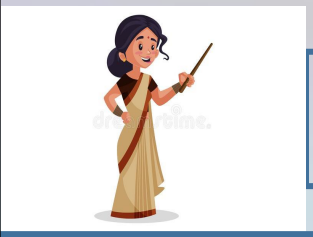
The New York Times

Task: Converted their Digital Library of Past Editions to Web friendly Format.

Infrastructure: 0 (Zero), As they rented Amazon EC2 and S3 cloud.

Time Taken: 36 Hours.

Cloud Computing: A Closure Look



Can we have a look at some practicle examples?

Application-2

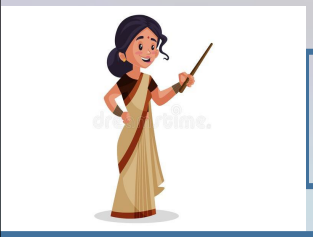
Small enterprises and start-ups can afford to translate their ideas into business results morequickly, without excessive up-front costs.

Example : Animoto

Task: Makes wonderful videos out of pictures, video fragments and music provided by users. **(So it need huge storage and processing)**

Infrastructure: 0 (Zero) resources. They don't own single server as everything is rented from Amazon Web Services

Cloud Computing: A Closure Look



Can we have a look at some practicle examples?

Application-4

End users can have their documents accessible from everywhere and any device.

Example : Apple iCloud

Task: Store Document in Cloud Then Access From Anywhere

Ex Usage: Take photo in your iPhone and edit it in your laptop without any burden of mailing or connecting phone etc.

Cloud Computing: A Closure Look

Birds Eye View of CLoud Computing

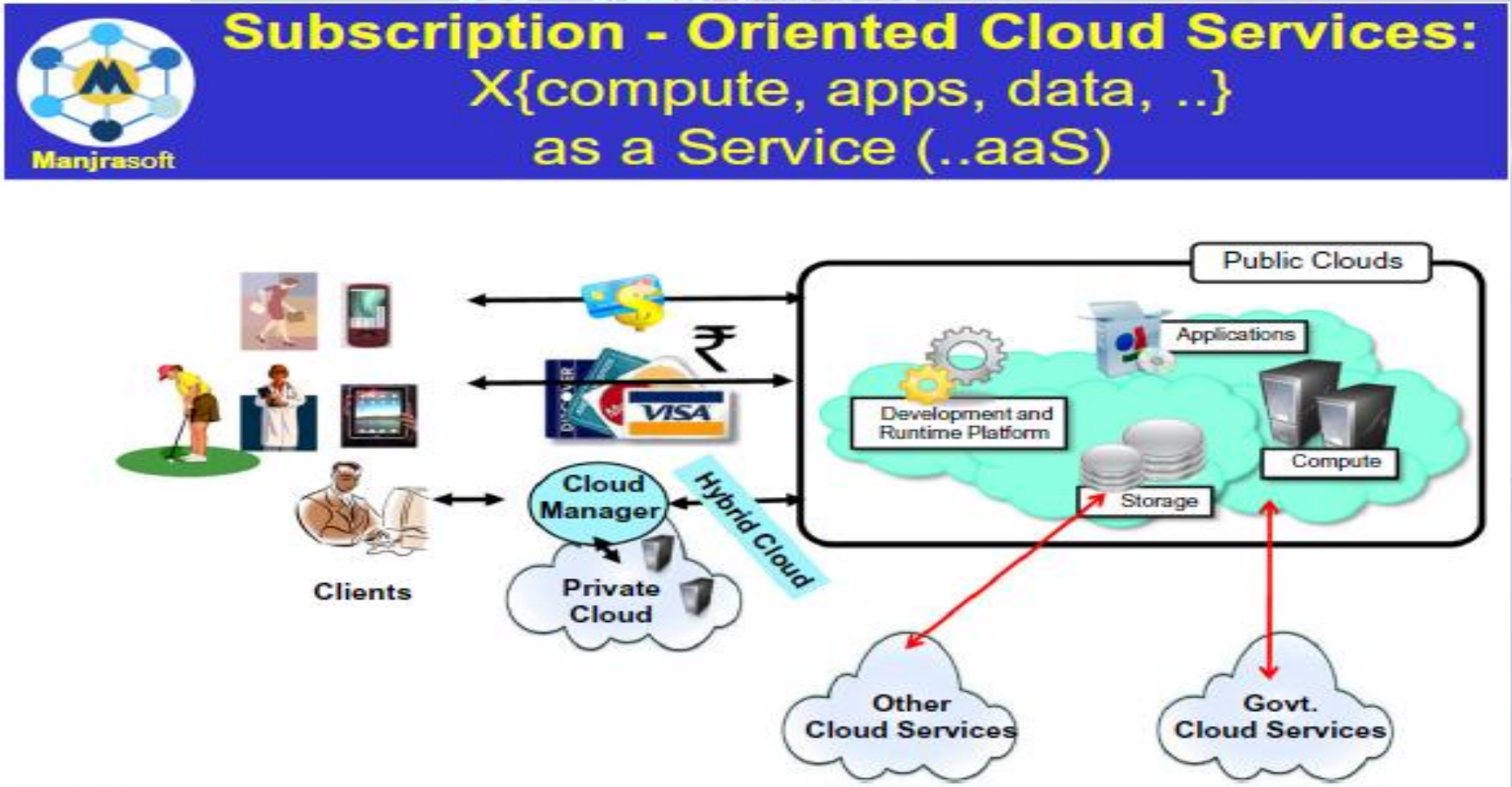


FIGURE 1.3

A bird's-eye view of cloud computing.

Cloud Computing: A Closure Look

Major Cloud Deployment Model

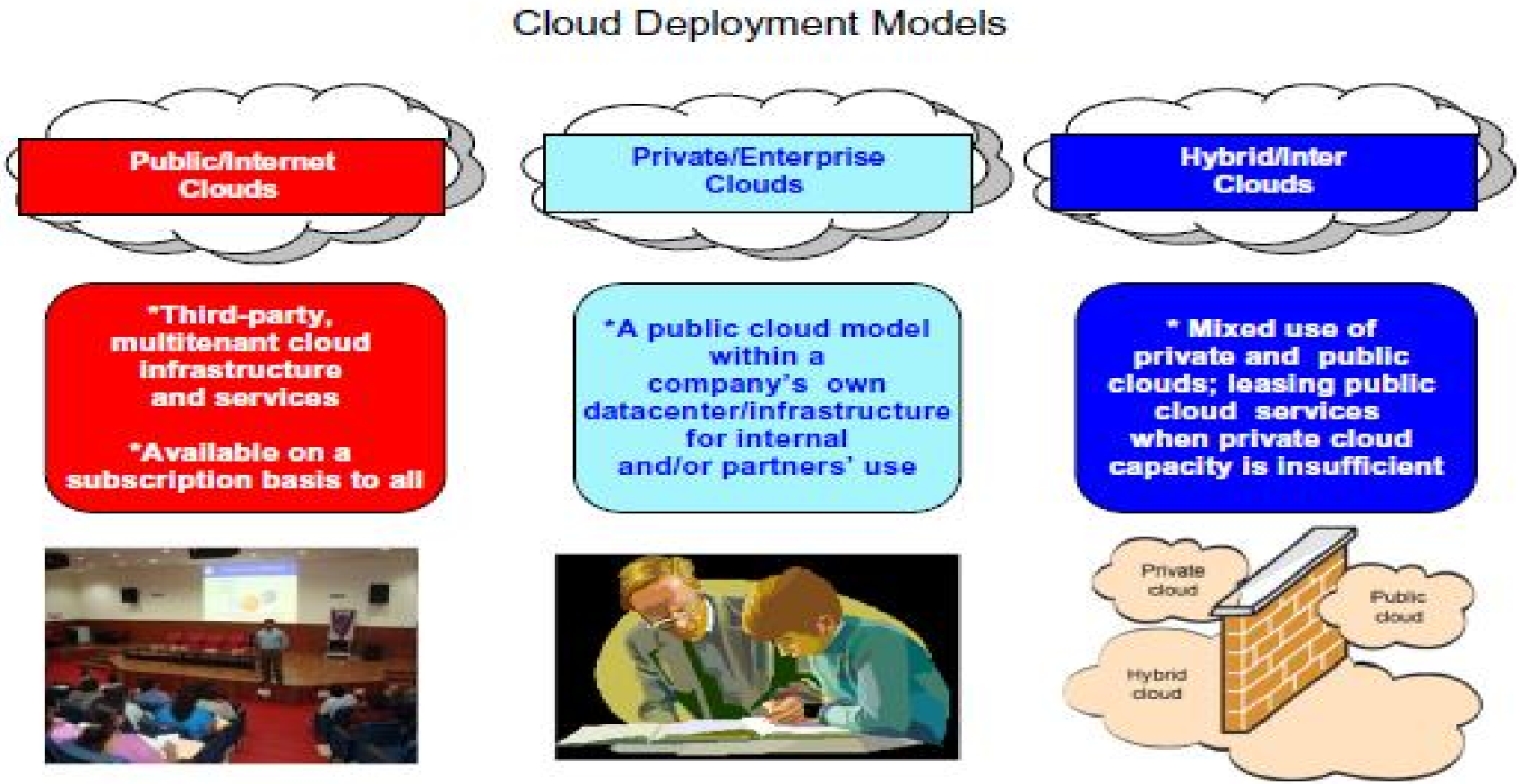
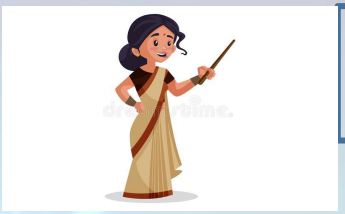


FIGURE 1.4

Major deployment models for cloud computing.

Cloud Computing: A Closure Look



Major Cloud Deployment Model

Cloud Computing: A Closure Look

Major Cloud Deployment Model

Why Private Cloud When We have Public cloud?

Private/Enterprise Clouds

*A public cloud model within a company's own datacenter/infrastructure for internal and/or partners' use

- For some companies there data may be confidential and scared to put in public cloud.
- Ex: Accenture left at least four AWS S3 storage buckets unsecured in 2017 with data like unbridled authentication details, confidential API data, digital certificates, decryption keys, user data, and meta info

Cloud Computing: A Closure Look

Major Cloud Deployment Model

Why Private Cloud When We have Public cloud?

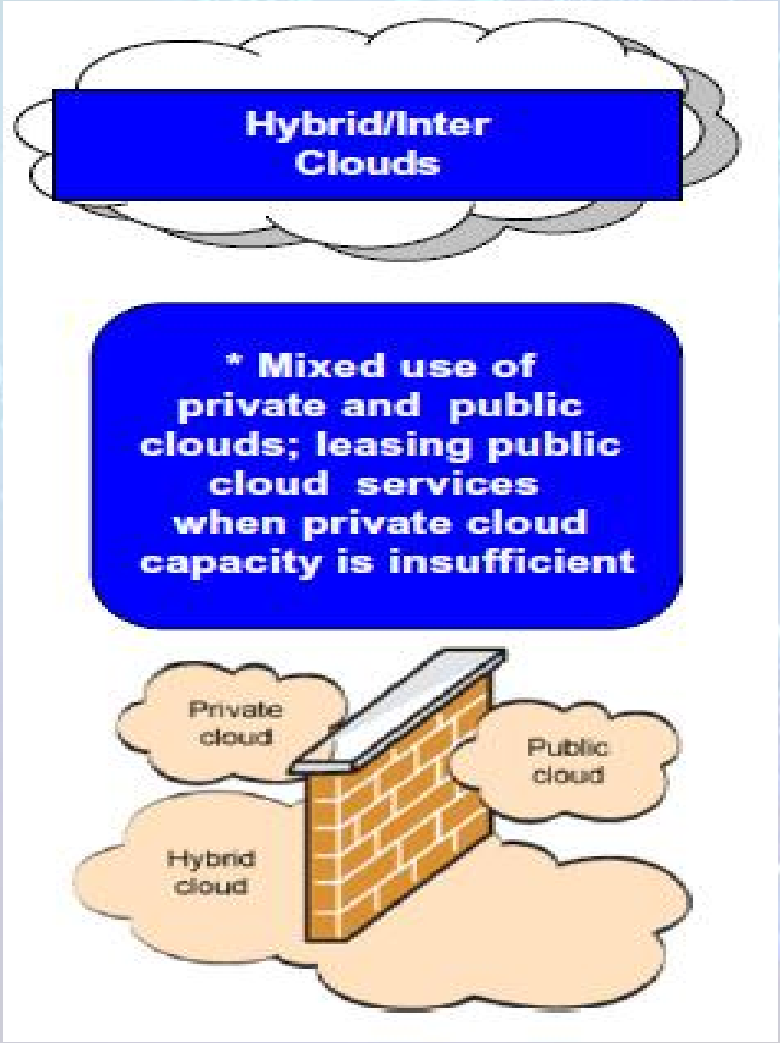
Private/Enterprise Clouds

*A public cloud model within a company's own datacenter/infrastructure for internal and/or partners' use

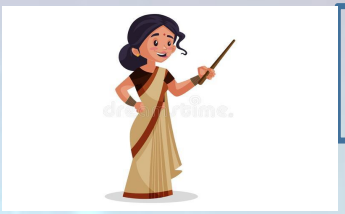
- US Federal Government started its own private cloud for government agencies as it doesn't want to put government data on private cloud.

Cloud Computing: A Closure Look

Major Cloud Deployment Model



Cloud Computing: Cloud Reference Model

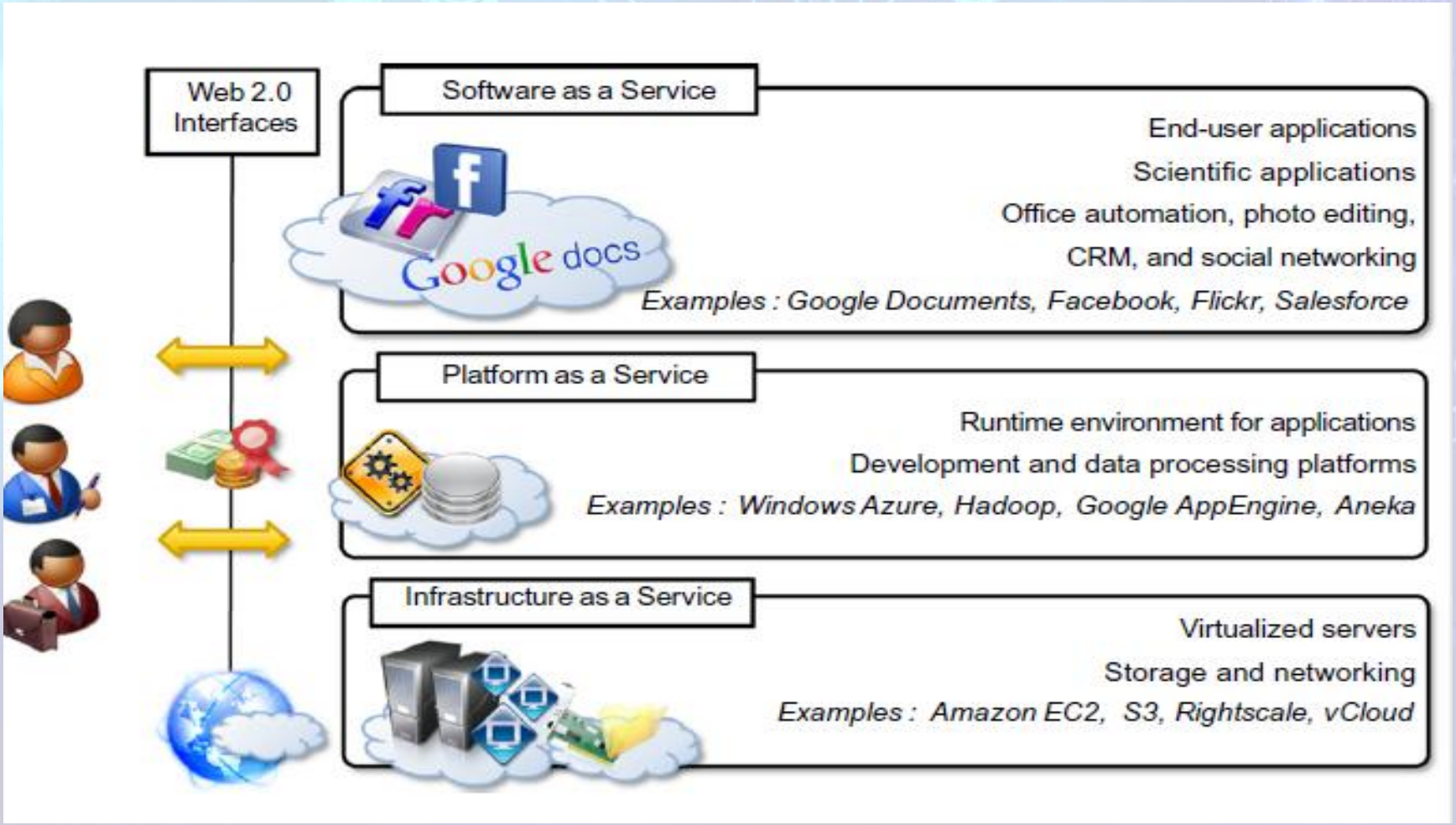


Different Types of Cloud Computing Services

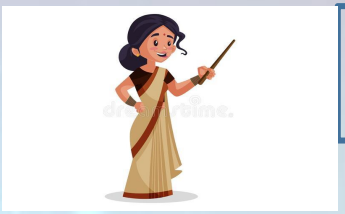
- Infrastructure-as-a-Service (Iaas)
- Platform-as-a-service (Paas)
- Software-as-a-service(Saas)

Cloud Computing: Cloud Reference Model

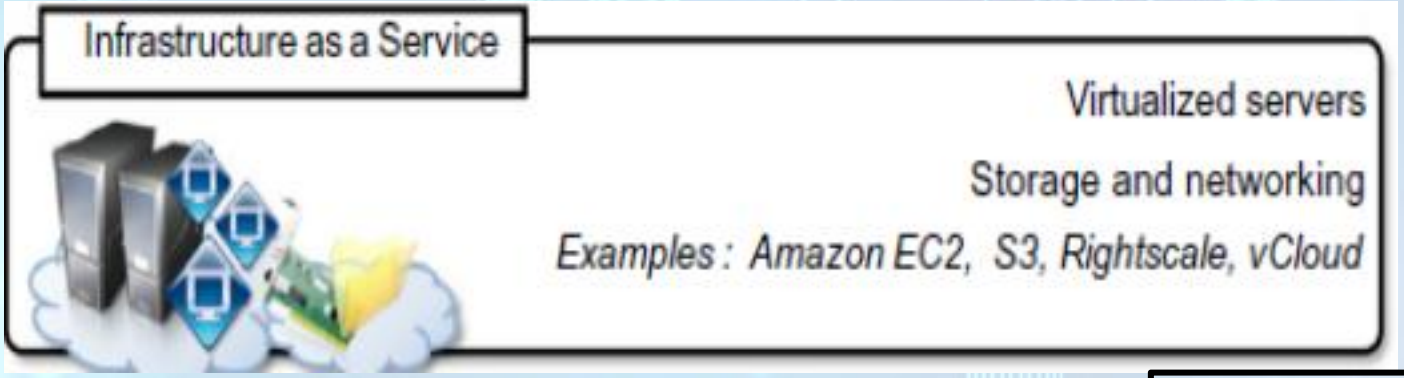
Different Types of Cloud Computing Services



Cloud Computing: Cloud Reference Model



Different Types of Cloud Computing Services

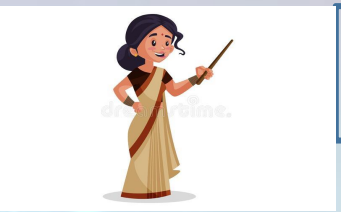


Infrastructure is provided as

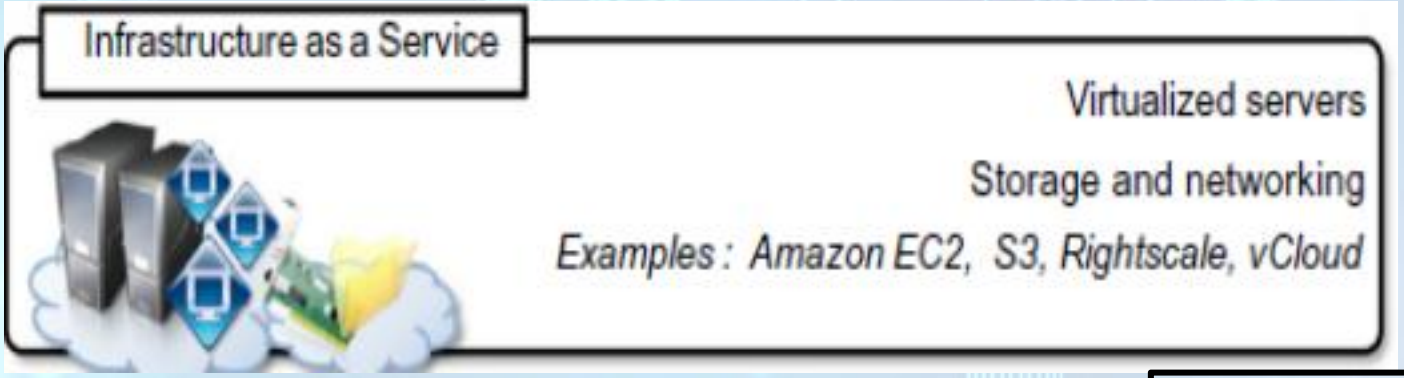
- ❖ Hardware
- ❖ Storage
- ❖ Networking

- •Virtual Machine Instances.
- •Paid usually in Dollars per hour /Rs. per hour
- •U can even go for monthly or yearly subscription

Cloud Computing: Cloud Reference Model



Different Types of Cloud Computing Services

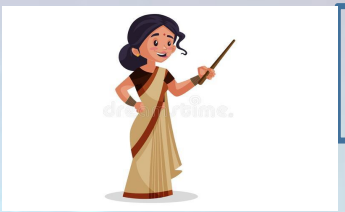


Infrastructure is provided as

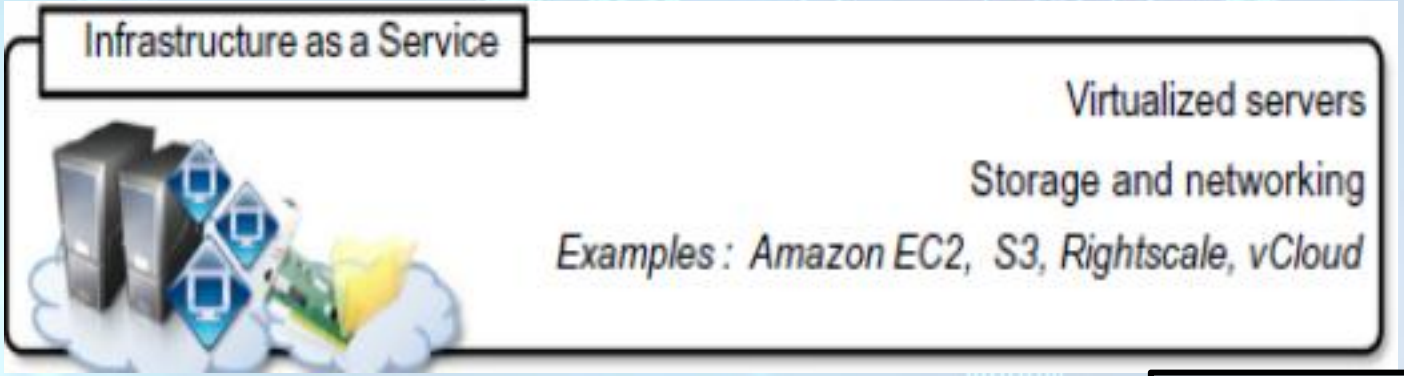
- ❖ Hardware
- ❖ Storage
- ❖ Networking

- Virtual Storage provided as raw disk space or object store.
- You can Store
  - Files
  - Objects/entities

Cloud Computing: Cloud Reference Model



Different Types of Cloud Computing Services

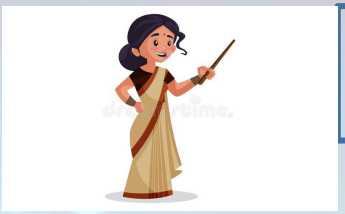


Infrastructure is provided as

- ❖ Hardware
- ❖ Storage
- ❖ Networking

- collection of services that manage the networking among virtual instances and their connectivity to the Internet.
- Ex: If you have asked for 10 VMs then with what speed they are connected to each other?

Cloud Computing: Cloud Reference Model



Different Types of Cloud Computing Services

Platform as a Service

Runtime environment for applications

Development and data processing platforms

Examples : Windows Azure, Hadoop, Google AppEngine, Aneka

- scalable and elastic runtime environments on demand and host the execution of applications.
- middleware platform where applications are deployed and executed.
- service provider to provide scalability and to manage fault tolerance, while users focus on the logic of the application developed

Cloud Computing: Cloud Reference Model

Different Types of Cloud Computing Services

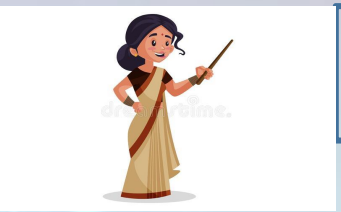
Software as a Service

End-user applications
Scientific applications
Office automation, photo editing,
CRM, and social networking

Examples : Google Documents, Facebook, Flickr, Salesforce

- Software Services on Demand
- More famous applications on cloud belong to office automation, document management, photo editing, and customer relationship management (CRM) software.
- Scalability is very good.

Cloud Computing: Characteristics and Benefits

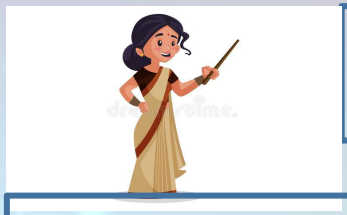


Interesting Characteristics of Cloud Computing

- No up-front commitments
- On-demand access
- Nice pricing
- Simplified application acceleration and scalability
- Efficient resource allocation
- Energy efficiency
- Seamless creation and use of third-party services

These characteristics provide benefits to both Cloud Service COnsumer (CSC) and Cloud Service Vendor(CSV)

Cloud Computing: Characteristics and Benefits



Cloud Benefits

- **Increase in Economical Return Due to Reduced Maintenance Cost and Operational Cost**

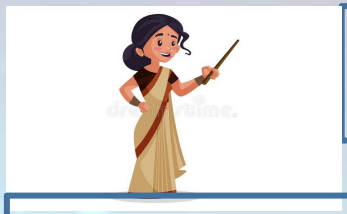
NO CLOUD

- ✓ Capital Cost in the beginning to buy IT infrastructure and software.
- ✓ Capital Cost is depreciated as the hardware and software cost will reduce wityh time.
- ✓ Once purchased, money need to be spent on maintaining them

With Cloud

- ✓ Only Utility Cost
- ✓ Pay for what you use.
- ✓ No investment in Beginning
- ✓ No Maintenance.

Cloud Computing: Characteristics and Benefits



Cloud Benefits

❖ **Increased Agility**

NO CLOUD

- ✓ To implement a change you are constrained by company infrastructure as already you have invested in it.
- ✓ So you are constrained by your investment.

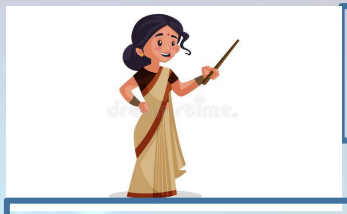
With Cloud

- ✓ There is no constraint and you can change more dynamically and flexibly.
- ✓ cloud computing allows organizations to react to unplanned surges in demand quite rapidly.

Ease of

- ✓ Infrastructure scalability with IaaS
- ✓ Scale applications with help of PaaS
- ✓ Elastically sized apps

Cloud Computing: Characteristics and Benefits



Cloud Benefits

- End users can benefit from cloud computing by having their data and the capability of operating on it always available, from anywhere, at any time, and through multiple devices

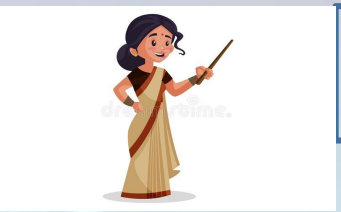
NO CLOUD

- ✓ You have to go to office to euse a particular software

With Cloud

- ✓ Web Based Interfaces to Software, which enables you to access them from your house.
- ✓ Processing capability same.
- ✓ Multitenancy provide better sharability
- ✓ Optimized resource Allocation.

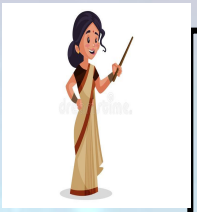
Cloud Computing: Characteristics and Benefits



Cloud Benefits

- service orientation and on-demand access create new opportunities for composing systems and applications with a flexibility not possible before cloud computing

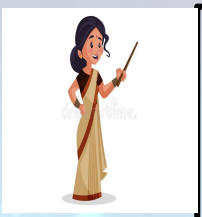
Cloud Computing: Challenges Ahead



Challenges:

- Practical Aspects like Configuration, Networking and Sizing
- Dynamic Provisioning of Services
  - Ex: In order to maximize profit
    - In IaaS How many resources to be provided?
    - How Long?
  - Some times user doesn't know exactly how much is required. So he may waste the resources.

Cloud Computing: Challenges Ahead



Security in terms of confidentiality, secrecy and data protection.

- Different legislation about privacy in different countries may potentially create disputes as to the rights that third parties (including government agencies) have to your data.
  - Ex:
    - European Countries are very p[articular about privacy.
    - What is European Firm uses cloud vendor from US

Cloud Computing: Challenges Ahead

News Article in "The Wire"

Date: 26th, May 2021

New Delhi: WhatsApp has filed a legal complaint in Delhi against the Indian government seeking to block regulations coming into force on Wednesday that experts say would compel the California-based Facebook unit to break privacy protections.

The lawsuit, described to Reuters by people familiar with it, asks the Delhi high court to declare that one of the new rules is a violation of privacy rights in India's constitution since it requires social media companies to identify the "first originator of information" when authorities demand it.

Cloud Computing: Challenges Ahead

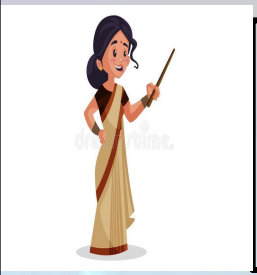
News Article in "The Wire"

Date: 26th, May 2021

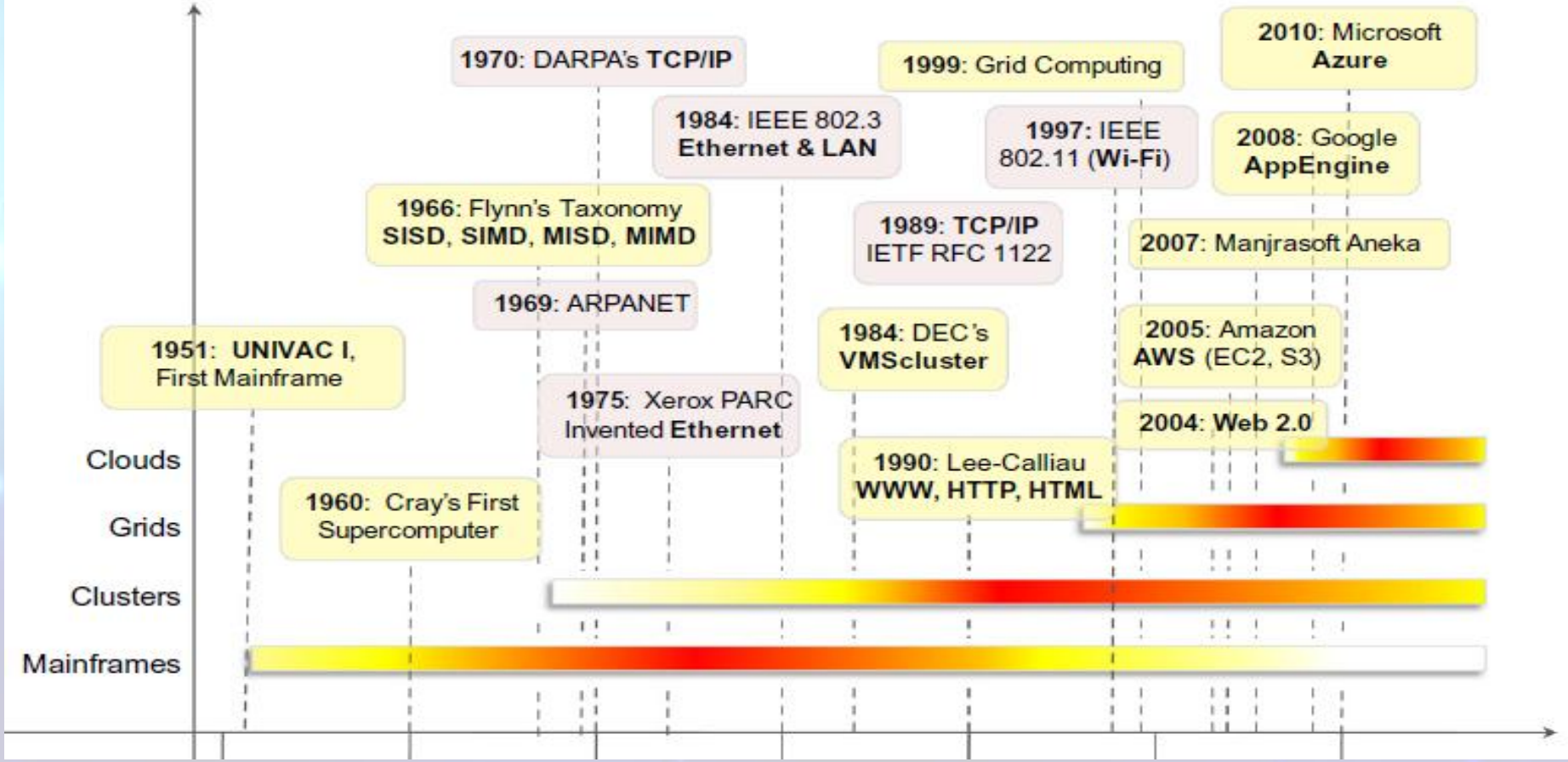
Cont.....

While the law requires WhatsApp to unmask only people credibly accused of wrongdoing, the company says it cannot do that alone in practice. Because messages are end-to-end encrypted, to comply with the law WhatsApp says it would have break encryption for receivers, as well as "originators", of messages.

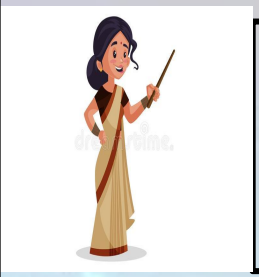
Cloud Computing: Historical Developments



When did we actually think about renting computing resources???



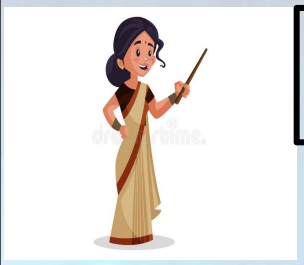
Cloud Computing: Historical Developments



Five Technologies which played important role in cloud computing

- Distributed Systems
- Virtualization
- web 2.0
- Service Orientation
- Utility Computing

Cloud Computing: Distributed Systems



Definition As Provided by Andrew S. Tanenbaum

A distributed system is a collection of independent computers that appears to its users as a single coherent system.

How did it help in Cloud Computing!!!!!!

Cloud Computing: Distributed Systems

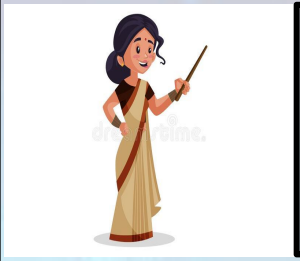
How Distributed system and Cloud Computing are almost similar!!!!!!!

A distributed system is a collection of independent computers that appears to its users as a single coherent system.

Same as above two points(Marked in red),

- Cloud also hides complex architecture and provide single interface to user.

Cloud Computing: Distributed Systems



How Distributed system and Cloud Computing are almost similar!!!!!!!

Primary purpose ofdistributed system is

Share resources and Utilize them Better

For cloud also it is same

- With the same concept resources are rented.
- Do you know!!!, that Amazon, Google etc. First developed a data center for themselves.
- Much of the resources were wasted there. SO they decided to rent it out....

Cloud Computing: Distributed Systems

How Distributed system and Cloud Computing are almost similar!!!!!!!

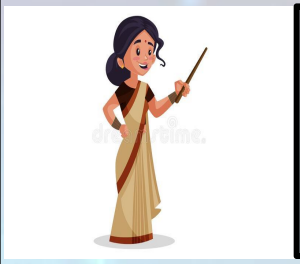
Primary purpose ofdistributed system is

Share resources and Utilize them Better

For cloud also it is same

- With the same concept resources are rented.
- Do you know!!!, that Amazon, Google etc. First developed a data center for themselves.
- Much of the resources were wasted there. SO they decided to rent it out....

Cloud Computing: Distributed Systems

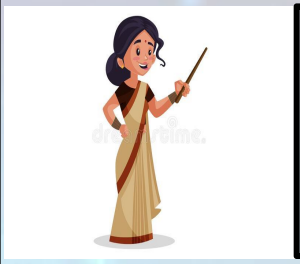


How Distributed system and Cloud Computing are almost similar!!!!!!!

Some Common Features of Cloud and Distried Systems

- Heterogenity
- Concurrency
- Continuous Availability
- Independent Failure

Cloud Computing: Distributed Systems



Three Major Milestones in Distributed Systems that led to Cloud Computing are

- Mainframes
- Cluster Computing
- Grid Computing

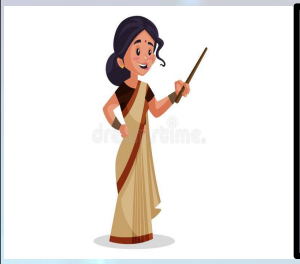
Cloud Computing: Distributed Systems

Three Major Milestones in Distributed Systems that led to Cloud Computing are

MAINFRAMES

- First Large computational facilities with multiple processing units.
- They have features like
  - Powerful
  - Massive I/O
  - Highly reliable

Cloud Computing: Distributed Systems

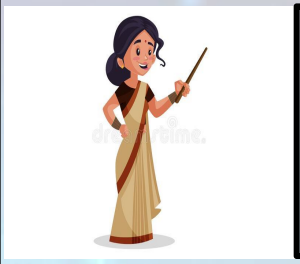


Three Major Milestones in Distributed Systems that led to Cloud Computing are

MAINFRAMES

- They were used by large organizarions for purposes like
  - Online Transactions
  - Enterprise Resource Planning
- They are not pure distributed systems
  - But they were the first to use multiple processor

Cloud Computing: Distributed Systems

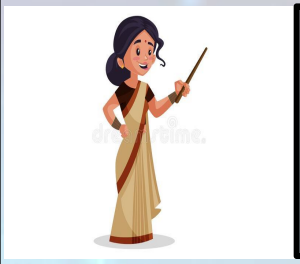


Three Major Milestones in Distributed Systems that led to Cloud Computing are

MAINFRAMES

- They almost did "Batch Processing"

Cloud Computing: Distributed Systems



Three Major Milestones in Distributed Systems that led to Cloud Computing are

Clusters

- Low-cost alternative for mainframes and super computers.
- In short it is supercomputer of middle class people.
- It's pretty simple.
  - You have many desktops and laptops???
  - Then connect them by high-bandwidth network.
  - Install clustering software
  - Now all them work together as one entity

Cloud Computing: Distributed Systems

Three Major Milestones in Distributed Systems that led to Cloud Computing are

Clusters.. Appeared in 80s

- Cluster is standard technology for parallel and high performance computing.
- This technology provided supercomputer like processing power available to common people.
- Ex:
  - MPI (Message Passing Interface)
  - Parallel Virtual Machines (PVM)

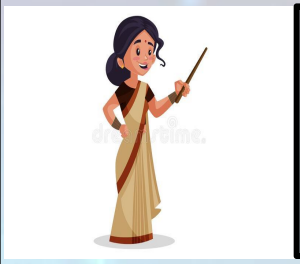
Cloud Computing: Distributed Systems

Three Major Milestones in Distributed Systems that led to Cloud Computing are

Clusters

- It is easily scalable.
  - You want to increase the speed of your game?????
    - ask your friends for their laptop for a while add them to your cluster and start gaming....

Cloud Computing: Distributed Systems



Three Major Milestones in Distributed Systems that led to Cloud Computing are

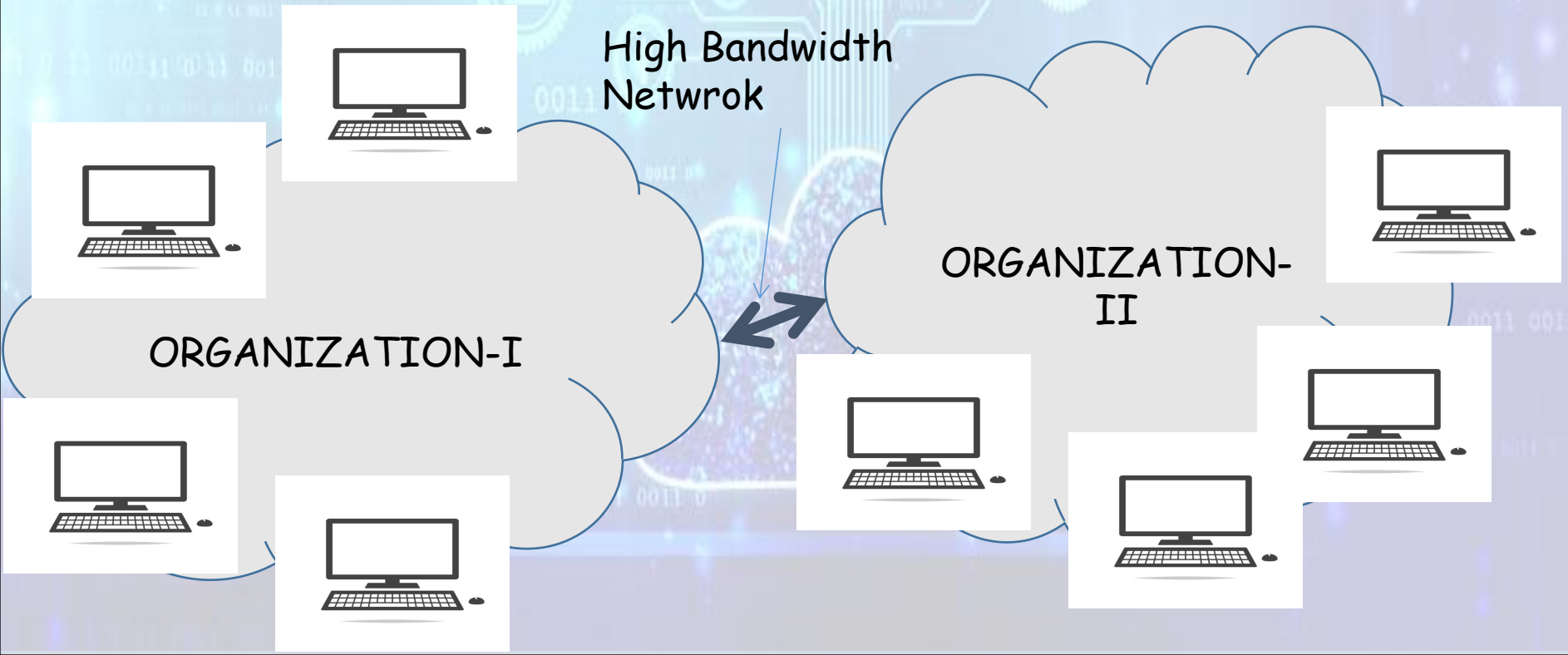
Grids

- As an analogy to the power grid, grid computing proposed a new approach to access large computational power, huge storage facilities, and a variety of services.
- Users can "consume" resources in the same way as they use other utilities such as power, gas, and water

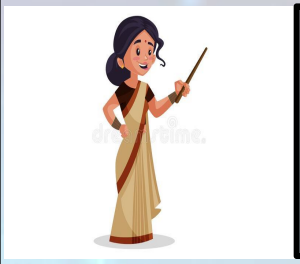
Cloud Computing: Distributed Systems

Three Major Milestones in Distributed Systems that led to Cloud Computing are

Grids: Initial View



Cloud Computing: Distributed Systems

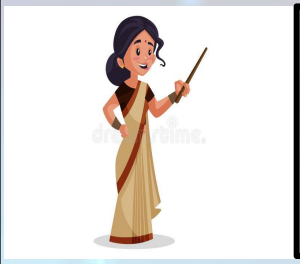


Three Major Milestones in Distributed Systems that led to Cloud Computing are

Grids: Initial View

Different from a "large cluster," a computing grid was a dynamic aggregation of heterogeneous computing nodes, and its scale was nationwide or even worldwide.

Cloud Computing: Distributed Systems



Three Major Milestones in Distributed Systems that led to Cloud Computing are

Grids: Incidents which led to the development of Grid Tech

- Clusters became quite common
- They were often underutilized
- New problems required power beyond the range of one cluster.
- Improvement in Internet technology with high bandwidth.

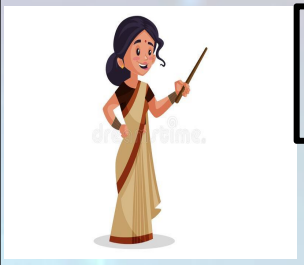
Cloud Computing: Distributed Systems

Three Major Milestones in Distributed Systems that led to Cloud Computing are

Grids

- Cloud computing has the features of Mainframe, cluster and Grid computing
- But most of the people beleive that CLOUD COMPUTING is successor of GRID COMPUTING.

Cloud Computing: Virtualization

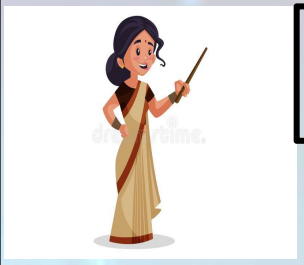


What is the idea of Virtualization?

abstraction of some of the fundamental elements for computing such as hardware,runtime environments, storage, and networking.

situation in which a subject is very general and not based on real situations

Cloud Computing: Virtualization



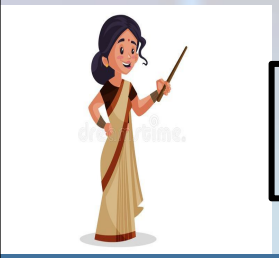
What is the idea of Virtualization?

Can you beleive!!!!!!!!!!!!!!!!!!!!!!!!!!

- Virtualization was there from 40 years.
- But people didn't know how to use it properly

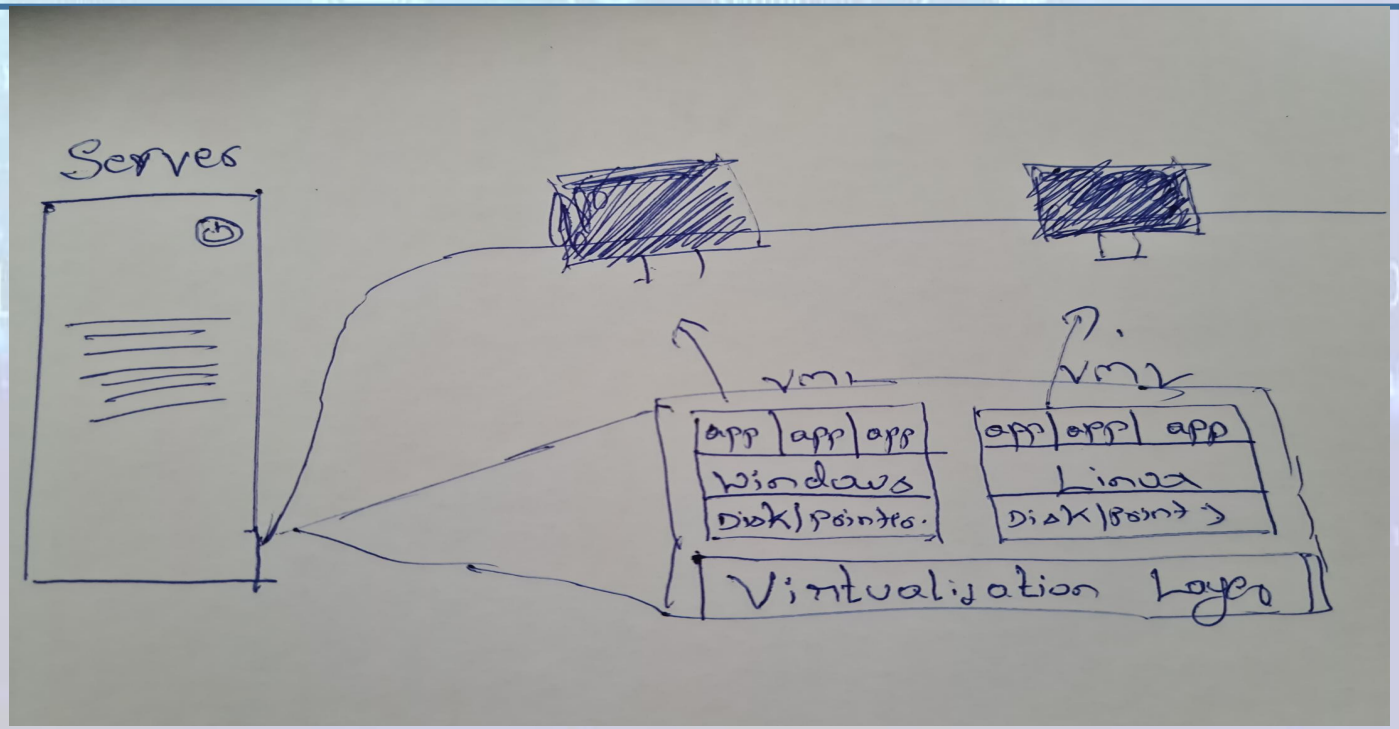
AND TODAY COMPLETE CLOUD COMPUTING IS POSSIBLE BECAUSE OF VIRTUALIZATION.

Cloud Computing: Virtualization

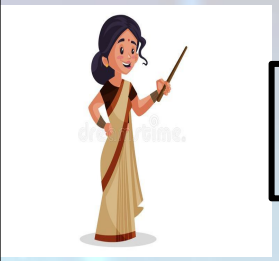


What is the idea of Virtualization?

Virtualization is essentially a technology that allows creation of different computing environments.



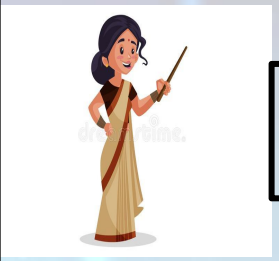
Cloud Computing: Virtualization



What is the idea of Virtualization?

- Environments are called virtual because they simulate the interface that is expected by a guest.
- hardware virtualization:
  - simulating the hardware interface expected by an operating system.

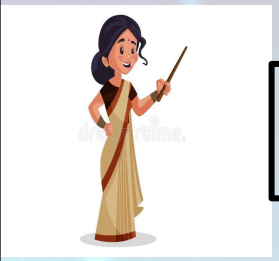
Cloud Computing: Virtualization



What is the idea of Virtualization?

- hardware virtualization:
  - It allows coexistence of different software stacks on top of the same hardware.
  - Virtual Machine Instances work in complete isolation from one another

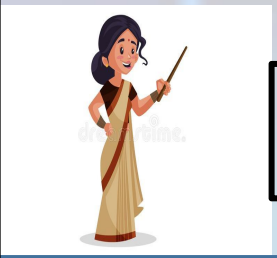
Cloud Computing: Virtualization



What is the idea of Virtualization?

- Ex of Hardware Virtualizarion
  - VMWare
  - EC2 by Amazon
- Hardware Virtualization, Storage and Network virtualization provide complete IT infrastructure.

Cloud Computing: Virtualization

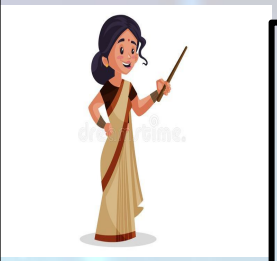


What is the idea of Virtualization?

Process Virtual Machines:

- For Runtime Virtualization.
- User is to just worry about his/her software development.
- Every other runtime environment softwares are taken care by cloud.
- Ex:
  - Google App Engine, Azure by Microsoft.

Cloud Computing: Web 2.0



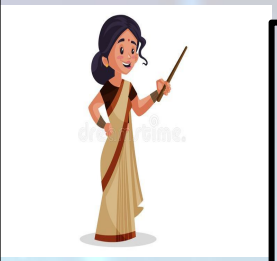
Why web technology is important for cloud computing?????

- The Web is the primary interface through which cloud computing delivers its services.

Obviously!!!
How can you access anything without connecting to the server through browser!!!!

- Google docs, Pics, facebook, mail etc. etc....
- Now a days we use apps if we have smart phones.
- Otherwise we use broeser (Web 2.0)

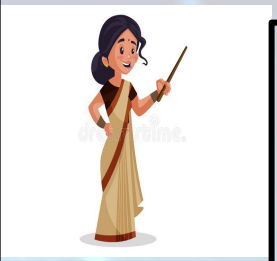
Cloud Computing: Web 2.0



Why web technology is important for cloud computing?????

- Facilities Provided by Web 2.0
  - Interactive Information Sharing
  - Collaboration
  - User Centered Design
  - Application Composition
  - Interactivity
  - Flexibility

Cloud Computing: Web 2.0

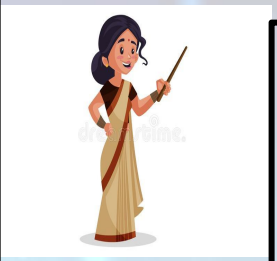


Why web technology is important for cloud computing?????

- Facilities Provided by Web 2.0
  - Interactive Information Sharing
  - Collaboration
  - User Centered Design
  - Application Composition
  - Interactivity
  - Flexibility

Provides Web based access to all the functions provided by Desktop Applications.

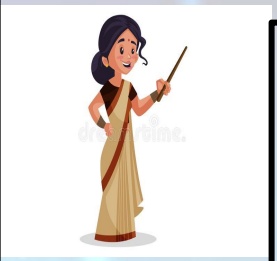
Cloud Computing: Web 2.0



Technologies which helped to provide the capabilities for Web.

- XML
- AJAX
- Web Services
- etc.

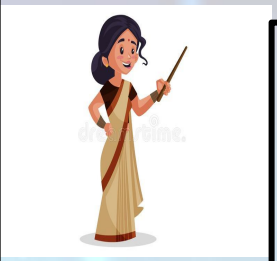
Cloud Computing: Web 2.0



Technologies which helped to provide the capabilities for Web.

- Web 2.0 is very dynamic
  - improve continuously.
  - new updates and features are integrated at a constant rate according to trend.
  - Users can take advantage of the new software features simplyby interacting with cloud applications.

Cloud Computing: Web 2.0



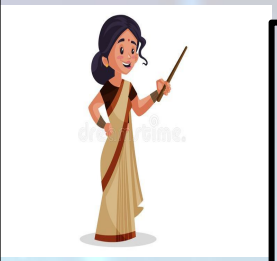
Technologies which helped to provide the capabilities for Web.

- Web 2.0 is very dynamic
  - improve continuo
  - are integrated at a
  - d.
  - the new software
  - cting with cloud

It is possible because of

- Light Weight Deployment of Applications
- Loose Coupling (New apps are synthesized with existing apps)
- Available to everyone because of media accessibility and affordability.

Cloud Computing: Web 2.0



Technologies which helped to provide the capabilities for Web.

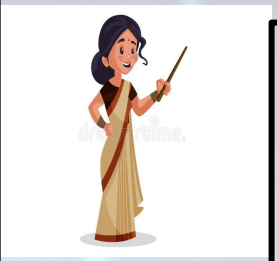
Well we owe "Darcy DiNucci" a lot for web 2.0

"Darcy DiNucci is an author, web designer and expert in user experience. DiNucci coined the term Web 2.0 in 1999 and predicted the influence it would have on public relations."

Source

Wikipedia

Cloud Computing: Web 2.0

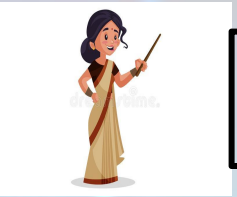


Technologies which helped to provide the capabilities for Web.

Well we owe "Darcy DiNucci" a lot for web 2.0

He defined web2.0 framework for providing Rich Internet Applications (RIA) which are basic for Cloud Computing.

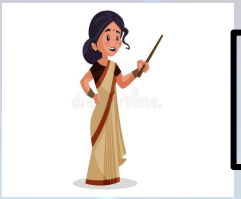
Cloud Computing: Service Oriented Computing



What is Service Oriented Computing (SoC)

- This approach adopts the concept of services as the main building blocks of application.
- It supports the development of rapid, low-cost, flexible, interoperable, and evolvable applications and systems

Cloud Computing: Service Oriented Computing

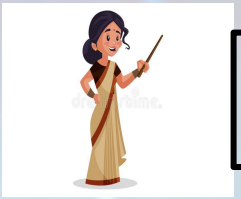


What is Service Oriented Computing (SoC)

- A service is an abstraction representing a self-describing and platform-agnostic component thatcan perform any function

Nothing is known

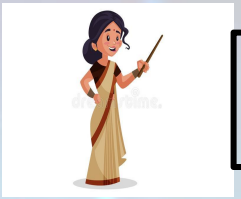
Cloud Computing: Service Oriented Computing



What is Service Oriented Computing (SoC)

- A service is supposed to be
  - Loosely coupled
  - Reusable
  - programming language independent
  - location transparent

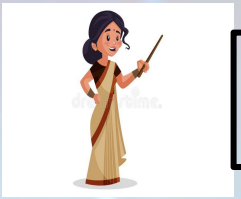
Cloud Computing: Service Oriented Computing



What is Service Oriented Computing (SoC)

- A SoC uses two components
  - Quality of Service (QoS)
  - Software-as-a-Service

Cloud Computing: Service Oriented Computing



What is Service Oriented Computing (SoC)

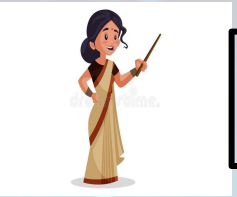
- A SoC uses two components
  - Quality of Service (QoS)
  - Software-as-a-Service

- Functional and Non-functional Attributes to access behavior of service.

Ex: Response Time, Bandwidth etc

Ex: Scalability, Adaptability etc.

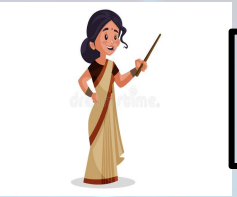
Cloud Computing: Service Oriented Computing



What is Service Oriented Computing (SoC)

- A SoC uses two components
  - Quality of Service (QoS)
  - Software-as-a-Service
- Established through SLA (Service Level Agreements)

Cloud Computing: Service Oriented Computing

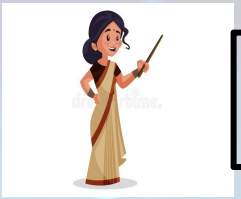


What is Service Oriented Computing (SoC)

- A SoC uses two components
  - Quality of Service (QoS)
  - Software-as-a-Service

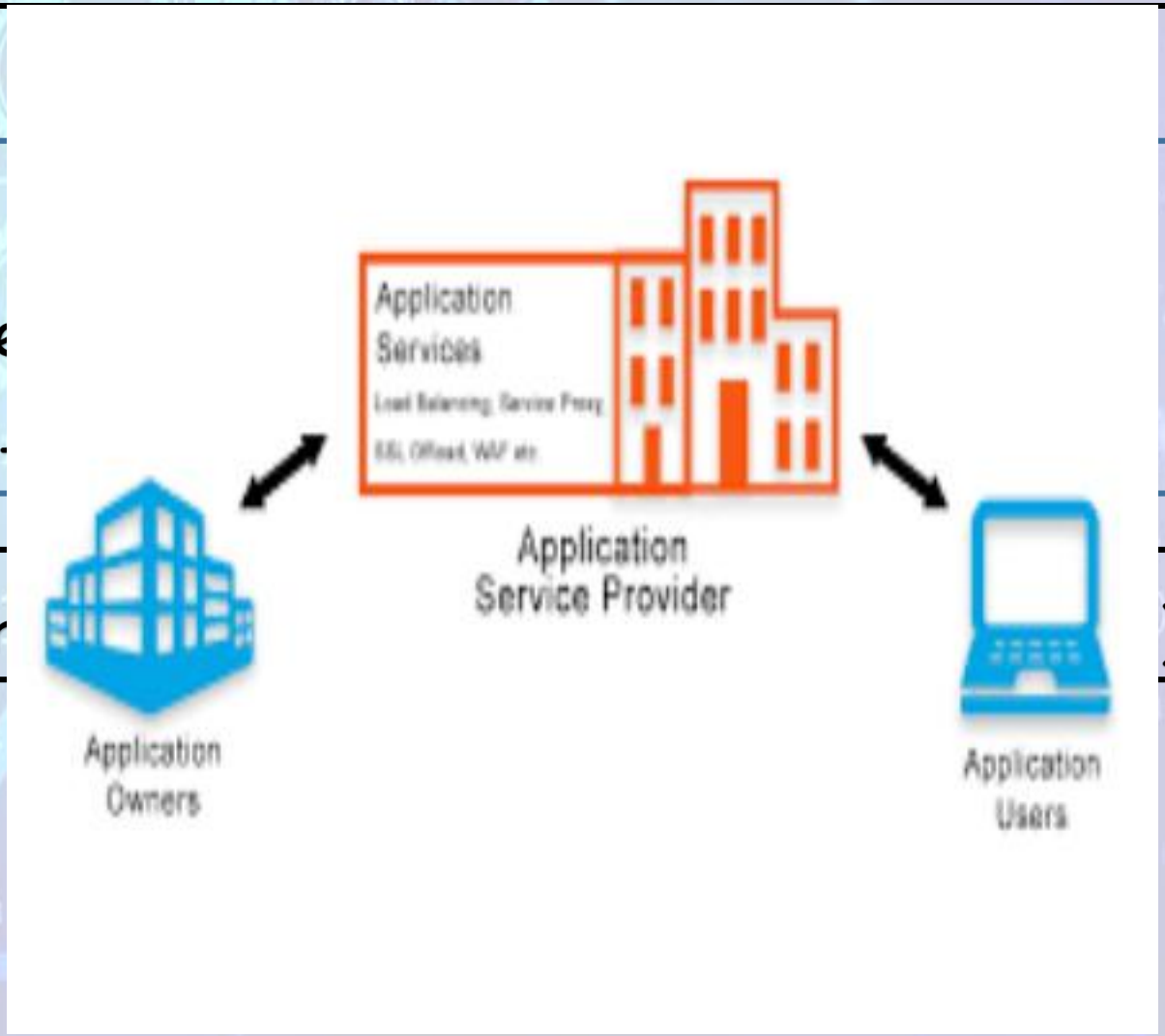
- It got name from Application Service Providers (ASPs)

Cloud Computing: Service Oriented Computing

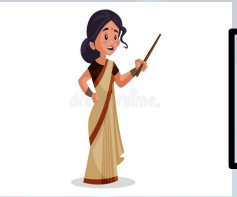


What is Service Oriented Computing (SoC)

- A SoC uses two
  - Quality of Se
  - Software-as-
- It got name fr)



Cloud Computing: Service Oriented Computing

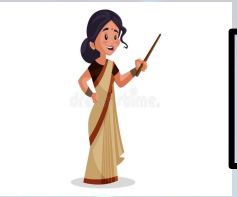


What is Service Oriented Computing (SoC)

- A SoC uses two components
  - Quality of Service (QoS)
  - Software-as-a-Service

- Client is free from any software maintenance and upgrades.

Cloud Computing: Service Oriented Computing

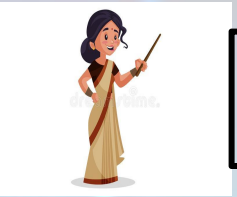


What is Service Oriented Computing (SoC)

- A SoC uses two components
  - Quality of Service (QoS)
  - Software-as-a-Service

- The SaaS approach reaches its full development with service-oriented computing (SOC), where loosely coupled softwarecomponents can be exposed and priced singularly, rather than entire applications

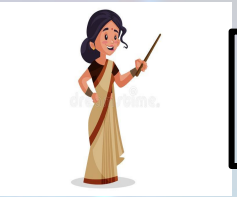
Cloud Computing: Service Oriented Computing



What is Service Oriented Computing (SoC)

- Web Services: Software components accessible through HTTP.
- Web services can be deduced from Web Service Description Language (WSDL)
- XML format

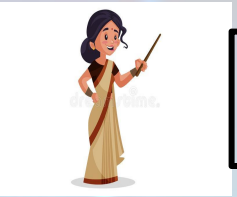
Cloud Computing: Service Oriented Computing



What is Service Oriented Computing (SoC)

- WSDL provides:
  - Characteristics of Services
  - Methods
  - Description
  - Parameters to pass
  - Return Type

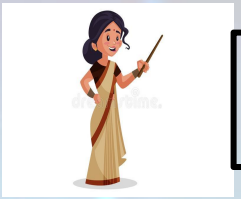
Cloud Computing: Service Oriented Computing



What is Service Oriented Computing (SoC)

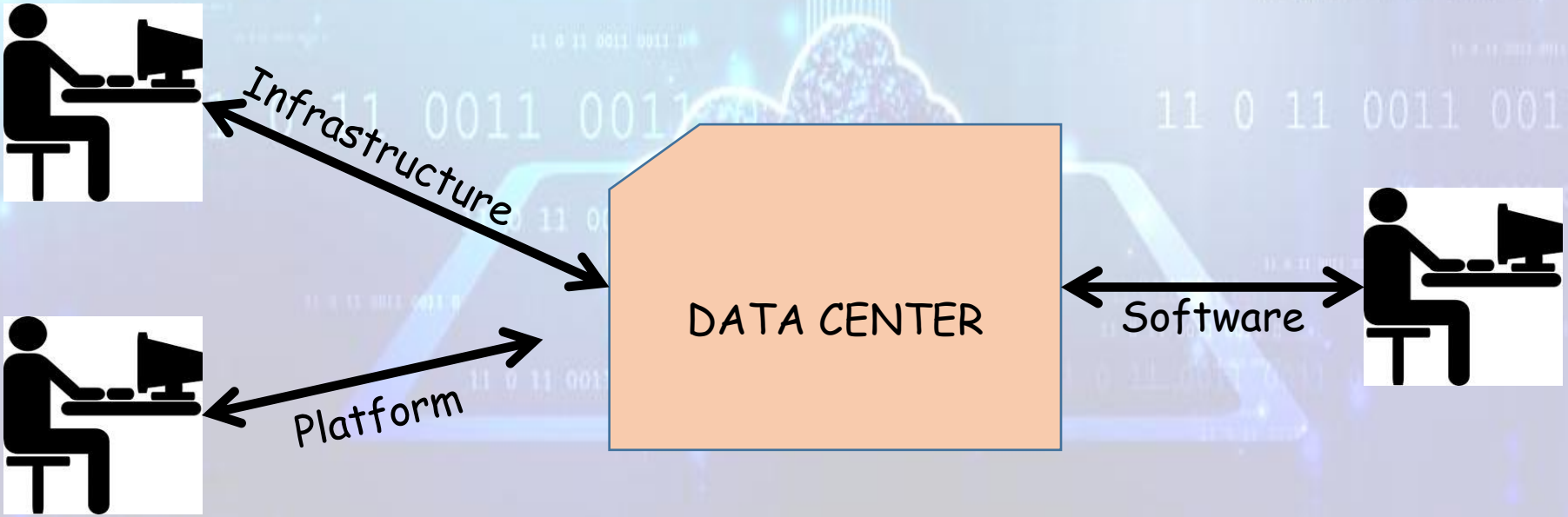
- We can interact with WSDL using SOAP (Simple Object Access Protocol)
- SOAP and WSDL on HTTP makes services platform independent.

Cloud Computing: Utility Oriented Computing

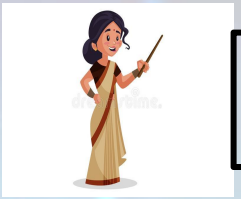


What is Utility Computing?

- It is a vision where resources such as storage, compute power, applications, and infrastructure are packaged and offered on a pay-per-use basis.

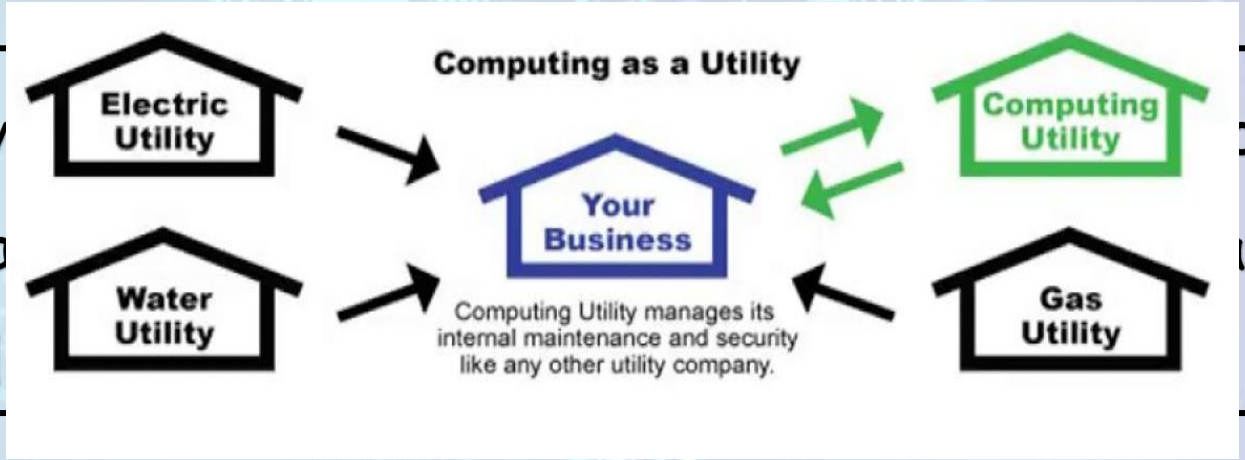


Cloud Computing: Utility Oriented Computing



What is Utility Computing?

- It is a v … compute power, c … ged and offered …



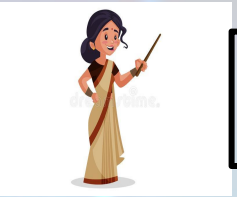
Infrastructure

Platform

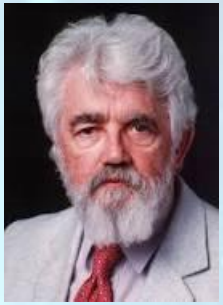
DATA CENTER

Software

Cloud Computing: Utility Oriented Computing



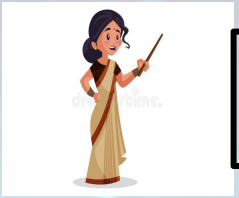
What is Utility Computing?



John McCarthy
American Computer Scientist

If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a public utility, just as the telephone system is a public utility The computer utility could become the basis of a new and important industry. (1961)

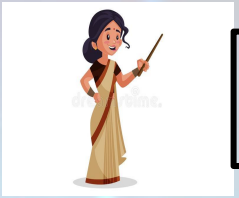
Cloud Computing: Utility Oriented Computing



What is Utility Computing?

- It started during Mainframe era only.
- Not only businesses but also research institutes became acquainted with the idea of leveraging an external IT infrastructure on demand.
- Computational Science always wanted resource for "Grand Challenge" problem.
- Not only businesses but also research institutes became acquainted with the idea of leveraging an external IT infrastructure on demand.

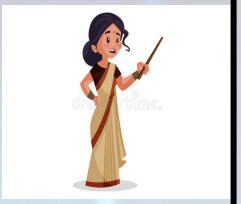
Cloud Computing: Utility Oriented Computing



What is Utility Computing?

- utility computing made it is easier to provide a trading infrastructure where grid products—storage, computation, and services—are bid for or sold.
- e-commerce technologies provided the infrastructure support for utility computing.
- In the late 1990s a significant interest in buying any kind of good online spread to the wider public (Online Shopping)

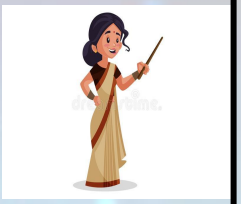
SoA (Service Oriented Architecture): Provided a method to service through software, which was the base for CLOUD COMPUTING.



Building cloud computing environments

Application Development

- Applications hosted on cloud are capable to scale dynamically--> Web Apps may take this as advantage.
  - With web 2.0 now web is hosting very rich user apps.
- Applications which are resource intensive also can go for cloud apps.
  - may be data intensive or compute intensive.
  - Best suited for scientific applications.
  - Resource intensive are not interasctive---Mostly Batch Processing type



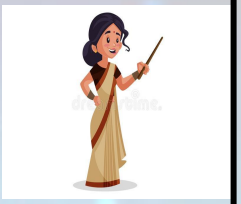
Building cloud computing environments

Application Development

Cloud computing provides on-demand and dynamic scaling across entire stack, by

- Providing methods for renting resources
- offering scalable and dynamic sizing runtime environments.
- Providing applications that mimic desktop apps but hosted and provided by provider.

Cloud Computing: Application Development

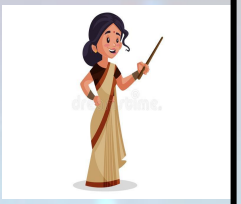


Building cloud computing environments

Infrastructure and System Development

- An Application development on cloud platform needs knowledge across alll cloud enebling technologies like
  - Distributed Compouting
  - Web 2.0
  - Virtualization
  - Service Orientation.

Cloud Computing: Application Development

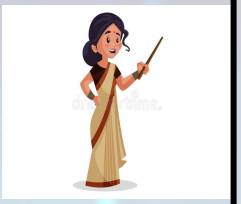


Building cloud computing environments

Infrastructure and System Development

- An Application development on cloud platform needs knowledge across alll cloud enebling technologies like
  - **Distributed Compouting**
  - Web 2.0
  - Virtualization
  - Service Orientation.

Cloud Computing: Application Development

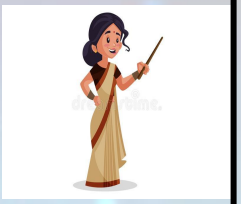


Building cloud computing environments

Infrastructure and System Development

- Distributed Compouting
  - Cloud is distributed platform.
  - Major challenges for cloud engineers
    - Accessability of resources.
    - Extreme dynamism (New Nodes and services)
  - Integration between cloud resources and existing system deployment is another concern

Cloud Computing: Application Development

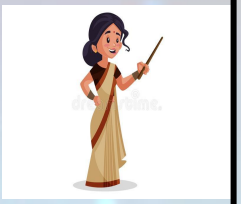


Building cloud computing environments

Infrastructure and System Development

- Distributed Compouting
  - Integration between cloud resources and existing system deployment is another concern
    - IaaS allows you to add or delete. But how you use it depends on the your wisdom.
    - PaaS allows you to lease hardware for your software design.
      - What if user asks more than he want?
      - Can vendor do fine control:? Or should it be transparent

Cloud Computing: Application Development

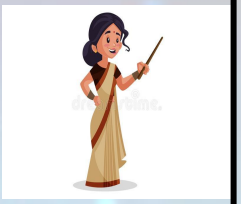


Building cloud computing environments

Infrastructure and System Development

- An Application development on cloud platform needs knowledge across alll cloud enebling technologies like
  - Distributed Compouting
  - **Web 2.0**
  - Virtualization
  - Service Orientation.

Cloud Computing: Application Development

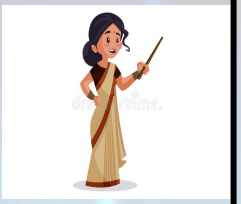


Building cloud computing environments

Infrastructure and System Development

- Web 2.0
  - Provides interfaces to delivery and management of cloud services.
  - service orientation is the underlying paradigm for cloud computing
  - Cloud computing is often summarized with the acronym XaaS—Everything-as-a-Service

Cloud Computing: Application Development



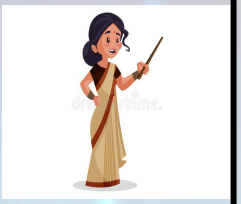
Building cloud computing environments

Infrastructure and System Development

- Web 2.0
  - There is no commonality in the way services ar eprovisioned-

    -----But Web 2.0 interface makes it easier.

Cloud Computing: Application Development

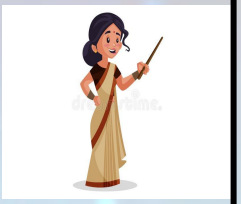


Building cloud computing environments

Infrastructure and System Development

- An Application development on cloud platform needs knowledge across alll cloud enebling technologies like
  - Distributed Compouting
  - Web 2.0
  - **Virtualization**
  - Service Orientation.

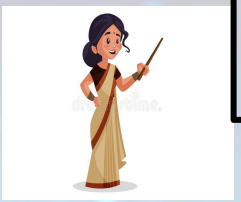
Cloud Computing: Application Development



Building cloud computing environments

Infrastructure and System Development

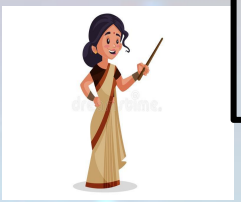
- Virtualization
  - This technology is a core feature of the infrastructure used by cloud providers.
  - the virtualization concept is more than 40 years old
  - cloud computing introduces new challenges, especially in the management of virtual environments,
    - May be in abstractions of virtual hardware
    - in abstraction of runtime environment.



Amazon Web Services (AWS)

- AWS
  - Provides IaaS --> Virtual compute, Storage and Network3
  - Famous Services
    - EC2--> Compute Service
    - S3--> Storage Service
- Elastic Compute Cloud (EC2)

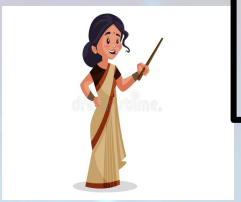
Cloud Computing: Computing Platforms and Technologies



Amazon Web Services (AWS)

- AWS--> Elastic Compute Cloud (EC2)
  - Example: Check this Video

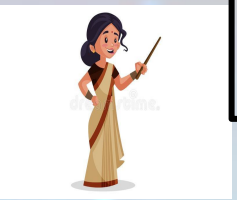
Computing Platforms and Technologies



Amazon Web Services (AWS)

- AWS--> Elastic Compute Cloud (EC2)
  - Huge variety of Virtual Hardware Configurations
  - GPU as a service
  - Cluster as a instance as a Service
- How to access??
  - AWS web portal
  - Welll your running Virtual Machine (Amazon Machine Image) you can store on Amazon S3

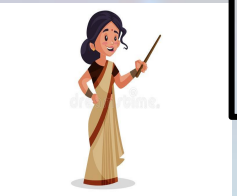
Computing Platforms and Technologies



Amazon Web Services (AWS)

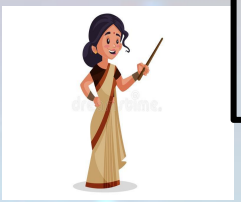
- AWS--> Simple Storage Services (S3)
  - Store objects
  - Organized into buckets.
  - Stored in binary form
- Ex: Check this Video

Computing Platforms and Technologies



Google App Engine (GAE)

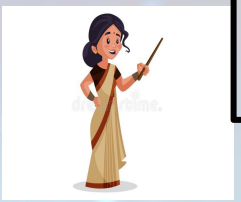
- Scalable Runtime Environement.
- Mostly Web Applications
- If you develop your software here then what is the advanatge???
  - Well google has lots of resources, you can use them
  - In-memory cache.
  - Scalable Data Store.
  - Job Queues et.



Google App Engine (GAE)

- GAE Software Development Kit (SDK) is available.

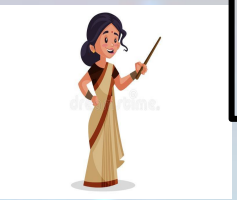
Computing Platforms and Technologies



Microsoft Azure

- Cloud Operating system
- Provides scalable Runtime Environment.
- Applications are organized by roles
  - Web Role
  - Worker Role
  - VM Role
- Extra features provided like Storage, Networking, Cache etc.

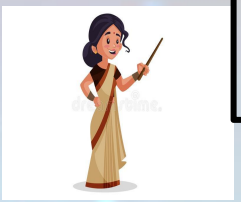
Computing Platforms and Technologies



Hadoop

- By Apache
- For processing Large Data Sets
- Uses Map-Reduce Technnique

Computing Platforms and Technologies

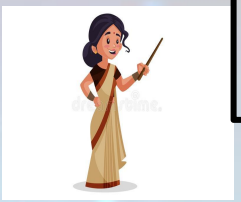


Hadoop

- By Apache
- For processing Large Data Sets
- Uses Map-Reduce Technnique

MAPPING(DISTRIBUTING)
DATA ACROSS NODES

Computing Platforms and Technologies

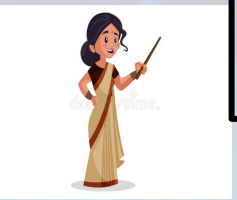


Hadoop

- By Apache
- For processing Large Data Sets
- Uses Map-Reduce Technnique

Collecting Result From Individual Nodes

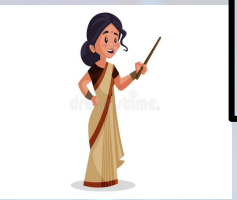
Computing Platforms and Technologies



Hadoop

- By Apache
- For processing Large Data Sets
- Uses Map-Reduce Technnique
- Yahoo Main Sponser
- User just need to provide **Data** and **MAP-REDUCE Functions**.

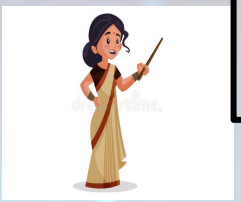
Computing Platforms and Technologies



Force.com and SalesForce.com

- Force.com: Allows to develop Social Enterprise Applications.
- SalesForce.com: uilt Using Force.com
  - SaaS
  - Mainly Provides Customer Relationship Management Software (CRM)

Computing Platforms and Technologies



Manjrasoft Aneka

- Cloud Application Platform
- Provides platform for developing Scalable Applications.
- Also provide Runtime Environmetn with heterogeneous hardware.
  - Allows different abstractions like tasks, distributed threads and map reduce.
  - service-oriented architecture manages Scheduling, Execution, Accounting, Billing, Storage and QoS

VIRTUALIZATION

VIRTUALIZATION
Introduction

VIRTUALIZATION
Introduction

Technical Definition

VIRTUALIZATION
Introduction

Reasons for Renewed Interest in virtualization

- Increased Performance and Computing Capacity
- Underutilized Hardware and Software Resources
- Lack of space
- Greening Initiative
- Rise of Administrative Costs

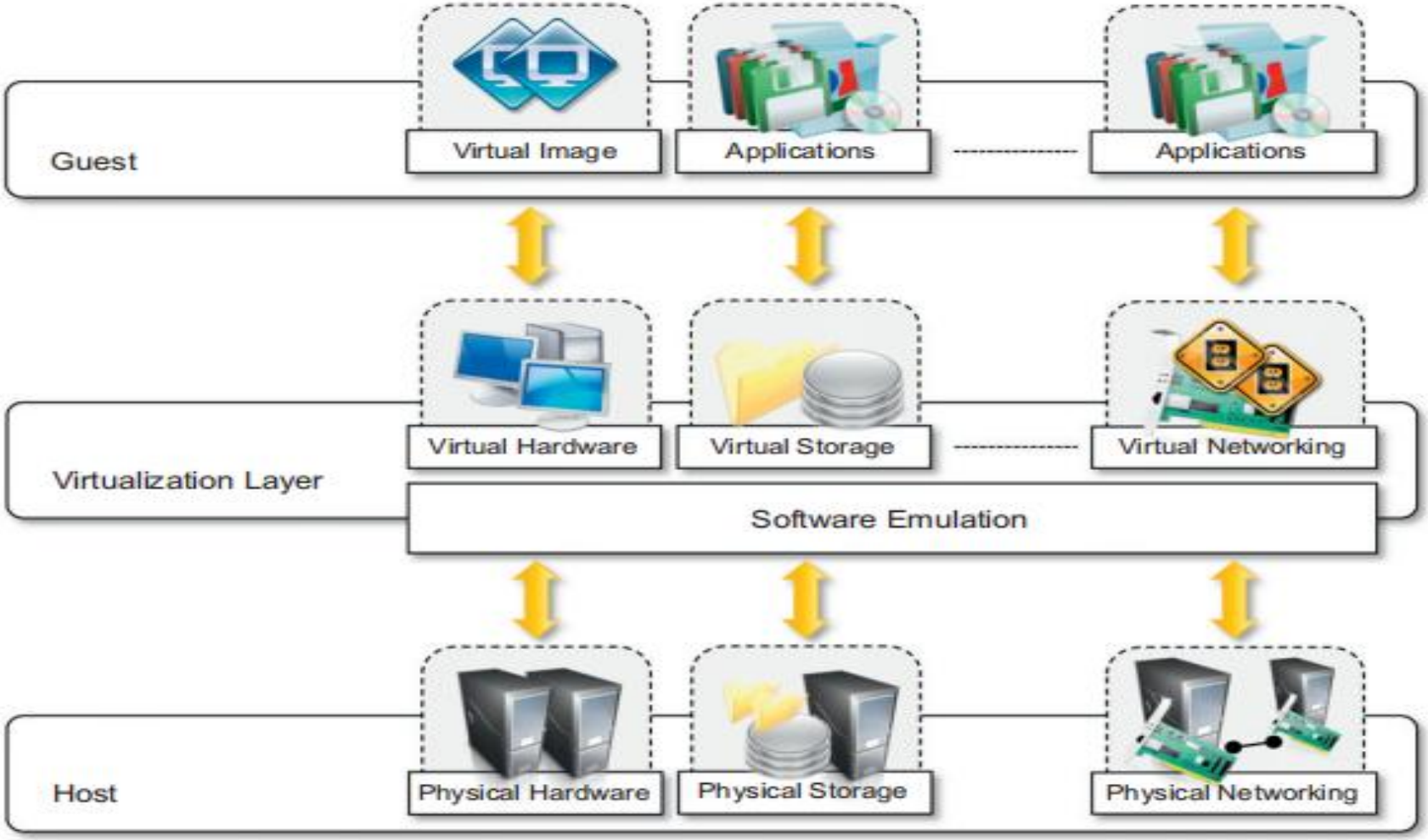
1995	JAVA released where Applets are executed in JVM
2002	.NET by microsoft
2006	Virtualization was used by Google

VIRTUALIZATION

Characteristics of Virtualized Environments

VIRTUALIZATION

Characteristics of Virtualized Environments



VIRTUALIZATION

Characteristics of Virtualized Environments

Advantages of Virtualized Solutions

- Increased Security
  - Its an Emulated Environement
  - OPerations performed on VM not directly on host - So you can easily control and filter.

JVM and .NET runtime saved host machine by running program on virtual environment.

VMs created by softwares like virtual box: File system of Virtual computers completely separated by host

VIRTUALIZATION
Characteristics of Virtualized Environments

Advantages of Virtualized Solutions

- Increased Security
- Managed Execution

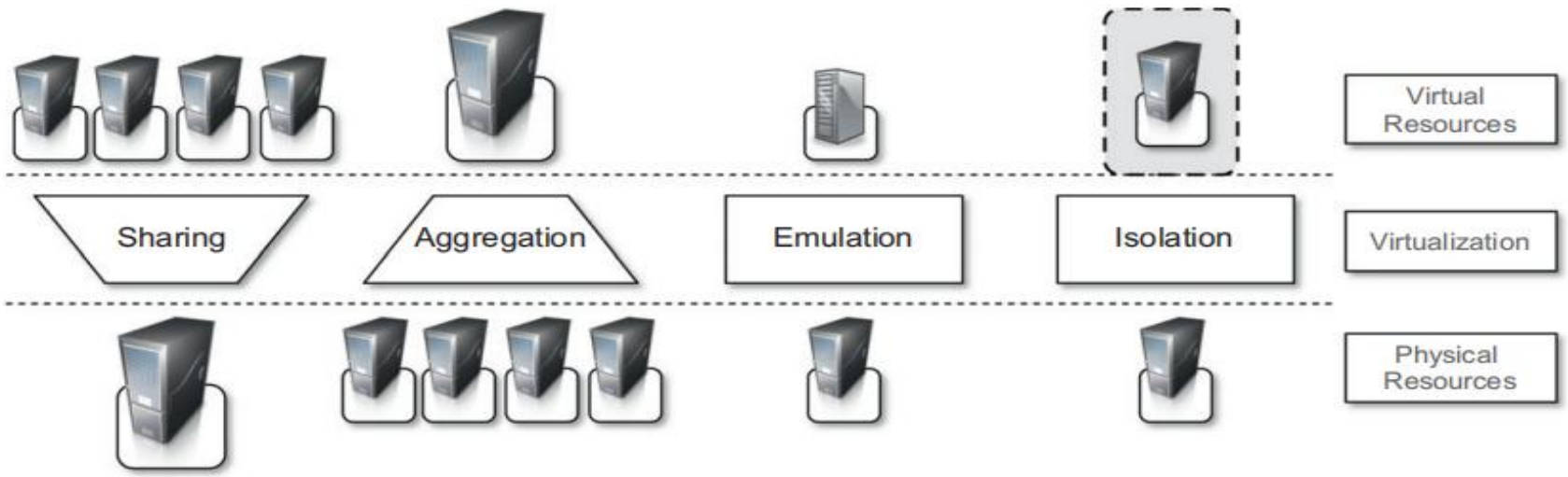


FIGURE 3.2

Functions enabled by managed execution.

VIRTUALIZATION

Characteristics of Virtualized Environments

Advantages of Virtualized Solutions

- Increased Security
- Managed Execution
  - Emulation
    - a completely different environment with respect to the host can be emulated, thus allowing the execution of guest programs requiring specific characteristics that are not present in the physical host.

VIRTUALIZATION
Characteristics of Virtualized Environments

Advantages of Virtualized Solutions

- Increased Security
- Managed Execution

Performance Tuning: Helps in Qos and SLA provisioning

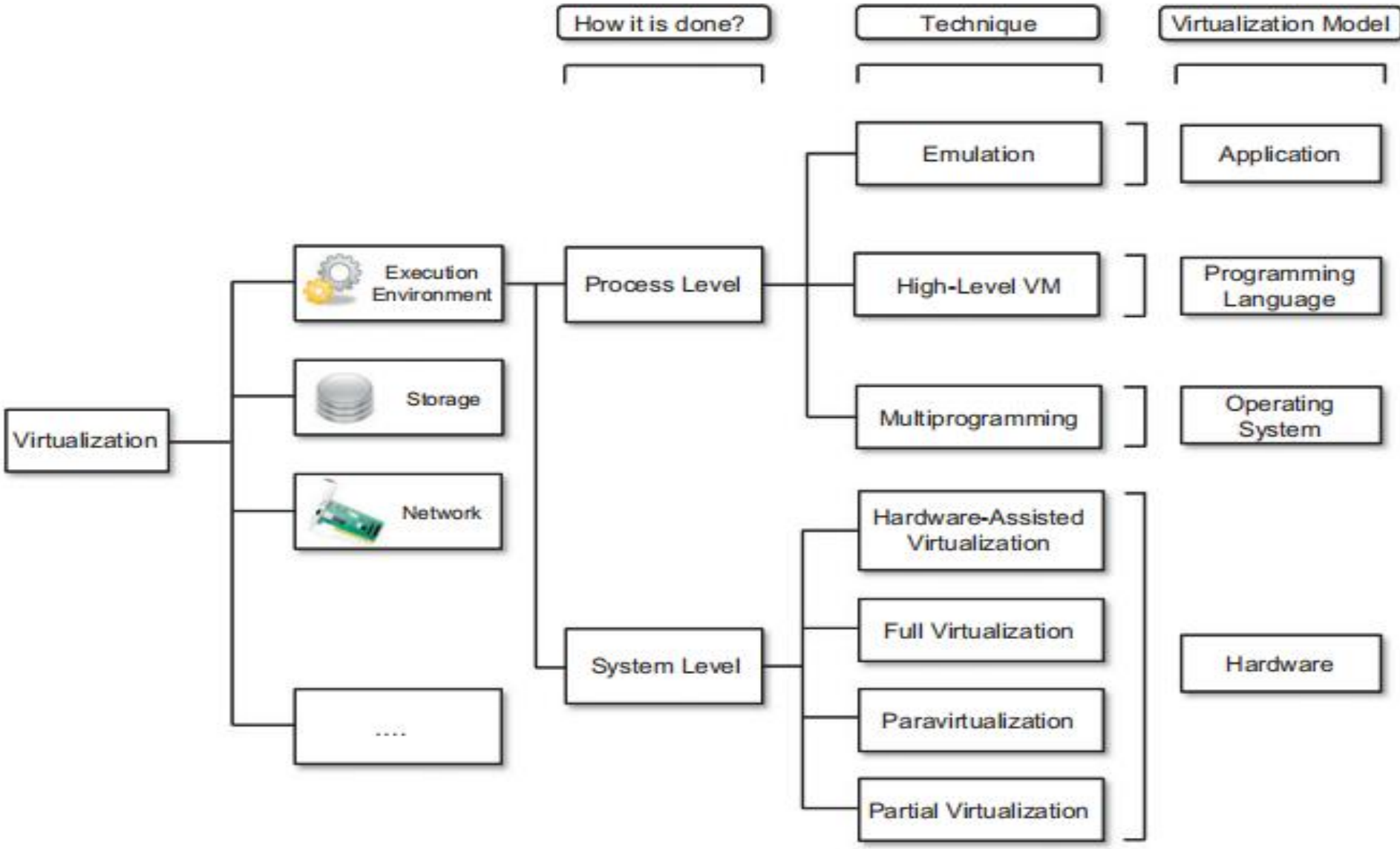
VIRTUALIZATION

Characteristics of Virtualized Environments

Advantages of Virtualized Solutions

- Increased Security
- Managed Execution
- Portability
  - H/W Virtualization: Virtual Image on any machine
  - Programming Level Virtualization: Binary Code can be run on any machine with JVM
  - portability allows having your own system always with you and ready to use as long as the required virtual machine manager is available

VIRTUALIZATION
Taxonomy of Virtualization Techniques



VIRTUALIZATION

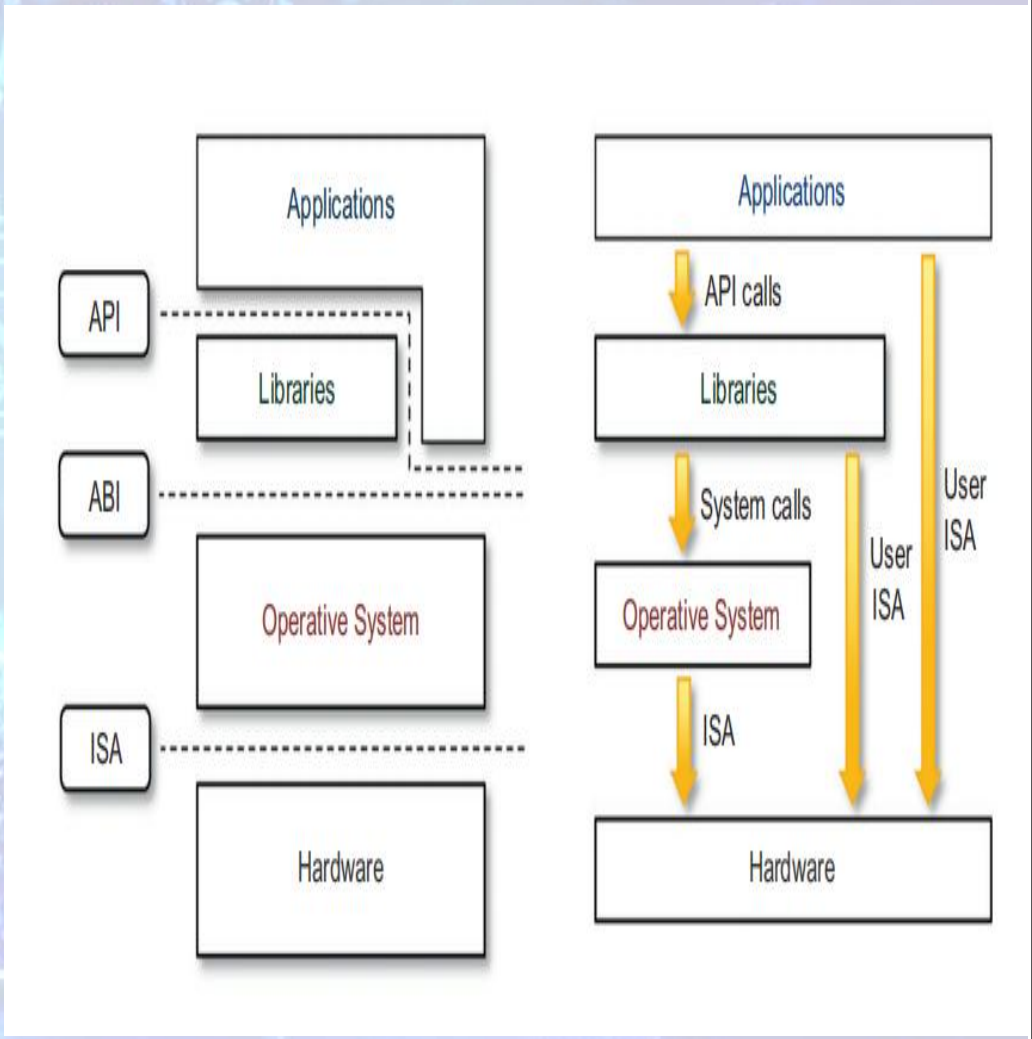
Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Techniques That Emulate separate from the one hosting virtualization.
  - Machine Reference Model

VIRTUALIZATION

Taxonomy of Virtualization Techniques

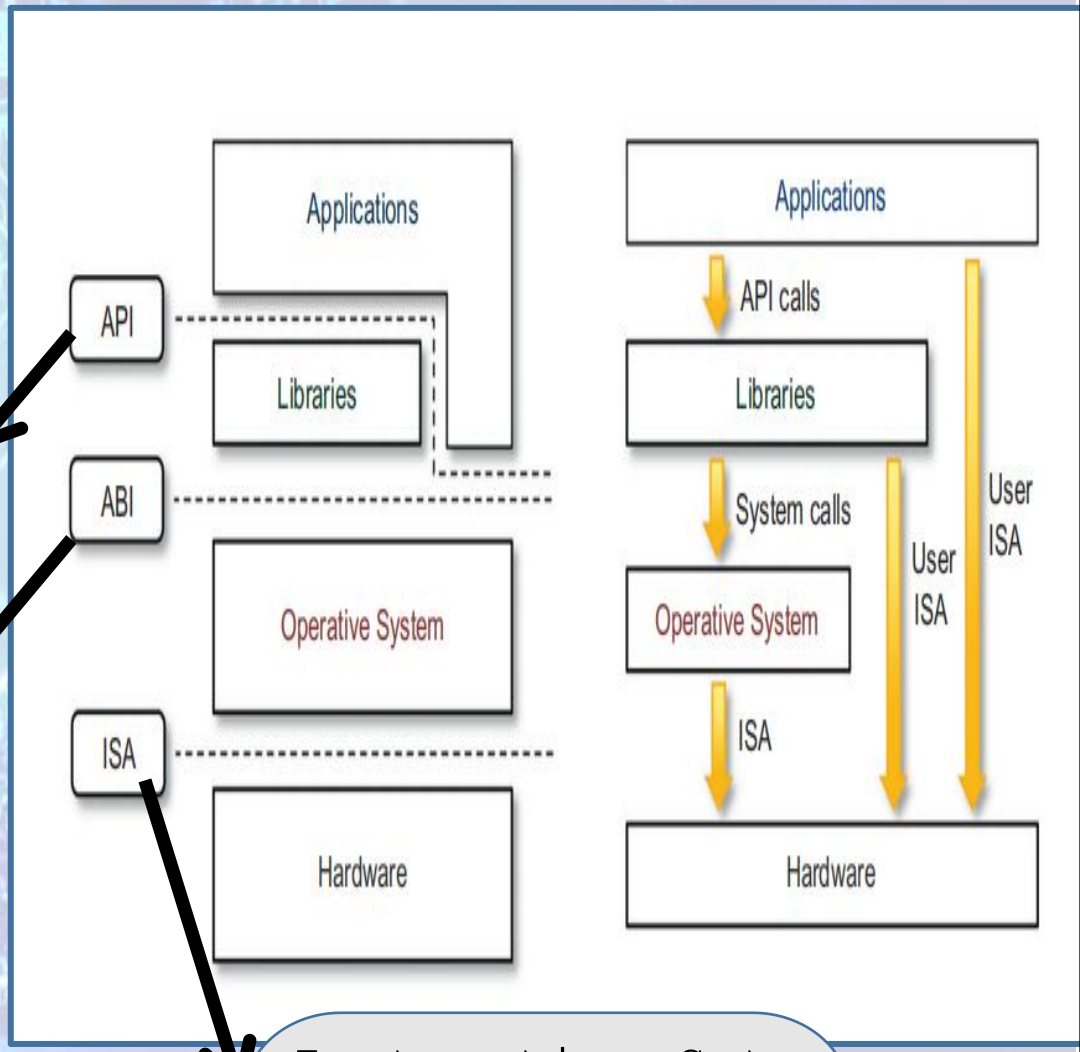
- ExecutionVirtualization
  - Techniques That Emulate separate from the one hosting virtualization.
  - Machine Reference Model



VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Techniques That Emulate separate from the one
  - Machine Reference Model



Application Program Interface

Application Binary Interface

Instruction Set Architecture

VIRTUALIZATION

Taxonomy of Virtualization Techniques

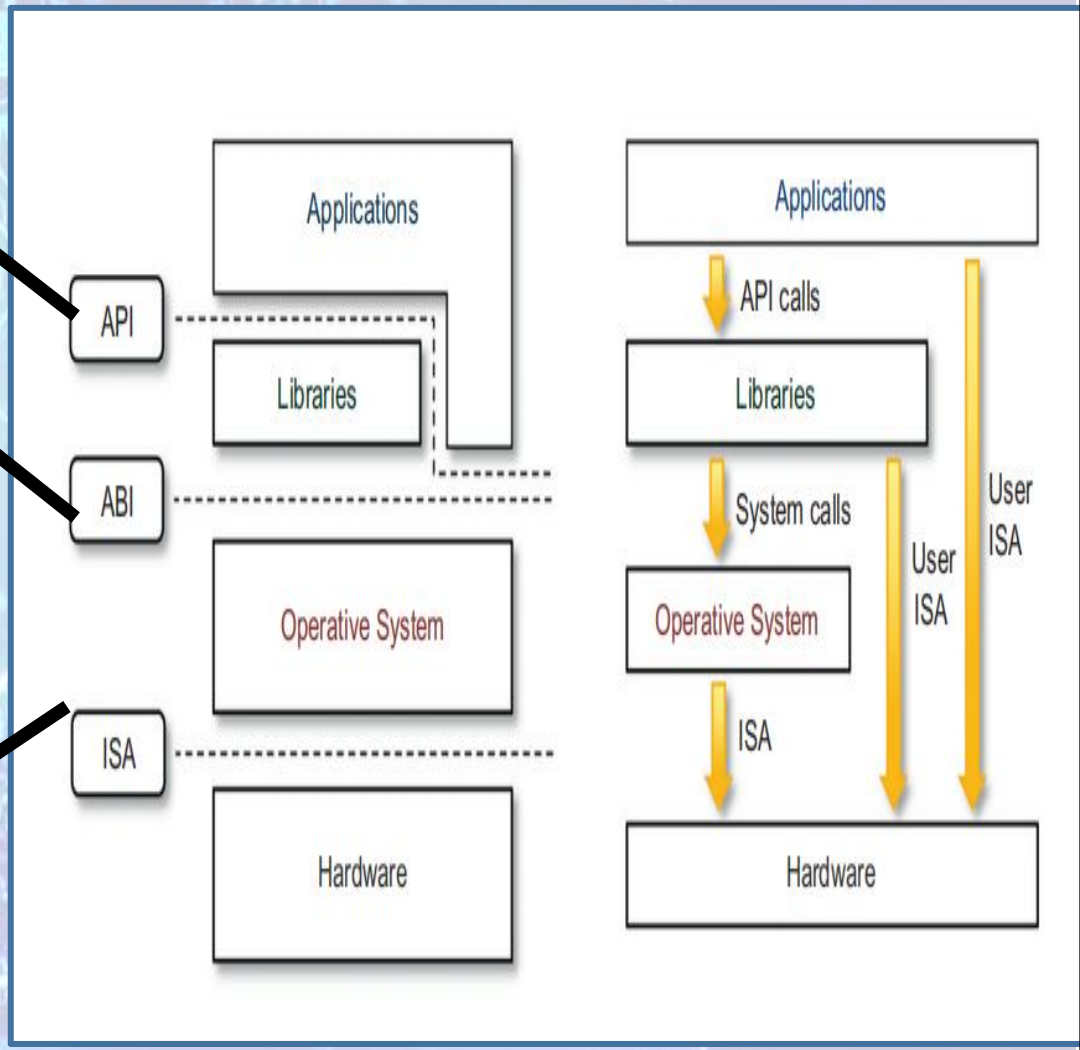
- Application Program Interface

Virtualization

- Application Binary Interface

Instruction Set Architecture

- Instruction set of processor
- Registers and Memory
- Interrupts handling
- System ISA and User ISA



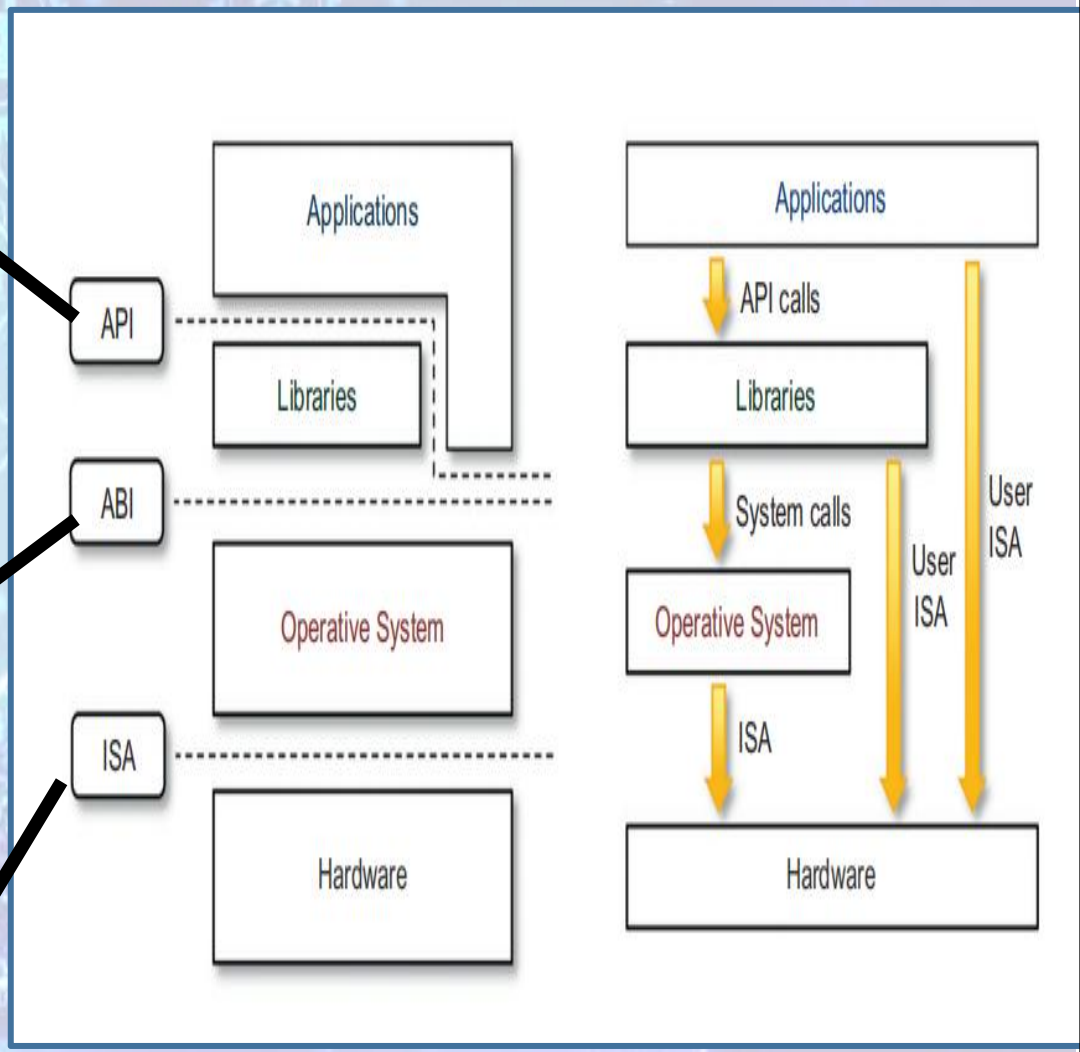
VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Application Program Interface

- Application Binary Interface
  - Separates OS from Apps
  - Low level data types
  - Function calls etc.
  - System Calls
  - App runs on any OS because of this

- Instruction Set Architecture



VIRTUALIZATION

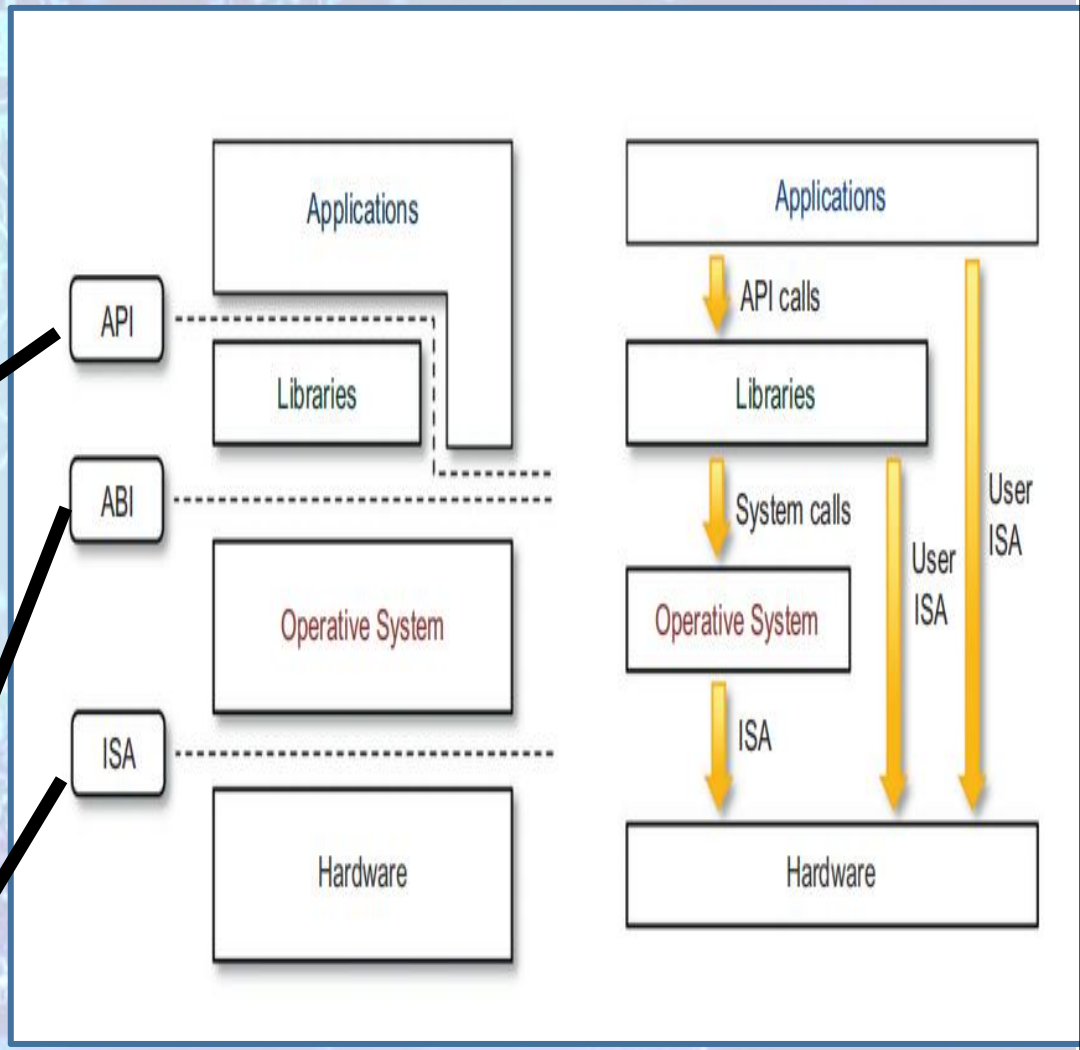
Taxonomy of Virtualization Techniques

Application Program Interface

- Interface software to any OS or library

Application Binary Interface

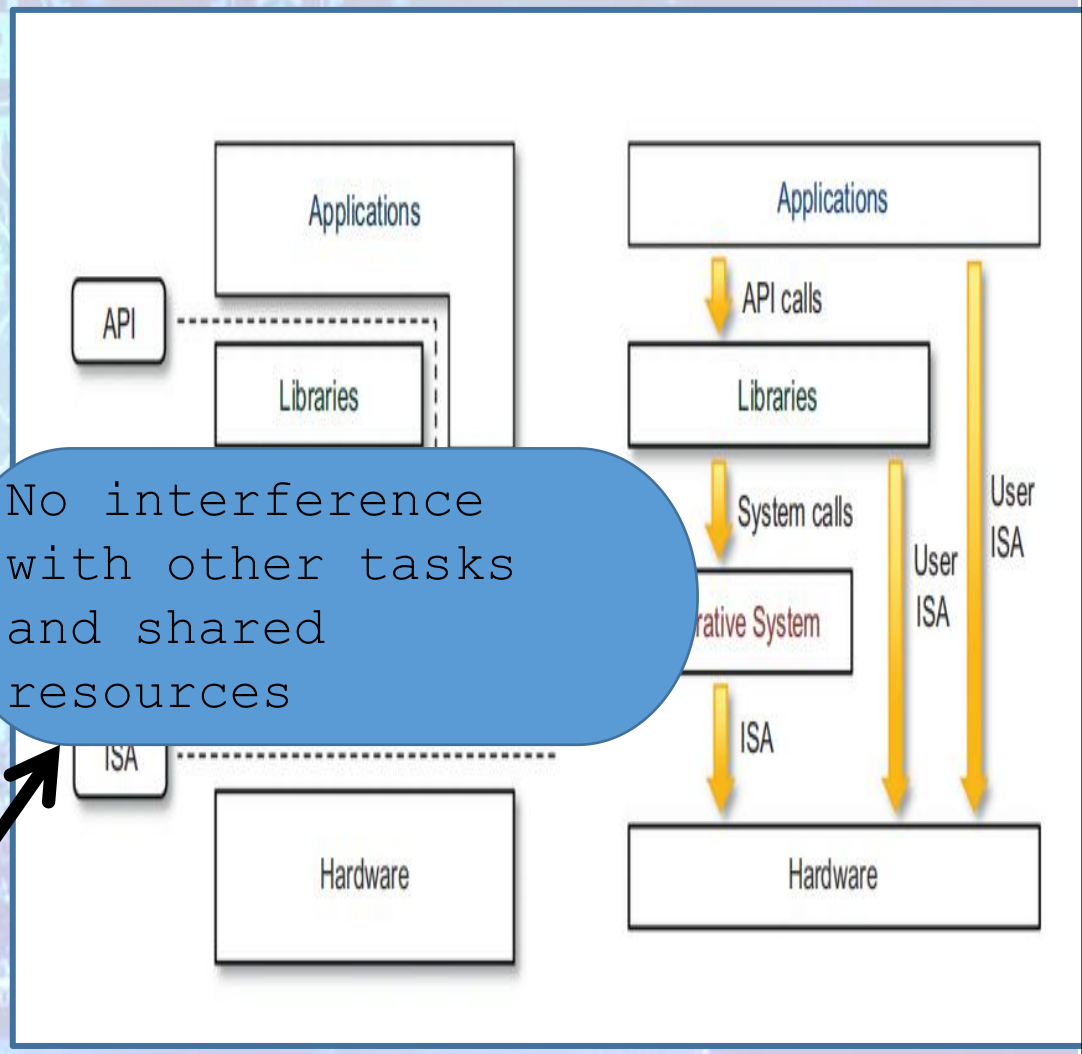
Instruction Set Architecture



VIRTUALIZATION

Taxonomy of Virtualization Techniques

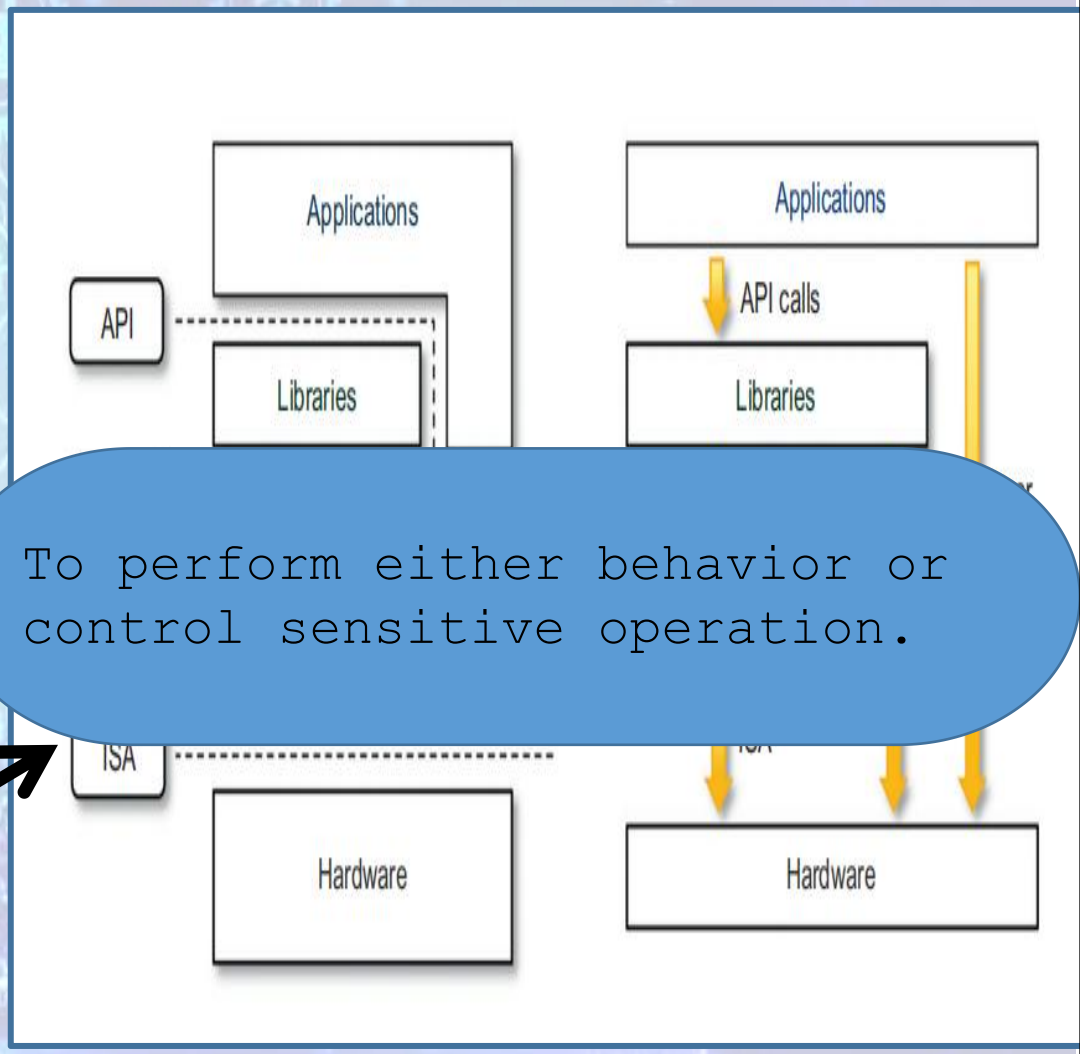
- Execution Virtualization
  - Techniques That Emulate separate from the one hosting virtualization.
  - Machine Reference Model.
  - machine Instruction set
    - Privileged
    - Non-privileged



VIRTUALIZATION

Taxonomy of Virtualization Techniques

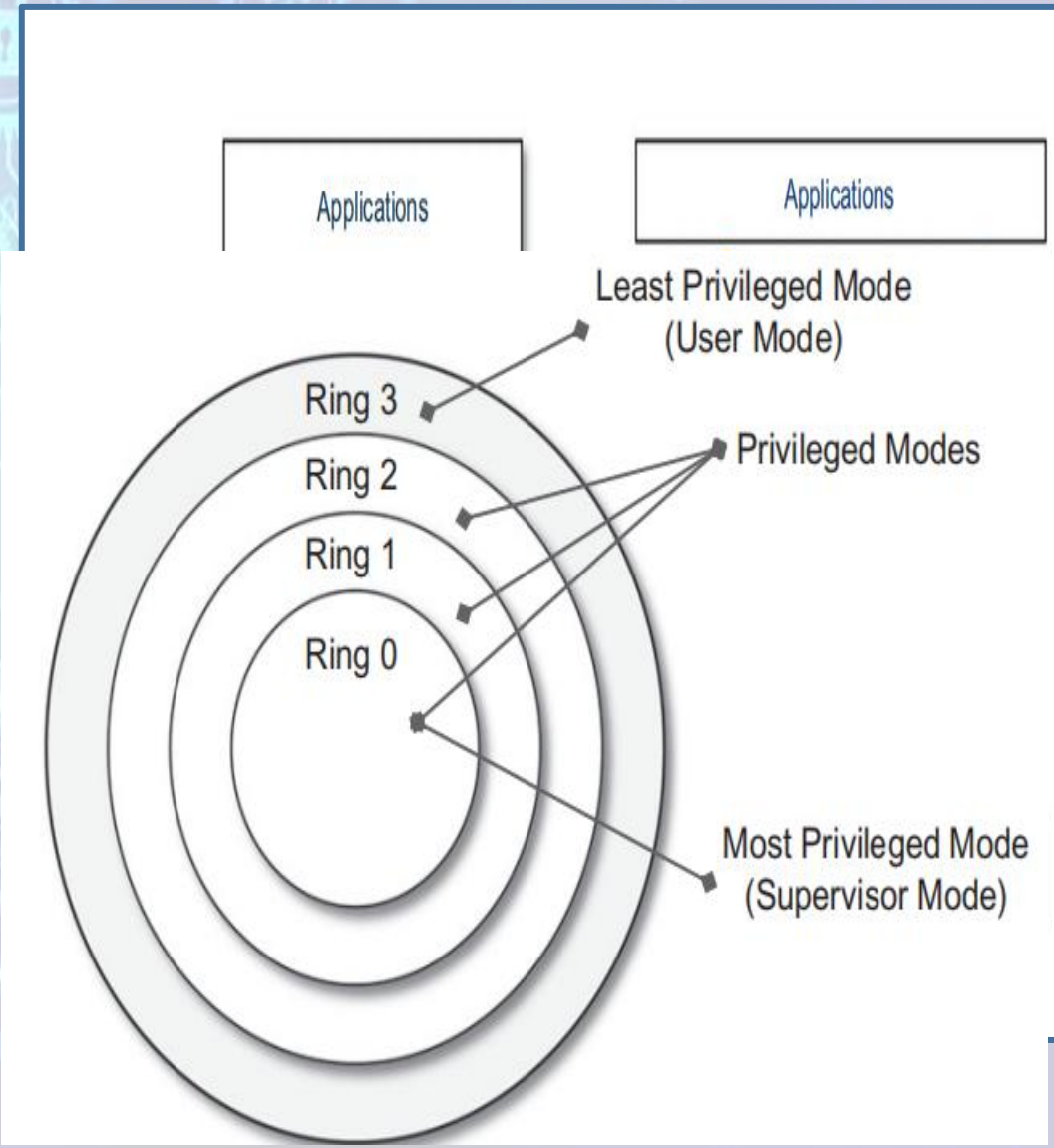
- Execution Virtualization
  - Techniques That Emulate separate from the one hosting virtualization.
  - Machine Reference Model.
  - machine Instruction set
    - Privileged
    - Non-privileged



VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Techniques That Emulate separate from the one hosting virtualization.
  - Machine Reference Model.
  - machine Instruction set
    - Privileged
    - Non-privileged



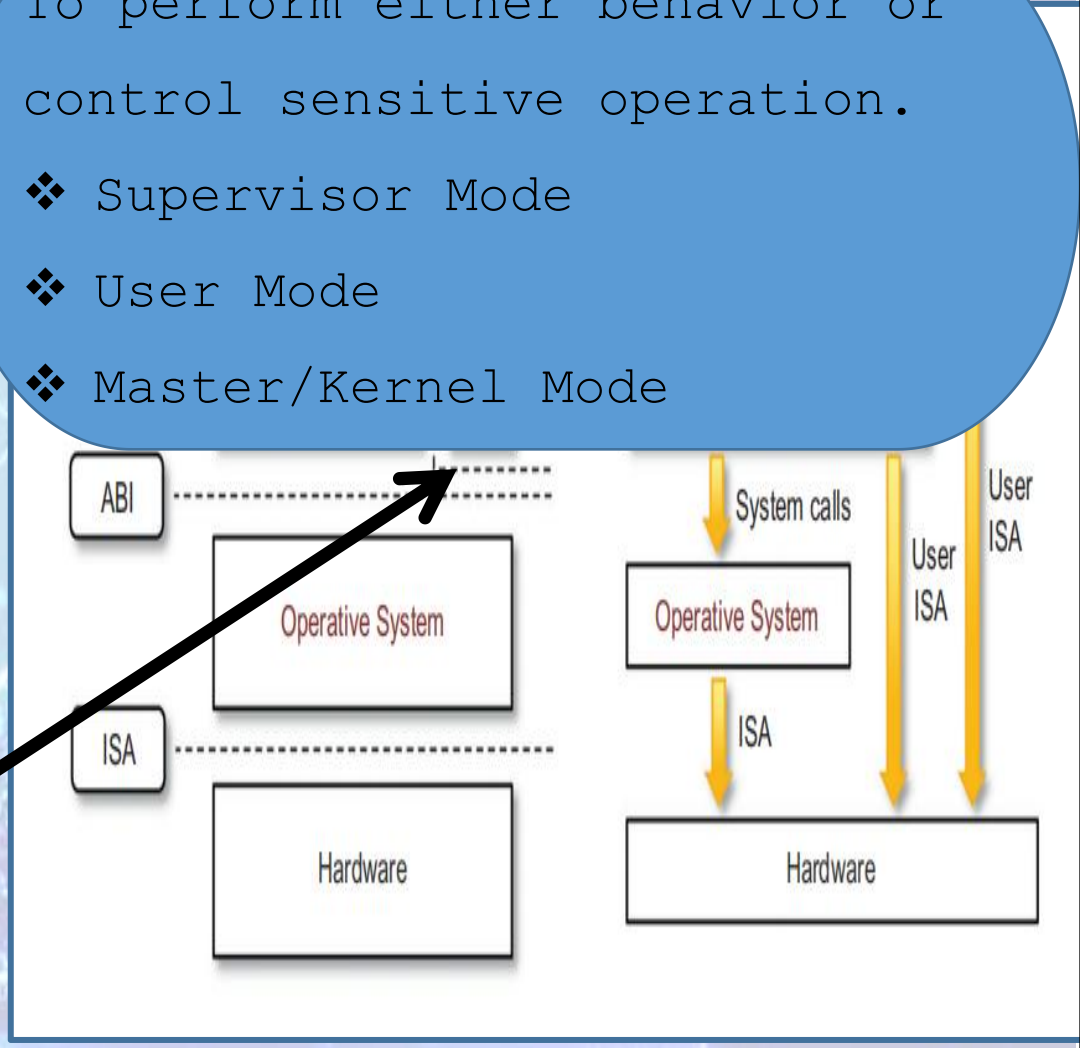
VIRTUALIZATION

taxonomy of Virtualization Techniques

- Execution Virtualization
  - Techniques That Emulate separate from the one hosting virtualization.
  - Machine Reference Model.
  - machine Instruction set
    - Privileged
    - Non-privileged

To perform either behavior or control sensitive operation.

- Supervisor Mode
- User Mode
- Master/Kernel Mode



VIRTUALIZATION

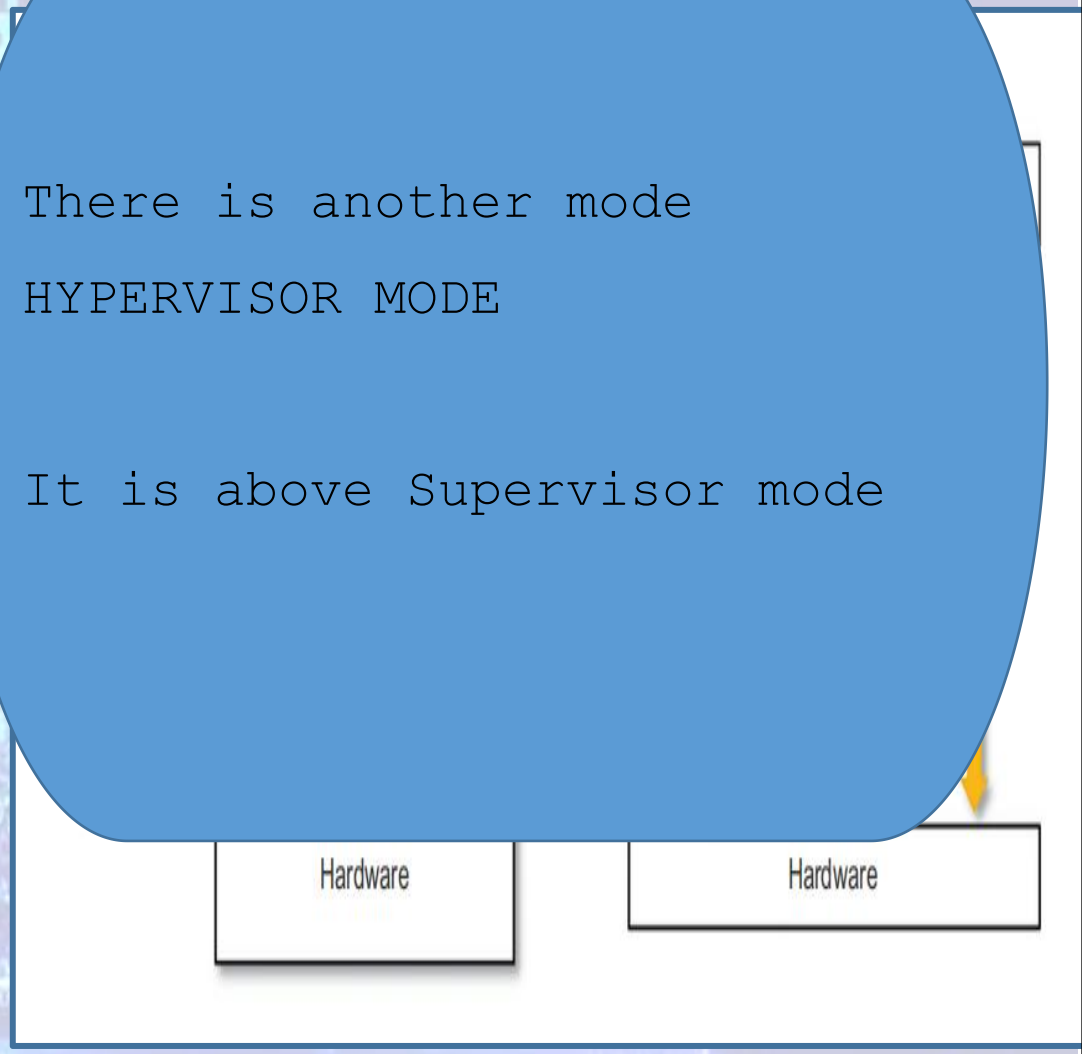
Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Techniques That Emulate separate from the one hosting virtualization.
  - Machine Reference Model.
  - machine Instruction set
    - Privileged
    - Non-privileged

There is another mode

HYPERVISOR MODE

It is above Supervisor mode

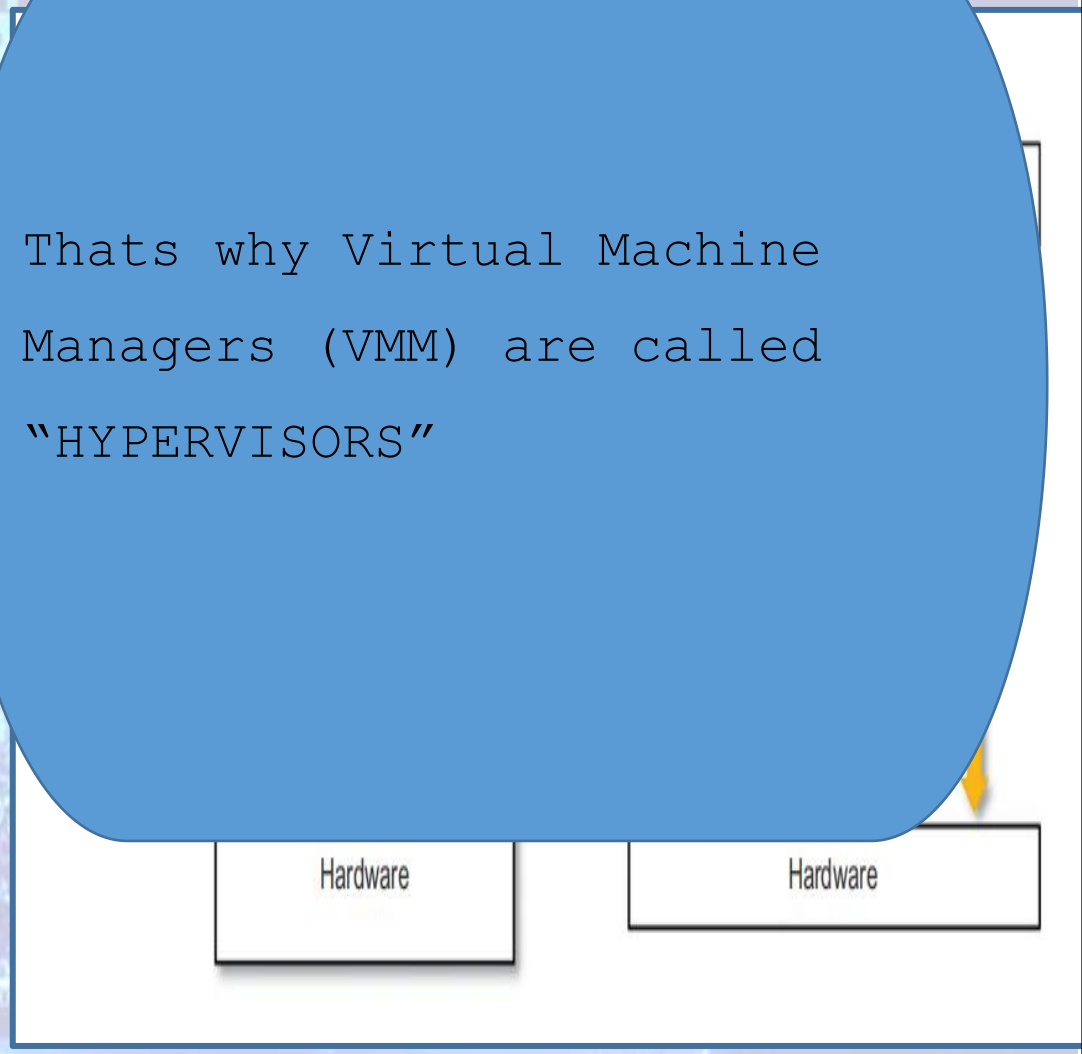


VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Techniques That Emulate separate from the one hosting virtualization.
  - Machine Reference Model.
  - machine Instruction set
    - Privileged
    - Non-privileged

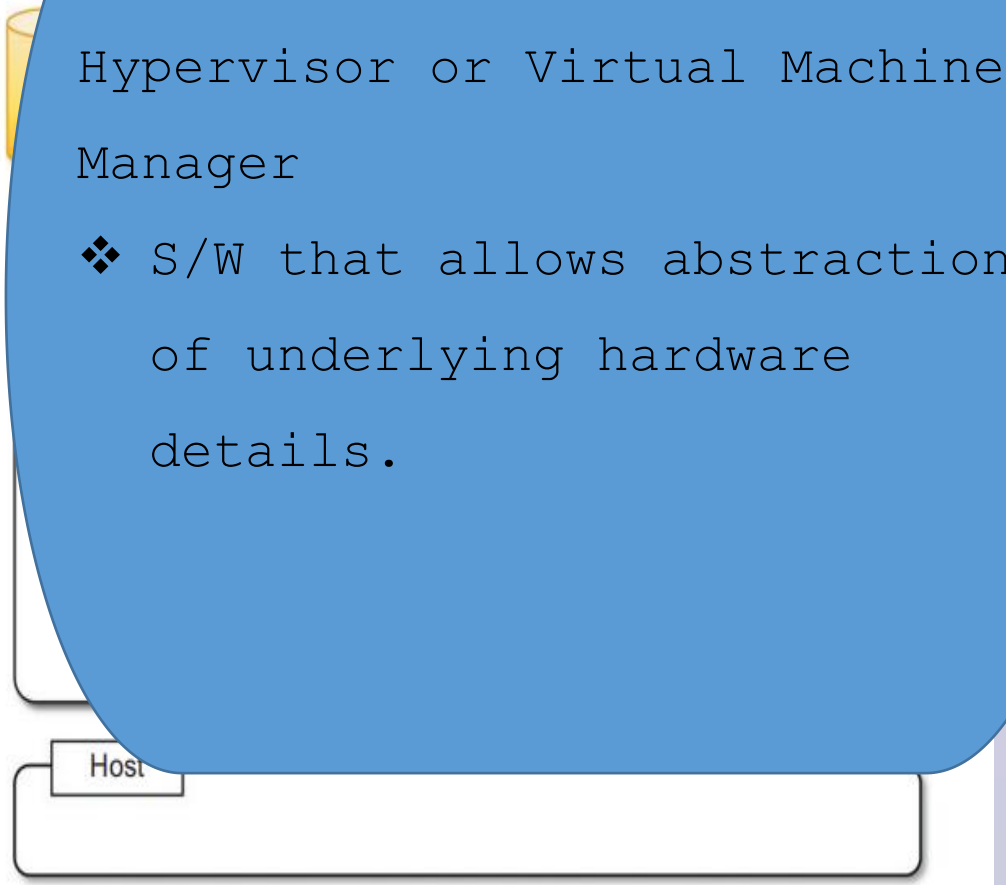
Thats why Virtual Machine Managers (VMM) are called "HYPERVISORS"



VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
- Hardware Level Virtualization
  - Provide Abstract Hardware on which guest OS can be run.



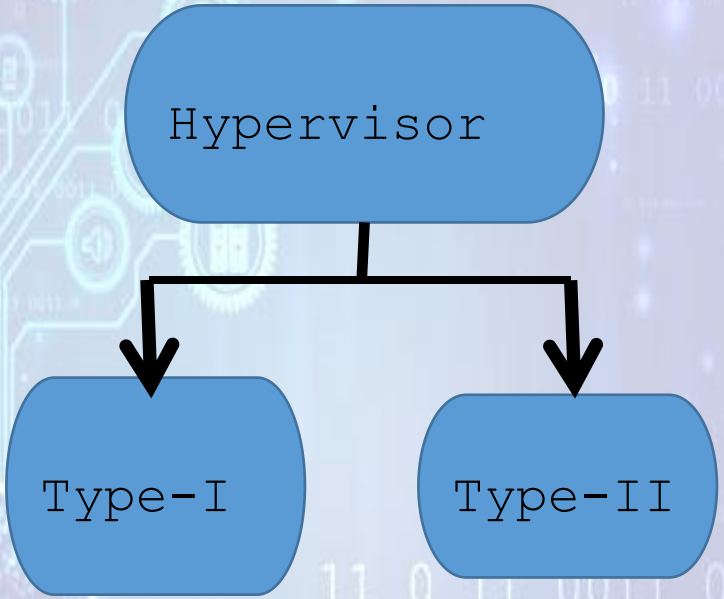
Hypervisor or Virtual Machine Manager

- S/W that allows abstraction of underlying hardware details.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

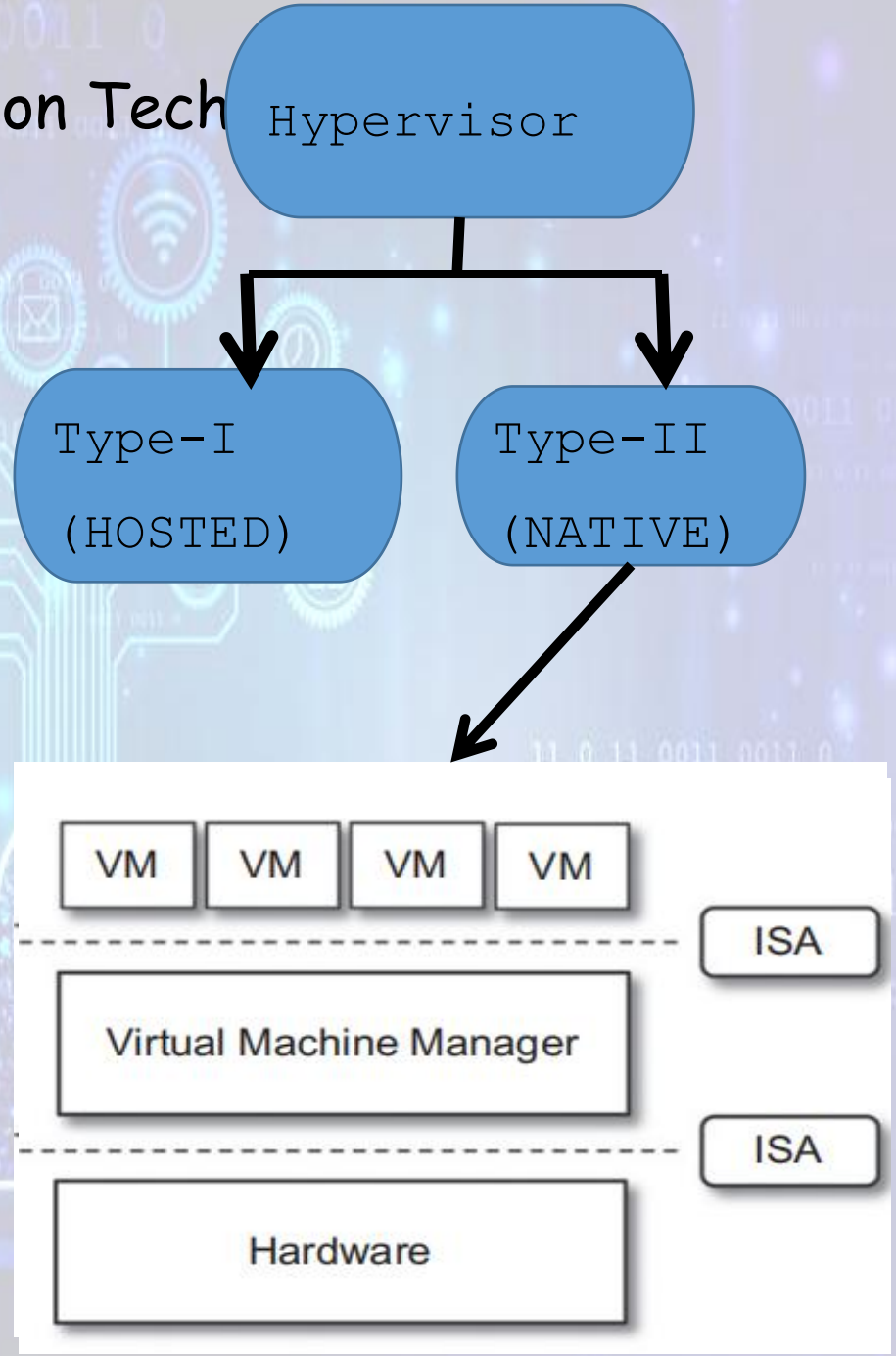
- Execution Virtualization
- Hardware Level Virtualization
  - Provide Abstract Hardware on which guest OS can be run.



VIRTUALIZATION

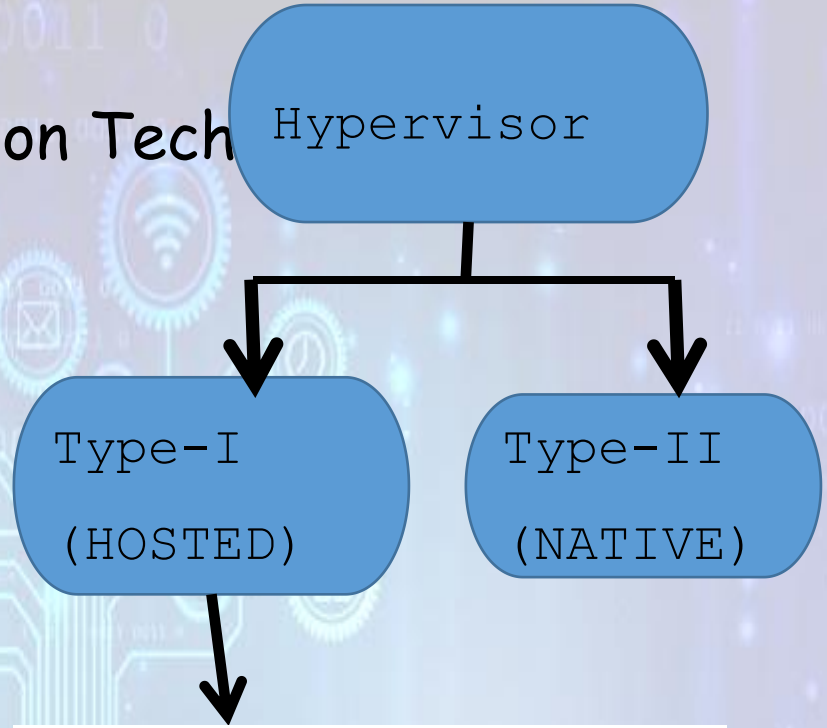
Taxonomy of Virtualization Tech

- Execution Virtualization
- Hardware Level Virtualization
  - Provide Abstract Hardware on which guest OS can be run.

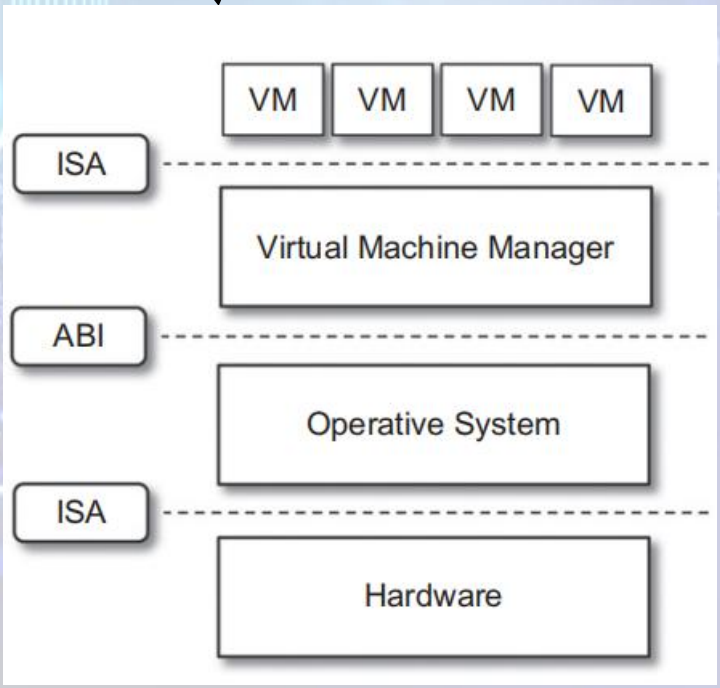


VIRTUALIZATION

Taxonomy of Virtualization Tech



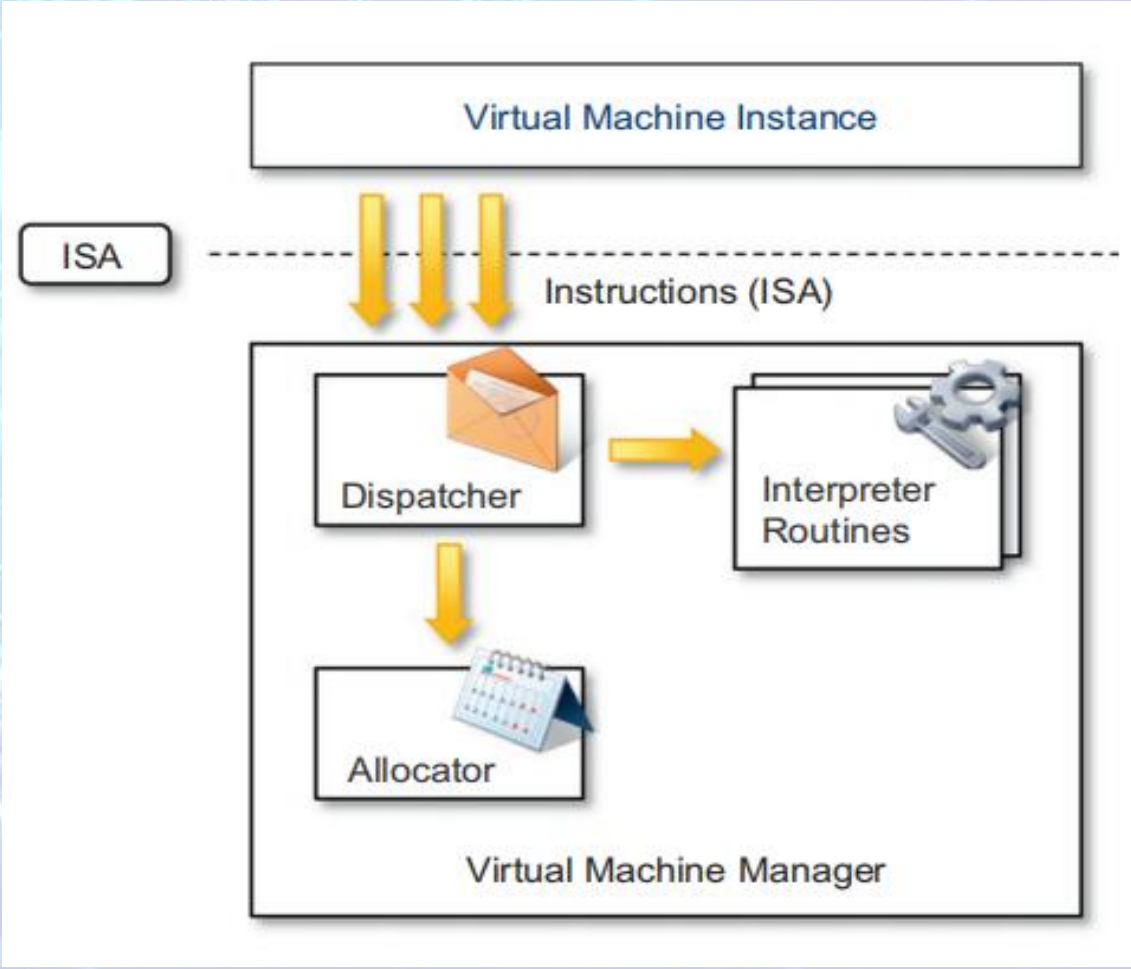
- Execution Virtualization
- Hardware Level Virtualization
  - Provide Abstract Hardware on which guest OS can be run.



VIRTUALIZATION
Taxonomy of Virtualization Techniques

Execution Virtualization

- Hardware Level Virtualization



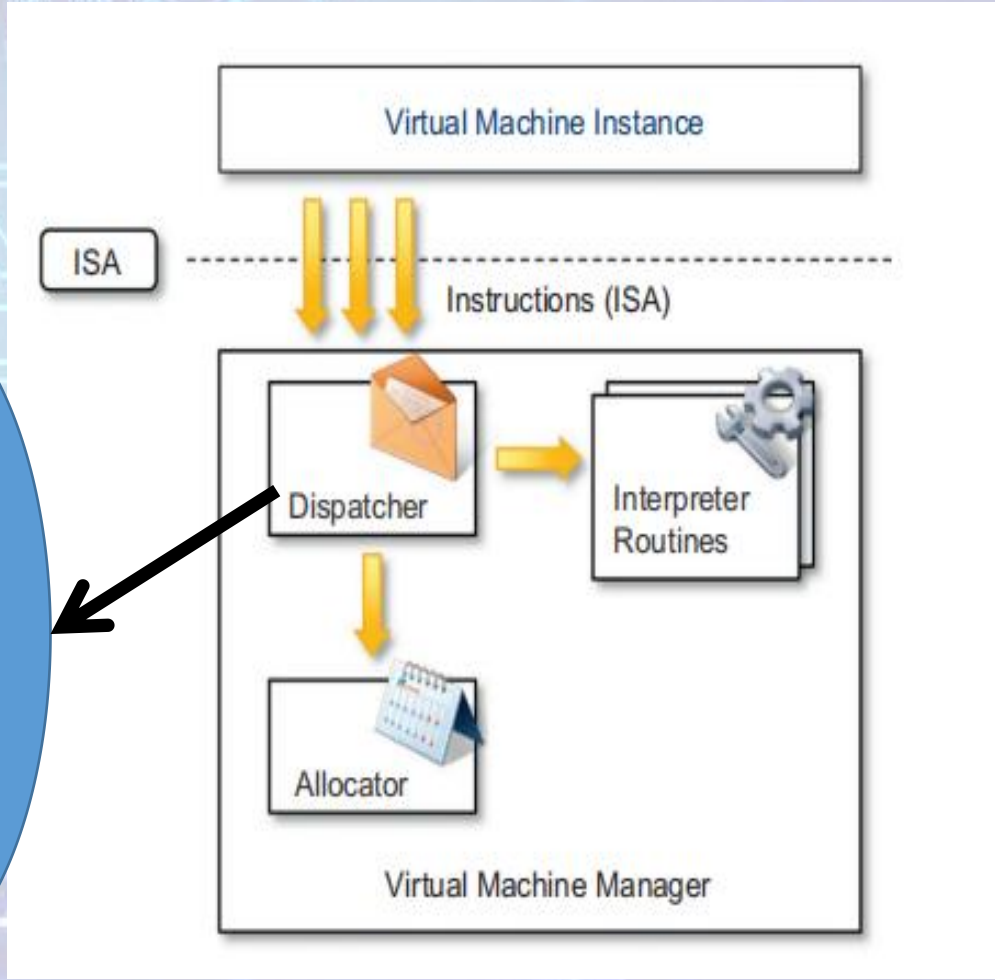
Hypervisor Reference Architecture

VIRTUALIZATION
Taxonomy of Virtualization Techniques

Execution Virtualization

- Hardware Level Virtualization

Instructions from VM will be distributed to either Allocator or Interpretor



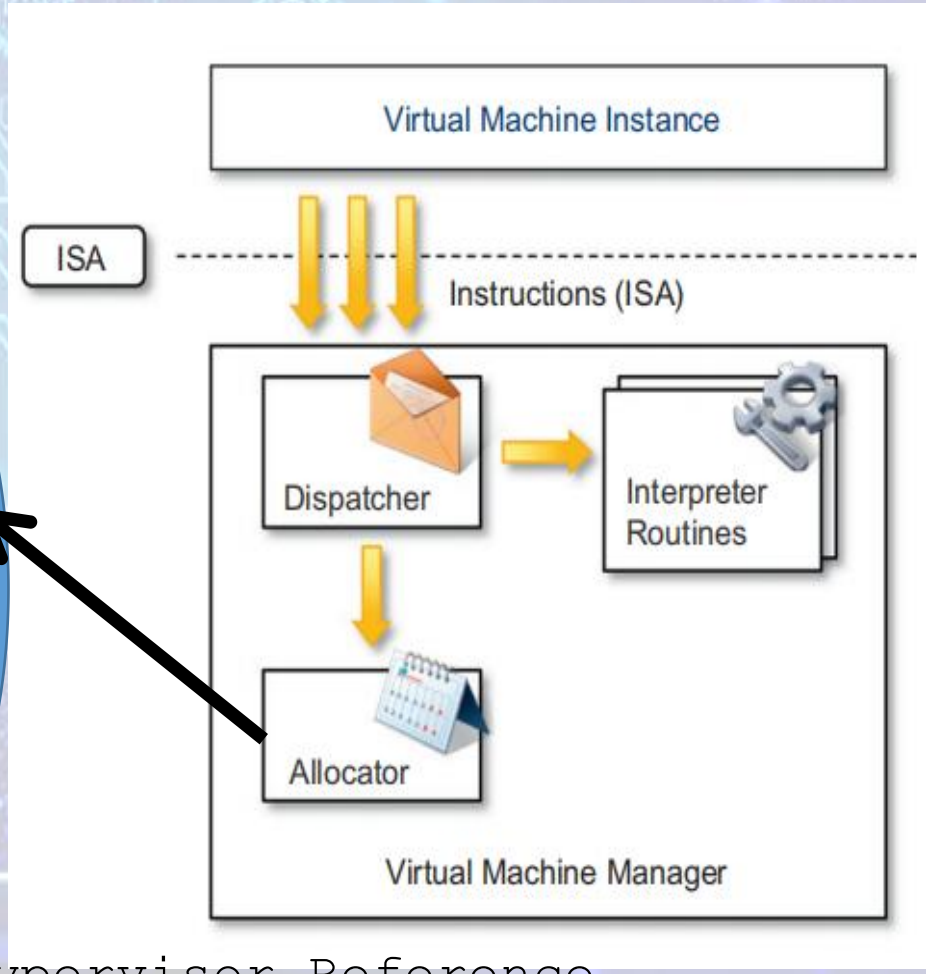
Hypervisor Reference Architecture

VIRTUALIZATION
Taxonomy of Virtualization Techniques

Execution Virtualization

- Hardware-Level Virtualization

What all the system resources I should provide to this VM?



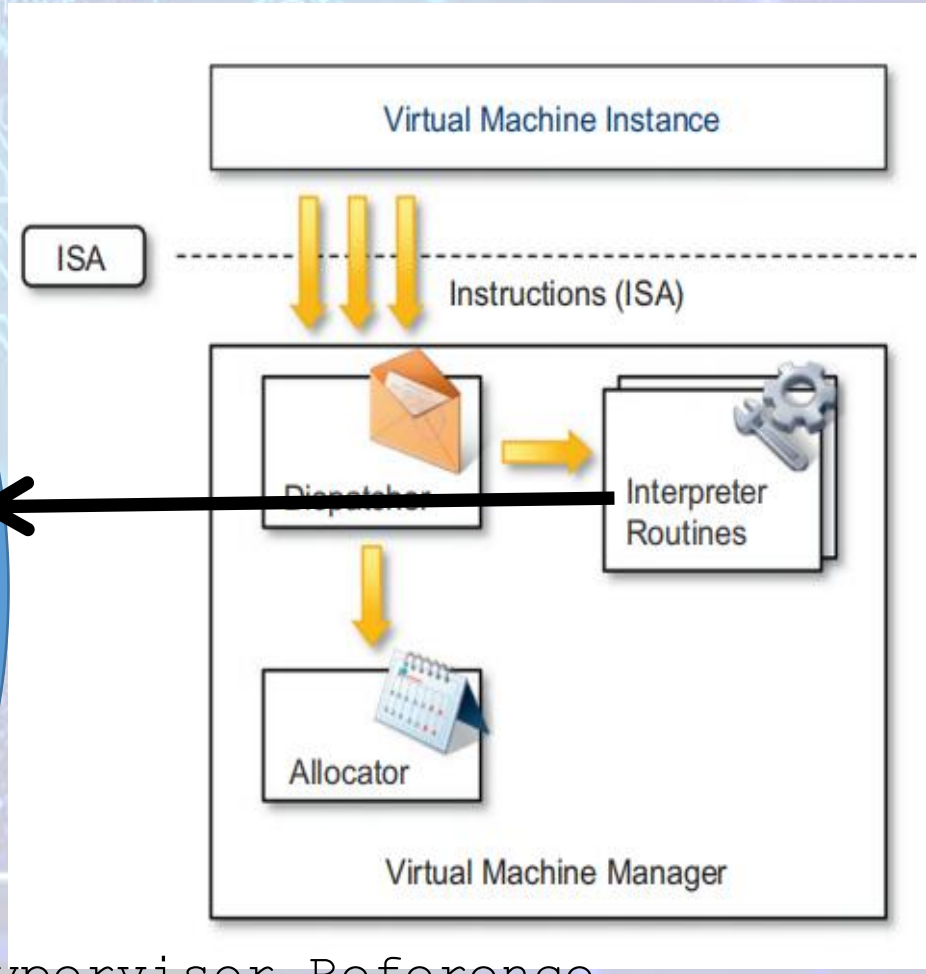
Hypervisor Reference Architecture

VIRTUALIZATION
Taxonomy of Virtualization Techniques

Execution Virtualization

- Hardware-Level Virtualization

Called whenever VM executes a PRIVILEGED INSTRUCTION



Hypervisor Reference Architecture

VIRTUALIZATION

Taxonomy of Virtualization Techniques

The design and architecture of a virtual machine manager, together with the underlying hardware design of the host machine, determine the full realization of hardware virtualization, where a guest operating system can be transparently executed on top of a VMM as though it were run on the underly_x0002_ing hardware.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

Three Crieteria to be satisfied by VMM to efficiently support virtualization

1. Equivalence: Guest should have same feature as it run directly on host.
2. Resource Control: VMM should have complete control of resources.
3. Efficiency

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
- Hardware Level Virtualization

Theorem 3.1:

For any conventional third generation computer, a VMM may be constructed if the set of sensitive instructions for that computer is a subset of the set of privileged instructions.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

Theorem 3.1:

For any conventional third generation computer, a VMM may be constructed if the set of sensitive instructions for that computer is a subset of the set of privileged instructions.

It just means that any instruction capable of changing the configuration should be a privileged instruction and run through VMM

VIRTUALIZATION
Taxonomy of Virtualization Techniques

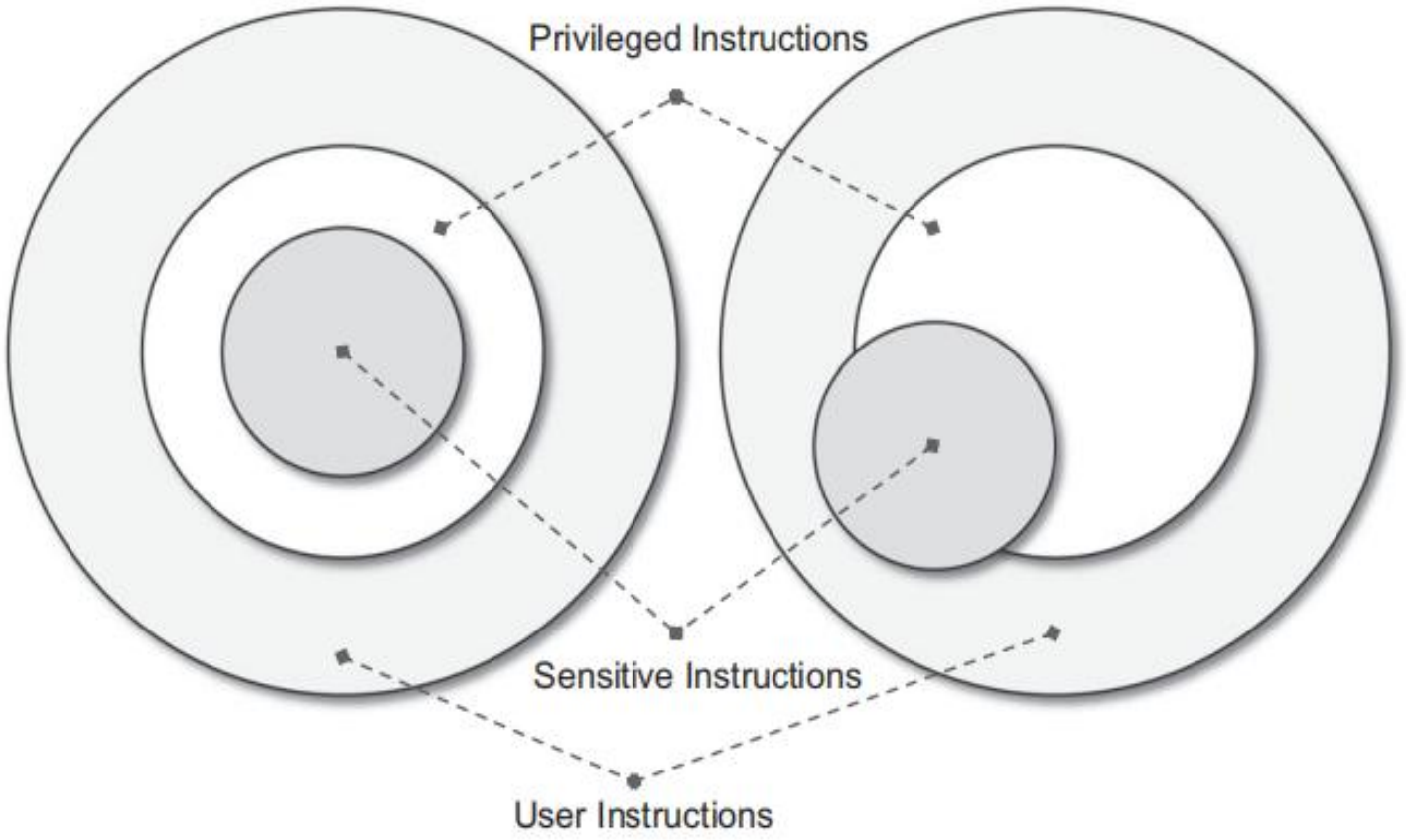


FIGURE 3.9

A virtualizable computer (left) and a nonvirtualizable computer (right).

VIRTUALIZATION

Taxonomy of Virtualization Techniques

Theorem 3.2:

A conventional third-generation computer is recursively virtualizable if:

- It is virtualizable and
- A VMM without any timing dependencies can be constructed for it.

VMM on another VMM

VIRTUALIZATION

Taxonomy of Virtualization Techniques

Theorem 3.3:

A hybrid VMM may be constructed for any conventional third-generation machine in which the set of user-sensitive instructions is a subset of the set of privileged instructions.

Hybrid Virtual Machine (HVM)

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
      - Hardware support for building VMM directly on it
      - IBM Sytem/370, X86-64 bit by Intel VT and AMD V

X86 Emulation was costly in terms of performanc: According to article published by Popek and Goldberg)

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
      - Hardware support for building VMM directly on it
      - IBM Sytem/370, X86-64 bit by Intel VT and AMD V

So BINARY-TRANSLATION was used. Sensitive instruction which doesn't go for TRAP were handled differently by VMM, which reduced their performance.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
      - Hardware support for building VMM directly on it
      - IBM Sytem/370, X86-64 bit by Intel VT and AMD V
      - So in 2006 AMD in INTEL introduced processor extension.
      - Result is Kernel-based Virtual Machine (KVM), VirtualBox, Xen, VMware, Hyper-V, Sun xVM, Parallels, a

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
    - Full Virtualization
      - Ability to run an OS or program on VM without any modification.
      - Advantages: Complete Emulation, Security, Ease of Emulation.

VIRTUALIZATION

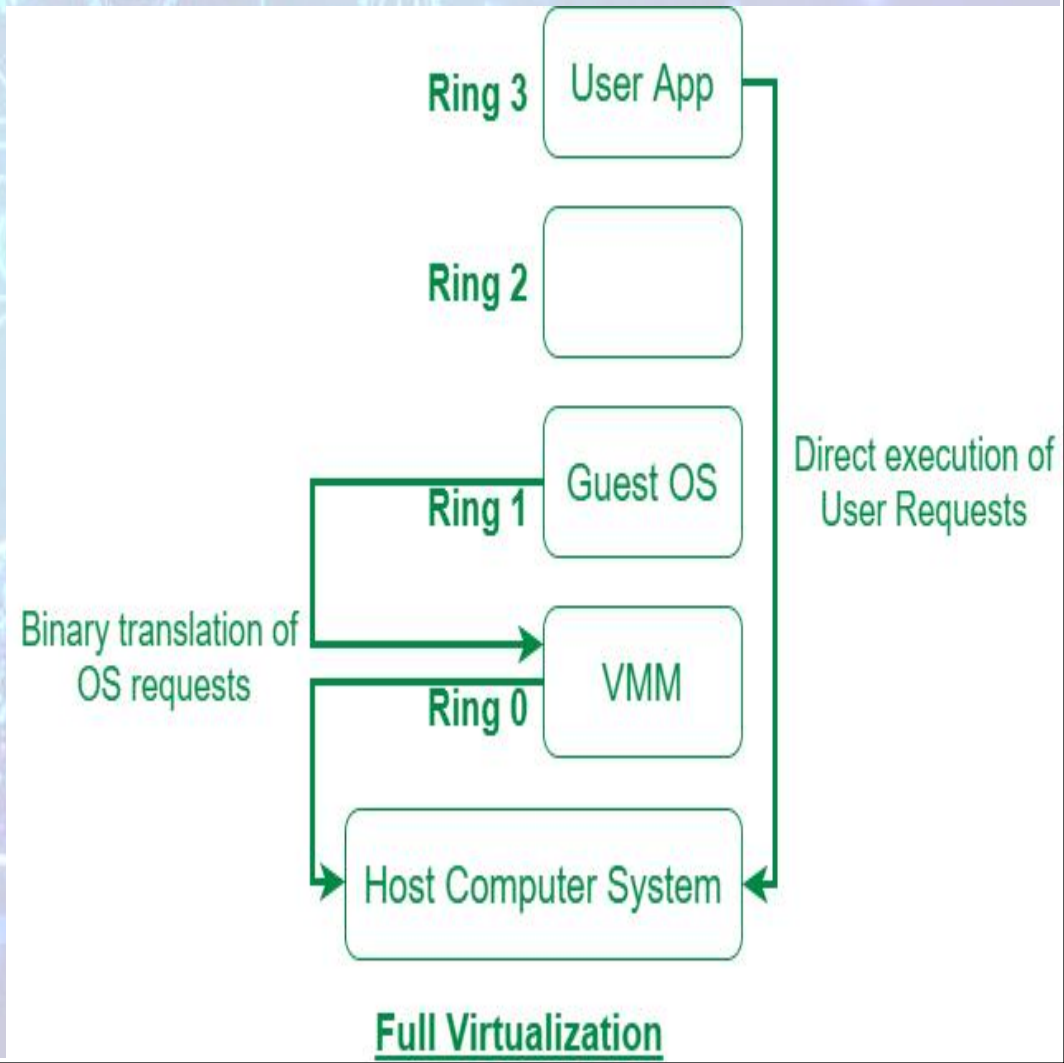
Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
      - Full Virtualization
        - Problem: Some instruction execution like where VMM may have to interfere.
        - Simple Soln: Let VMM handle every instruction. (Performance reduces)
        - Perfect Soln: VMM has to differentiate instruction which can be directly executed on hardware or which it has to handle.

QUIZZ

VIRTUALIZATION
Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
    - Full Virtualization



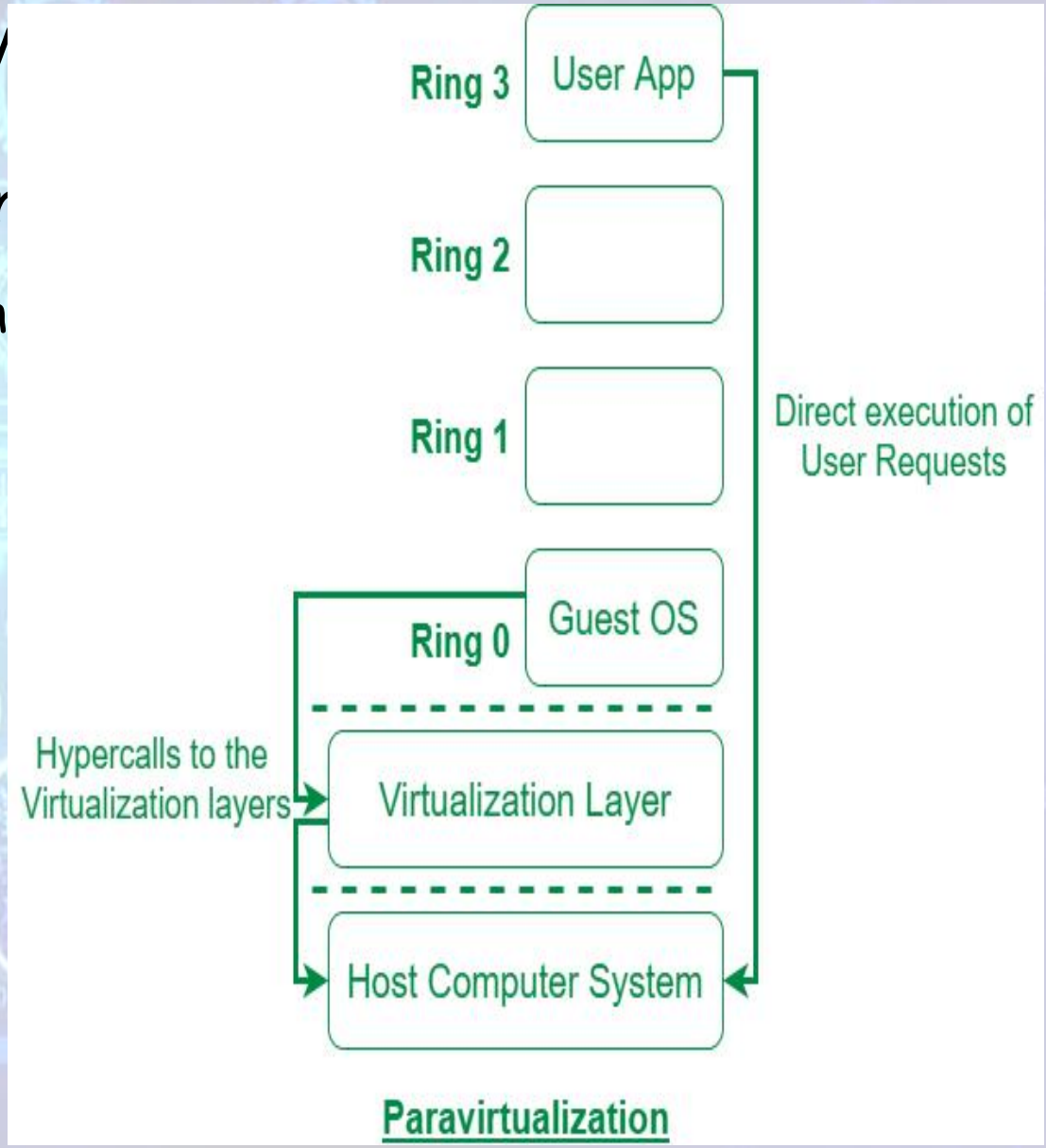
VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
    - Full Virtualization
    - Para Virtualization
      - Paravirtualization techniques expose a software interface to the virtual machine that is slightly modified from the host and, as a consequence, guests need to be modified.

VIRTUALIZATION
Taxonomy of V

- Execution Virtualizatior
  - Hardware Virtualization
    - Hardware Assisted Virtualization
    - Full Virtualization
    - Para Virtualization



VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
    - Full Virtualization
    - Para Virtualization
      - Guest OS need to be modified which is possible onl;y if source code is available.
      - Naming: University of Washington
      - Xen hypervisor uses this.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
    - Full Virtualization
    - Para Virtualization
      - What if I run Windows OS in guest machine?
      - Device driver that redirect critical instruction to hypervisor APIs

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
      - Full Virtualization
      - Para Virtualization
      - Partial Virtualization
        - Partial Emulation of underlying hardware.
        - Not all features of OS can be supported.
        - Ex: Address space in Time Sharing Applications.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
    - Hardware Assisted Virtualization
    - Operating system level Virtualization
      - Separate Environment for applications which are managed consurrently.
      - No Hypervisor.
      - OS kernel manages everything.
      - Kernel is responsible for sharing resources.
      - EX; UNIX CHROOT: Each process ROOT directory changes.3.
      - NO OVERHEAD

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization

Gives

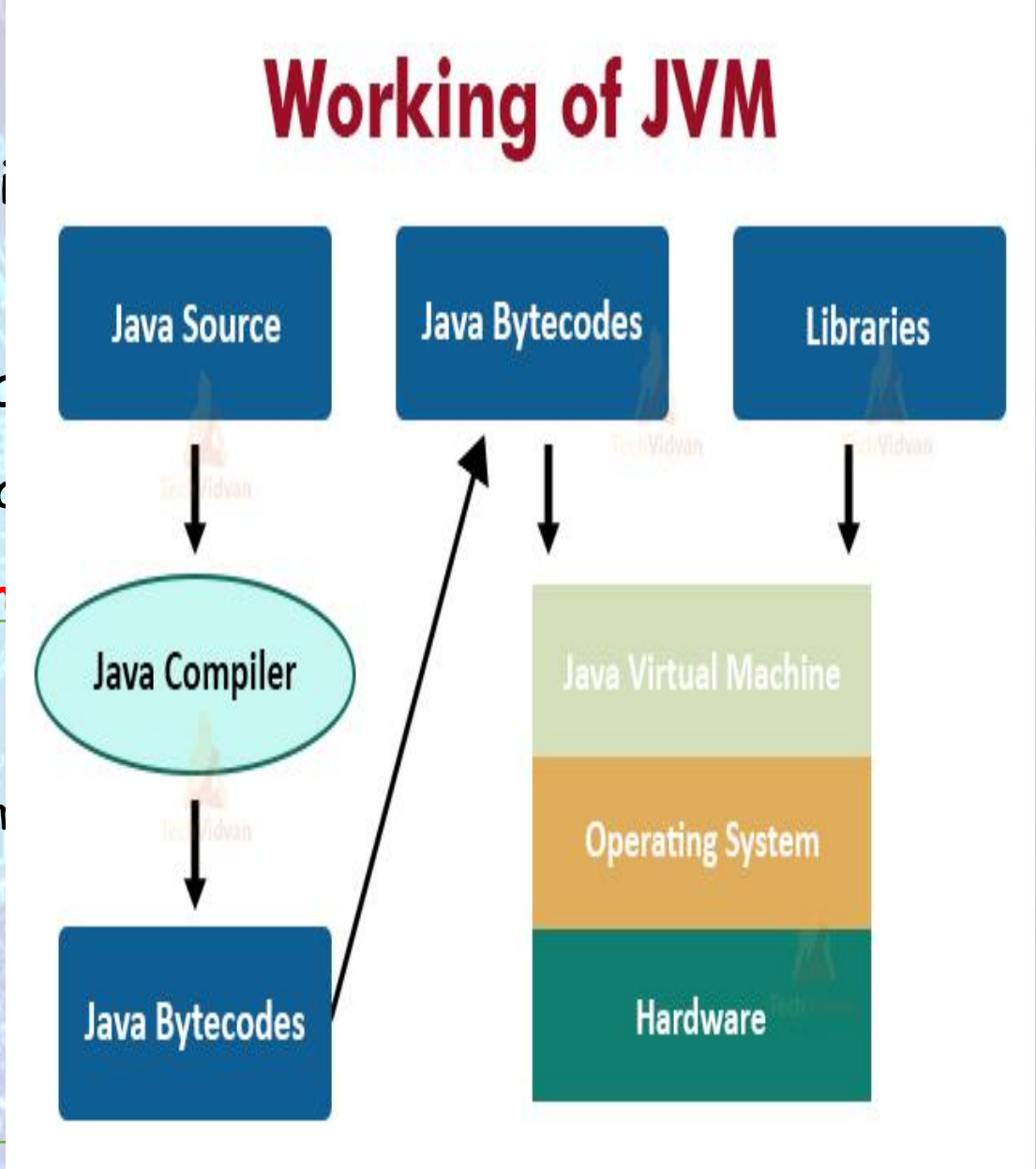
- Ease of Application Deployment
- Managed Execution
- Portability

VIRTUALIZATION
Taxonomy of Vi

- Execution Virtualizc
  - Hardware Virtualizc
  - Programming Lar

Gives

- Ease of Application Deploym
- Managed Execution
- Portability



VIRTUALIZATION
Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization

1966	BASIC Combined Programming Language
1996	JAVA bu Sun
	Python, Ruby, Pascal etc. also started using JVM

VIRTUALIZATION

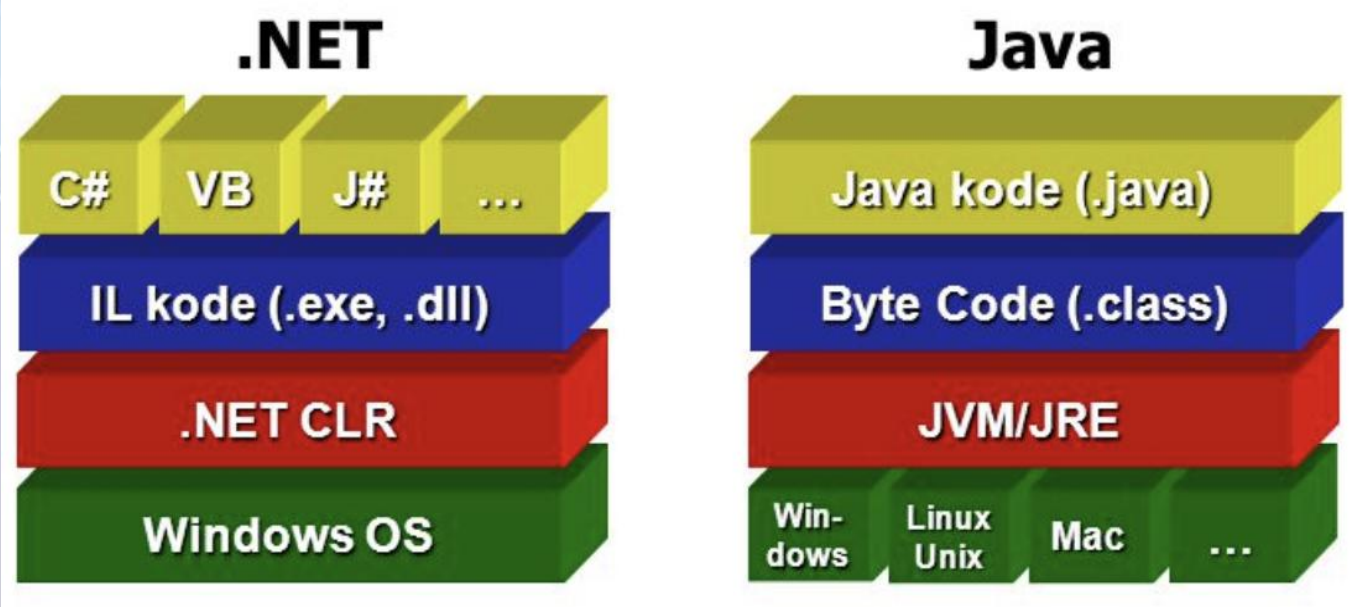
Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization

- Common Language Interface- Philosophy of .NET framework.

VIRTUALIZATION
Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization



VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization

- Both are stack based VMs

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization

- Both are stack based VMs -
  - memory structure where the operands are stored is a stack data structure.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization

- Both are stack based VMs -
  - Easily Portable
  - Easily Interpreted and Executed.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization
- Process Virtual Machines: Uniform Execution Environment Across Different Platforms.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization

- Process Virtual Machines: Uniform Execution Environment Across Different Platforms.

NO NEED TO PROVIDE DIFFERENT VERSIONS FOR DIFFERENT OSs

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization

- Process Virtual Machines: Uniform Execution Environment Across Different Platforms.

SECURITY

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization
  - Application Level Virtualization

- Allows applications to run on platform where they don't have expected environment

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization
  - Application Level Virtualization

- How is it possible?
- Well we emulate OS and Libraries
  - Interpretation
  - Binary Translation

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization
  - Application Level Virtualization

- Interpretation?
  - Every Source Instruction is interpreted and its equivalent native ISA instruction is run.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization
  - Application Level Virtualization

- Binary Translation?
  - Source Instruction is interpreted to native instruction with a completely new equivalent function.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization
  - Application Level Virtualization

- Advantage?
  - If some library is missing..
  - VMM is quite thin.
  - Allows incompatible applications to run together.

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization
  - Application Level Virtualization

Programming Level

- Across All Programs

Application Level

- Across Programs using particular Library or Environement

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
  - Hardware Virtualization
  - Programming Language Level Virtualization
  - Application Level Virtualization

- Example: Wine Software (Provides Windows Like Environment on Linux)

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
- Other Types of Virtualization
  - Storage Virtualization

- Differentiate Physical hardware from logical representation.
- Storage can be accessed through logical path
- Storage Area Network

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
- Other Types of Virtualization
  - Storage Virtualization
  - Network Virtualization

Ex: VLAN

- combines hardware appliances and specific software for the creation and management of a virtual network
- can aggregate different physical networks into a single logical network

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
- Other Types of Virtualization
  - Storage Virtualization
  - Network Virtualization
  - Desktop Virtualization

Ex: Windows Remote Services, VNC, X Server etc.

- desktop virtualization addresses the problem of making the same desktop envi_x0002_ronment accessible from everywhere
- Indirectly you are accessing the resources of the remote machine

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
- Other Types of Virtualization
  - Storage Virtualization
  - Network Virtualization
  - Desktop Virtualization

Ex: Sun Virtual Desktop Infrastructure,Parallel VDI etc.

- desktop virtualization addresses the problem of making the same desktop envi_x0002_ronment accessible from everywhere
- Indirectly you are accessing the resources of the remote machine

VIRTUALIZATION

Taxonomy of Virtualization Techniques

- Execution Virtualization
- Other Types of Virtualization
  - Storage Virtualization
  - Network Virtualization
  - Desktop Virtualization

Ex: Sun Virtual Desktop Infrastructure,Parallel VDI etc.

- desktop virtualization addresses the problem of making the same desktop envi_x0002_ronment accessible from everywhere
- Indirectly you are accessing the resources of the remote machine

VIRTUALIZATION

Virtualization and Cloud Computing

- Why Virtualization is important in Cloud Computing?

- It provides IT services with
  - Customization
  - Security
  - Isolation
  - Manageability

- Hardware Virtualization - IaaS
- Programming Language Virtualization- PaaS

VIRTUALIZATION

Virtualization and Cloud Computing

- Why Virtualization is important in Cloud Computing?

- Virtualization also provides
  - Isolation
  - Fine Control
- Same resources can be shared between VMs without them interfering

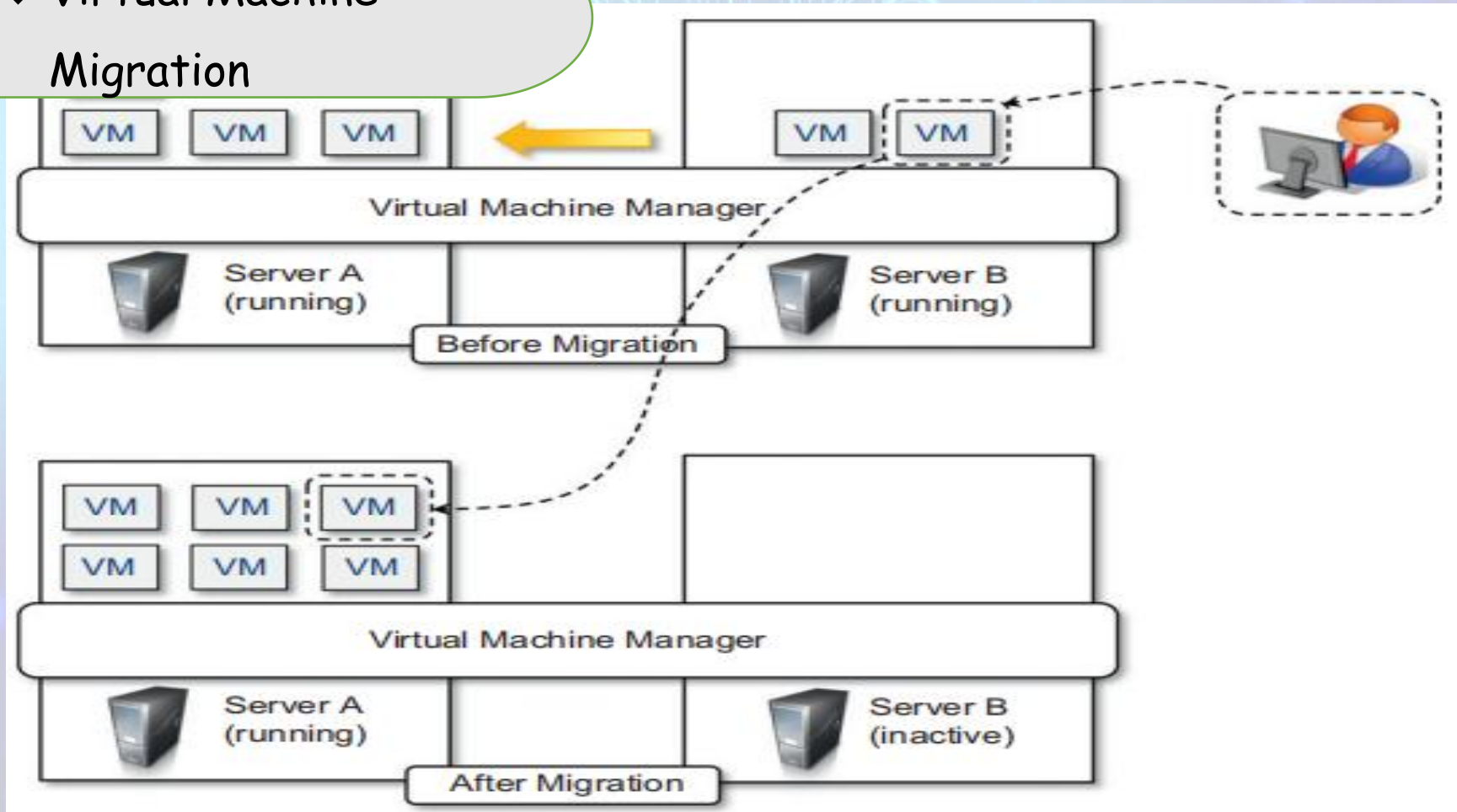
- Server Consolidation: aggregating virtual machines over a smaller number of resources that become fully utilized.

VIRTUALIZATION

Virtualization and Cloud Computing

- Why Virtualization is important in Cloud Computing?

- Virtual Machine Migration



VIRTUALIZATION

Virtualization and Cloud Computing

- Why Virtualization is important in Cloud Computing?

- Virtual Machine Migration- Two Types
  - Stop the VM and Migrate.
  - Live Migration: Moving Instance while still running.

- Consolidation and Migration are **POSSIBLE for IaaS** and **NOT POSSIBLE in PaaS**

VIRTUALIZATION

Virtualization and Cloud Computing

- Why Virtualization is important in Cloud Computing?

- STOREAGE VIRTUALIZATION
  - Large Storage Facility is divided into slices and provided as service.
  - Secure and protect the hosting environment.

- **CLOUD COMPUTING ALSO REVAMPED DESKTOP COMPUTING.**

VIRTUALIZATION
PROS and CONS of Virtualization

- Advantages
  - Managed Execution and Isolation
    - Allows secured and controllable environments.
    - Sandbox configuration prevents harmful intervention in borders.
    - Resource allocation and partitioning is simplified

VIRTUALIZATION
PROS and CONS of Virtualization

- Advantages
  - Portability
    - VM instances are are in-terms of files which can be easily transfered.
  - Self-contained
    - Their only point of contact is VMM

VIRTUALIZATION
PROS and CONS of Virtualization

- Advantages
  - Portability
  - Self-contained
    - Together they reduce cost-of-maintenance and administration.

VIRTUALIZATION
PROS and CONS of Virtualization

- Advantages
  - More Efficient use of resources.
    - VMs co-exist and share the reosurces without interfering with host.

VIRTUALIZATION
PROS and CONS of Virtualization

- DISADVANTAGES
  - Performance Degradation
    - Guest can experience increased latencies.

VIRTUALIZATION
PROS and CONS of Virtualization

- DISADVANTAGES
  - Performance Degradation
    - Guest can experience increased latencies.
    - Causes may be
      - Maintaining the status of virtual processors

VIRTUALIZATION
PROS and CONS of Virtualization

- DISADVANTAGES
  - Performance Degradation
    - Guest can experience increased latencies.
    - Causes may be
      - Maintaining the status of virtual processors
      - Support of privileged instructions

VIRTUALIZATION
PROS and CONS of Virtualization

- DISADVANTAGES
  - Performance Degradation
    - Guest can experience increased latencies.
    - Causes may be
      - Maintaining the status of virtual processors
      - Support of privileged instructions
      - Support of paging within VM

VIRTUALIZATION
PROS and CONS of Virtualization

- DISADVANTAGES
  - Performance Degradation
    - Guest can experience increased latencies.
    - Causes may be
      - Maintaining the status of virtual processors
      - Support of privileged instructions
      - Support of paging within VM
      - Console functions

VIRTUALIZATION
PROS and CONS of Virtualization

- DISADVANTAGES
  - Performance Degradation
    - Guest can experience increased latencies.
    - Causes may be
      - Maintaining the status of virtual processors
      - Support of privileged instructions
      - Support of paging within VM
      - Console functions
      - VMM is executed and scheduled together with other applications, thus sharing with them the resources of the host.

VIRTUALIZATION
PROS and CONS of Virtualization

- DISADVANTAGES
  - Performance Degradation
  - Inefficiency and Degraded User Experience
    - Virtualization can sometime lead to an inefficient use of the host.
    - In the case of programming-level virtual machines, some of the features of the underlying operating systems may become inaccessible unless specific libraries are used.

VIRTUALIZATION
PROS and CONS of Virtualization

- DISADVANTAGES
  - Security holes and new threats
    - Virtualization opens the door to a new and unexpected form of phishing.
    - IaaS: malicious programs can preload themselves before the operating system and act as a thin virtual machine manager
    - BluePill
    - SubVirt

VIRTUALIZATION
Technology Examples

XEN-Paravirtualization

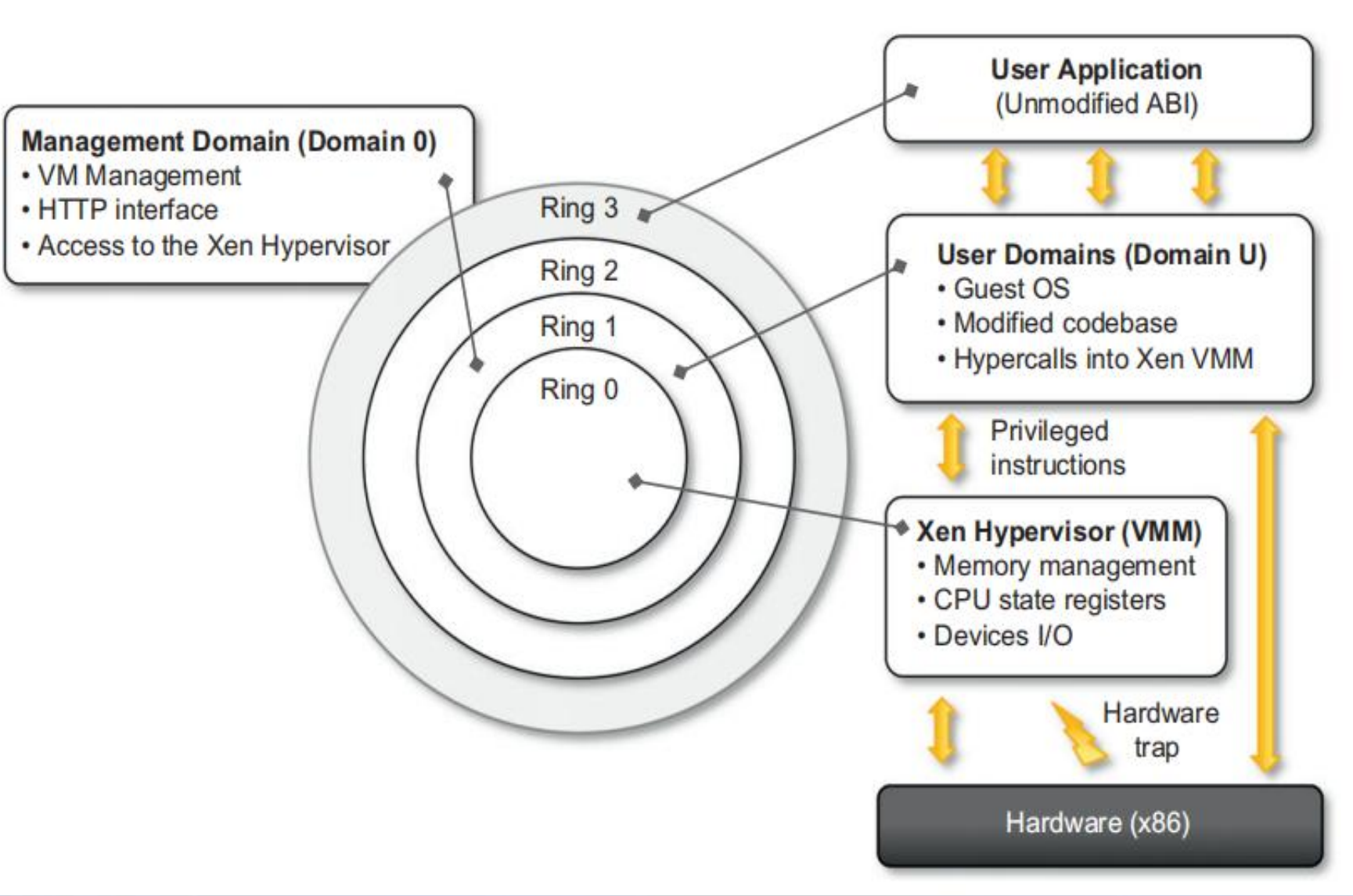
VIRTUALIZATION
Technology Examples

XEN-Paravirtualization

VIRTUALIZATION
Technology Examples: XEN

- Developed by University of Cambridge, UK
- Became famous because of Open-Source Backing.
- Hardware and Desktop Virtualization
- Xen Cloud Platform(XCP)
- Recently adopted full Virtualization

VIRTUALIZATION
Technology Examples: XEN



VIRTUALIZATION

Technology Examples: XEN

How Performance Loss is handled by XEN?

Instructions of Guest OS requiring special attention, are changed by XEN.

VIRTUALIZATION
Technology Examples: XEN

X86 Architecture Ring Security levels

- Ring-0: Kernel code where Xen is implemented.
- Ring-1: DOM-0 : boots after hypervisor. HTTPD is initialized here
- Ring-1 : DOM-U : Guest OS is hosted
- Ring-3 : For User Applications.

VIRTUALIZATION
Technology Examples: XEN

X86 Architecture Ring Security levels

- Ring-0: Kernel code where Xen is implemented.
- Ring-1: DOM-0 : boots after hypervisor. HTTPD is initialized here
- Ring-2 : DOM-U : Guest OS is hosted
- Ring-3 : For User Applications.

VIRTUALIZATION
Technology Examples: XEN

X86 Architecture Ring Security levels

- Ring-0: Kernel code where Xen is implemented.
- Ring-1: DOM-0 : boots after hypervisor. HTTPD is initialized here
- Ring-2 : DOM-U : Guest OS is hosted
- Ring-3 : For User Applications.

VIRTUALIZATION
Technology Examples: XEN

X86 Architecture Ring Security levels

X86 architecture has a fault:
Some User Instructions may jump from Ring 3 to Ring 0

VIRTUALIZATION
Technology Examples: XEN

X86 Architecture Ring Security levels

- Xen itself is implemented in Ring-0 this error can be handled.

X86 architecture has a fault:
Some User Instructions may jump from Ring 3 to Ring 0

VIRTUALIZATION
Technology Examples: XEN

X86 Architecture Ring Security levels

- Because Xen in Ring-0 this error can be handled better.
- Such Instructions are changed in Guest OS to Hyper Calls rather than System Calls.

VIRTUALIZATION
Technology Examples: XEN

X86 Architecture Ring Security levels

- Because Xen in Ring-0 this error can be handled better.
- Such Instructions are changed in Guest OS to Hyper Calls rather than System Calls.
- This is a limitation of Xen-Hypervisor. it is more suitable for Open Source kind of software.

VIRTUALIZATION

Technology Examples: VMWare

VMWARE

FULL VIRTUALIZATION

VIRTUALIZATION

Technology Examples: VMWare

- Underlying Hardware is replicated and made available to Guest OS

VIRTUALIZATION

Technology Examples: VMWare

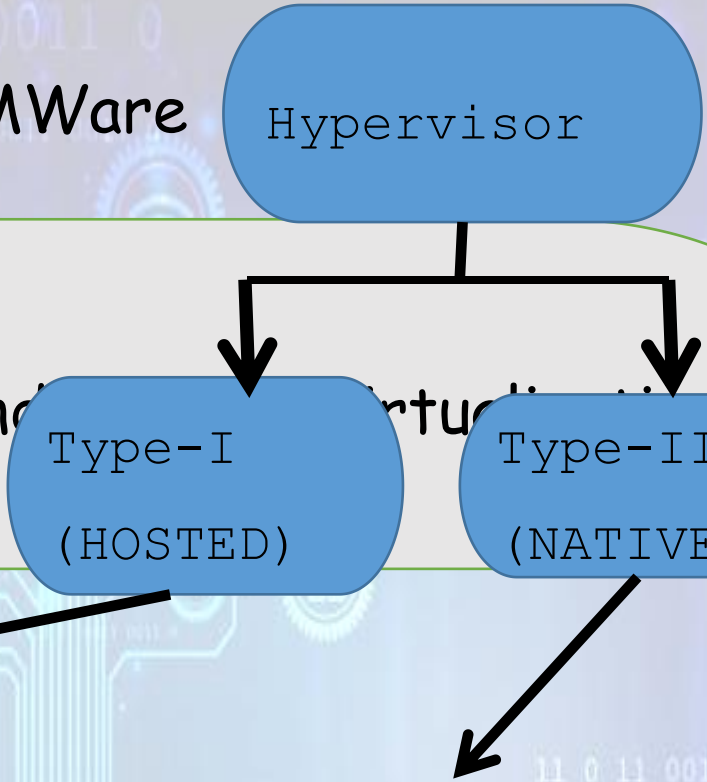
- Underlying Hardware is replicated and made available to Guest OS.
- guest OS is not even aware of VMM.

VIRTUALIZATION

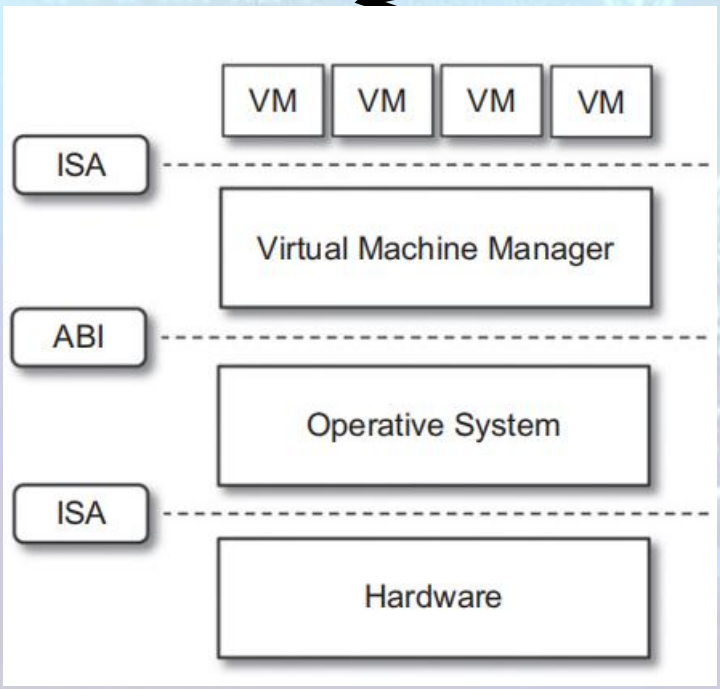
Technology Examples: VMWare

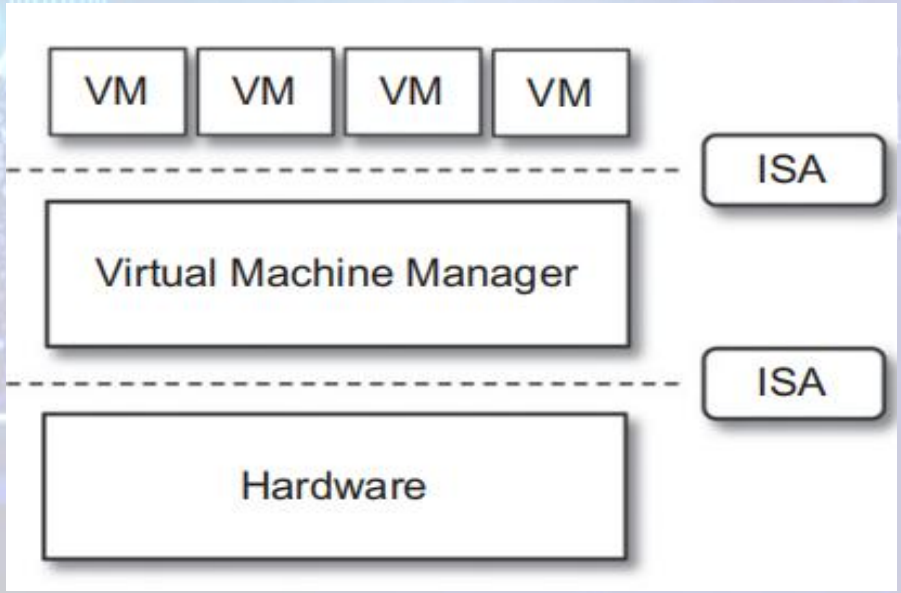
- It provides both Type-I and Type-II virtualization

VIRTUALIZATION
Technology Examples: VMWare



- It provides both Type-I and





VIRTUALIZATION

Technology Examples: VMWare

- Full Virtualization and Binary Translation
  - VMWare is very Famous for virtualizing X86 architecture.

VIRTUALIZATION

Technology Examples: VMWare

- Full Virtualization and Binary Translation
  - VMWare is very Famous for virtualizing X86 architecture.
  - Now we have Hardware Assisted Virtualization with Intel VT-x and AMD-V

VIRTUALIZATION

Technology Examples: VMWare

- Full Virtualization and Binary Translation
  - VMWare is very Famous for virtualizing X86 architecture.
  - Now we have Hardware Assisted Virtualization with Intel VT-x and AMD-V
  - Before that we VMWare was using Binary Translation

VIRTUALIZATION

Technology Examples: VMWare

- Full Virtualization and Binary Translation
  - X86 doesn't satisfy first theorem. (Sensitive are not part of privileged)

VIRTUALIZATION

Technology Examples: VMWare

- Full Virtualization and Binary Translation
  - X86 doesn't satisfy first theorem. (Sensitive are not part of privileged).
  - Binary Translation: Offending Instructions are converted to other eqivalent instructions whch does same job but are not sensitive.

VIRTUALIZATION

Technology Examples: VMWare

- Full Virtualization and Binary Translation
  - X86 doesn't satisfy first theorem. (Sensitive are not part of privileged).
  - Binary Translation: Offending Instructions are converted to other eqivalent instructions whch does same job but are not sensitive.
  - Equivalent instructions are cached so that they can be used further easily .

VIRTUALIZATION

Technology Examples: VMWare

- Full Virtualization and Binary Translation -

  ADVANTAGES

  - NO Need to change Guest OS.

VIRTUALIZATION

Technology Examples: VMWare

- Full Virtualization and Binary Translation - ADVANTAGES
  - NO Need to change Guest OS.
- What is the other Option?
  - Translating Instruction at run-time, which is little time consuming.

VIRTUALIZATION

Technology Examples: VMWare

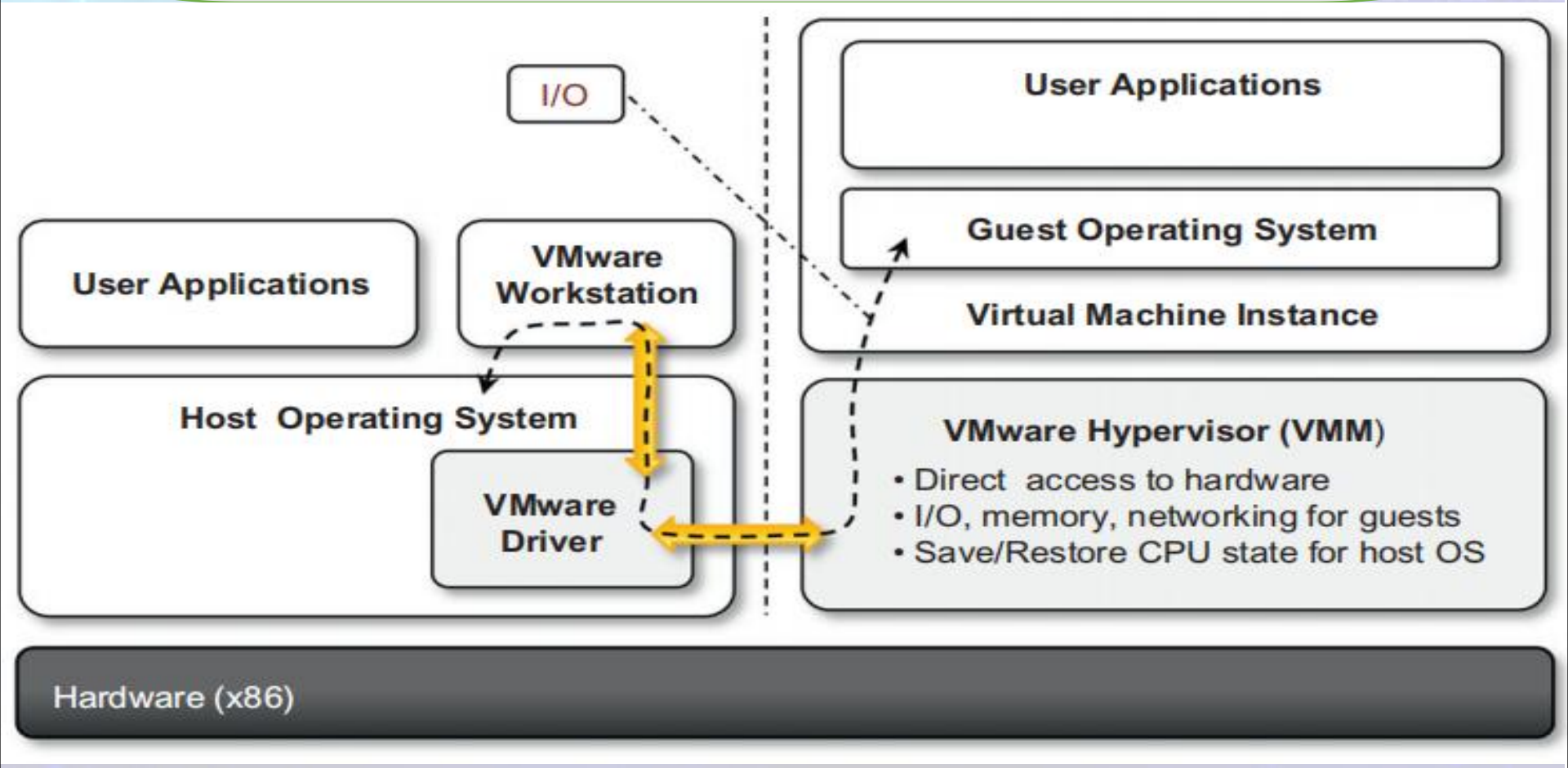
- Full Virtualization and Binary Translation - ADVANTAGES
  - NO Need to change Guest OS.
  - Then why we don't use binary soluiton always?
    - It can be applied only on the subset of instructions while others directly run on OS.
    - This reduces the performance.

VIRTUALIZATION
Technology Examples: VMWare

- End-User (Desktop) Virtualization
  - OS and Application level Virtualization.
  - VMWare Workstation (Windows)
  - VMWare Fusion(Mac)

VIRTUALIZATION
Technology Examples: VMWare

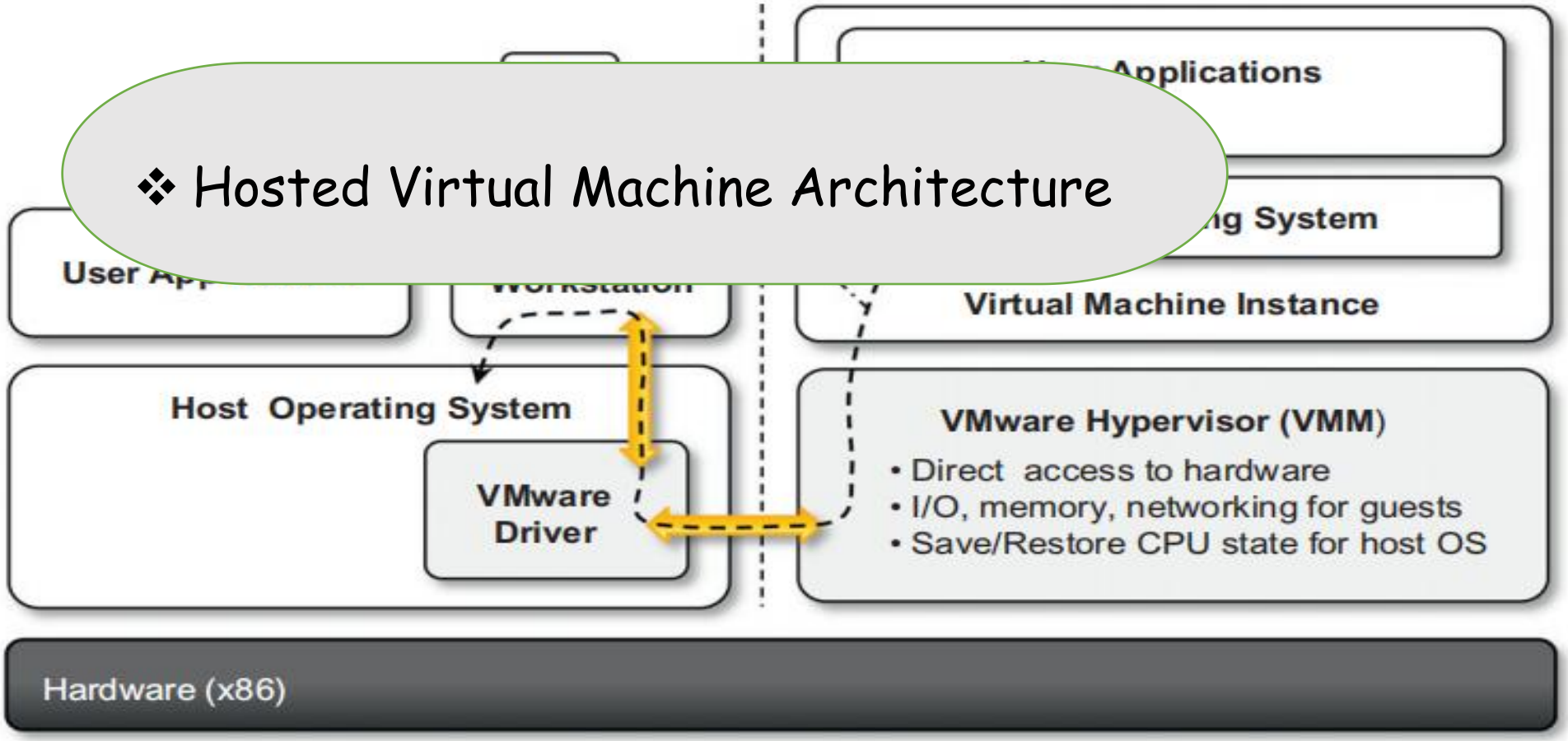
- End-User (Desktop) Virtualization



VIRTUALIZATION
Technology Examples: VMWare

- End-User (Desktop) Virtualization

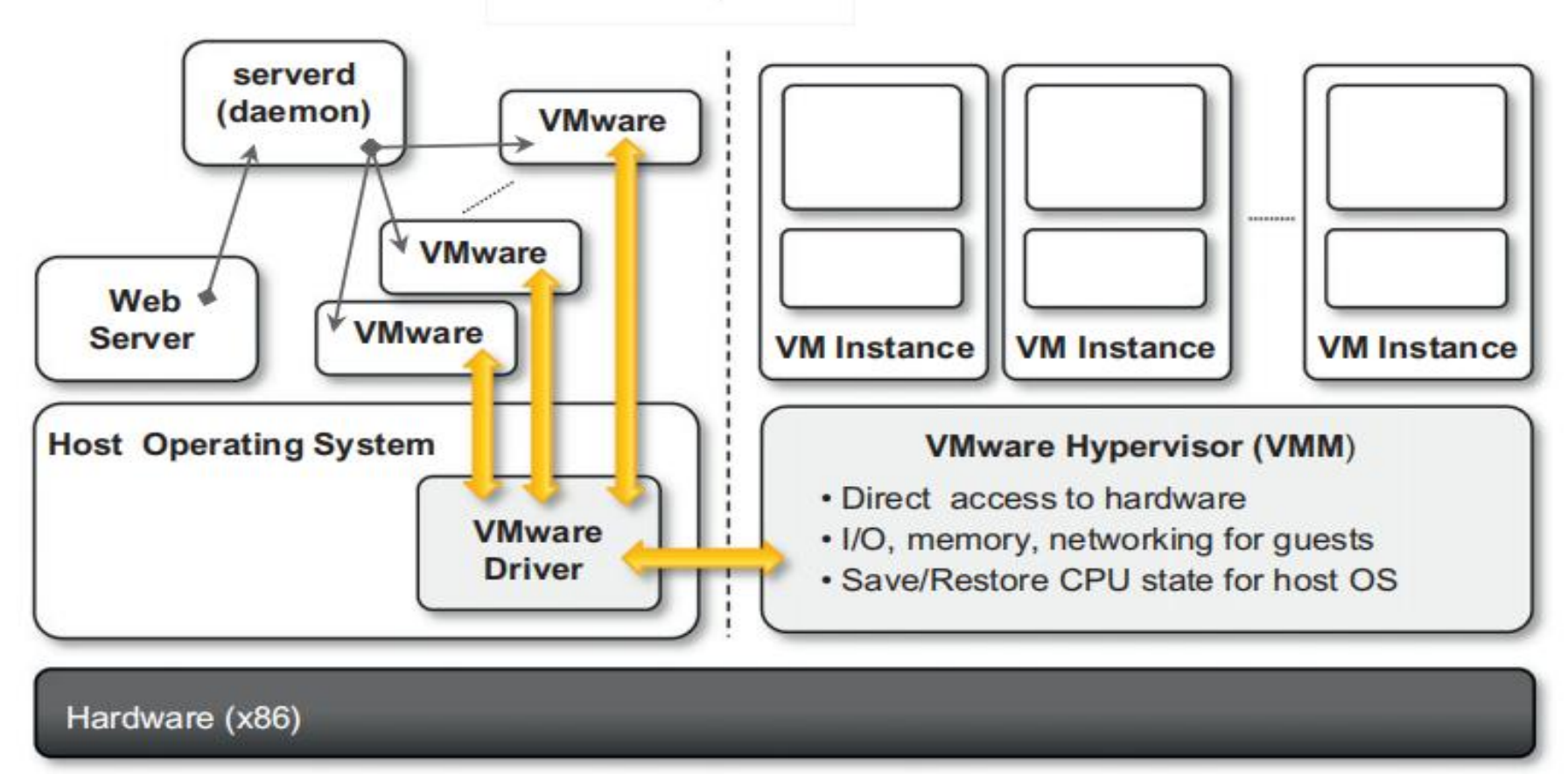
- Hosted Virtual Machine Architecture



VIRTUALIZATION
Technology Examples: VMWare

- Other Services
  - VMWare Player
  - VMWare ACE
  - VMWare Thin App

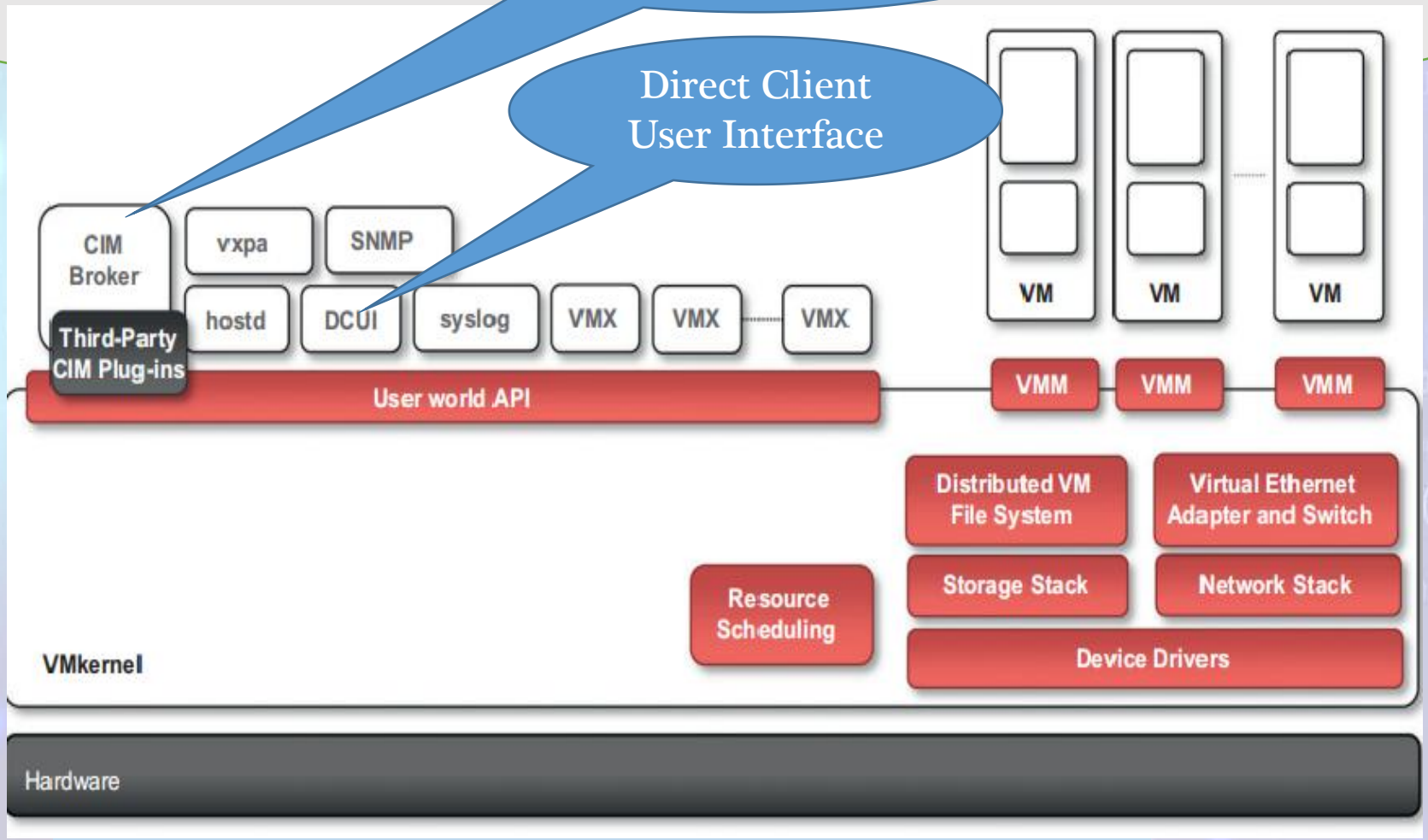
- Other Services
  - Server Virtualization



VMWare GSX Server Architecture

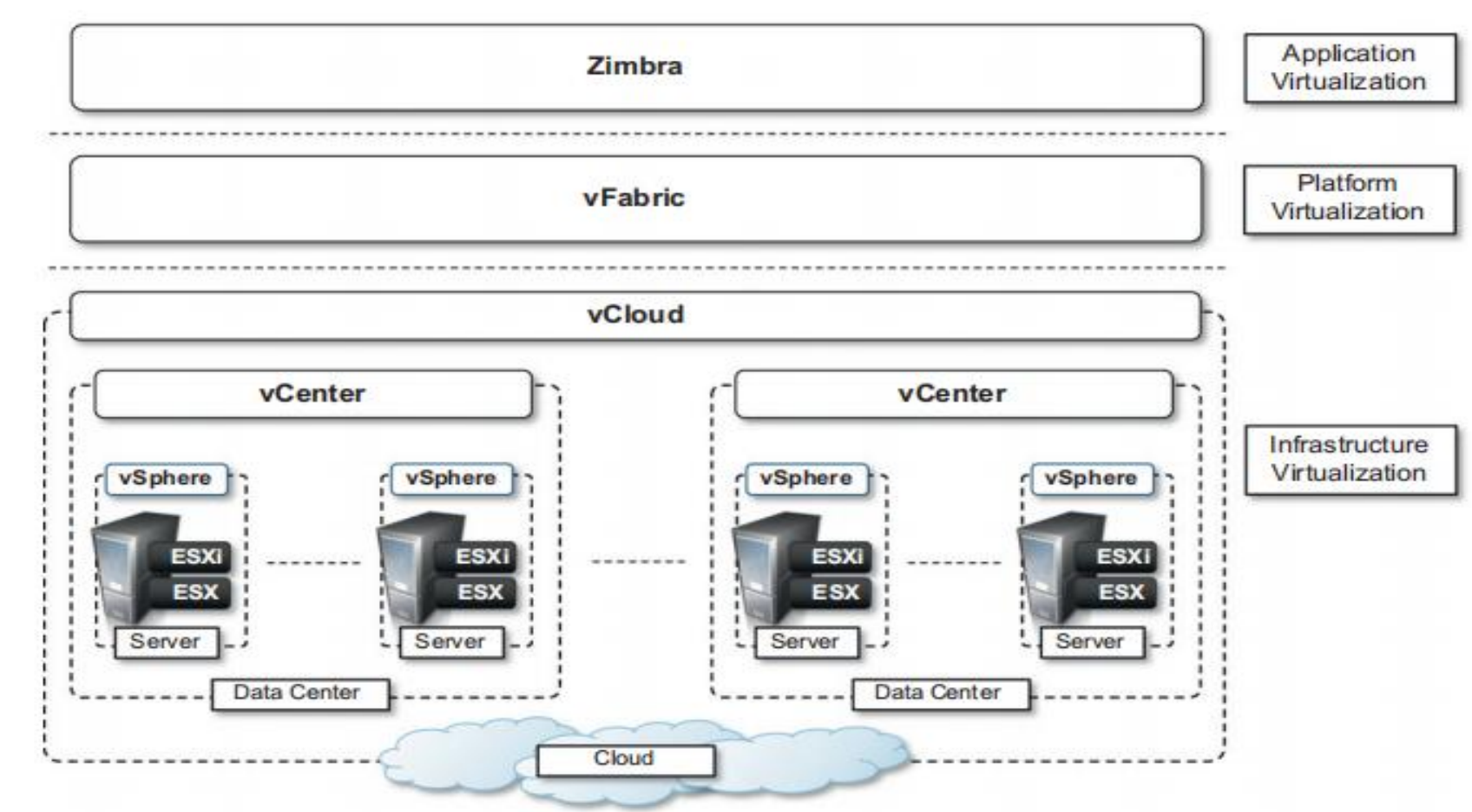
VIRTUALIZATION
Technol

❖ Other Servic



VMWare ESXi Server Architecture

- Other Services
  - Infrastructure Virtualization and CLoud Computing Solutions



VMWare Cloud Solution Stack

VIRTUALIZATION
Technology Examples: VMWare

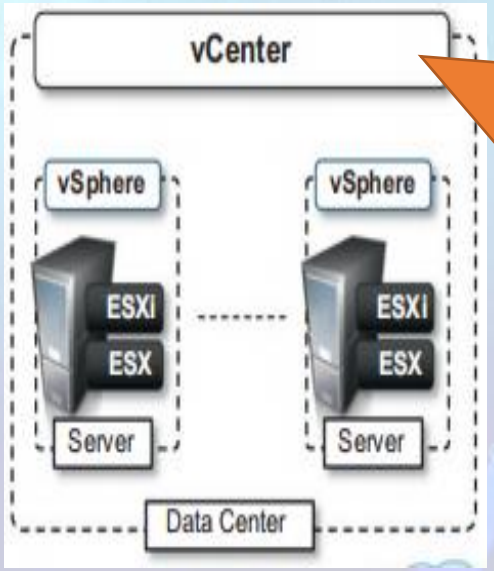
- Other Services
  - Infrastructure Virtualization and CLoud Computing Solutions

- Virtualization Software
- Virtual File System, Virtual Storage and Virtual Network.
- VM Migration, Data Migration, Recovery etc.

VMWare Cloud Solution Stack

VIRTUALIZATION
Technology Examples: VMWare

- Other Services
  - Infrastructure Virtualization and CLoud Computing Solutions

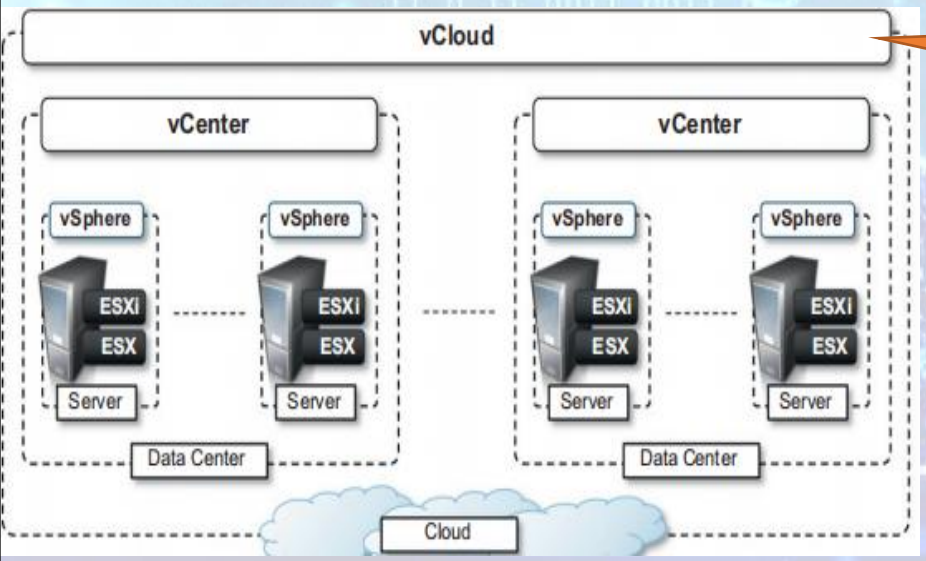


- Infrastructure Management
- All the vSpheres insalled in a data center are controlled by vCenter.

VMWare Cloud Solution Stack

VIRTUALIZATION
Technology Examples: VMWare

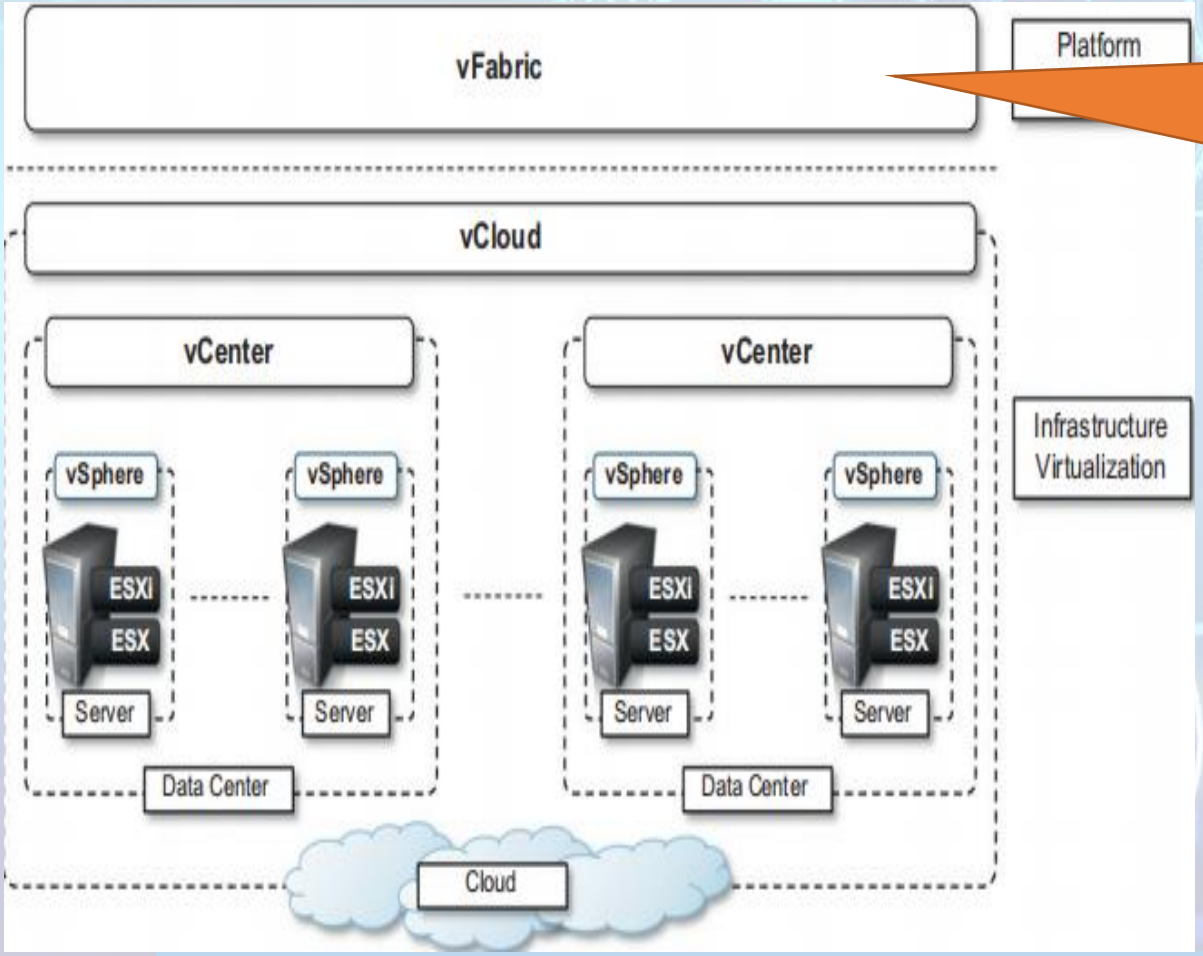
- Other Services
  - Infrastructure Virtualization and CLoud Computing Solutions



- Virtualized Data Centers are converted to IaaS cloud

VMWare Cloud Solution Stack

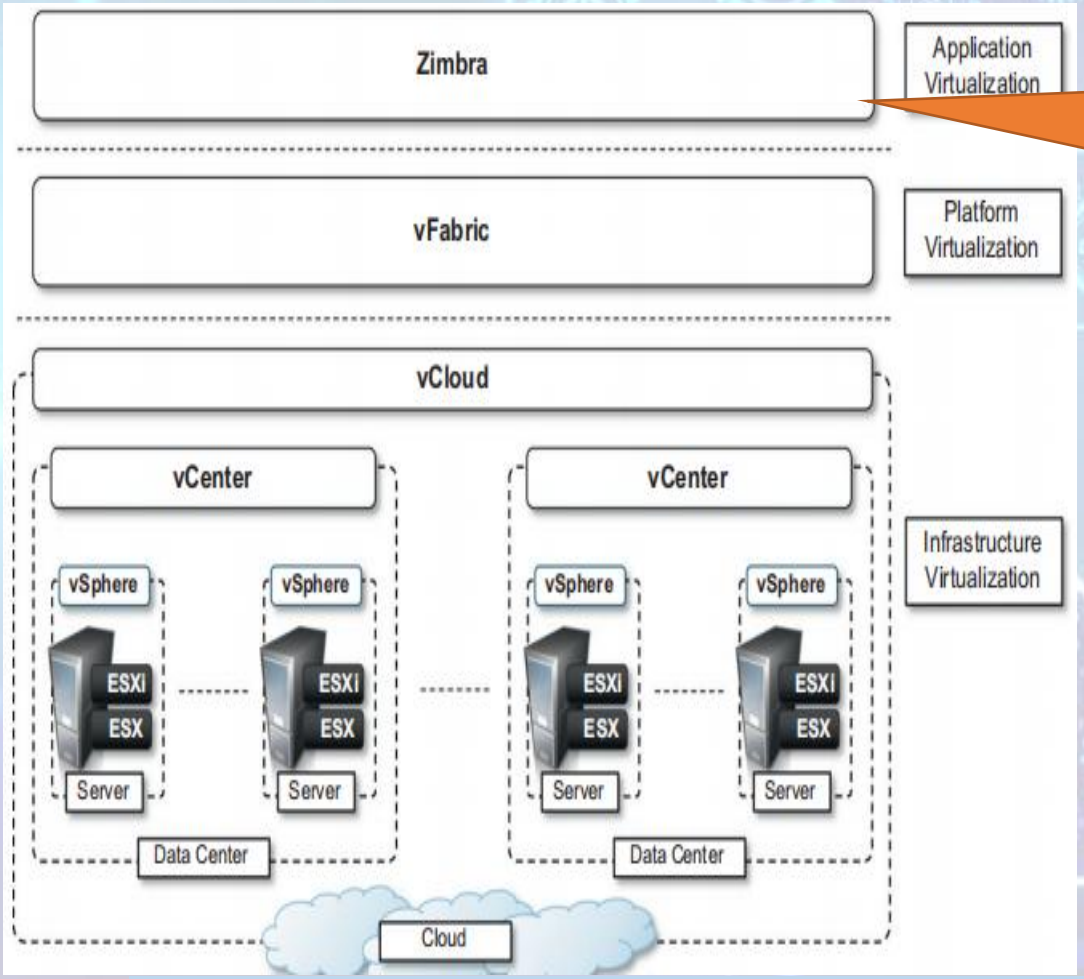
VIRTUALIZATION
Technology Examples: VMWare



- PaaS
- U can develop scalable WEB APPLICATIONS

VMWare Cloud Solution Stack

VIRTUALIZATION
Technology Examples: VMWare



- SaaS
- A software used for -------

VMWare Cloud Solution Stack

VIRTUALIZATION

Technology Examples: Hyper-V

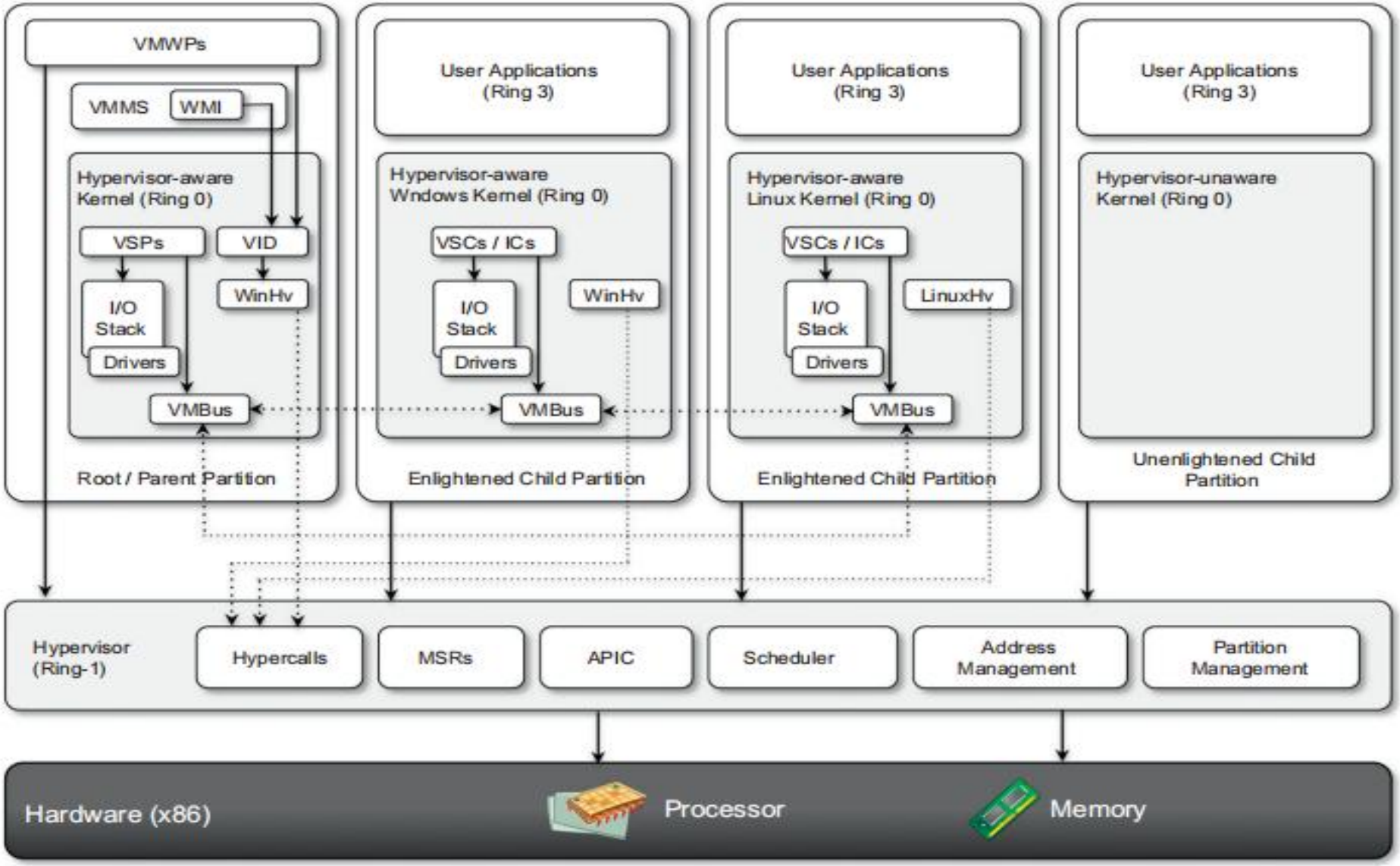
Microsoft Hyper-V

Microsoft Hyper-V

ARCHITECTURE

VIRTUALIZATION
Technology Examples: Hyper-

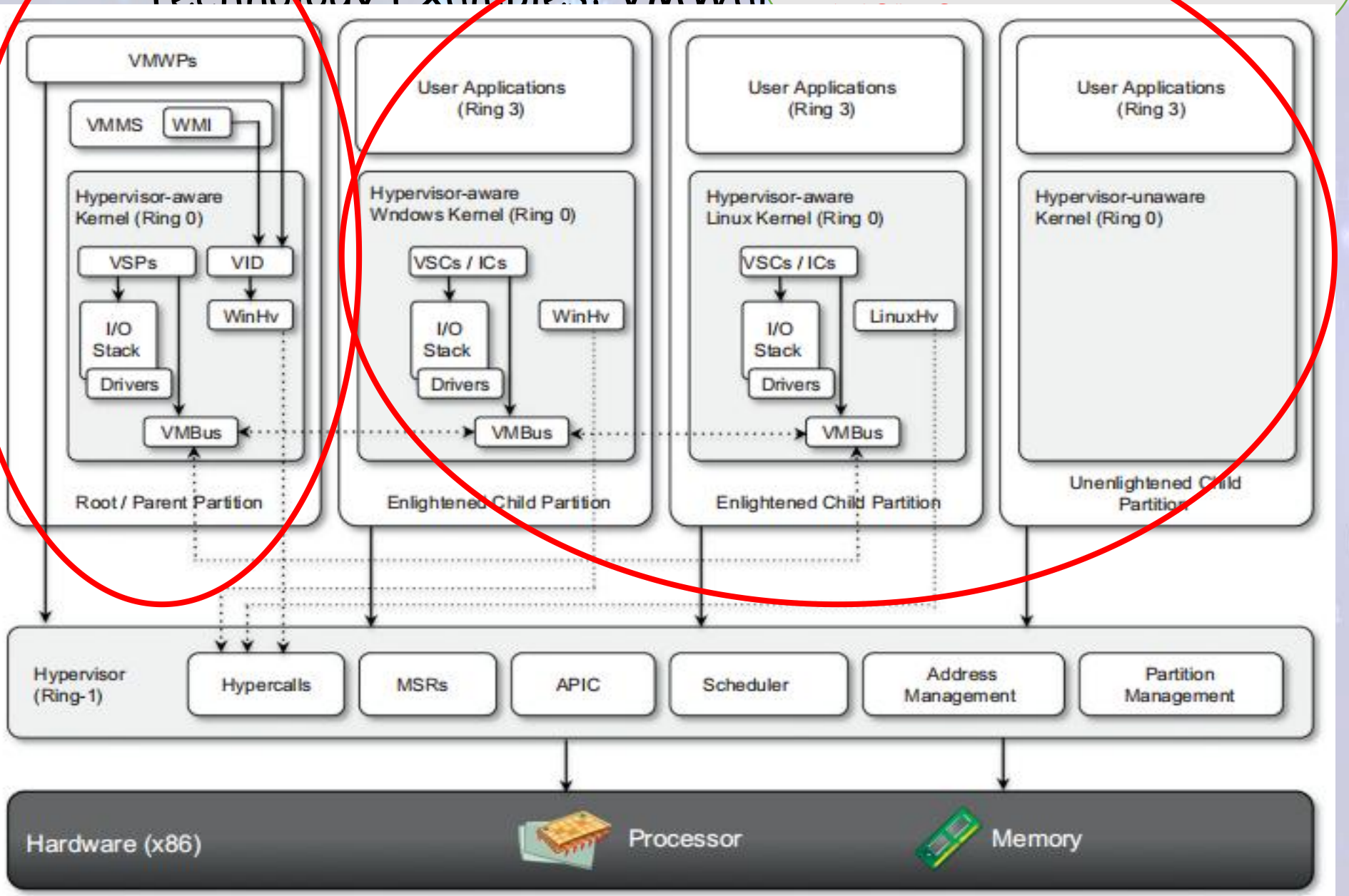
Microsoft Hyper-V
ARCHITECTURE



VIRTUALIZATION

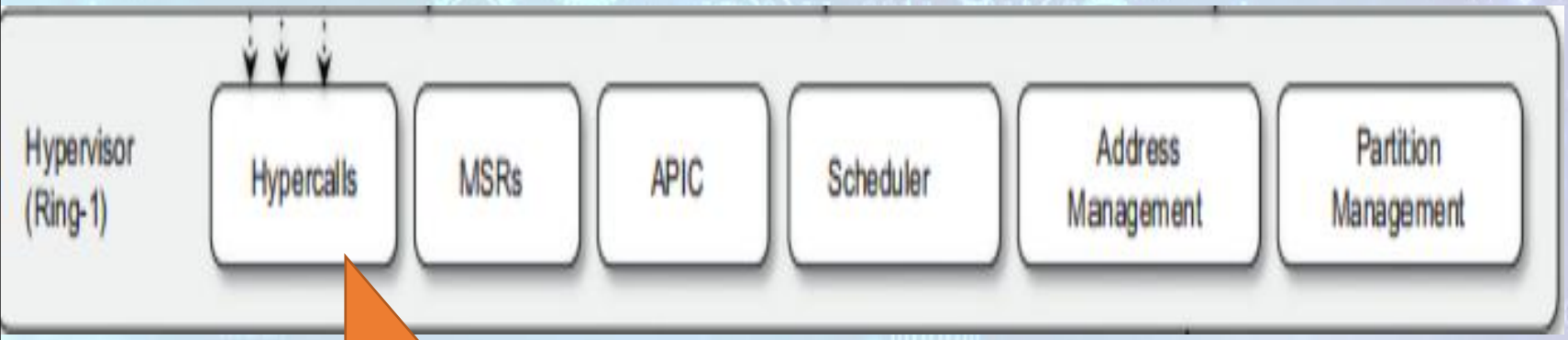
Technology Examples: VMWa

Microsoft Hyper-V



VIRTUALIZATION
Technology Examples: VMWare

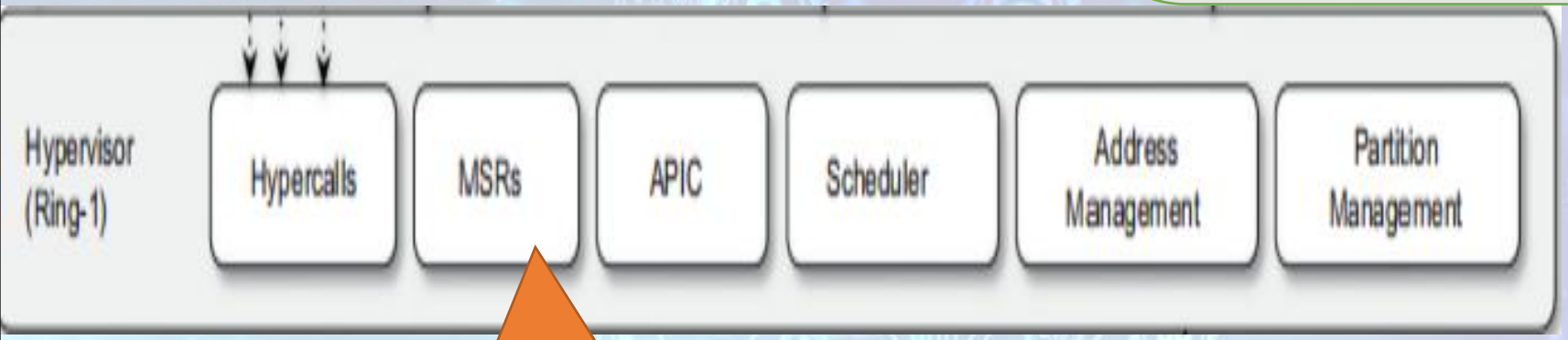
Microsoft Hyper-V



- Entry Point - For All Partitions - Sensitive Instructions
- Parent partition ---Uses it ---- Create Child Partition

VIRTUALIZATION
Technology Examples: VMWare

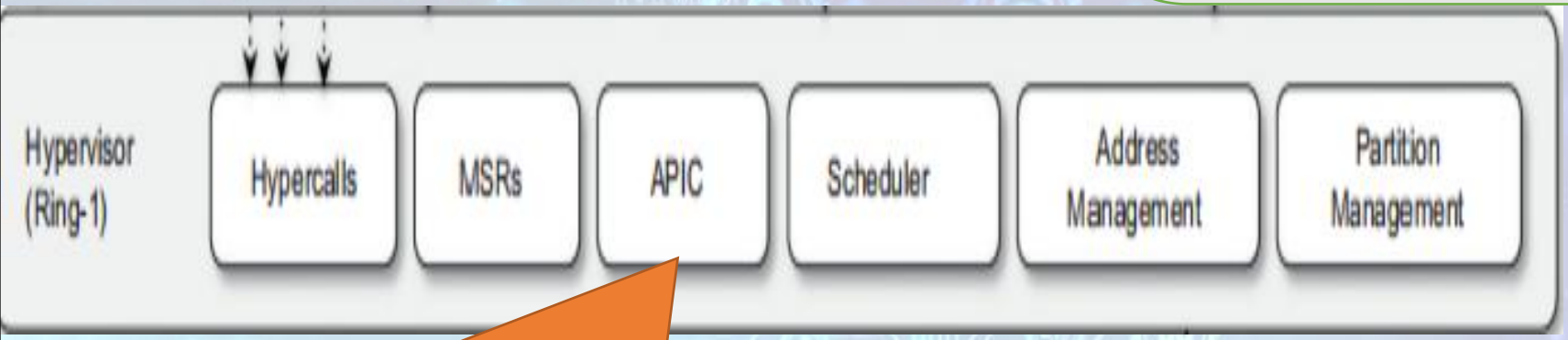
Microsoft Hyper-V



- Memory Service Routines: MEMORY CONTROL andACESS
- Uses Input/Output Memory Management Unit

VIRTUALIZATION
Technology Examples: VMWare

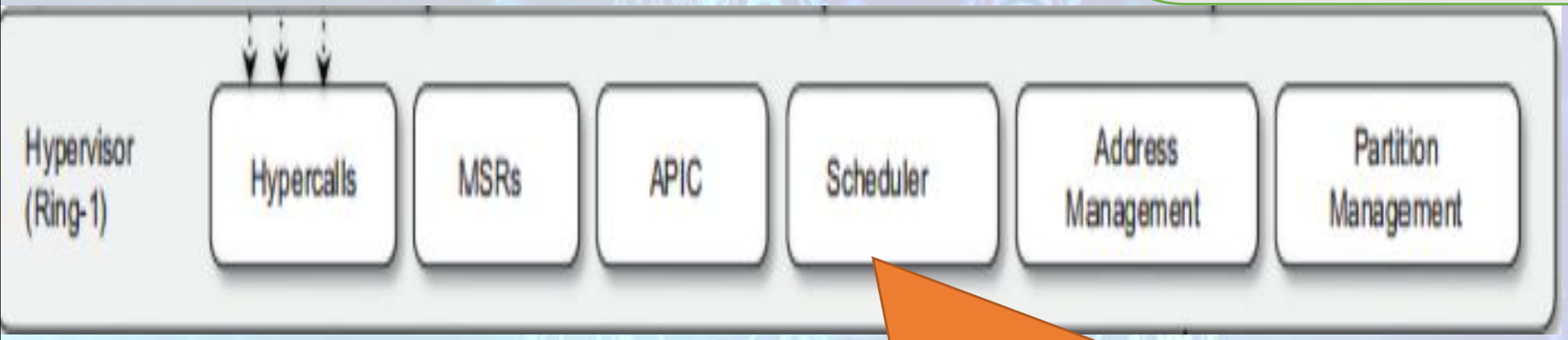
Microsoft Hyper-V



- Advanced programmable interrupt controller.
- Hardware signals are handled.
- Virtual Processor --- Handled by--- Synthetic Interrupt Controller
- Synthetic Interrupt Controller----uses---APIC to handle hardware

VIRTUALIZATION
Technology Examples: VMWare

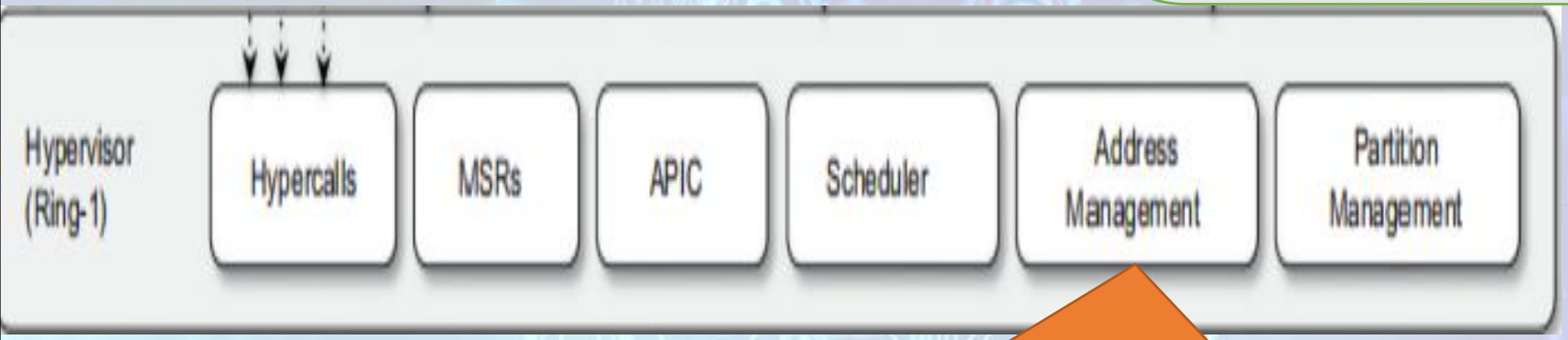
Microsoft Hyper-V



- Scheduling Virtual Processor to Actual Processor.
- Policies ---- set by-----Parental Partition

VIRTUALIZATION
Technology Examples: VMWare

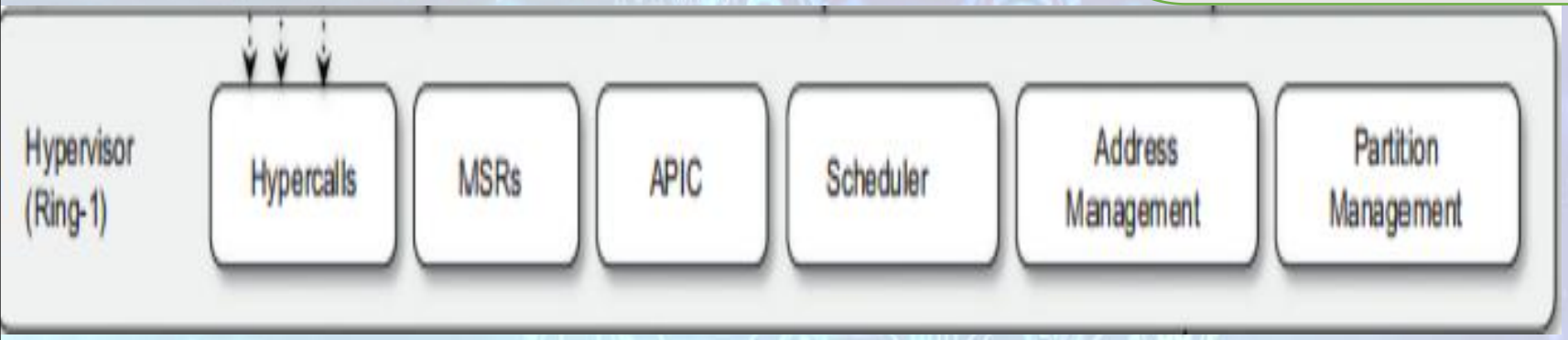
Microsoft Hyper-V



- Manage Virtual Addresses ------ of Guest VMs

VIRTUALIZATION
Technology Examples: VMWare

Microsoft Hyper-V



- Partitions Creation
- Management
- Destruction.
- Enumeration
- Configuration

VIRTUALIZATION
Technology Examples: VMWare

Enlightened I/O and Synthetic Devices

- Optimized I/O operations