Cloud Computing

IMIT-3201

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ARCHITECTURE - Deployment Models

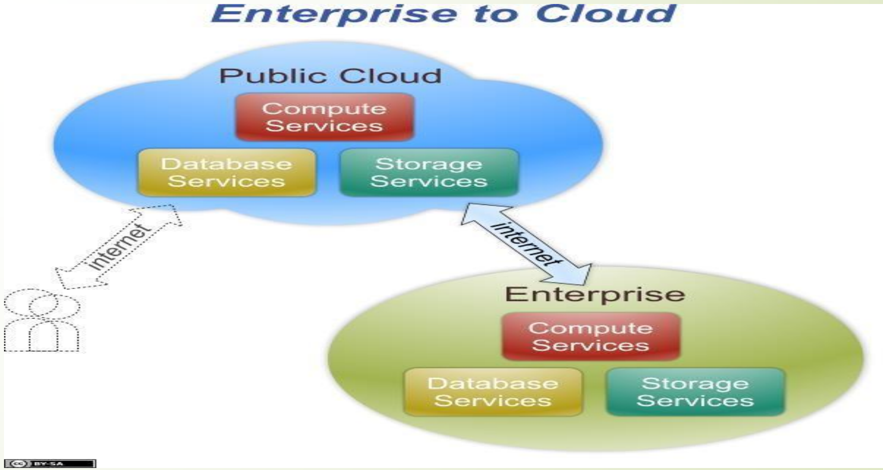
Deployment Models

- Public Cloud
- Private Cloud
- Hybrid Cloud
- Community Cloud

Public Cloud

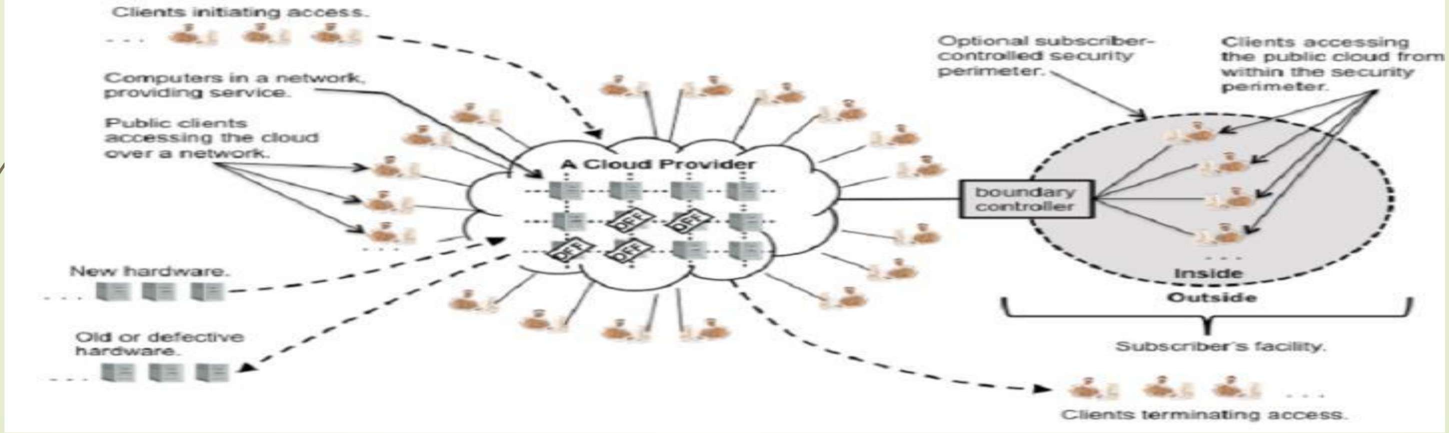
- Cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.

- Examples of Public Cloud:
- Google App Engine
- Microsoft Windows Azure
- IBM Smart Cloud
- Amazon EC2



Public Cloud

- In Public setting, the provider's computing and storage resources are potentially large; the communication links can be assumed to be implemented over the public Internet; and the cloud serves a diverse pool of clients (and possibly attackers).


Clients initiating access.
Computers in a network, providing service.
Public clients accessing the cloud over a network.
New hardware.
Old or defective hardware.
A Cloud Provider
OFF
Optional subscriber-controlled security perimeter.
Clients accessing the public cloud from within the security perimeter.
boundary controller
Inside
Outside
Subscriber's facility.
Clients terminating access.

Public Cloud

- **Workload locations are hidden from clients (public):**
  - In the public scenario, a provider may migrate a subscriber's workload, whether processing or data, at any time.
  - Workload can be transferred to data centres where cost is low
  - Workloads in a public cloud may be relocated anywhere at any time unless the provider has offered (optional) location restriction policies
- **Risks from multi-tenancy (public):**
  - A single machine may be shared by the workloads of any combination of subscribers (a subscriber's workload may be co-resident with the workloads of competitors or adversaries)
- Introduces both reliability and security risk

Public Cloud

- Organizations considering the use of an on-site private cloud should consider:
  - **Network dependency (public):**
    - Subscribers connect to providers via the public Internet.
    - Connection depends on Internet's Infrastructure like
      - Domain Name System (DNS) servers
      - Router infrastructure,
      - Inter-router links

Public Cloud

- **Limited visibility and control over data regarding security (public):**
  - The details of provider system operation are usually considered proprietary information and are not divulged to subscribers.
  - In many cases, the software employed by a provider is usually proprietary and not available for examination by subscribers
  - A subscriber cannot verify that data has been completely deleted from a provider's systems.
- **Elasticity: illusion of unlimited resource availability (public):**
  - Public clouds are generally unrestricted in their location or size.
  - Public clouds potentially have high degree of flexibility in the movement of subscriber workloads to correspond with available resources.

Public Cloud

- **Low up-front costs to migrate into the cloud (public)**
- **Restrictive default service level agreements (public):**
  - The default service level agreements of public clouds specify limited promises that providers make to subscribers

Cloud Migration

- Cloud Migration is a transformation from old traditional business operations to digital business operations and the process refers to moving the digital business operations to cloud. That means data, applications or other business elements are moved into a cloud computing environment. For example moving data and applications from a local, on-premises data center to the cloud.

- **Cloud Migration Strategy :**

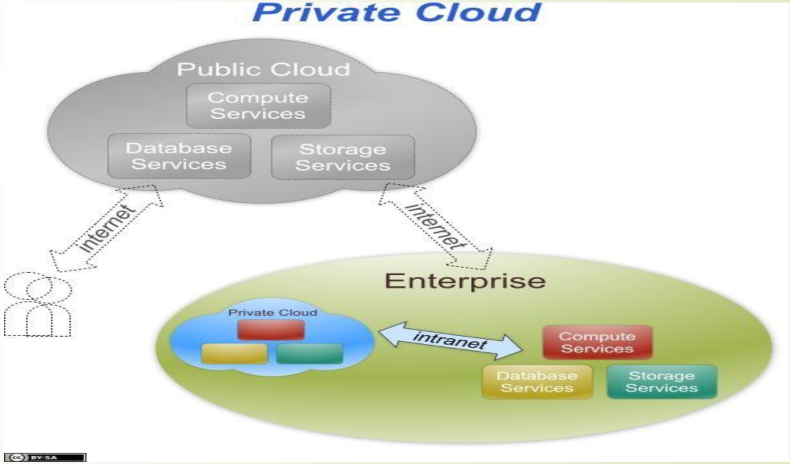
5 R's represents the cloud migration strategy.

1. **Rehost :** It refers to take the application to the new hosted cloud environment by selecting IaaS (Infrastructure as a Service).
2. **Refactor :** It refers to reuse the application code and frameworks and running the application on a PaaS (Platform as a Service).
3. **Revise :** It refers to expanding code base and then deploying it either by rehosting or refactoring.
4. **Rebuild :** It refers to re-architecting the application from the beginning up on a PaaS provider's platform.
5. **Replace :** It refers to replacing the old application with a new built SaaS (software as a Service).

Private Cloud

- The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned, managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.

- Examples of Private Cloud:
  - Eucalyptus
  - Ubuntu Enterprise Cloud - UEC
  - Amazon VPC (Virtual Private Cloud)
  - VMware Cloud Infrastructure Suite
  - Microsoft ECI data center.

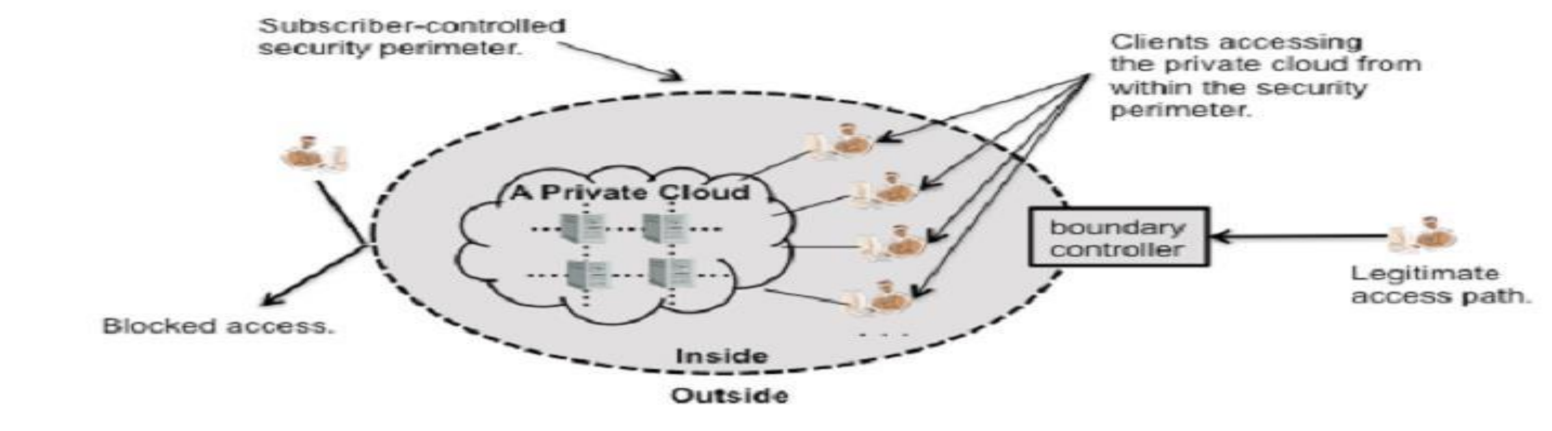


Private Cloud

- Contrary to popular belief, private cloud may exist off premises and can be managed by a third party. Thus, two private cloud scenarios exist, as follows:
- On-site Private Cloud
  - Applies to private clouds implemented at a customer's premises.
- Outsourced Private Cloud
  - Applies to private clouds where the server side is outsourced to a hosting company.

On-site Private Cloud

- The security perimeter extends around both the subscriber's on-site resources and the private cloud's resources.
- Security perimeter does not guarantees control over the private cloud's resources but subscriber can exercise control over the resources.


Subscriber-controlled security perimeter.
Clients accessing the private cloud from within the security perimeter.
A Private Cloud
boundary controller
Legitimate access path.
Blocked access.
Inside
Outside

Source: LeeBadger, and Tim Grance "NIST DRAFT Cloud Computing Synopsis and Recommendations "

On-site Private Cloud

- Organizations considering the use of an on-site private cloud should consider:
  - **Network dependency (on-site-private):**
  - **Subscribers still need IT skills (on-site-private):**
    - Subscriber organizations will need the traditional IT skills required to manage user devices that access the private cloud, and will require cloud IT skills as well.
  - **Workload locations are hidden from clients (on-site-private):**
    - To manage a cloud's hardware resources, a private cloud must be able to migrate workloads between machines without inconveniencing clients. With an on-site private cloud, however, a subscriber organization chooses the physical infrastructure, but individual clients still may not know where their workloads physically exist within the subscriber organization's infrastructure

On-site Private Cloud

- **Risks from multi-tenancy (on-site-private):**
  - Workloads of different clients may reside concurrently on the same systems and local networks, separated only by access policies implemented by a cloud provider's software. A flaw in the software or the policies could compromise the security of a subscriber organization by exposing client workloads to one another
- **Data import/export, and performance limitations (on-site-private):**
  - On-demand bulk data import/export is limited by the on-site private cloud's network capacity, and real-time or critical processing may be problematic because of networking limitations.

On-site Private Cloud

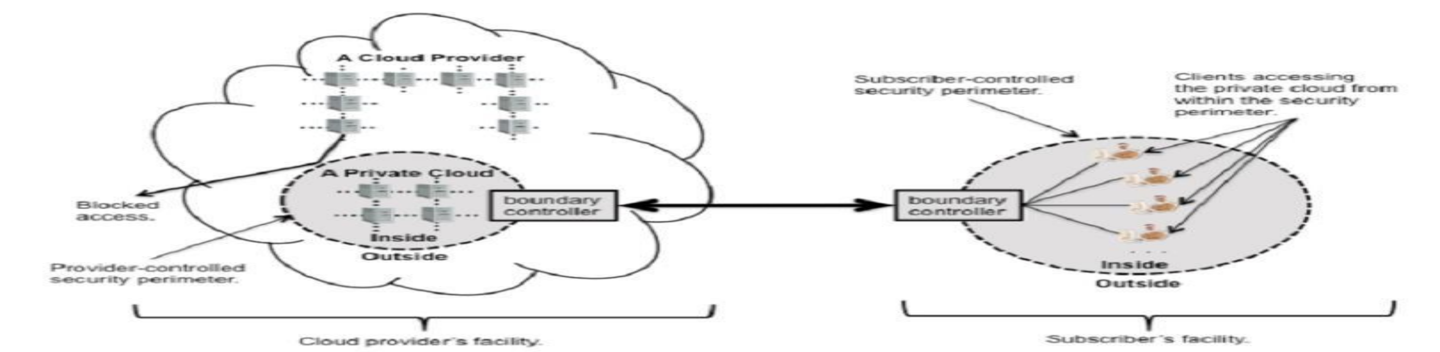
- **Potentially strong security from external threats (on-site-private):**
  - In an on-site private cloud, a subscriber has the option of implementing an appropriately strong security perimeter to protect private cloud resources against external threats to the same level of security as can be achieved for non-cloud resources.
- **Significant-to-high up-front costs to migrate into the cloud (on-site-private):**
  - An on-site private cloud requires that cloud management software be installed on computer systems within a subscriber organization. If the cloud is intended to support process-intensive or data-intensive workloads, the software will need to be installed on numerous commodity systems or on a more limited number of high-performance systems. Installing cloud software and managing the installations will incur significant up-front costs, even if the cloud software itself is free, and even if much of the hardware already exists within a subscriber organization.

On-site Private Cloud

- **Limited resources (on-site-private):**
  - An on-site private cloud, at any specific time, has a fixed computing and storage capacity that has been sized to correspond to anticipated workloads and cost restrictions.

Outsourced Private Cloud

- Outsourced private cloud has two security perimeters, one implemented by a cloud subscriber (on the right) and one implemented by a provider.
- Two security perimeters are joined by a protected communications link.
- The security of data and processing conducted in the outsourced private cloud depends on the strength and availability of both security perimeters and of the protected communication link.


A Cloud Provider
A Private Cloud
Blocked access.
boundary controller
Inside
Outside
Provider-controlled security perimeter.
Cloud provider's facility.
Subscriber-controlled security perimeter.
Clients accessing the private cloud from within the security perimeter.
boundary controller
Inside
Outside
Subscriber's facility.

Outsourced Private Cloud

- Organizations considering the use of an outsourced private cloud should consider:
  - **Network Dependency (outsourced-private):**
    - In the outsourced private scenario, subscribers may have an option to provision unique protected and reliable communication links with the provider.
  - **Workload locations are hidden from clients (outsourced-private):**
  - **Risks from multi-tenancy (outsourced-private):**
    - The implications are the same as those for an on-site private cloud.

Outsourced Private Cloud

- **Data import/export, and performance limitations (outsourced-private):**
  - On-demand bulk data import/export is limited by the network capacity between a provider and subscriber, and real-time or critical processing may be problematic because of networking limitations. In the outsourced private cloud scenario, however, these limits may be adjusted, although not eliminated, by provisioning high-performance and/or high-reliability networking between the provider and subscriber.
- **Potentially strong security from external threats (outsourced-private):**
  - As with the on-site private cloud scenario, a variety of techniques exist to harden a security perimeter. The main difference with the outsourced private cloud is that the techniques need to be applied both to a subscriber's perimeter and provider's perimeter, and that the communications link needs to be protected.

Outsourced Private Cloud

- **Modest-to-significant up-front costs to migrate into the cloud (outsourced-private):**
  - In the outsourced private cloud scenario, the resources are provisioned by the provider
  - Main start-up costs for the subscriber relate to:
    - Negotiating the terms of the service level agreement (SLA)
    - Possibly upgrading the subscriber's network to connect to the outsourced private cloud
    - Switching from traditional applications to cloud-hosted applications,
    - Porting existing non-cloud operations to the cloud
    - Training

Outsourced Private Cloud

- **Extensive resources available (outsourced-private):**
  - In the case of the outsourced private cloud, a subscriber can rent resources in any quantity offered by the provider. Provisioning and operating computing equipment at scale is a core competency of providers.

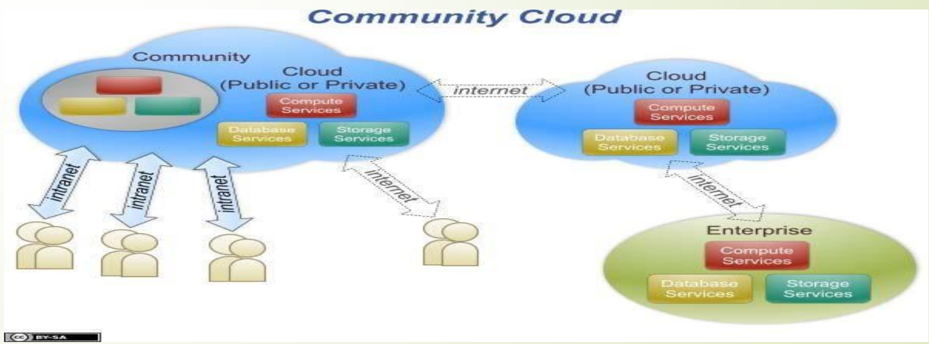
Community Cloud

- Cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community,

  a third party, or some combination of them, and it may exist on or off premises.

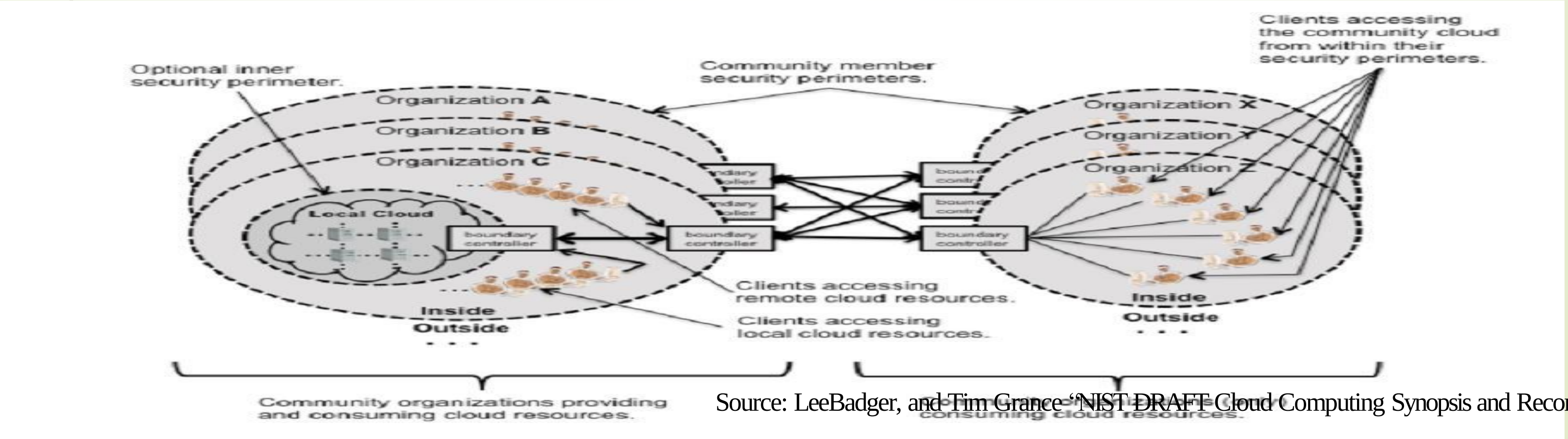
- Examples of Community Cloud:
  - Google Apps for Government
  - Microsoft Government Community

    Cloud



On-site Community Cloud

- Community cloud is made up of a set of participant organizations. Each participant organization may provide cloud services, consume cloud services, or both
- At least one organization must provide cloud services
- Each organization implements a security perimeter


Clients accessing the community cloud from within their security perimeters.
Optional inner security perimeter.
Community member security perimeters.
Organization A
Organization B
Organization C
Local Cloud
boundary controller
boundary controller
Organization X
Organization Y
Organization Z
boundary controller
Clients accessing remote cloud resources.
Clients accessing local cloud resources.
Inside
Outside
Inside
Outside
Community organizations providing and consuming cloud resources.
consuming cloud resources.

Source: LeeBadger, and Tim Grance “NIST DRAFT Cloud Computing Synopsis and Recommendations “

On-site Community Cloud

- The participant organizations are connected via links between the boundary controllers that allow access through their security perimeters
- Access policy of a community cloud may be complex
  - Ex. :if there are N community members, a decision must be made, either implicitly or explicitly, on how to share a member's local cloud resources with each of the other members
  - Policy specification techniques like role-based access control (RBAC), attribute-based access control can be used to express sharing policies.

On-site Community Cloud

- Organizations considering the use of an on-site community cloud should consider:
  - **Network Dependency (on-site community):**
    - The subscribers in an on-site community cloud need to either provision controlled inter-site communication links or use cryptography over a less controlled communications media (such as the public Internet).
    - The reliability and security of the community cloud depends on the reliability and security of the communication links.

On-site Community Cloud

- **Subscribers still need IT skills (on-site-community).**
  - Organizations in the community that provides cloud resources, requires IT skills similar to those required for the on-site private cloud scenario except that the overall cloud configuration may be more complex and hence require a higher skill level.
  - Identity and access control configurations among the participant organizations may be complex
- **Workload locations are hidden from clients (on-site-community):**
  - Participant Organizations providing cloud services to the community cloud may wish to employ an outsourced private cloud as a part of its implementation strategy.

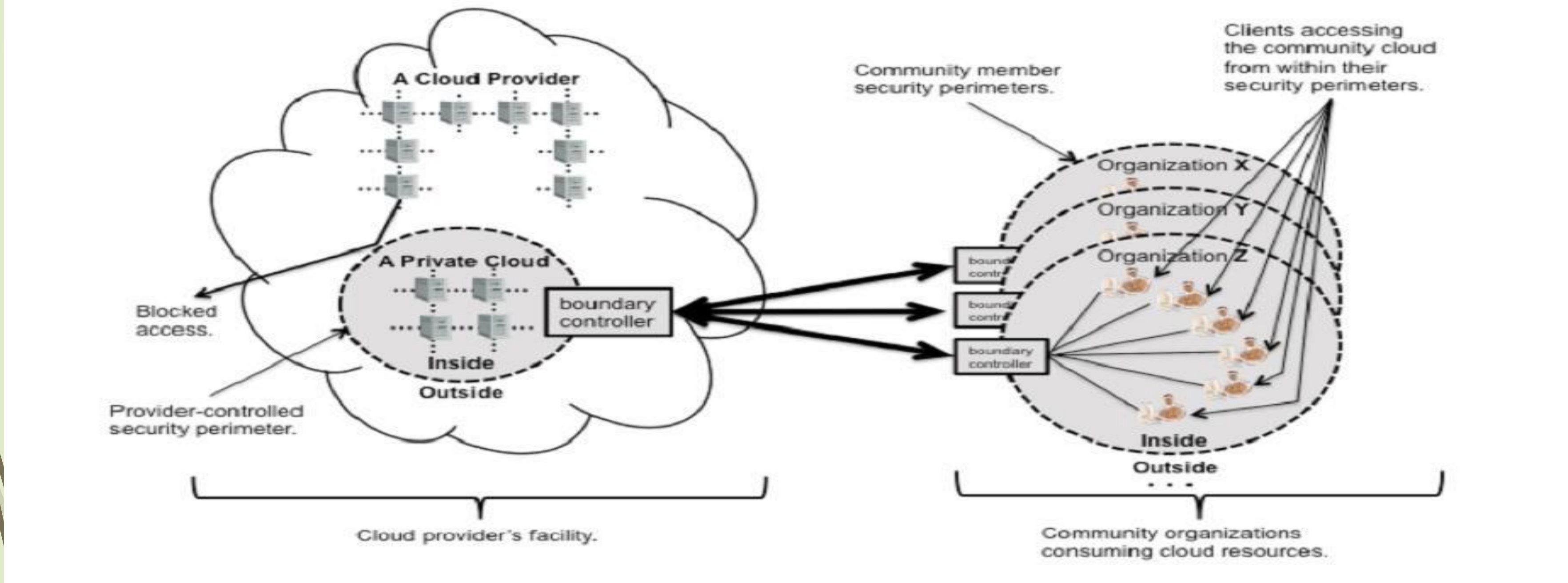
On-site Community Cloud

- **Data import/export, and performance limitations (on-site-community):**
  - The communication links between the various participant organizations in a community cloud can be provisioned to various levels of performance, security and reliability, based on the needs of the participant organizations. The network-based limitations are thus similar to those of the outsourced-private cloud scenario.
- **Potentially strong security from external threats (on-site-community):**
  - The security of a community cloud from external threats depends on the security of all the security perimeters of the participant organizations and the strength of the communications links. These dependencies are essentially similar to those of the outsourced private cloud scenario, but with possibly more links and security perimeters.

On-site Community Cloud

- **Highly variable up-front costs to migrate into the cloud (on-site-community):**
  - The up-front costs of an on-site community cloud for a participant organization depend greatly on whether the organization plans to consume cloud services only or also to provide cloud services. For a participant organization that intends to provide cloud services within the community cloud, the costs appear to be similar to those for the on-site private cloud scenario (i.e., significant-to-high).

Outsourced Community Cloud


A Cloud Provider
A Private Cloud
boundary controller
Inside
Outside
Blocked access.
Provider-controlled security perimeter.
Community member security perimeters.
Clients accessing the community cloud from within their security perimeters.
Organization X
Organization Y
Organization Z
boundary controller
Inside
Outside
Cloud provider's facility.
Community organizations consuming cloud resources.

Outsourced Community Cloud

- Organizations considering the use of an on-site community cloud should consider:
- **Network dependency (outsourced-community):**
  - The network dependency of the outsourced community cloud is similar to that of the outsourced private cloud. The primary difference is that multiple protected communications links are likely from the community members to the provider's facility.
- **Workload locations are hidden from clients (outsourced-community).**
  - Same as the outsourced private cloud

Outsourced Community Cloud

- **Risks from multi-tenancy (outsourced-community):**
  - Same as the on-site community cloud
- **Data import/export, and performance limitations (outsourced-community):**
  - Same as outsourced private cloud
- **Potentially strong security from external threats (outsourced-community):**
  - Same as the on-site community cloud
- **Modest-to-significant up-front costs to migrate into the cloud (outsourced-community):**
- Same as outsourced private cloud

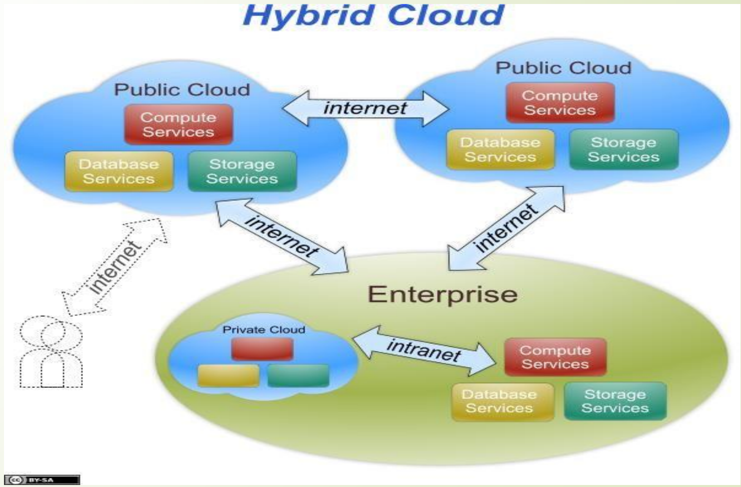
Outsourced Community Cloud

- **Extensive resources available (outsourced-community).**
  - Same as outsourced private cloud

Hybrid Cloud

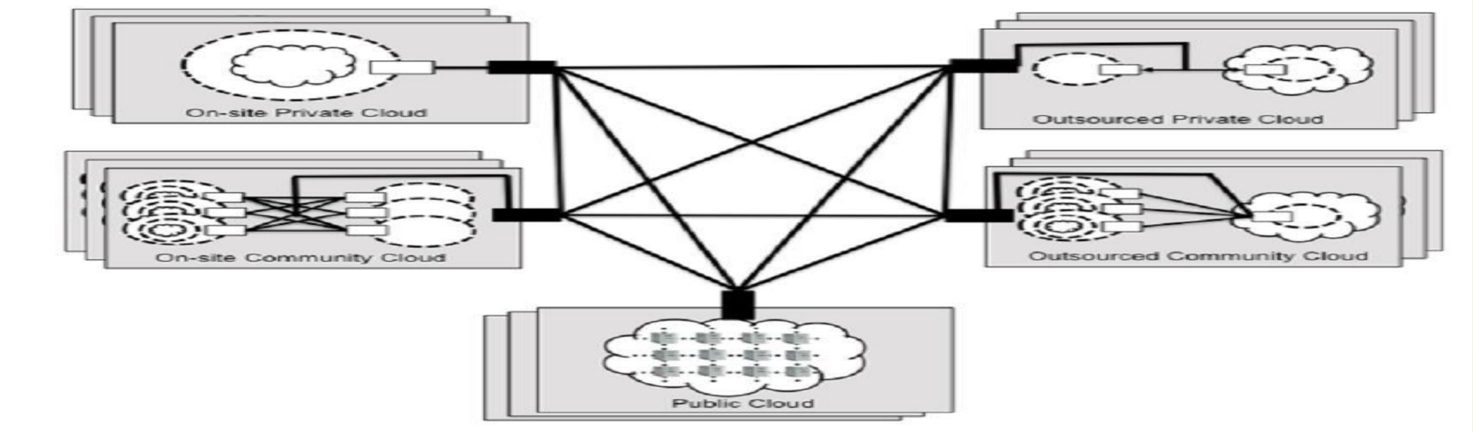
- The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public) that remain unique entities, but are bound together by standardized or proprietary technology that enables data and application portability

- Examples of Hybrid Cloud:
  - Windows Azure (capable of Hybrid Cloud)
  - VMware vCloud (Hybrid Cloud Services)



Hybrid Cloud

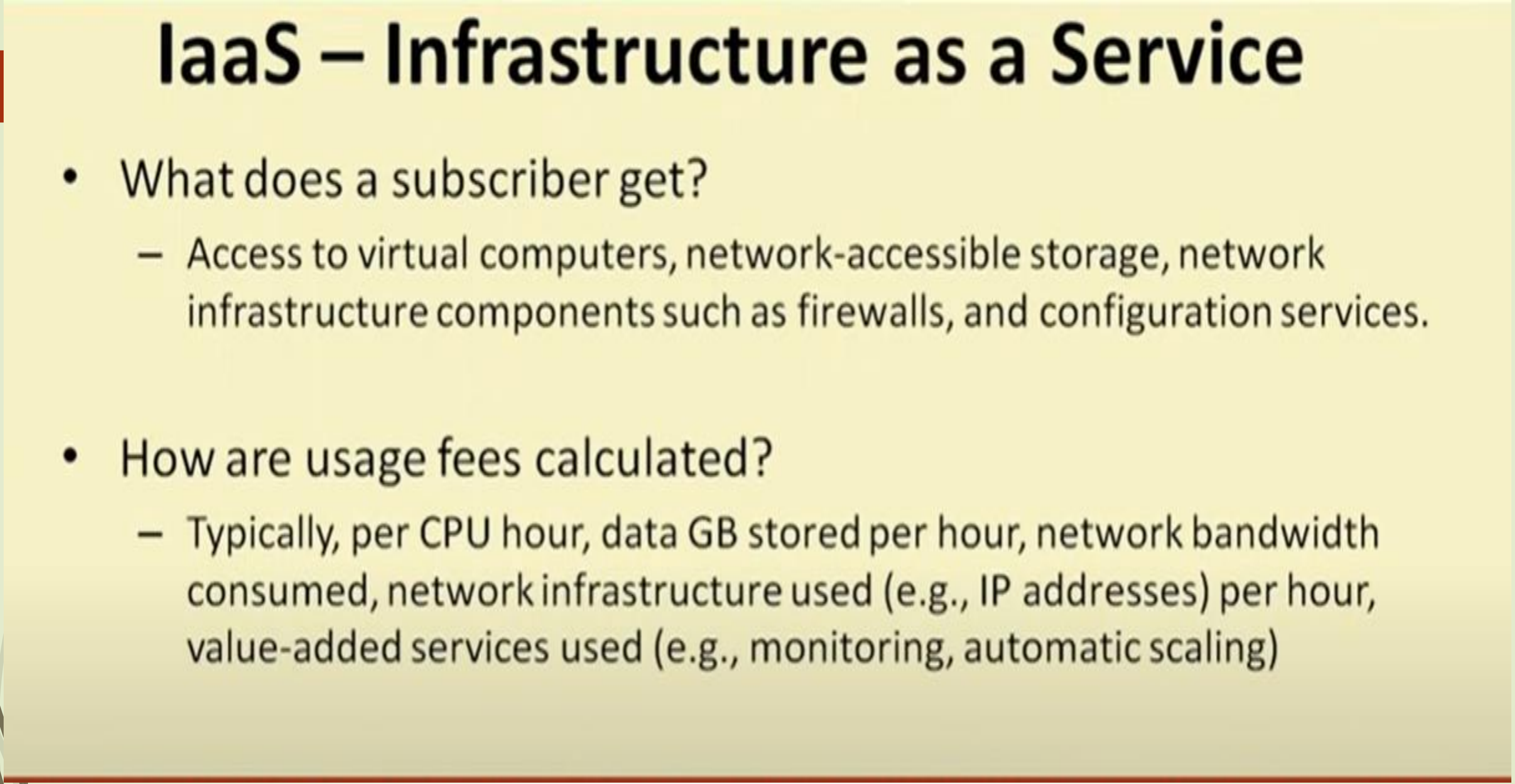
- A hybrid cloud is composed of two or more private, community, or public clouds.
- They have significant variations in performance, reliability, and security properties depending upon the type of cloud chosen to build hybrid cloud.



Hybrid Cloud

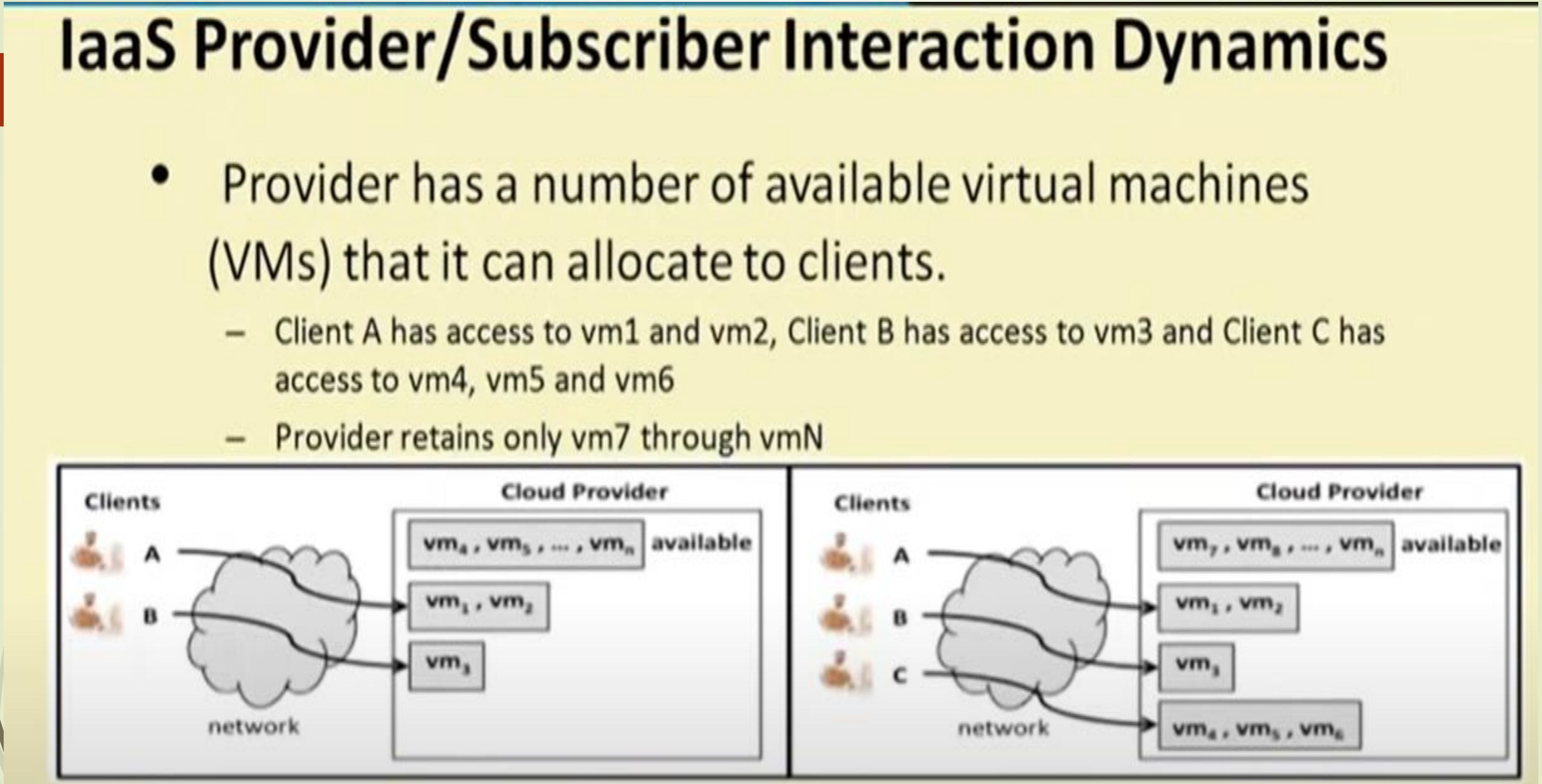
- A hybrid cloud can be extremely complex
- A hybrid cloud may change over time with constituent clouds joining and leaving.

Virtualization



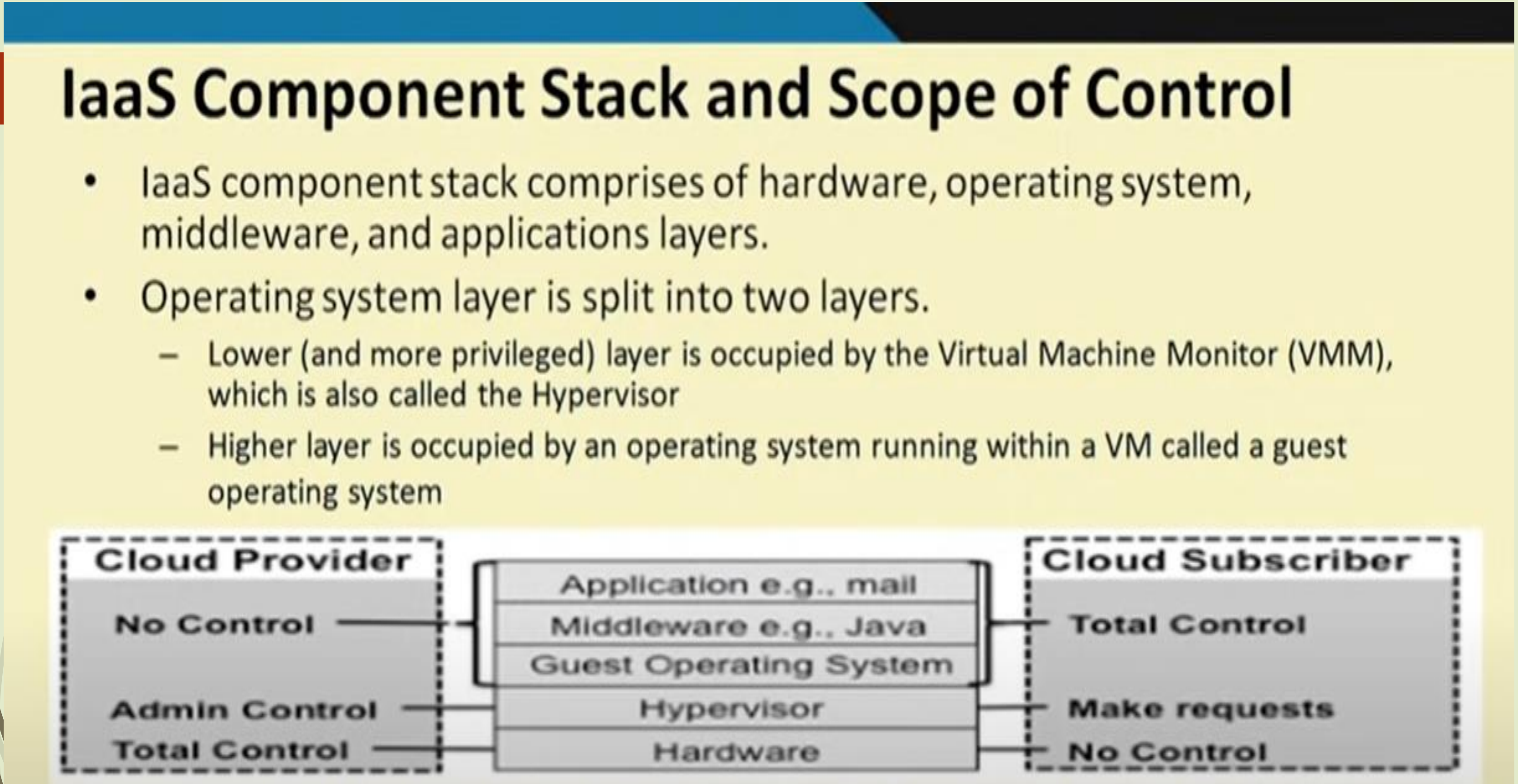
IaaS – Infrastructure as a Service

- What does a subscriber get?
  - Access to virtual computers, network-accessible storage, network infrastructure components such as firewalls, and configuration services.
- How are usage fees calculated?
  - Typically, per CPU hour, data GB stored per hour, network bandwidth consumed, network infrastructure used (e.g., IP addresses) per hour, value-added services used (e.g., monitoring, automatic scaling)



IaaS Provider/Subscriber Interaction Dynamics

- Provider has a number of available virtual machines (VMs) that it can allocate to clients.
  - Client A has access to vm1 and vm2, Client B has access to vm3 and Client C has access to vm4, vm5 and vm6
  - Provider retains only vm7 through vmN



IaaS Component Stack and Scope of Control

- IaaS component stack comprises of hardware, operating system, middleware, and applications layers.
- Operating system layer is split into two layers.
  - Lower (and more privileged) layer is occupied by the Virtual Machine Monitor (VMM), which is also called the Hypervisor
  - Higher layer is occupied by an operating system running within a VM called a guest operating system

Cloud Provider

No Control

Admin Control

Total Control

Application e.g., mail

Middleware e.g., Java

Guest Operating System

Hypervisor

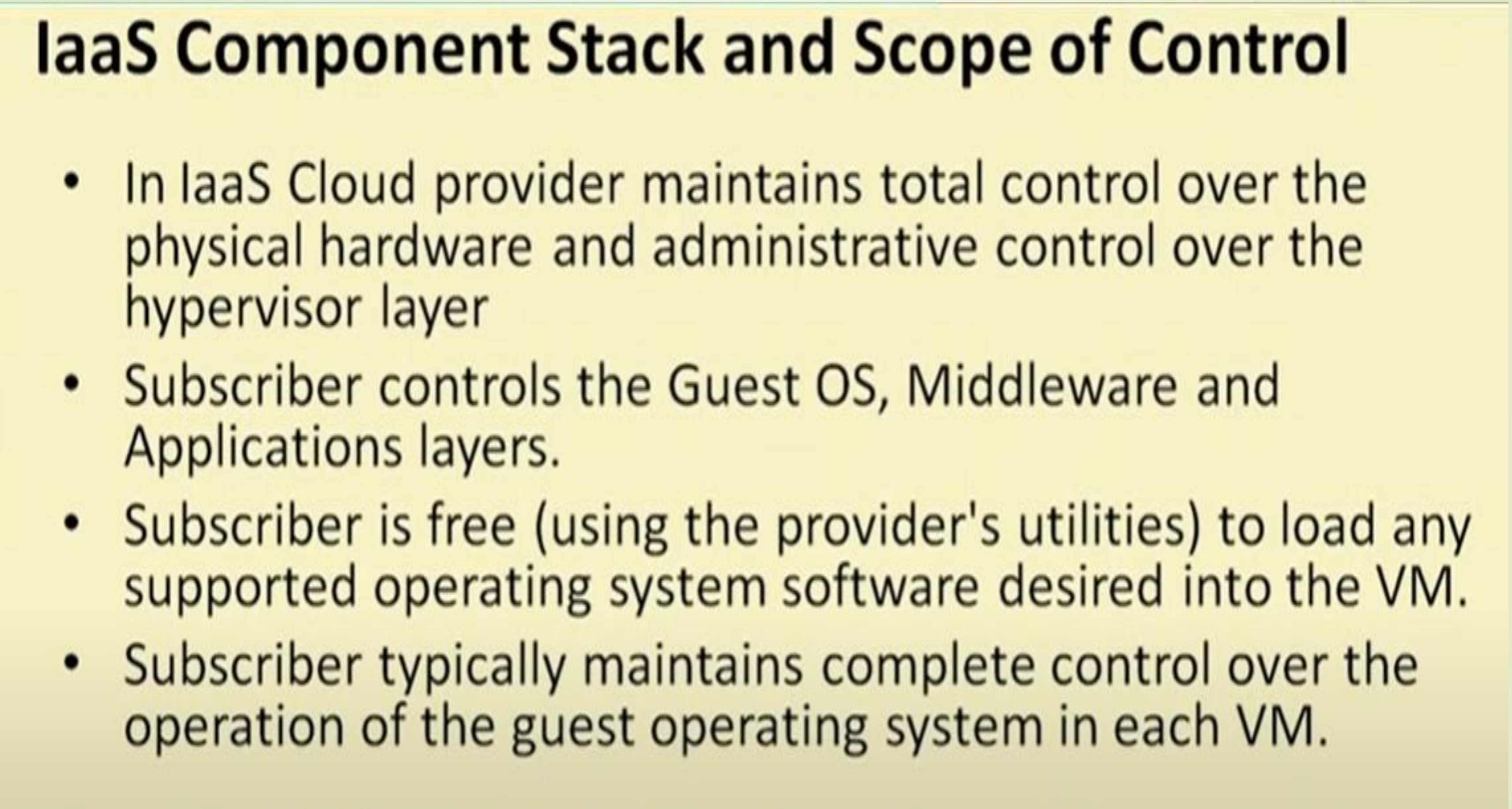
Hardware

Cloud Subscriber

Total Control

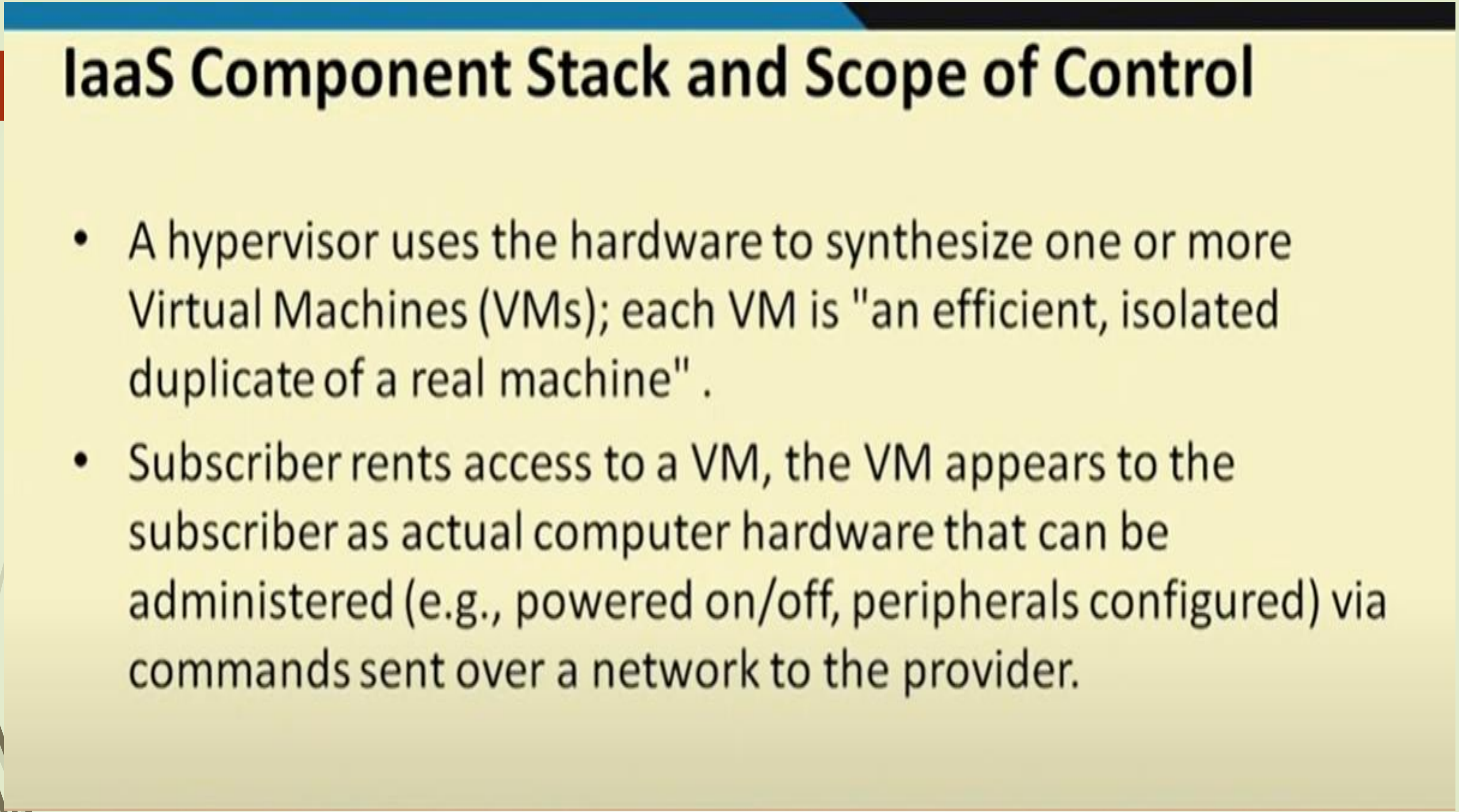
Make requests

No Control



IaaS Component Stack and Scope of Control

- In IaaS Cloud provider maintains total control over the physical hardware and administrative control over the hypervisor layer
- Subscriber controls the Guest OS, Middleware and Applications layers.
- Subscriber is free (using the provider's utilities) to load any supported operating system software desired into the VM.
- Subscriber typically maintains complete control over the operation of the guest operating system in each VM.

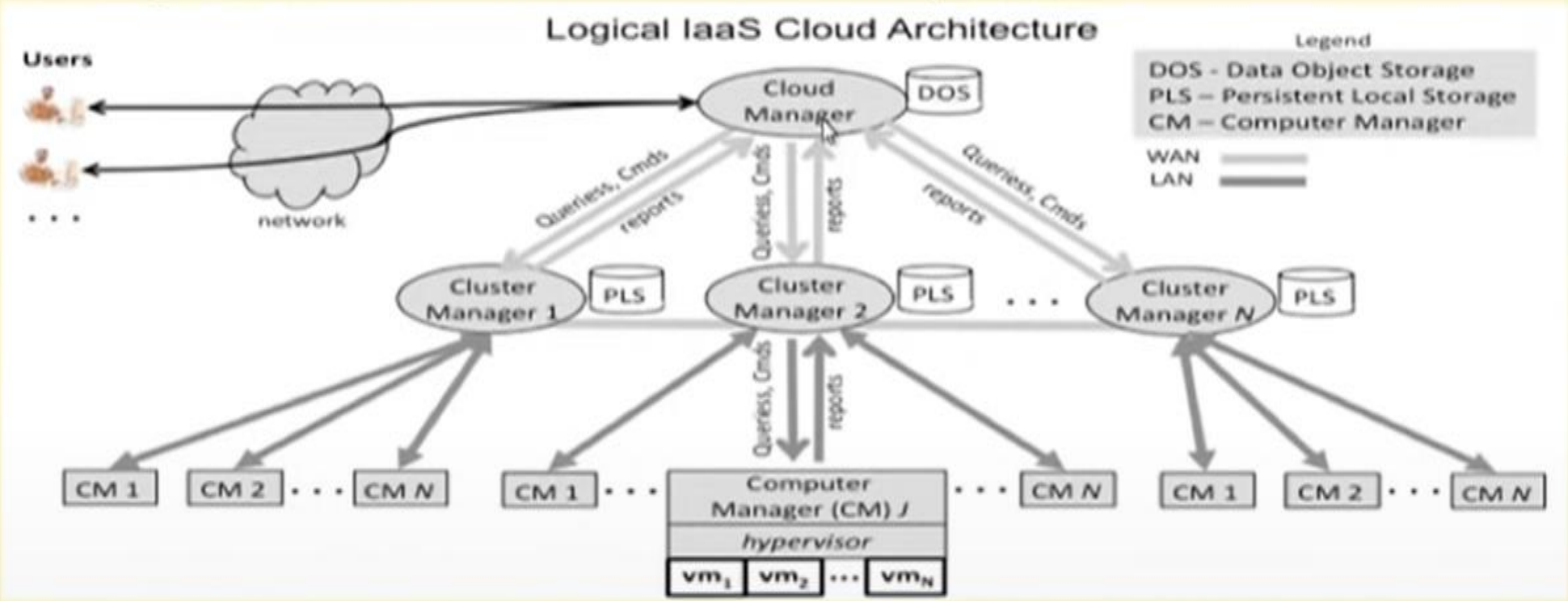


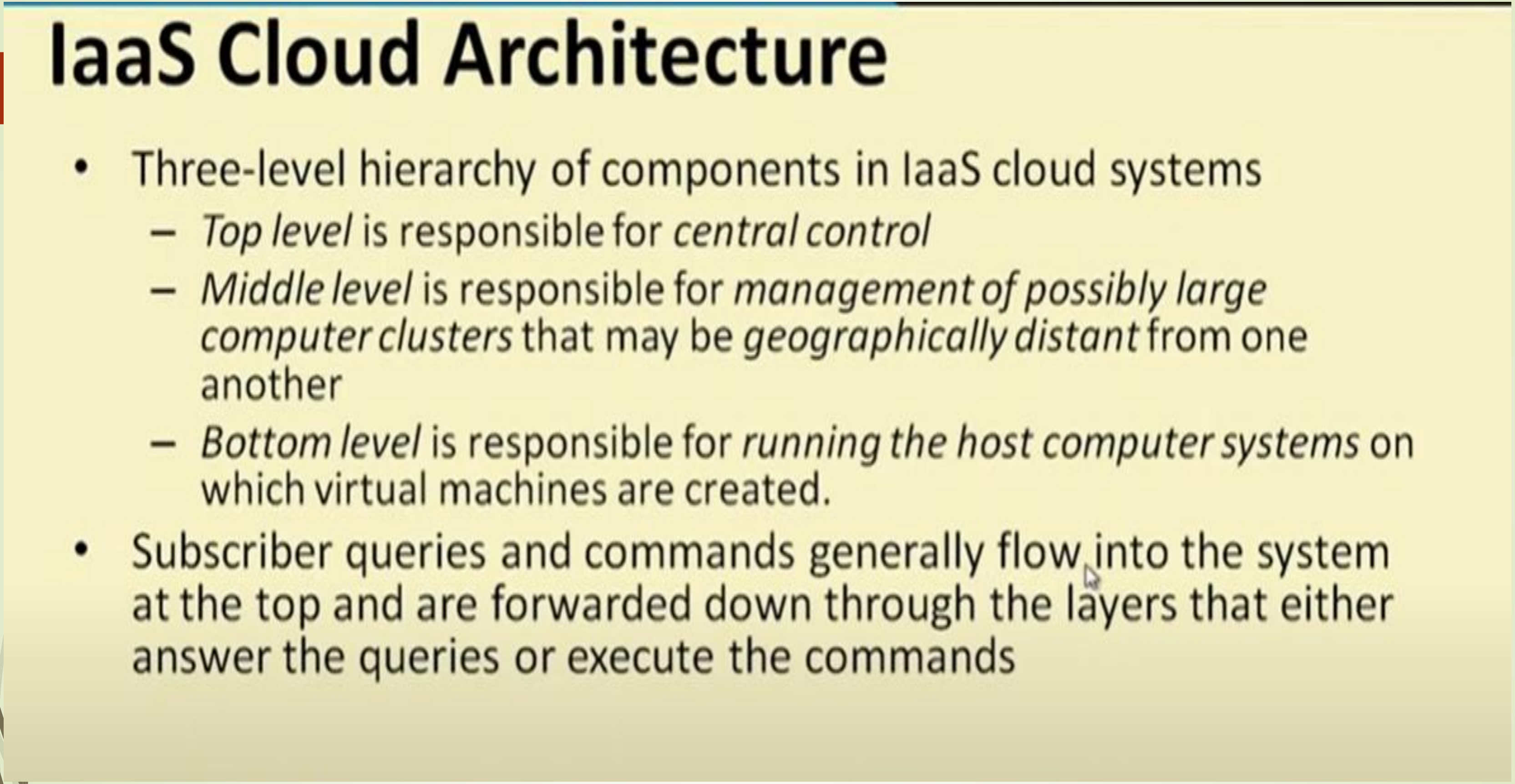
IaaS Component Stack and Scope of Control

- A hypervisor uses the hardware to synthesize one or more Virtual Machines (VMs); each VM is "an efficient, isolated duplicate of a real machine" .
- Subscriber rents access to a VM, the VM appears to the subscriber as actual computer hardware that can be administered (e.g., powered on/off, peripherals configured) via commands sent over a network to the provider.

IaaS Cloud Architecture

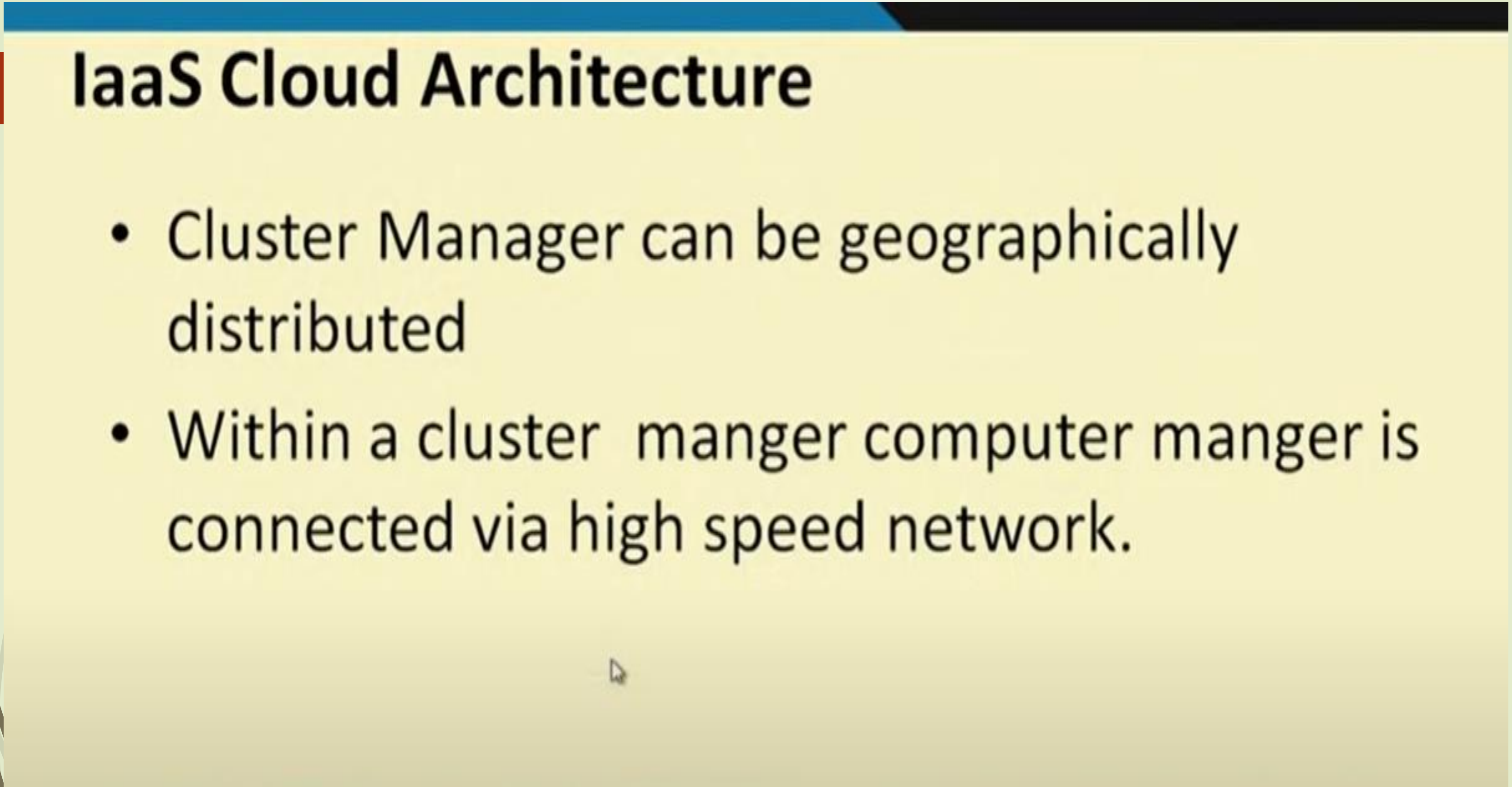
- Logical view of IaaS cloud structure and operation





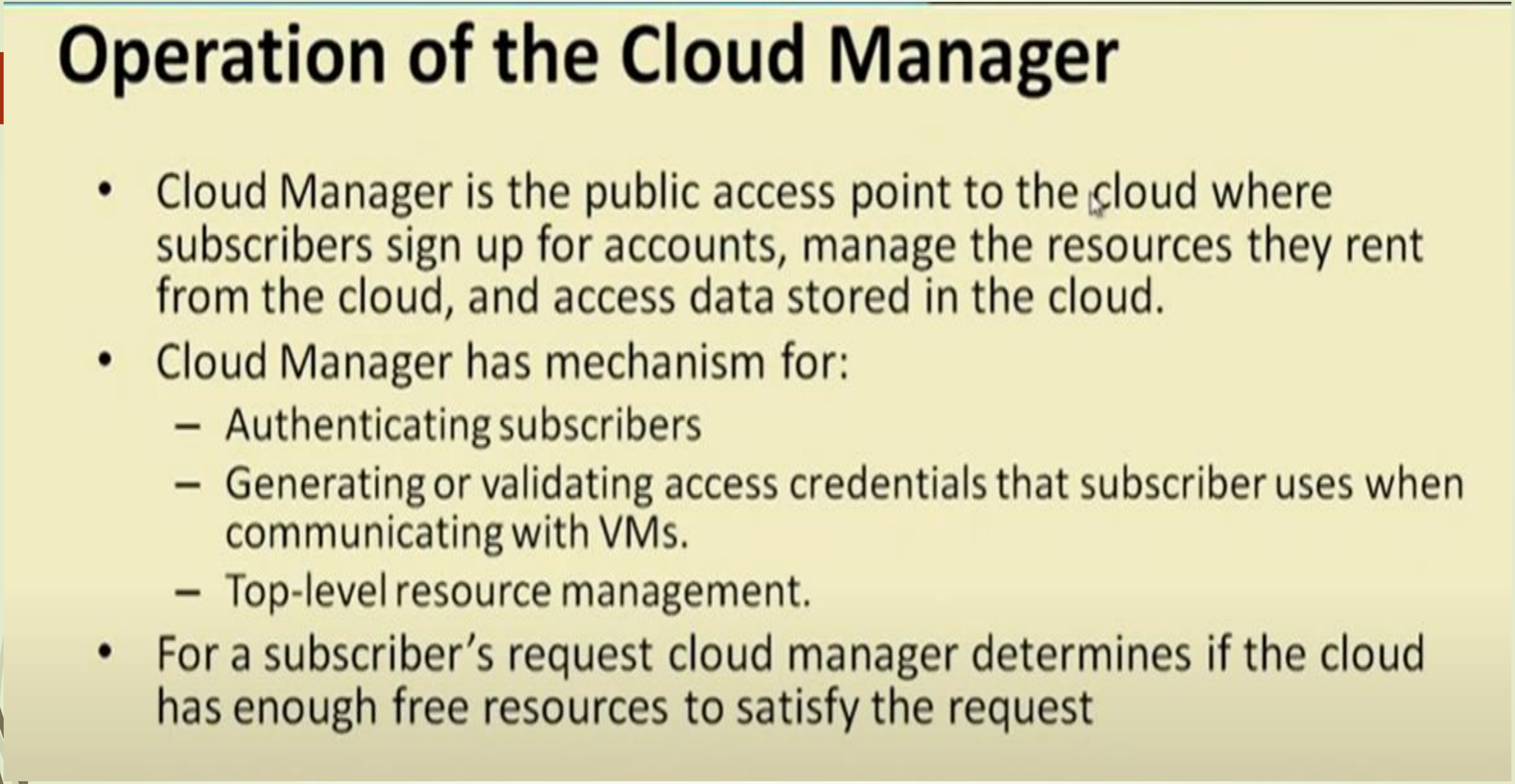
IaaS Cloud Architecture

- Three-level hierarchy of components in IaaS cloud systems
  - *Top level* is responsible for *central control*
  - *Middle level* is responsible for *management of possibly large computer clusters* that may be *geographically distant* from one another
  - *Bottom level* is responsible for *running the host computer systems* on which virtual machines are created.
- Subscriber queries and commands generally flow into the system at the top and are forwarded down through the layers that either answer the queries or execute the commands



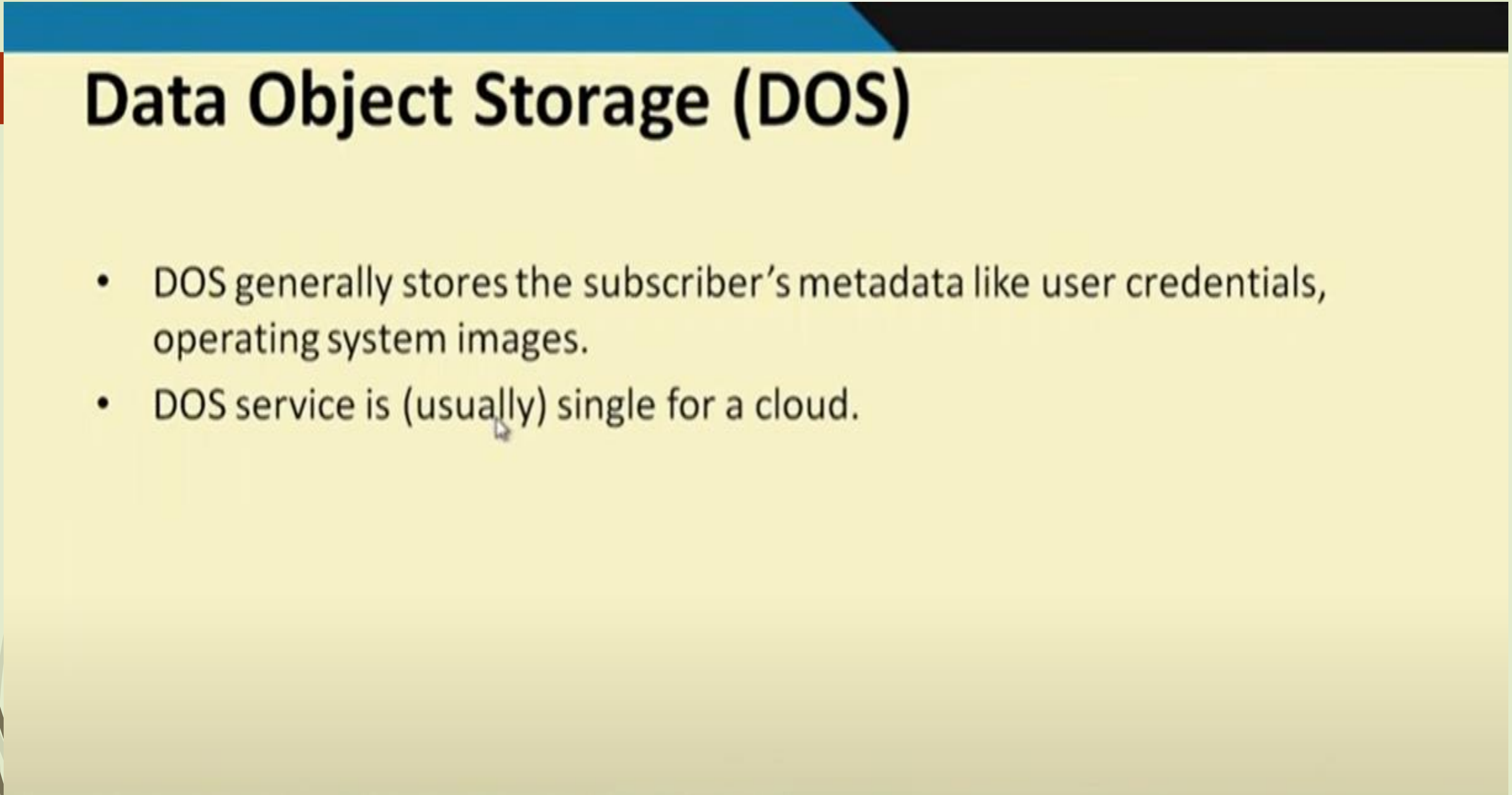
IaaS Cloud Architecture

- Cluster Manager can be geographically distributed
- Within a cluster manger computer manger is connected via high speed network.



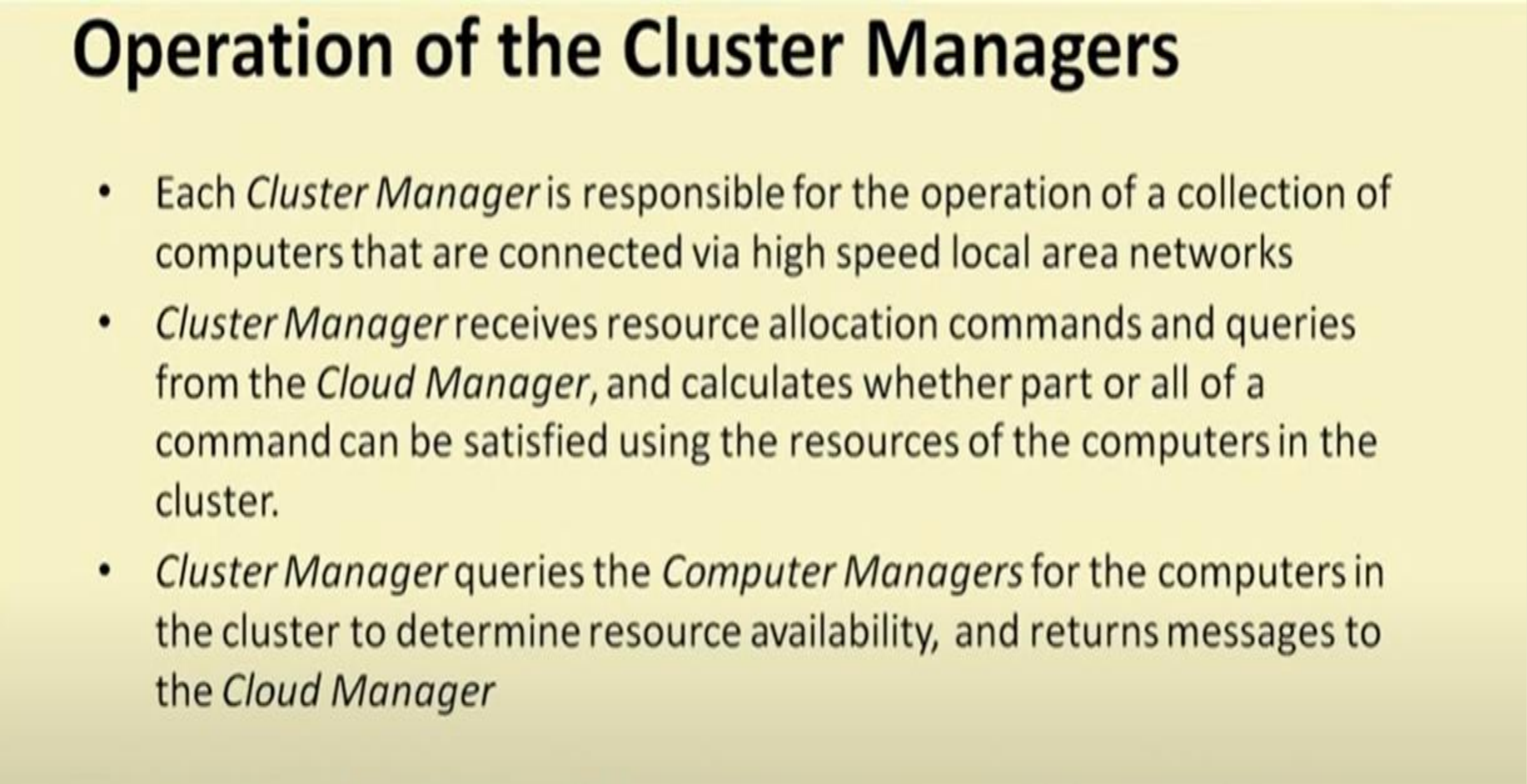
Operation of the Cloud Manager

- Cloud Manager is the public access point to the cloud where subscribers sign up for accounts, manage the resources they rent from the cloud, and access data stored in the cloud.
- Cloud Manager has mechanism for:
  - Authenticating subscribers
  - Generating or validating access credentials that subscriber uses when communicating with VMs.
  - Top-level resource management.
- For a subscriber's request cloud manager determines if the cloud has enough free resources to satisfy the request



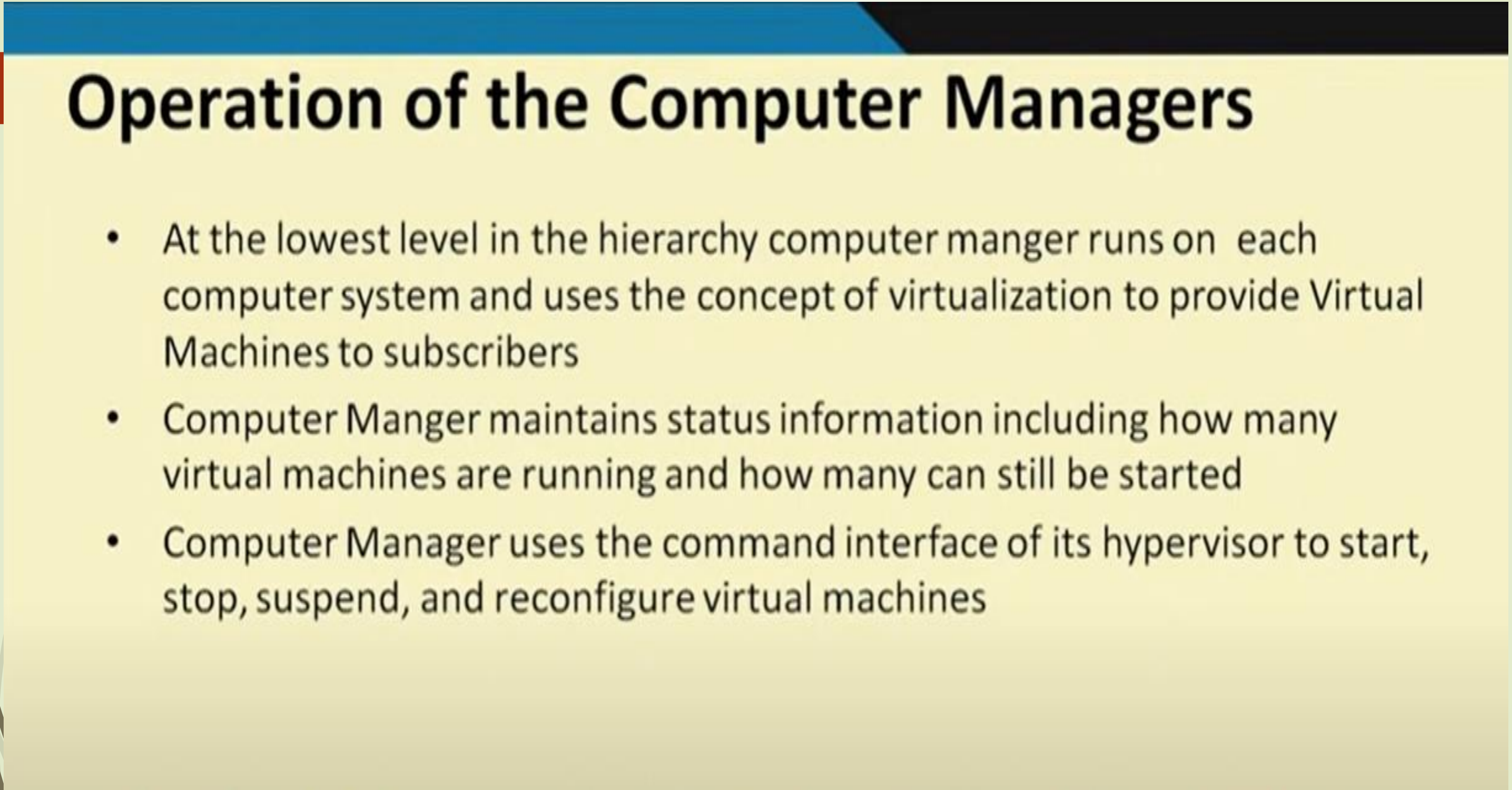
Data Object Storage (DOS)

- DOS generally stores the subscriber's metadata like user credentials, operating system images.
- DOS service is (usually) single for a cloud.



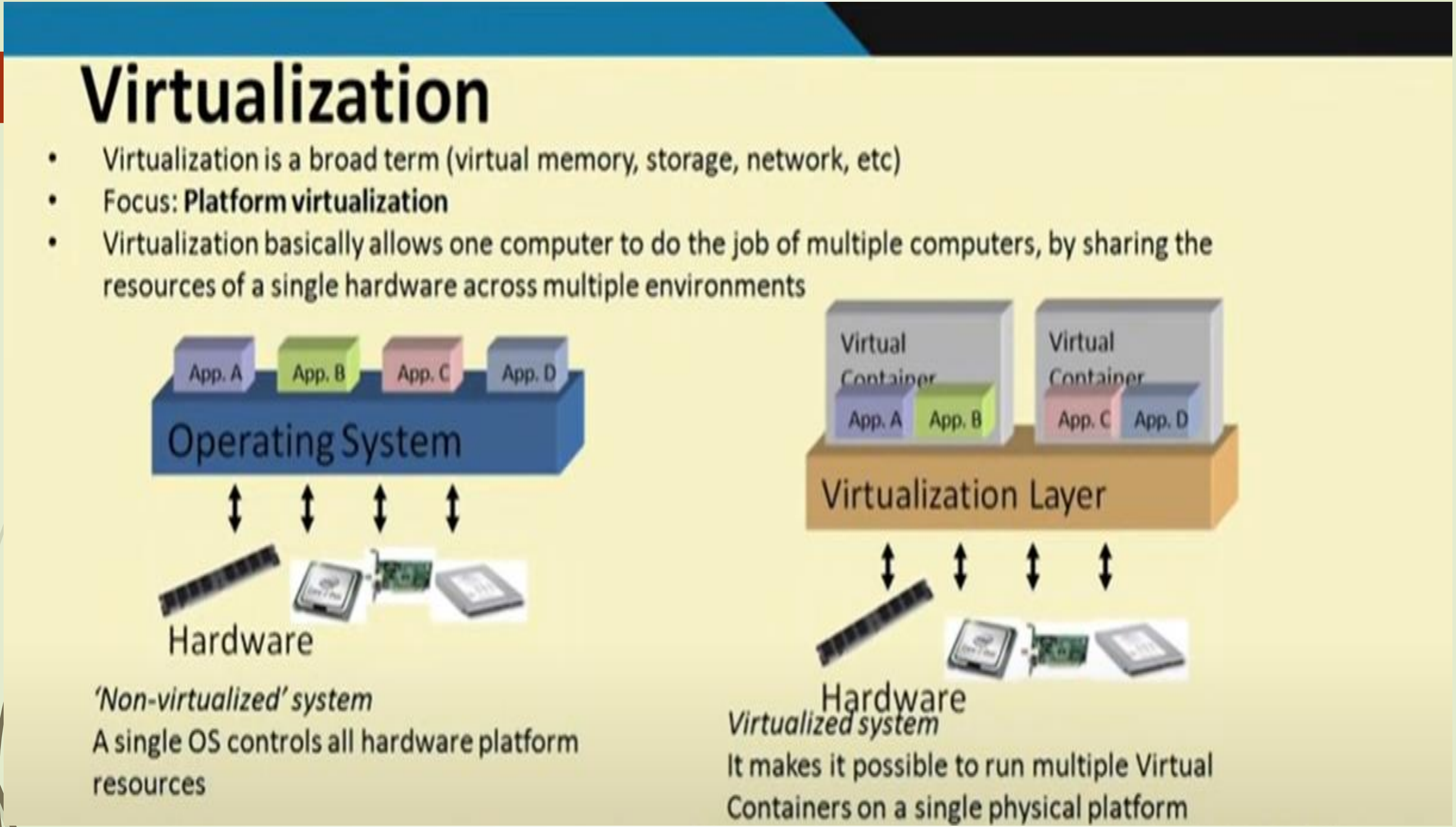
Operation of the Cluster Managers

- Each *Cluster Manager* is responsible for the operation of a collection of computers that are connected via high speed local area networks
- *Cluster Manager* receives resource allocation commands and queries from the *Cloud Manager*, and calculates whether part or all of a command can be satisfied using the resources of the computers in the cluster.
- *Cluster Manager* queries the *Computer Managers* for the computers in the cluster to determine resource availability, and returns messages to the *Cloud Manager*



Operation of the Computer Managers

- At the lowest level in the hierarchy computer manger runs on each computer system and uses the concept of virtualization to provide Virtual Machines to subscribers
- Computer Manger maintains status information including how many virtual machines are running and how many can still be started
- Computer Manager uses the command interface of its hypervisor to start, stop, suspend, and reconfigure virtual machines



Virtualization

- Virtualization is a broad term (virtual memory, storage, network, etc)
- Focus: **Platform virtualization**
- Virtualization basically allows one computer to do the job of multiple computers, by sharing the resources of a single hardware across multiple environments

'Non-virtualized' system

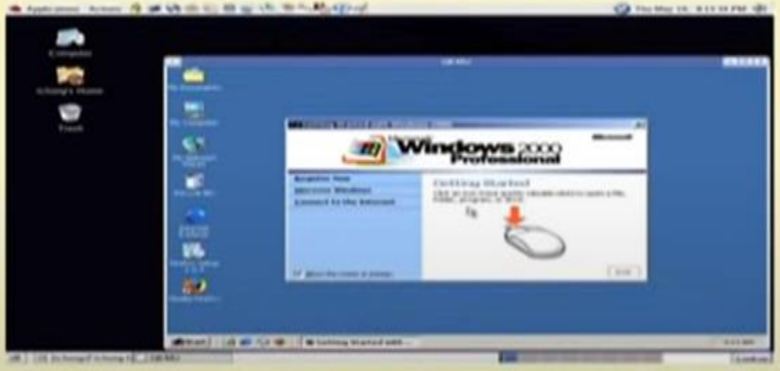
A single OS controls all hardware platform resources

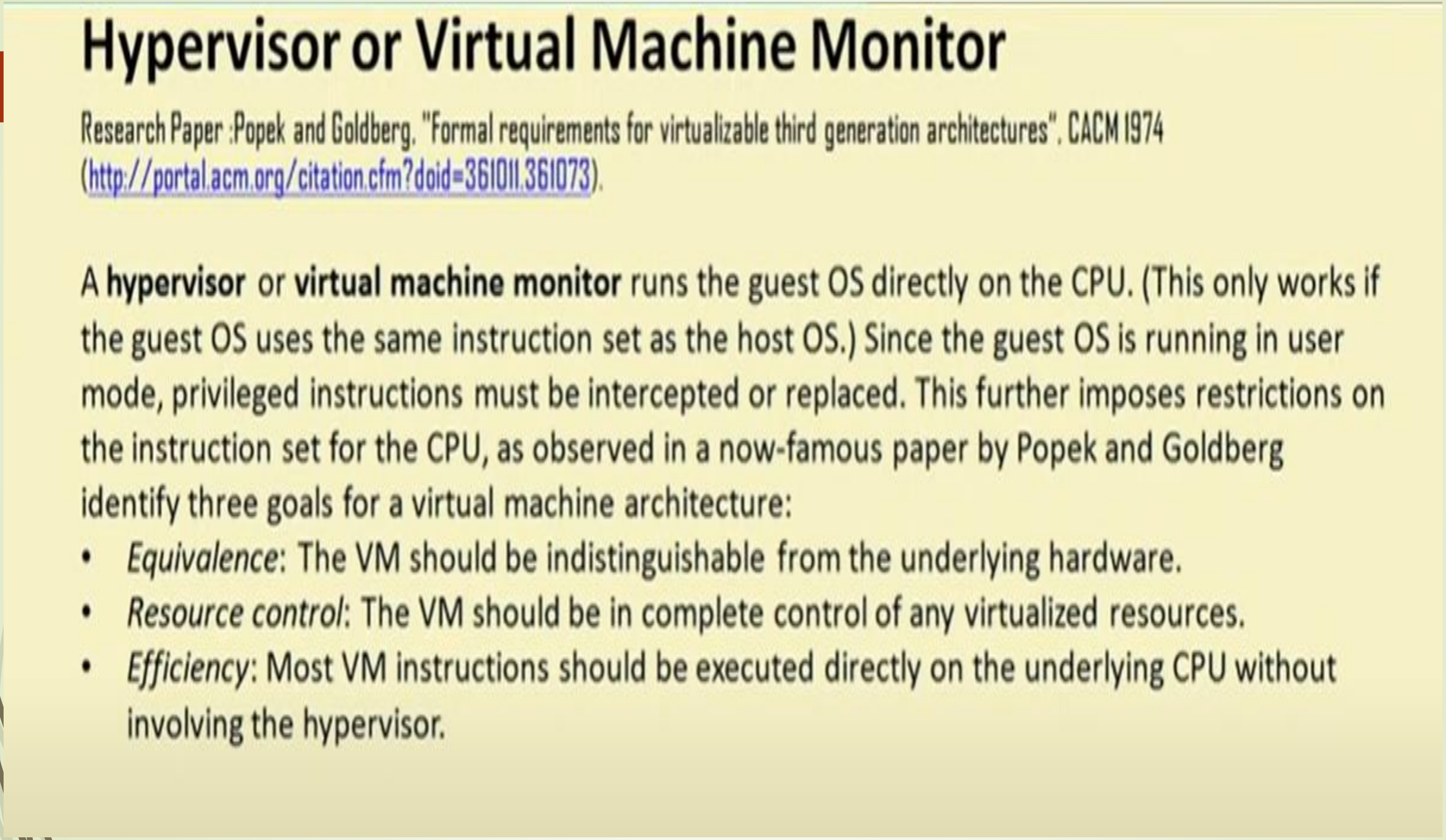
Virtualized system

It makes it possible to run multiple Virtual Containers on a single physical platform

Virtualization

- Virtualization is way to run **multiple operating systems** and **user applications** on the same hardware
  - E.g., run both Windows and Linux on the same laptop
- How is it different from **dual-boot**?
  - Both OSes run **simultaneously**
- The OSes are completely **isolated** from each other



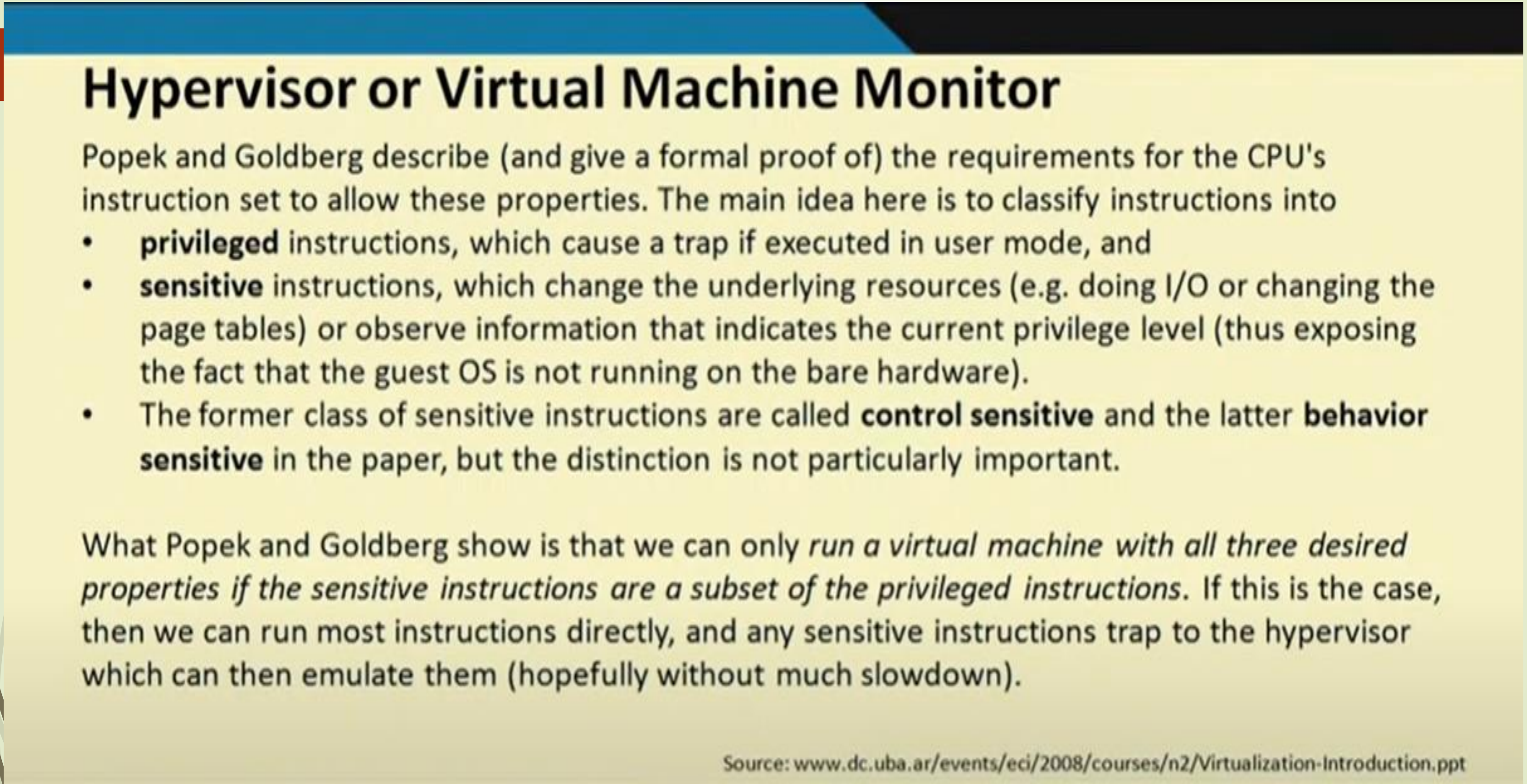


Hypervisor or Virtual Machine Monitor

Research Paper :Popek and Goldberg, "Formal requirements for virtualizable third generation architectures", CACM 1974 (http://portal.acm.org/citation.cfm?doid=361011.361073).

A **hypervisor** or **virtual machine monitor** runs the guest OS directly on the CPU. (This only works if the guest OS uses the same instruction set as the host OS.) Since the guest OS is running in user mode, privileged instructions must be intercepted or replaced. This further imposes restrictions on the instruction set for the CPU, as observed in a now-famous paper by Popek and Goldberg identify three goals for a virtual machine architecture:

- *Equivalence*: The VM should be indistinguishable from the underlying hardware.
- *Resource control*: The VM should be in complete control of any virtualized resources.
- *Efficiency*: Most VM instructions should be executed directly on the underlying CPU without involving the hypervisor.



Hypervisor or Virtual Machine Monitor

Popek and Goldberg describe (and give a formal proof of) the requirements for the CPU's instruction set to allow these properties. The main idea here is to classify instructions into

- **privileged** instructions, which cause a trap if executed in user mode, and
- **sensitive** instructions, which change the underlying resources (e.g. doing I/O or changing the page tables) or observe information that indicates the current privilege level (thus exposing the fact that the guest OS is not running on the bare hardware).
- The former class of sensitive instructions are called **control sensitive** and the latter **behavior sensitive** in the paper, but the distinction is not particularly important.

What Popek and Goldberg show is that we can only *run a virtual machine with all three desired properties if the sensitive instructions are a subset of the privileged instructions*. If this is the case, then we can run most instructions directly, and any sensitive instructions trap to the hypervisor which can then emulate them (hopefully without much slowdown).

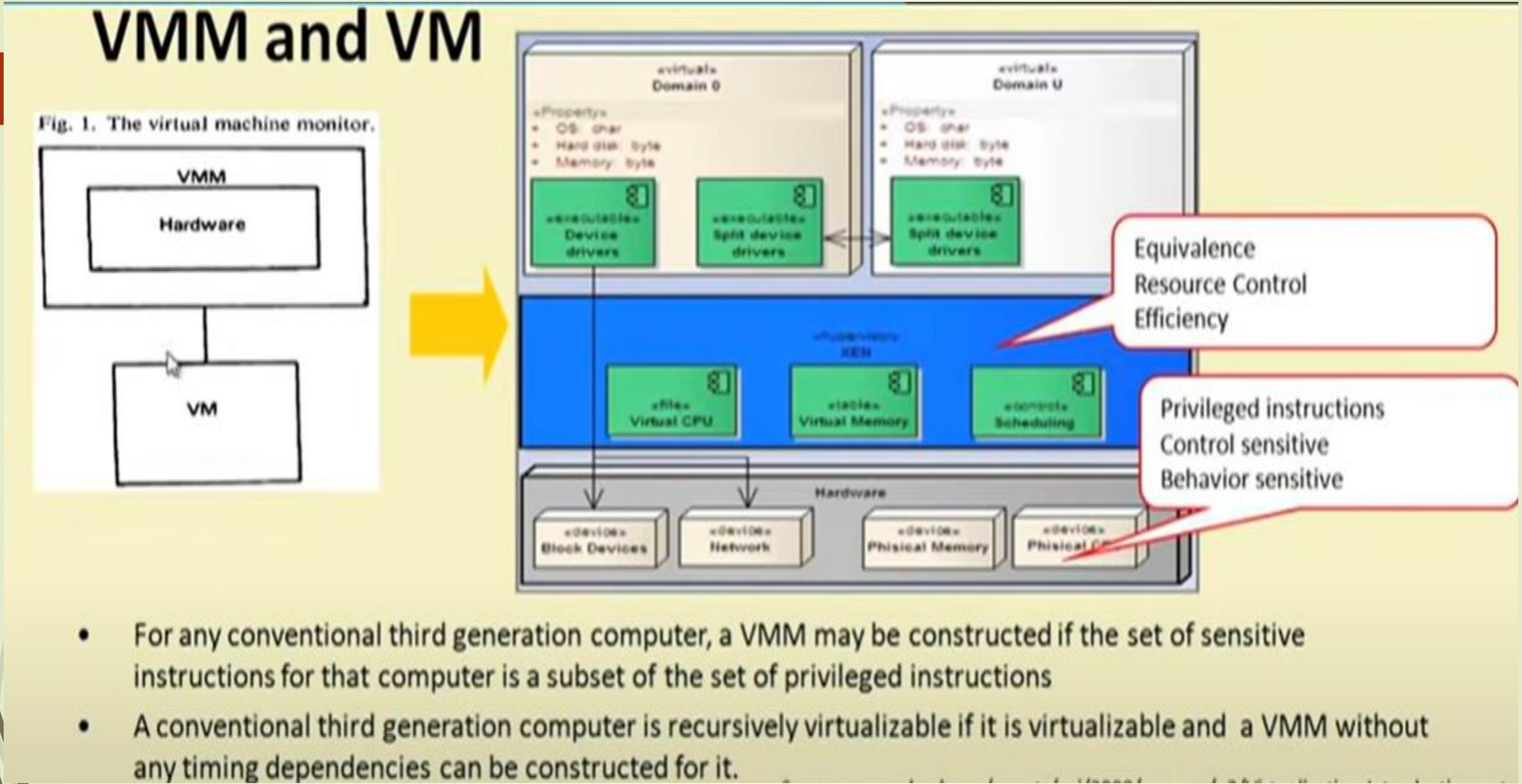
Source: www.dc.uba.ar/events/eci/2008/courses/n2/Virtualization-Introduction.ppt

VMware is defined as a set of software and solutions that help convert the actual computer, server, or pool of similar hardware into several virtual machines that may be used for a variety of tasks.

The term trap refers to a processor's mechanism for capturing an executing thread when an exception or an interrupt occurs and transferring control to a fixed location in the operating system.

A **page table** is a data structure used by a virtual memory system in a computer to store mappings between virtual addresses and physical addresses. Logical addresses are generated by the CPU for the pages of the processes therefore they are generally used by the processes.
Physical addresses are the actual frame address of the memory.

Whatever guest OS is running on the VM, the set of instructions needs to be converted so that they are understood by the hardware.



VMM and VM

Fig. 1. The virtual machine monitor.

Equivalence
Resource Control
Efficiency

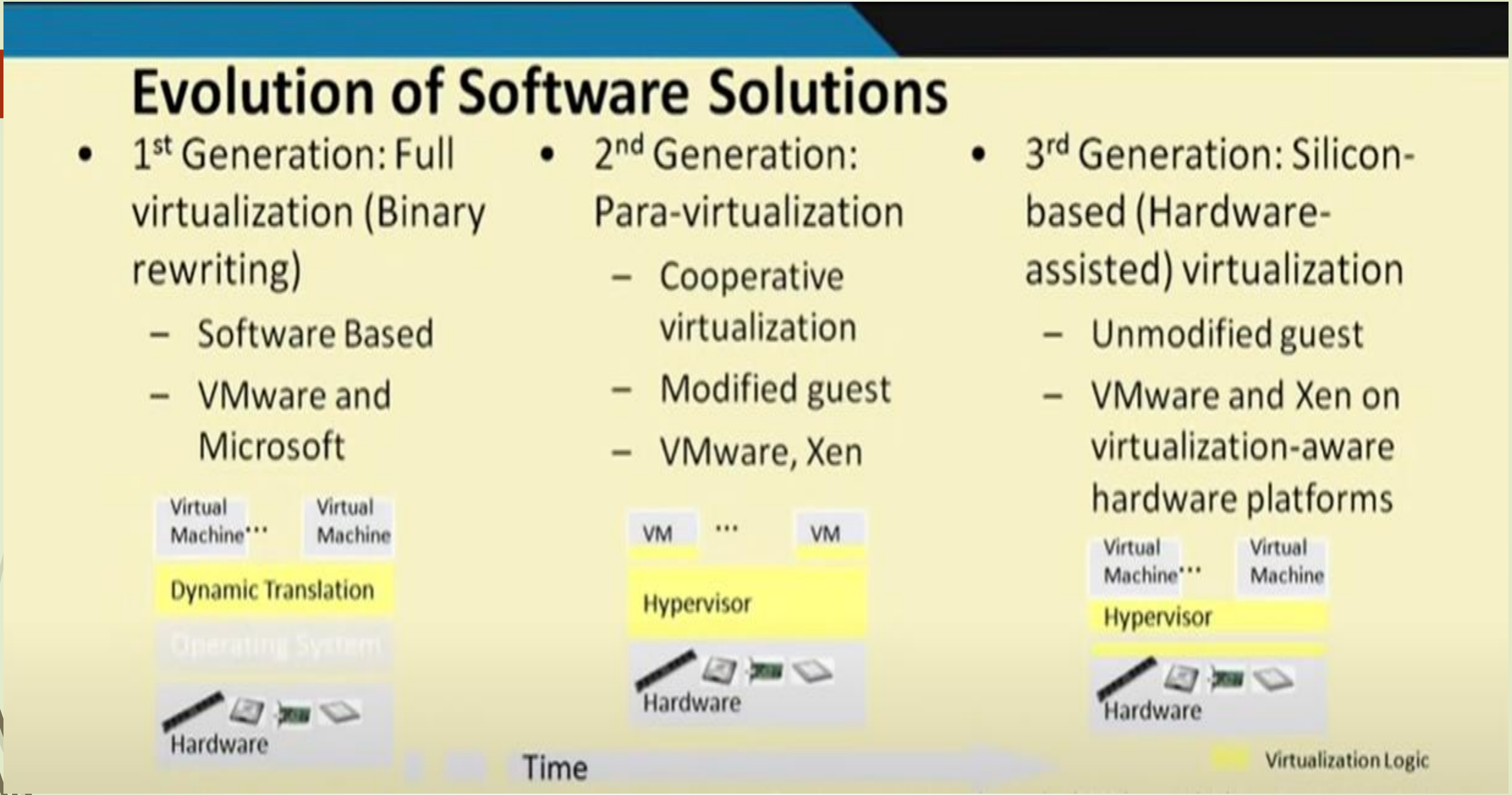
Privileged instructions
Control sensitive
Behavior sensitive

- 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
- A conventional third generation computer is recursively virtualizable if it is virtualizable and a VMM without any timing dependencies can be constructed for it.

Bare metal

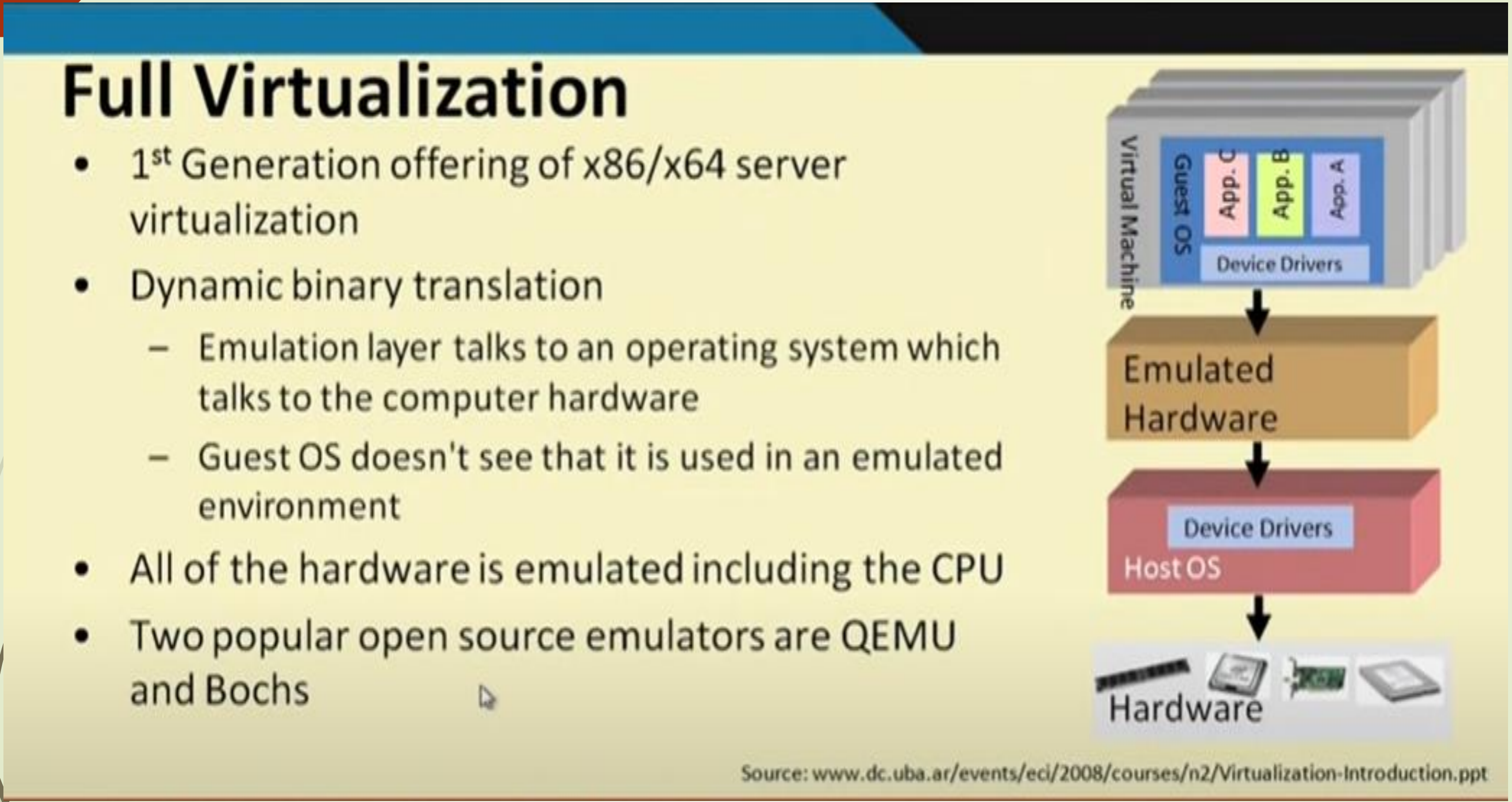
- Bare metal is a term used in enterprise computing environments to distinguish standard and barebone computers
- Bare metal is a computer system without a base operating system (OS) or installed applications.
- It is a computer’s hardware assembly, structure and components that is installed with either the firmware or basic input/output system (BIOS) software utility or no software at all.
- Typically, a computer shipped from a manufacturer is in a bare metal state and though installed software is not included, the computer contains essential hardware components, such as processors, motherboards, hard disks and network cards.
- A user accesses the mounted firmware/BIOS to operate the computer and install a preferred operating system (OS).
- If the firmware or BIOS utility are not available, they are installed with external storage sources, such as serial, parallel, Universal Serial Bus (USB) and optical storage devices.

Approaches to Server Virtualization



Evolution of Software Solutions

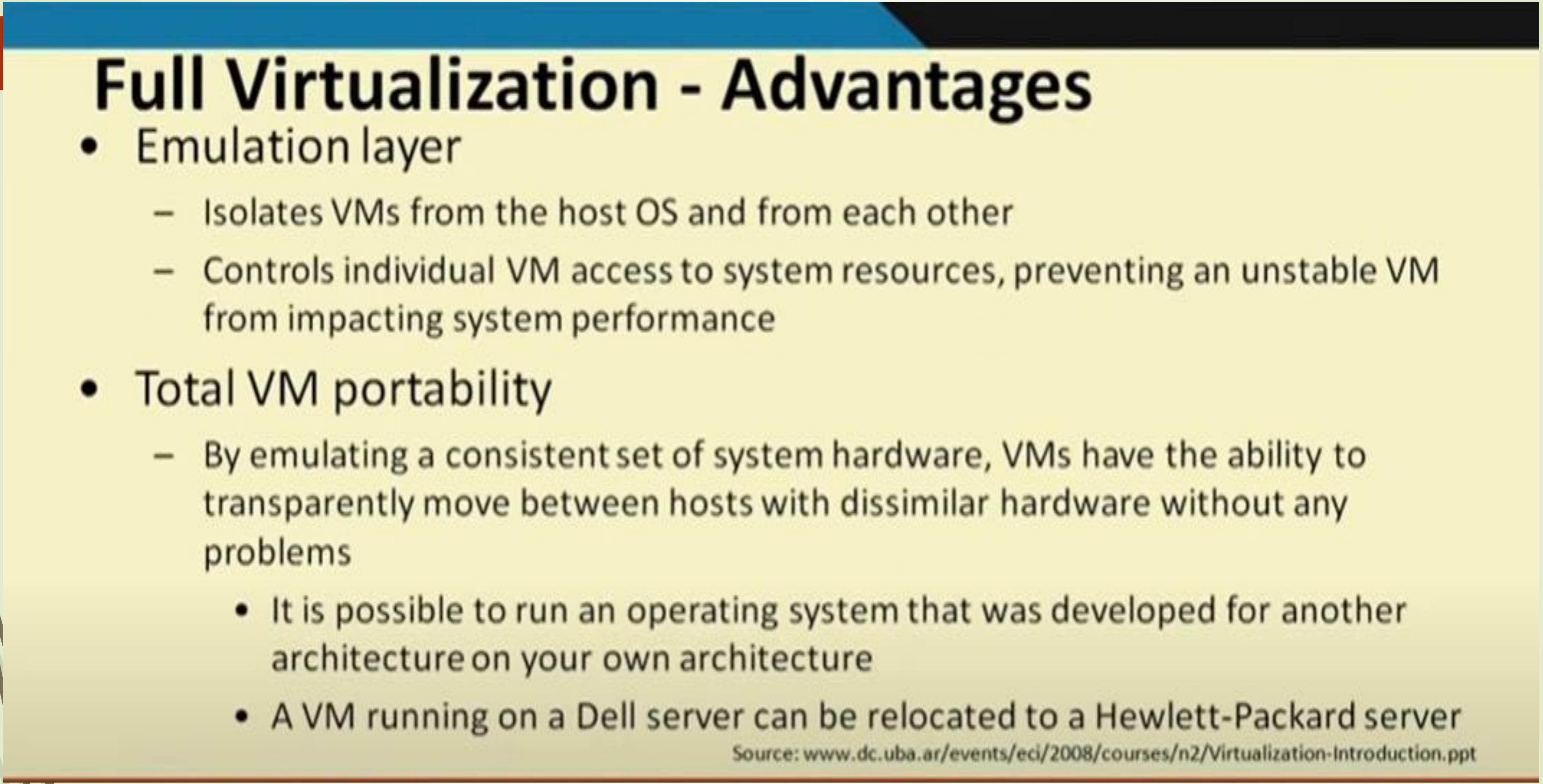
- 1st Generation: Full virtualization (Binary rewriting)
  - Software Based
  - VMware and Microsoft
- 2nd Generation: Para-virtualization
  - Cooperative virtualization
  - Modified guest
  - VMware, Xen
- 3rd Generation: Silicon-based (Hardware-assisted) virtualization
  - Unmodified guest
  - VMware and Xen on virtualization-aware hardware platforms



Full Virtualization

- 1st Generation offering of x86/x64 server virtualization
- Dynamic binary translation
  - Emulation layer talks to an operating system which talks to the computer hardware
  - Guest OS doesn't see that it is used in an emulated environment
- All of the hardware is emulated including the CPU
- Two popular open source emulators are QEMU and Bochs

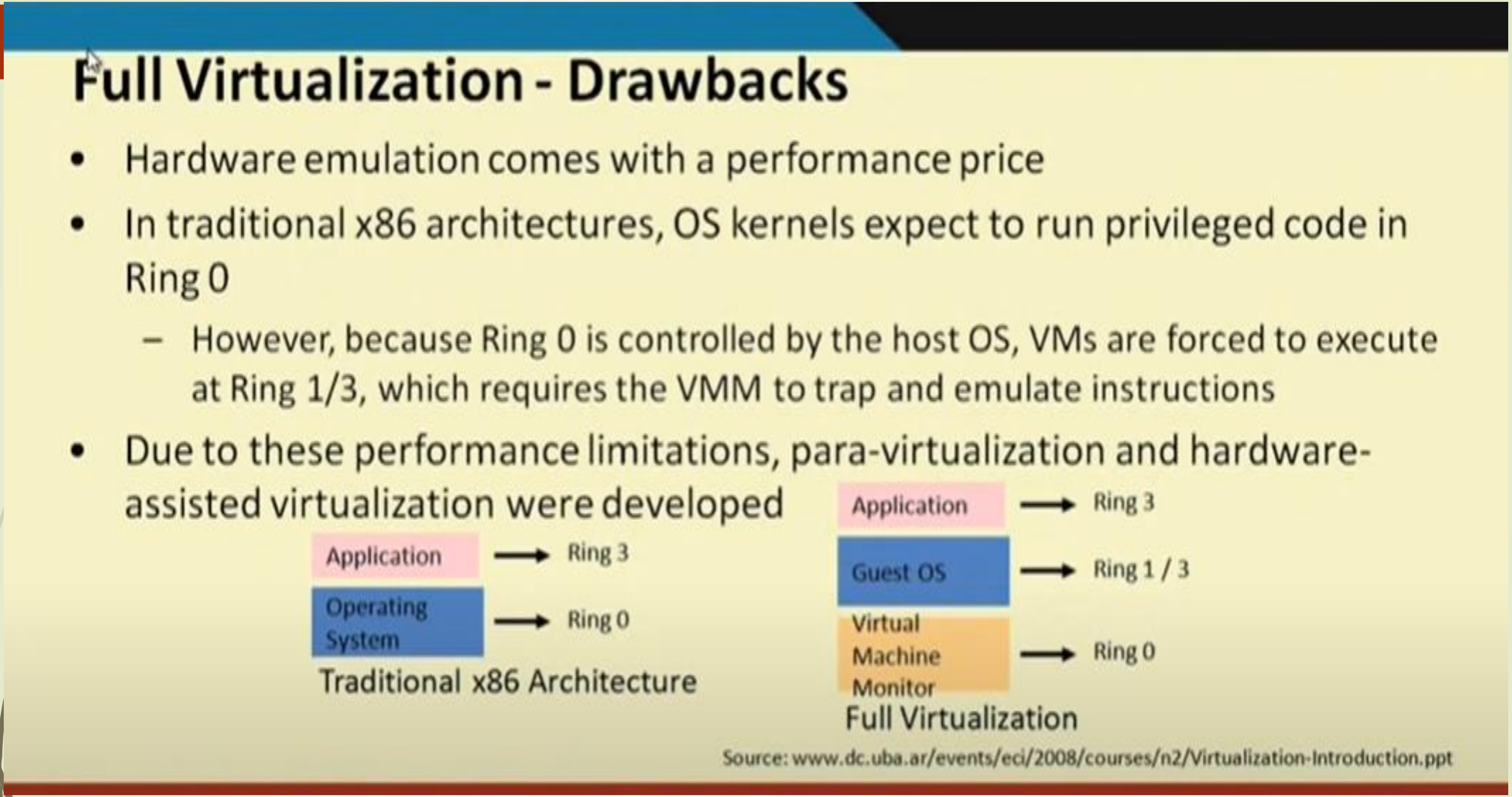
Source: www.dc.uba.ar/events/eci/2008/courses/n2/Virtualization-Introduction.ppt



Full Virtualization - Advantages

- Emulation layer
  - Isolates VMs from the host OS and from each other
  - Controls individual VM access to system resources, preventing an unstable VM from impacting system performance
- Total VM portability
  - By emulating a consistent set of system hardware, VMs have the ability to transparently move between hosts with dissimilar hardware without any problems
    - It is possible to run an operating system that was developed for another architecture on your own architecture
    - A VM running on a Dell server can be relocated to a Hewlett-Packard server

Source: www.dc.uba.ar/events/eci/2008/courses/n2/Virtualization-Introduction.ppt



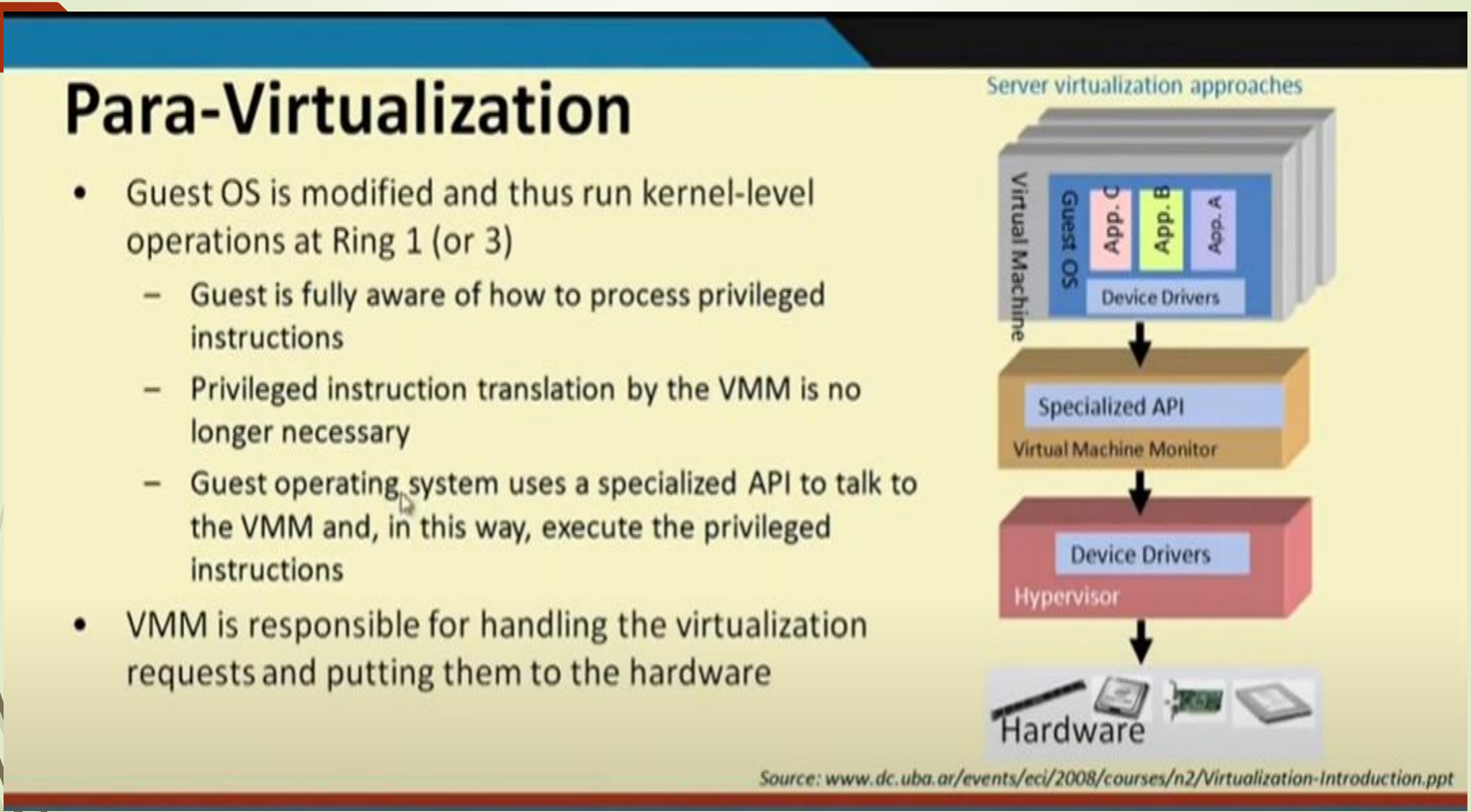
Full Virtualization - Drawbacks

- Hardware emulation comes with a performance price
- In traditional x86 architectures, OS kernels expect to run privileged code in Ring 0
  - However, because Ring 0 is controlled by the host OS, VMs are forced to execute at Ring 1/3, which requires the VMM to trap and emulate instructions
- Due to these performance limitations, para-virtualization and hardware-assisted virtualization were developed

Traditional x86 Architecture

Full Virtualization

Source: www.dc.uba.ar/events/eci/2008/courses/n2/Virtualization-Introduction.ppt

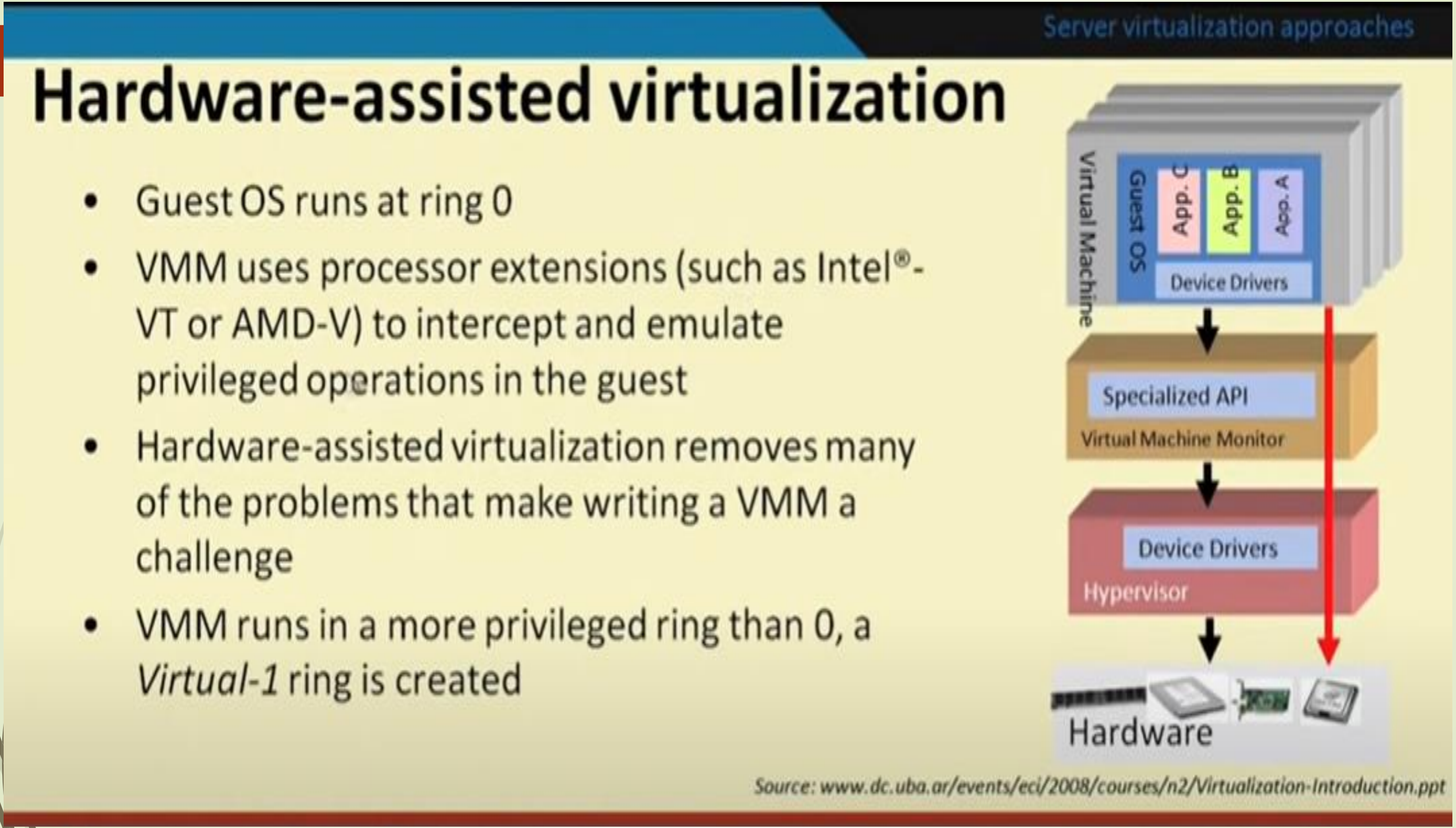


Para-Virtualization

- Guest OS is modified and thus run kernel-level operations at Ring 1 (or 3)
  - Guest is fully aware of how to process privileged instructions
  - Privileged instruction translation by the VMM is no longer necessary
  - Guest operating system uses a specialized API to talk to the VMM and, in this way, execute the privileged instructions
- VMM is responsible for handling the virtualization requests and putting them to the hardware

Server virtualization approaches

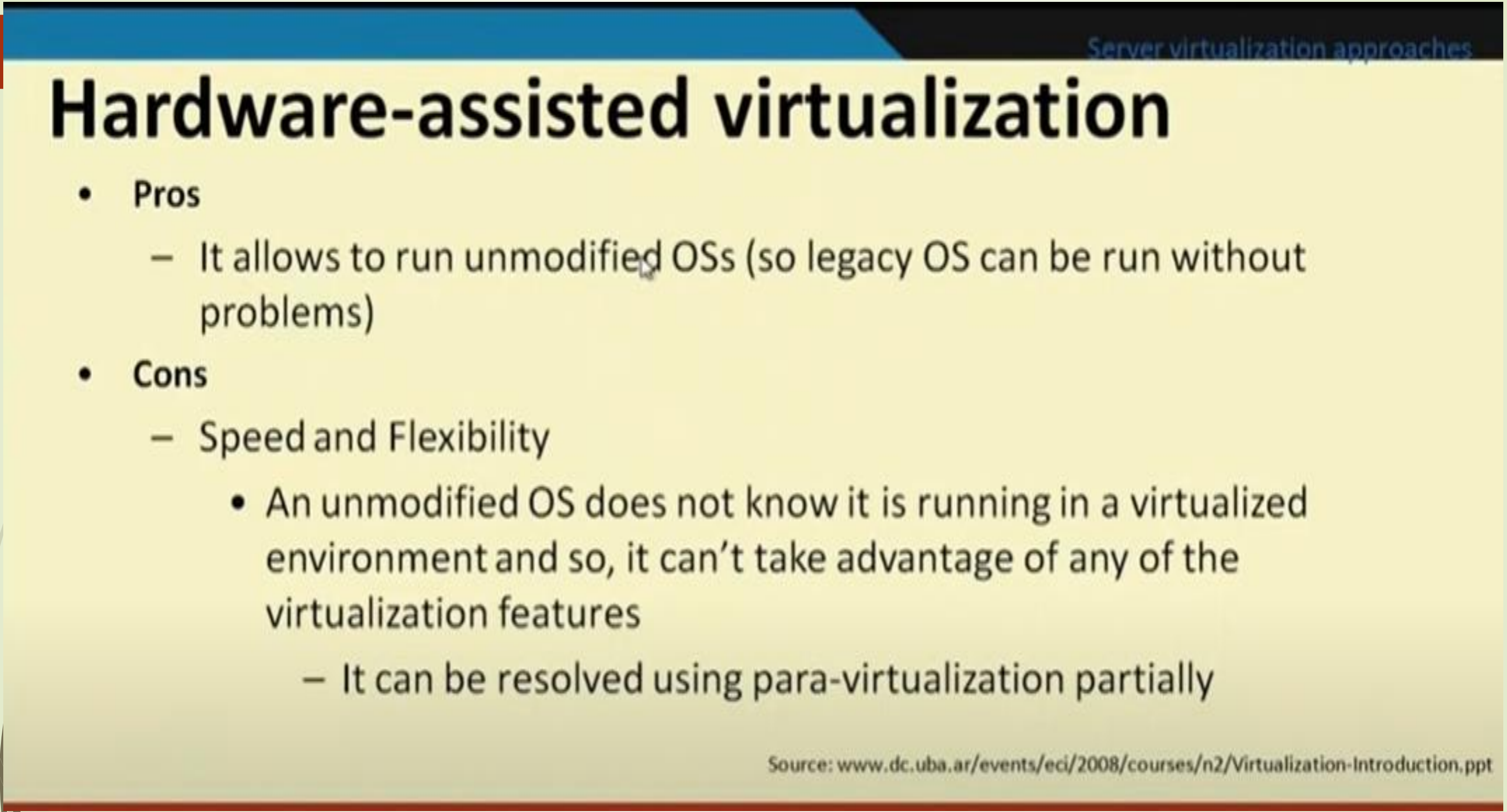
Source: www.dc.uba.ar/events/eci/2008/courses/n2/Virtualization-Introduction.ppt



Hardware-assisted virtualization

- Guest OS runs at ring 0
- VMM uses processor extensions (such as Intel®-VT or AMD-V) to intercept and emulate privileged operations in the guest
- Hardware-assisted virtualization removes many of the problems that make writing a VMM a challenge
- VMM runs in a more privileged ring than 0, a *Virtual-1* ring is created

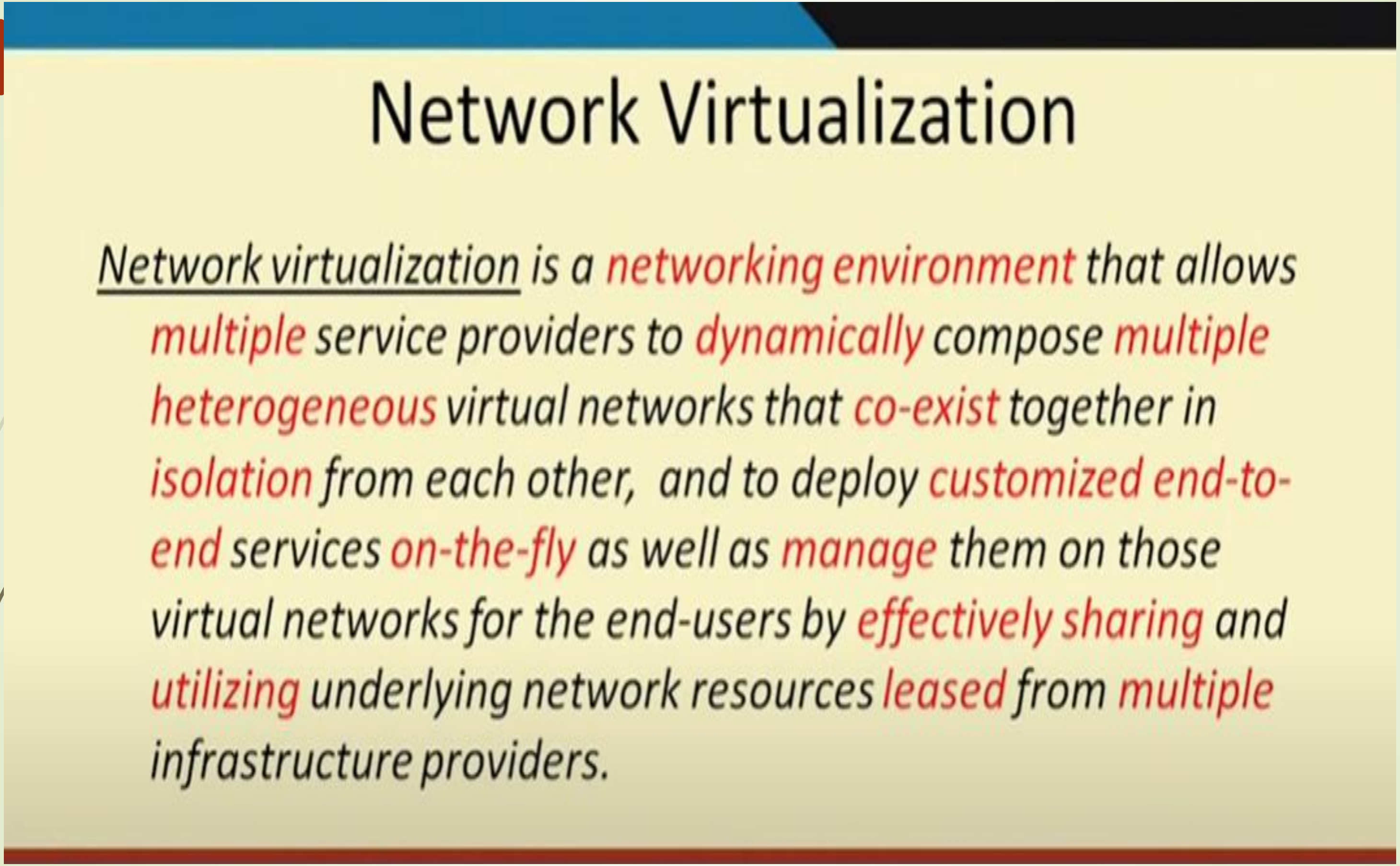
Source: www.dc.uba.ar/events/eci/2008/courses/n2/Virtualization-Introduction.ppt



Hardware-assisted virtualization

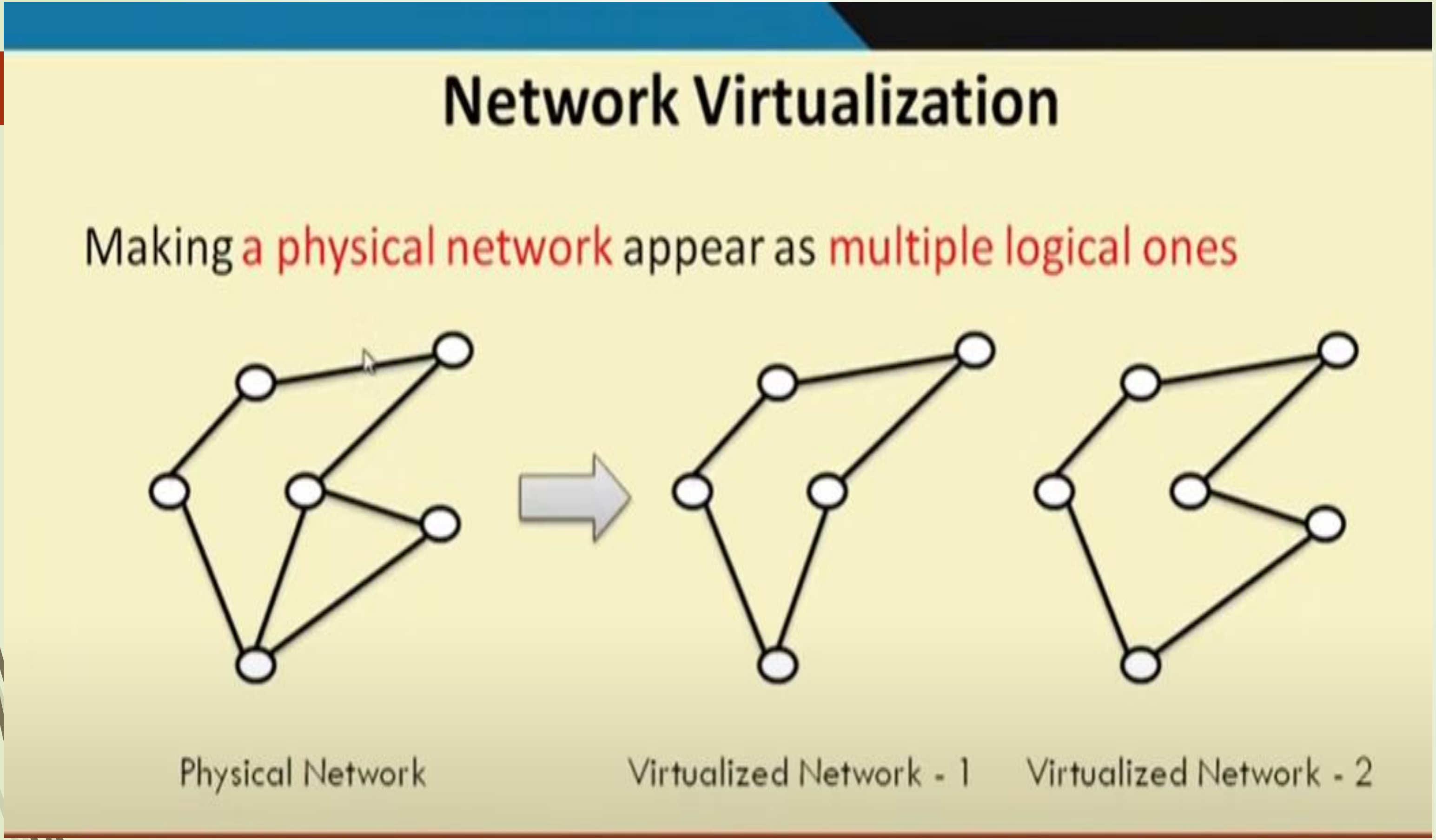
- **Pros**
  - It allows to run unmodified OSs (so legacy OS can be run without problems)
- **Cons**
  - Speed and Flexibility
    - An unmodified OS does not know it is running in a virtualized environment and so, it can't take advantage of any of the virtualization features
      - It can be resolved using para-virtualization partially

Source: www.dc.uba.ar/events/eci/2008/courses/n2/Virtualization-Introduction.ppt



Network Virtualization

Network virtualization is a networking environment that allows multiple service providers to dynamically compose multiple heterogeneous virtual networks that co-exist together in isolation from each other, and to deploy customized end-to-end services on-the-fly as well as manage them on those virtual networks for the end-users by effectively sharing and utilizing underlying network resources leased from multiple infrastructure providers.



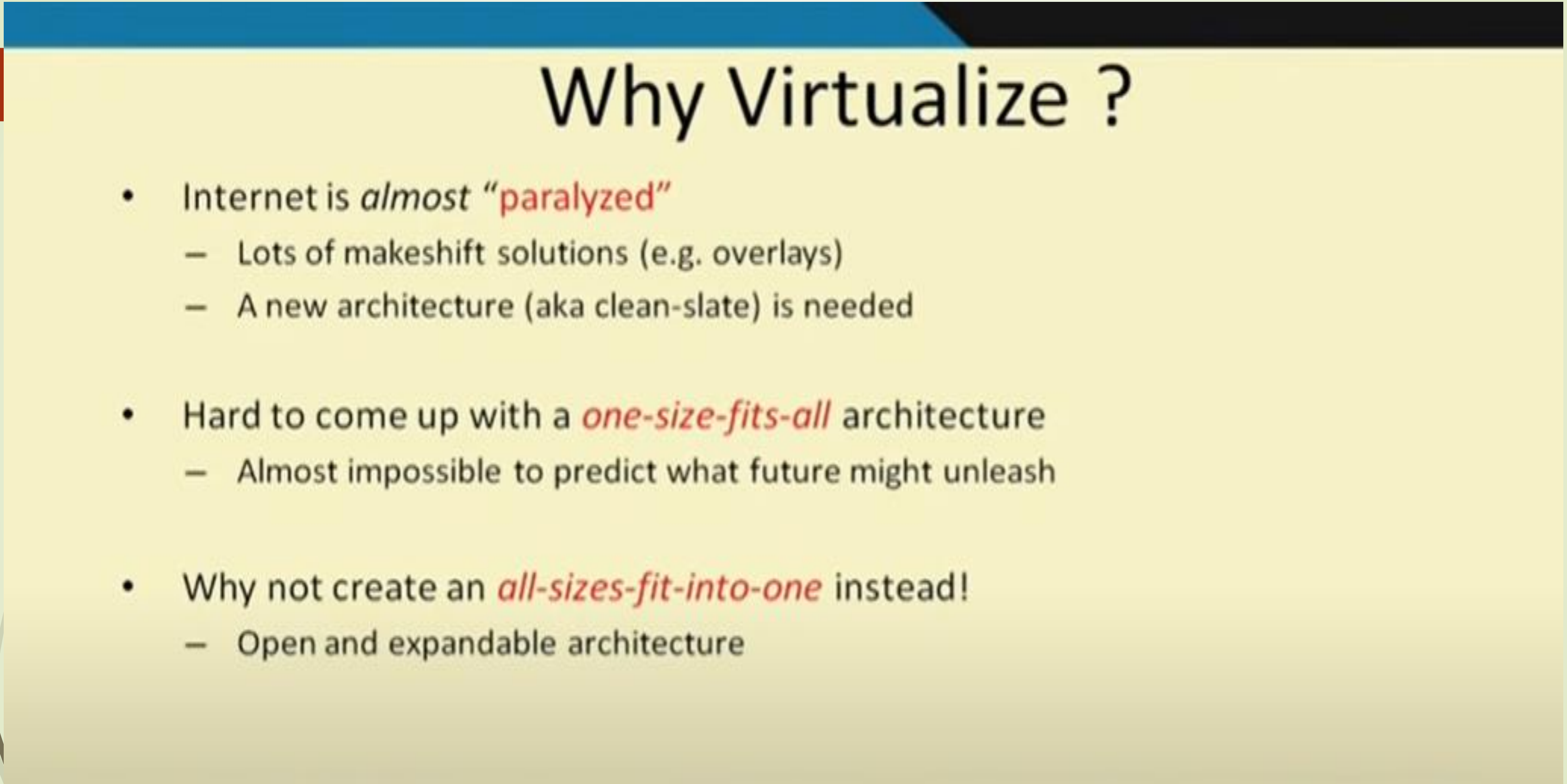
Network Virtualization

Making a physical network appear as multiple logical ones

Physical Network

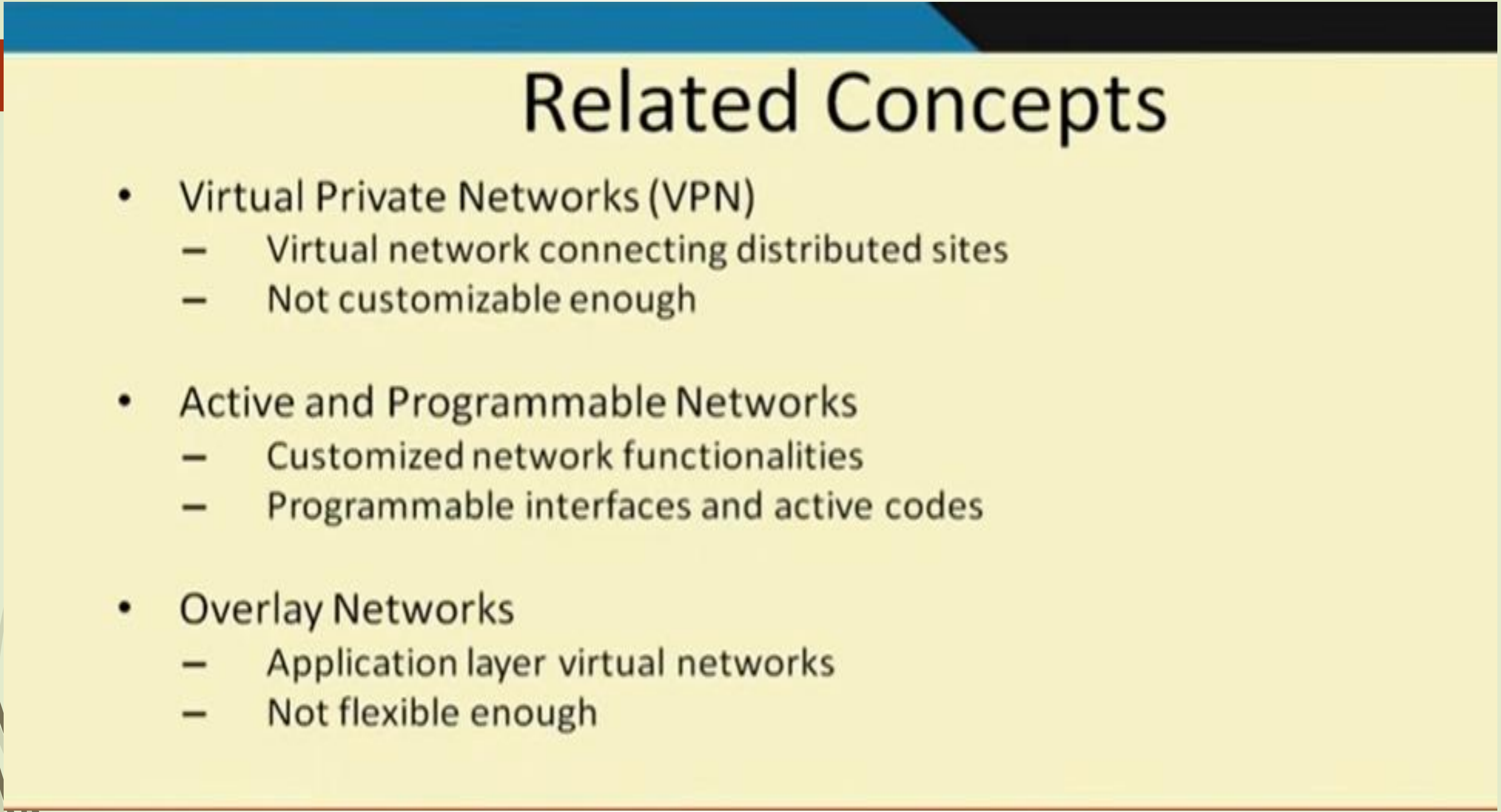
Virtualized Network - 1

Virtualized Network - 2



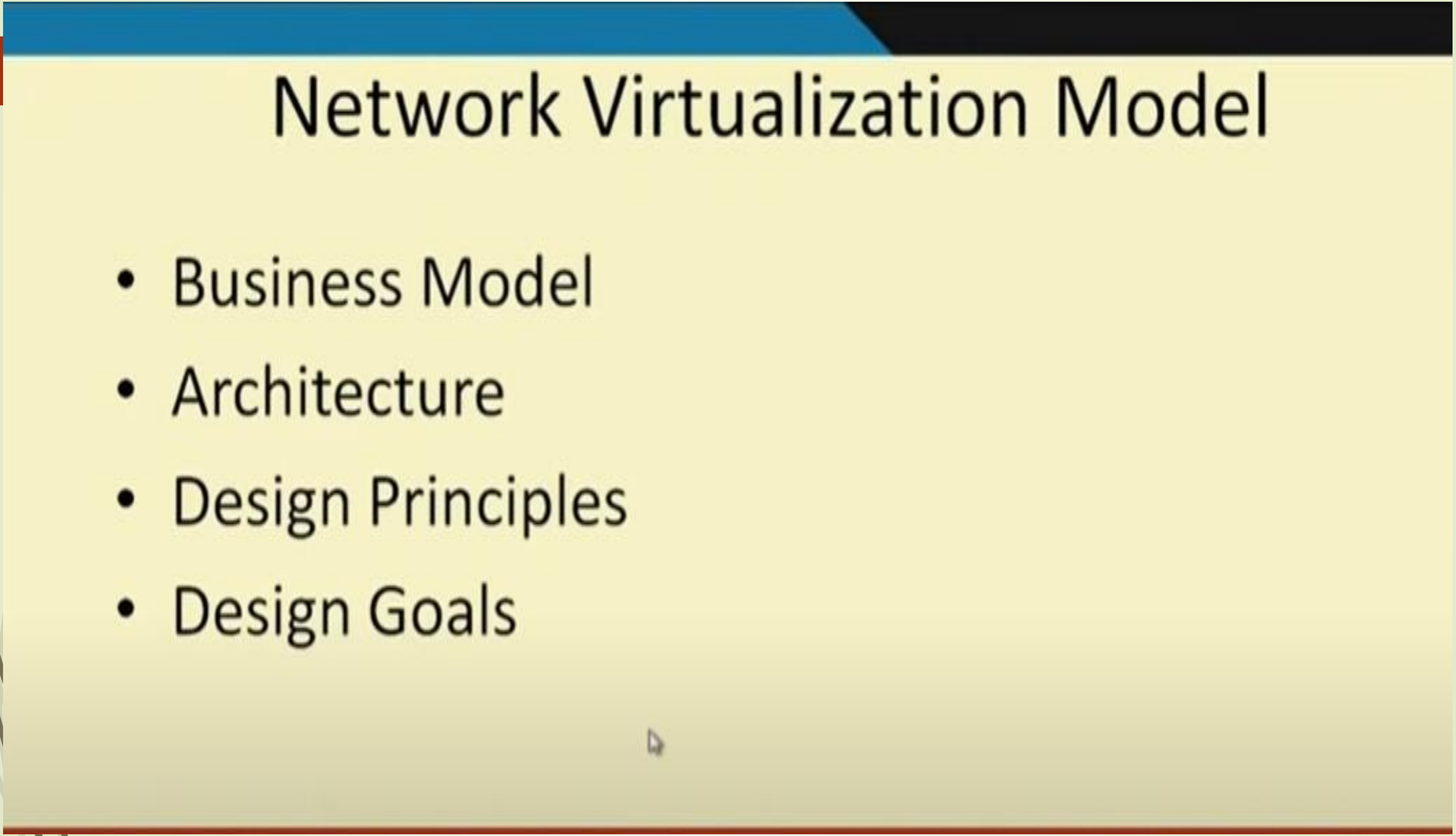
Why Virtualize ?

- Internet is *almost* “paralyzed”
  - Lots of makeshift solutions (e.g. overlays)
  - A new architecture (aka clean-slate) is needed
- Hard to come up with a *one-size-fits-all* architecture
  - Almost impossible to predict what future might unleash
- Why not create an *all-sizes-fit-into-one* instead!
  - Open and expandable architecture



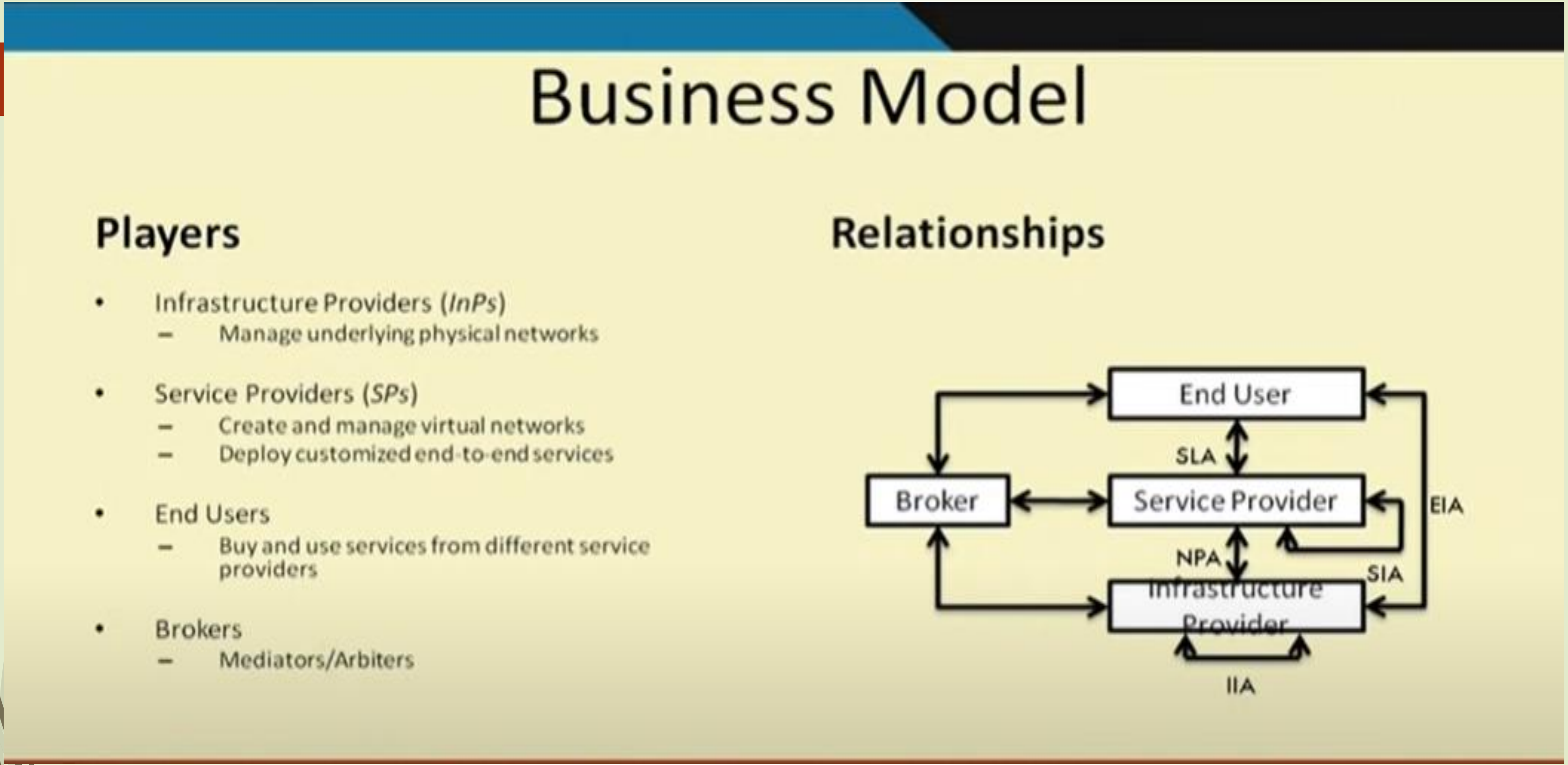
Related Concepts

- Virtual Private Networks (VPN)
  - Virtual network connecting distributed sites
  - Not customizable enough
- Active and Programmable Networks
  - Customized network functionalities
  - Programmable interfaces and active codes
- Overlay Networks
  - Application layer virtual networks
  - Not flexible enough



Network Virtualization Model

- Business Model
- Architecture
- Design Principles
- Design Goals



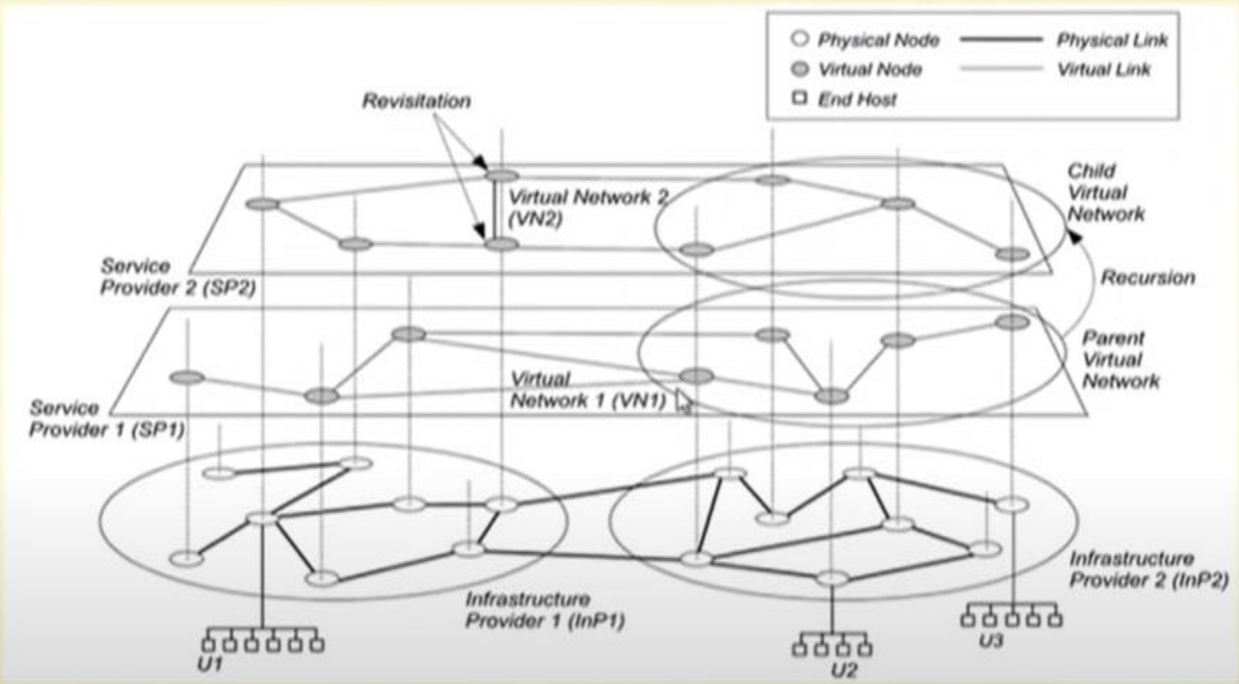
Business Model

Players

- Infrastructure Providers (*InPs*)
  - Manage underlying physical networks
- Service Providers (*SPs*)
  - Create and manage virtual networks
  - Deploy customized end-to-end services
- End Users
  - Buy and use services from different service providers
- Brokers
  - Mediators/Arbiters

Relationships

Architecture



Web Services, Service Oriented Architecture

What are "Web Services"?

"Software application identified by a URI, whose interfaces and bindings are capable of being defined, described, and discovered as XML artifacts" – W3C Web Services Architecture Requirements, Oct. 2002

"Programmable application logic accessible using Standard Internet Protocols…" – Microsoft

"An interface that describes a collection of operations that are network accessible through standardized XML messaging … " – IBM

"Software components that can be spontaneously discovered, combined, and recombined to provide a solution to the user's problem/request … " - SUN

- A Uniform Resource Identifier (URI) is a unique sequence of characters that identifies a logical or physical resource used by web technologies. URIs may be used to identify anything, including real-world objects, such as people and places, concepts, or information resources such as web pages and books.
- Common Object Request Broker Architecture: CORBA
- Distributed Computing Environment: DCE
- Remote Method Invocation: RMI
- Simple Mail Transfer Protocol: SMTP

History!

- Structured programming
- Object-oriented programming
- Distributed computing
- Electronic Data Interchange (EDI)
- World Wide Web
- Web Services

Distributed Computing

- When developers create substantial applications, often it is more efficient, or even necessary, for different task to be performed on different computers, called N-tier applications:
  - A 3-tier application might have a user interface on one computer, business-logic processing on a second and a database on a third – all interacting as the application runs.
- For distributed applications to function correctly, application components, e.g. programming objects, executing on different computers throughout a network must be able to communicate.

E.g.: DCE, CORBA, DCOM, RMI etc.

- Interoperability:
  - Ability to communicate and share data with software from different vendors and platforms
  - Limited among conventional proprietary distributed computing technologies

Electronic Data Interchange (EDI)

- Computer-to-computer exchange of business data and documents between companies using standard formats recognized both nationally and internationally.
- The information used in EDI is organized according to a specified format set by both companies participating in the data exchange.
- Advantages:
  - Lower operating costs
    - Saves time and money
  - Less Errors => More Accuracy
    - No data entry, so less human error
  - Increased Productivity
    - More efficient personnel and faster throughput
  - Faster trading cycle
    - Streamlined processes for improved trading relationships

Web Services

- Take advantage of OOP by enabling developers to build applications from existing software components in a modular approach:
  - Transform a network (e.g. the Internet) into one library of programmatic components available to developers to have significant productivity gains.
- Improve distributed computing interoperability by using open (non-proprietary) standards that can enable (theoretically) any two software components to communicate:
  - Also they are easier to debug because they are text-based, rather than binary, communication protocols

Web Services *(contd…)*

- Provide capabilities similar to those of EDI (Electronic Data Interchange), but are simpler and less expensive to implement.
- Configured to work with EDI systems, allowing organisations to use the two technologies together or to phase out EDI while adopting Web services.
- Unlike WWW
  - Separates visual from non-visual components
  - Interactions may be either through the browser or through a desktop client (Java Swing, Python, Windows, etc.)

Web Services *(contd…)*

- Intended to solve *three* problems:
  - **Interoperability**:
    - Lack of interoperability standards in distributed object messaging
    - DCOM apps strictly bound to Windows Operating system
    - RMI bound to Java programming language
  - **Firewall traversal**:
    - CORBA and DCOM used non-standard ports
    - Web Services use HTTP; most firewalls allow access though port 80 (HTTP), leading to easier and dynamic collaboration
  - **Complexity**:
    - Web Services: developer-friendly service system
    - Use open, text-based standards, which allow components written in different languages and for different platforms to communicate
    - Implemented incrementally, rather than all at once which lessens the cost and reduces the organisational disruption from an abrupt switch in technologies

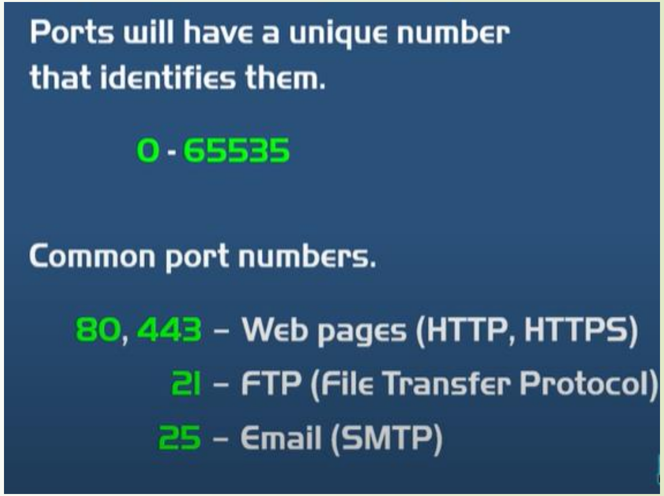
Firewall traversal

- Firewall traversal refers to a strategy of bypassing firewalls which are commonly used to block access to certain sites and communication protocols.
- Firewalls are an essential line of defense for personal computers and corporate networks, but many times they need to be bypassed.

- A port is a virtual point where network connections start and end.
- Ports are software-based and managed by a computer's operating system.

- Each port is associated with a specific process or service. Ports allow computers to easily differentiate between different kinds of traffic: emails go to a different port than webpages, for instance, even though both reach a computer over the same Internet connection.

- A non-standard port is one that which is used for a purpose other than its default assignment. example= instead of port 80 using web traffic, using port 8080.



Ports will have a unique number that identifies them.

0 - 65535

Common port numbers.

80, 443 – Web pages (HTTP, HTTPS)

21 – FTP (File Transfer Protocol)

25 – Email (SMTP)

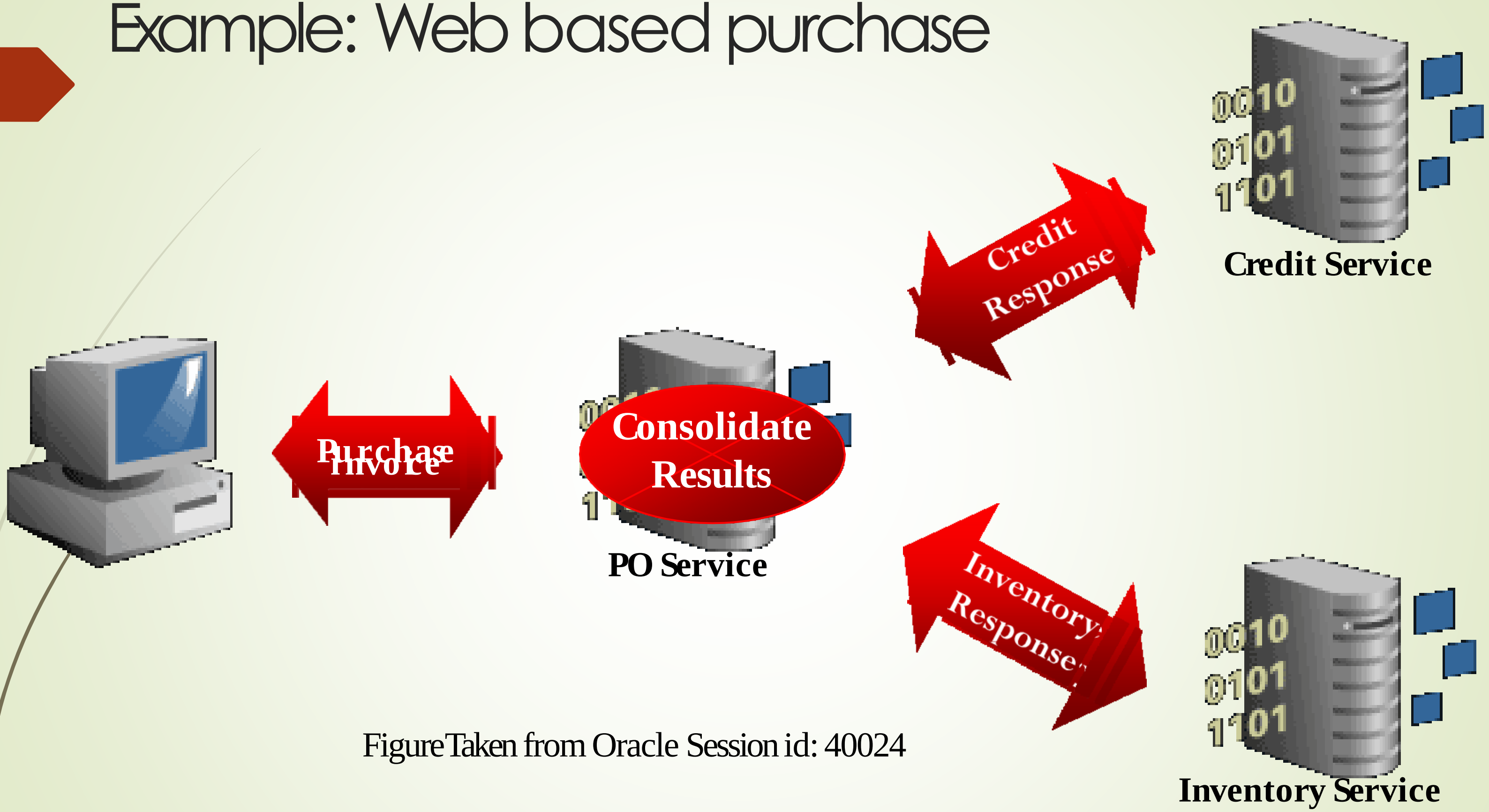
- The TCP protocol provides 16 bits for the port number, and this is interpreted as an unsigned integer; all values are valid, apart from 0, and so the largest port number is (2^16 - 1) or 65,535.
- Some attackers try to send malicious traffic to random ports in the hopes that those ports have been left "open," meaning they are able to receive traffic.
- This action is somewhat like a car thief walking down the street and trying the doors of parked vehicles, hoping one of them is unlocked.
- For this reason, firewalls should be configured to block network traffic directed at most of the available ports. There is no legitimate reason for the vast majority of the available ports to receive traffic.
- Properly configured firewalls block traffic to all ports by default except for a few predetermined ports known to be in common use.
- For instance, a corporate firewall could only leave open ports 25 (email), 80 (web traffic), 443 (web traffic), and a few others, allowing internal employees to use these essential services, then block the rest of the 65,000+ ports.
- As a more specific example, attackers sometimes attempt to exploit vulnerabilities in the RDP protocol by sending attack traffic to port 3389.
- To stop these attacks, a firewall may block port 3389 by default.
- Since this port is only used for remote desktop connections, such a rule has little impact on day-to-day business operations unless employees need to work remotely.

- UDDI stands for Universal Description, Discovery, and Integration. UDDI is a specification for a distributed registry of web services. UDDI is a platform-independent, open framework. UDDI can communicate via SOAP, CORBA, Java RMI Protocol.
- Web Services Description Language (WSDL) is a standard specification for describing networked, XML-based services. It provides a simple way for service providers to describe the basic format of requests to their systems regardless of the underlying run-time implementation.

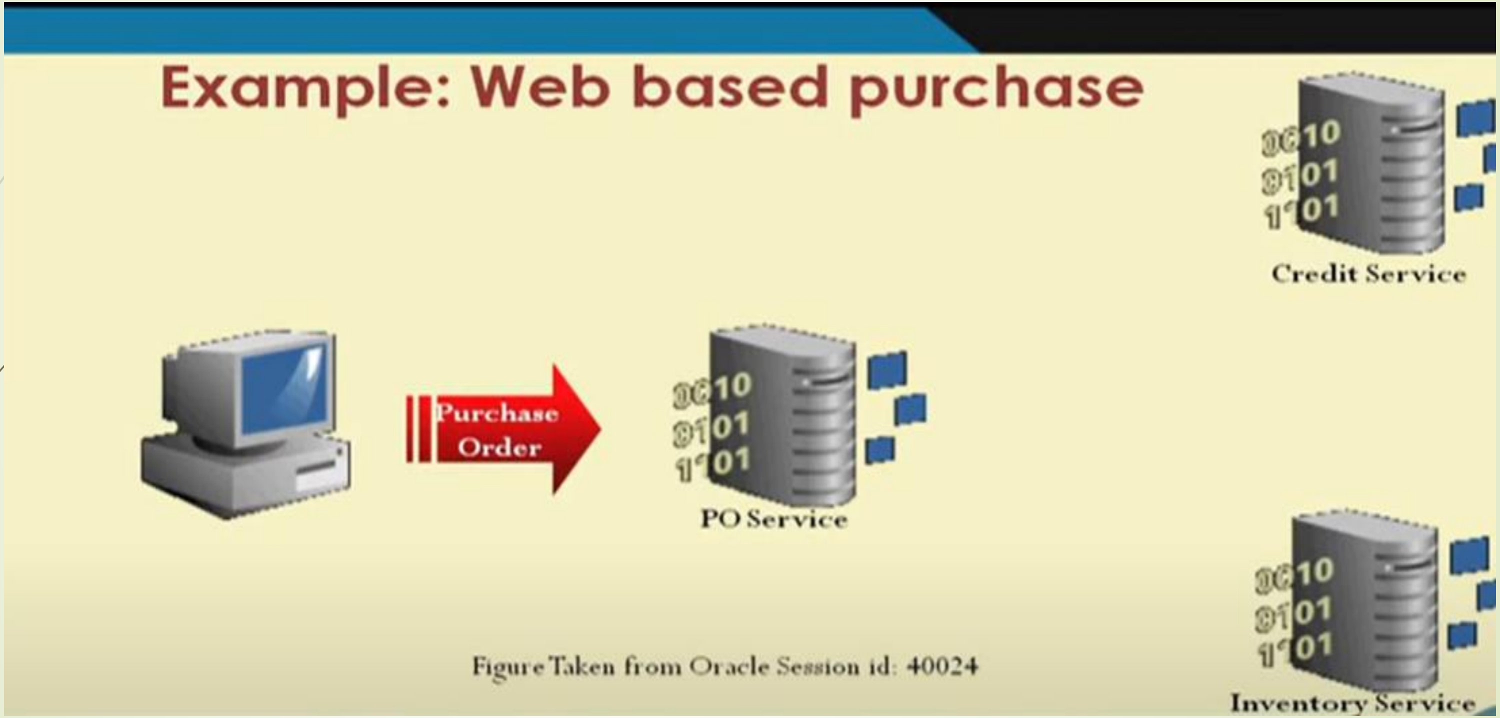
Web Service: Definition Revisited

- An application component that:
  - Communicates via open protocols (HTTP, SMTP, etc.)
  - Processes XML messages framed using SOAP
  - Describes its messages using XML Schema
  - Provides an endpoint description using WSDL
  - Can be discovered using UDDI

Example: Web based purchase

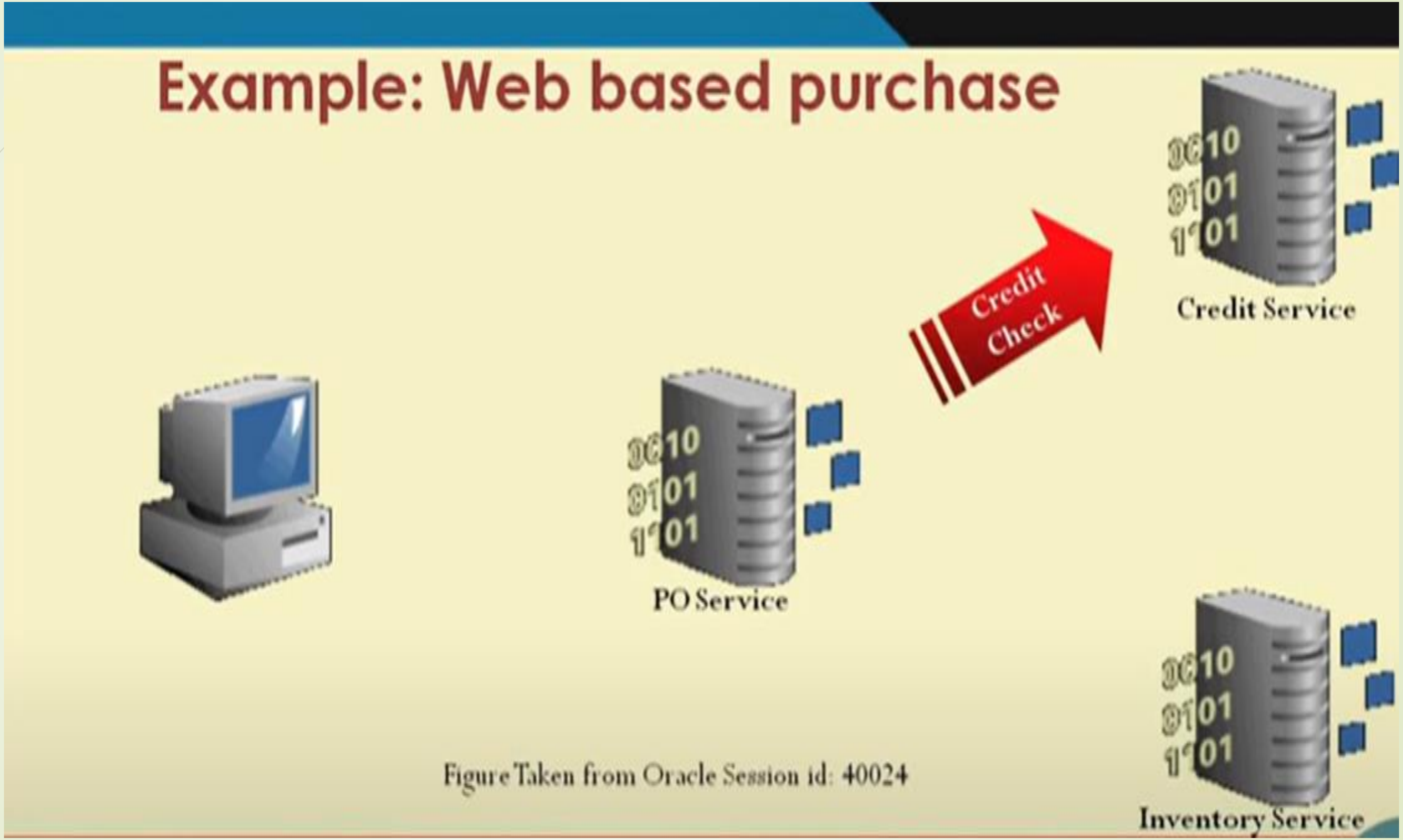


FigureTaken from Oracle Session id: 40024



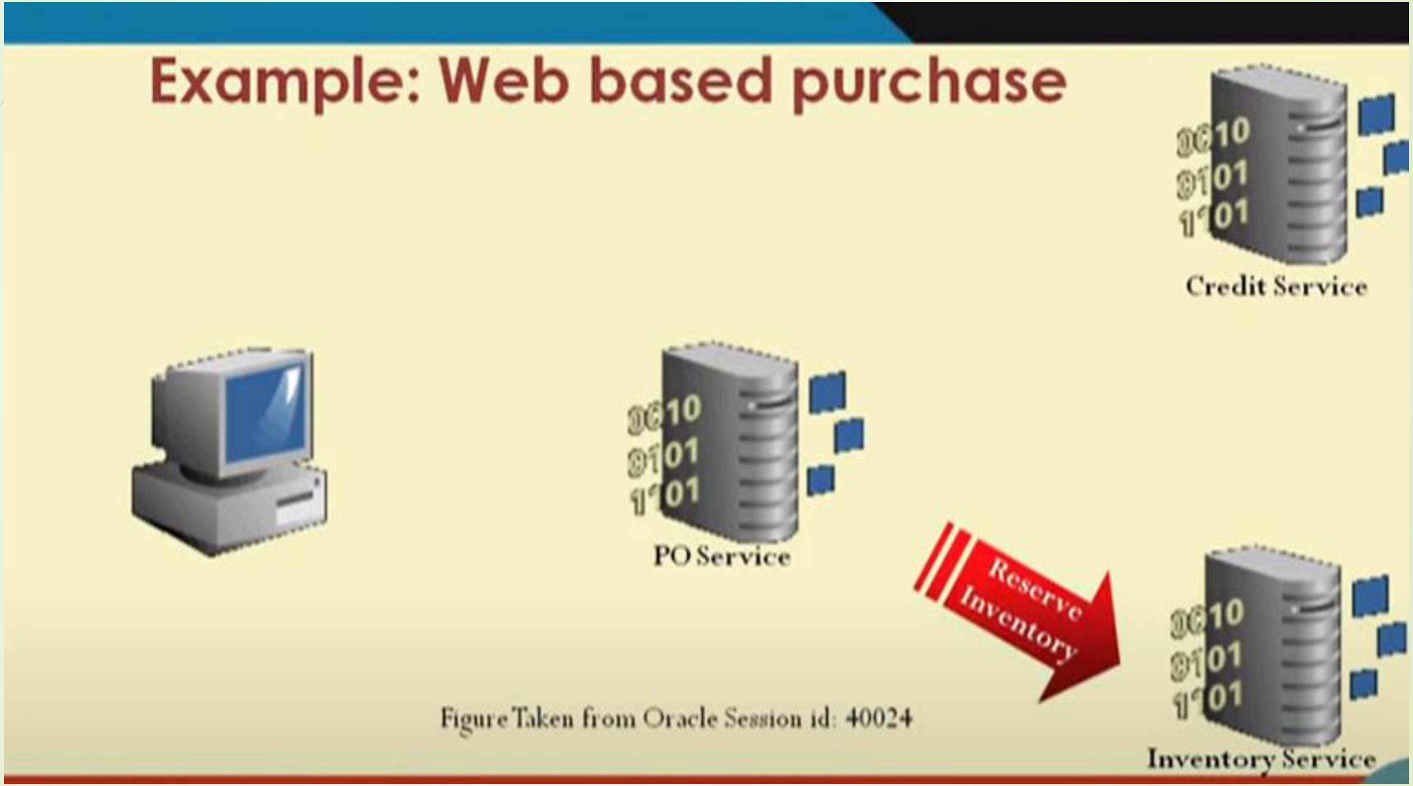
Example: Web based purchase

Figure Taken from Oracle Session id: 40024



Example: Web based purchase

Figure Taken from Oracle Session id: 40024



Example: Web based purchase

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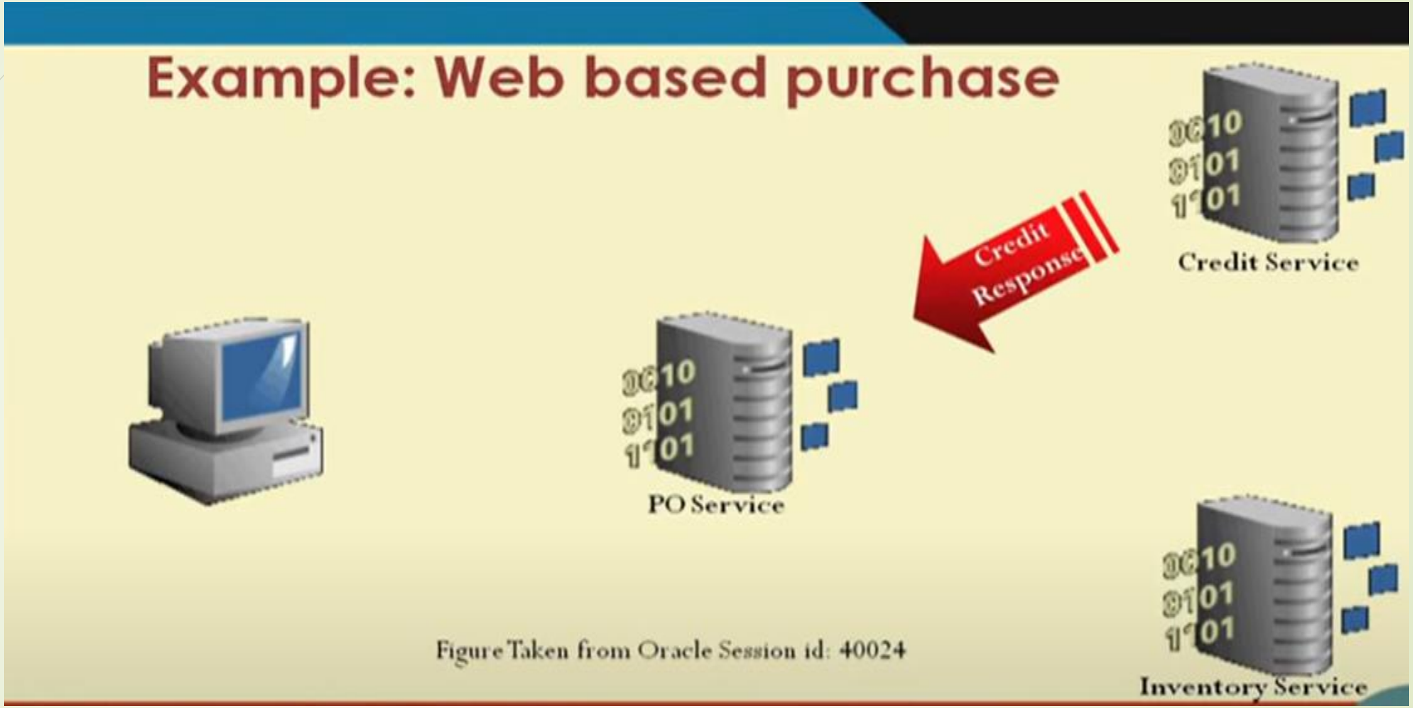

Example: Web based purchase

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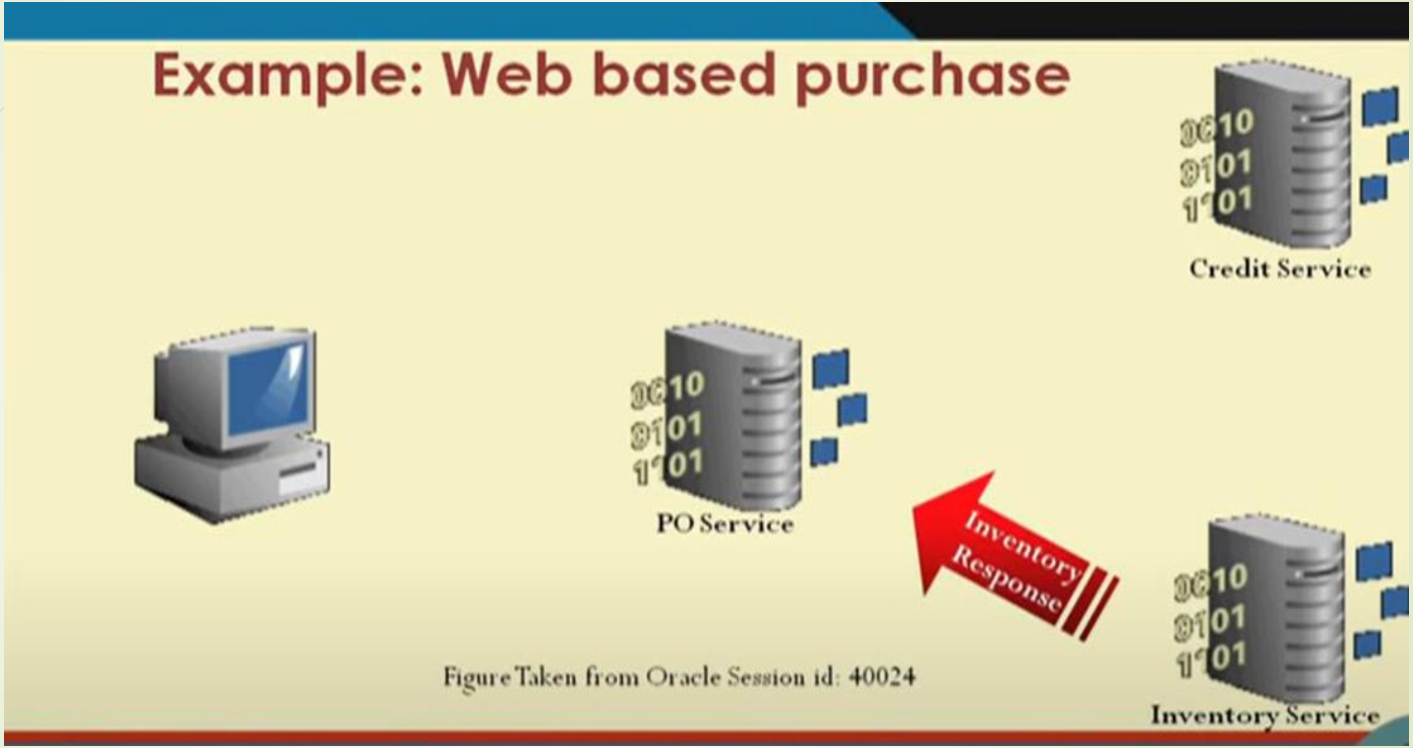

Example: Web based purchase

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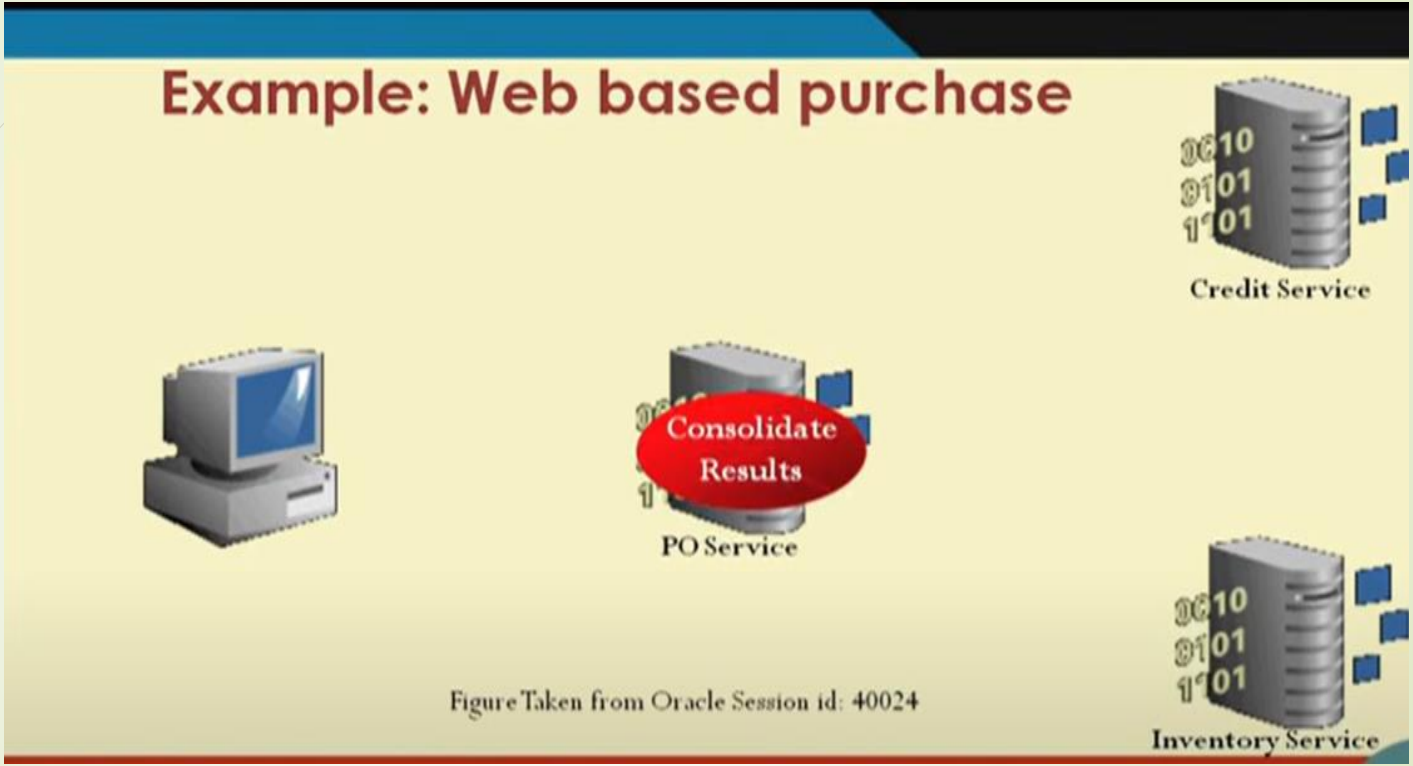

Example: Web based purchase

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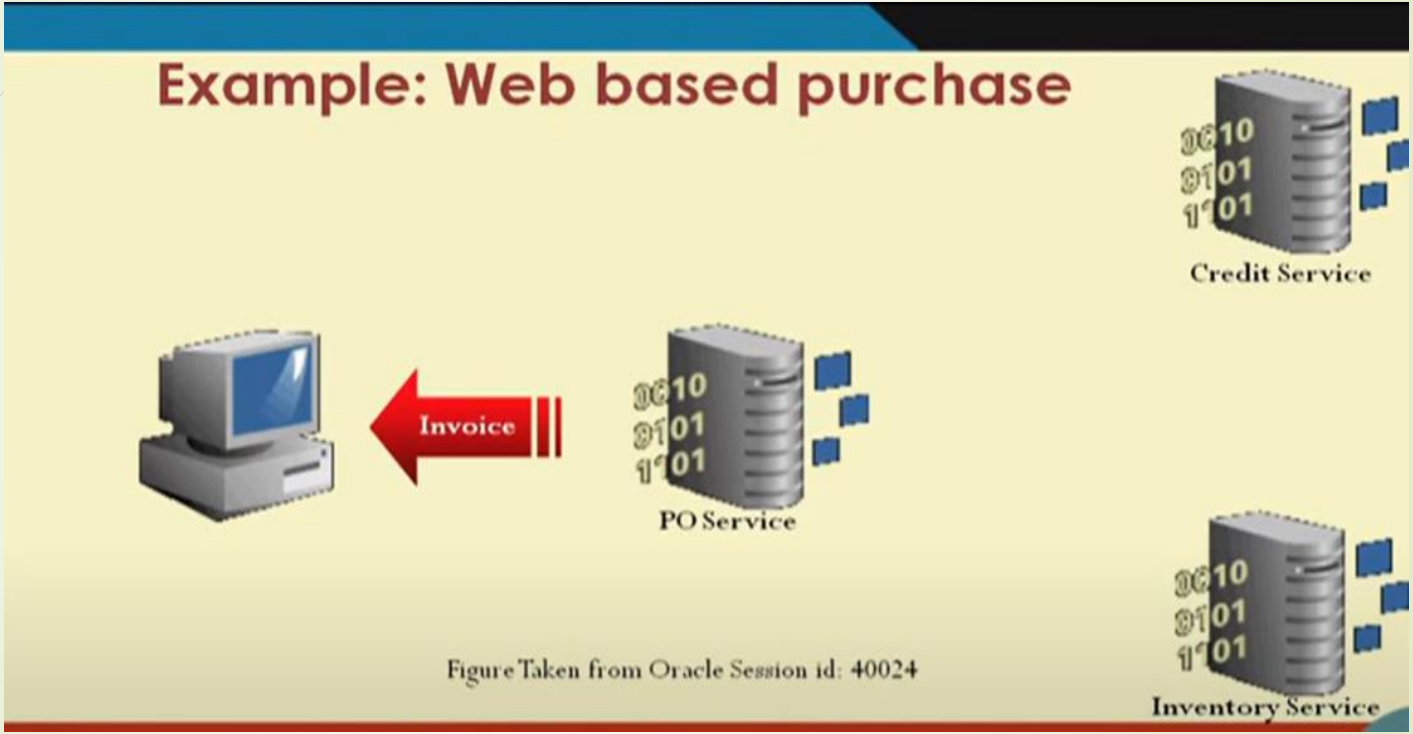


Example: Web based purchase

Credit Service

Invoice

PO Service

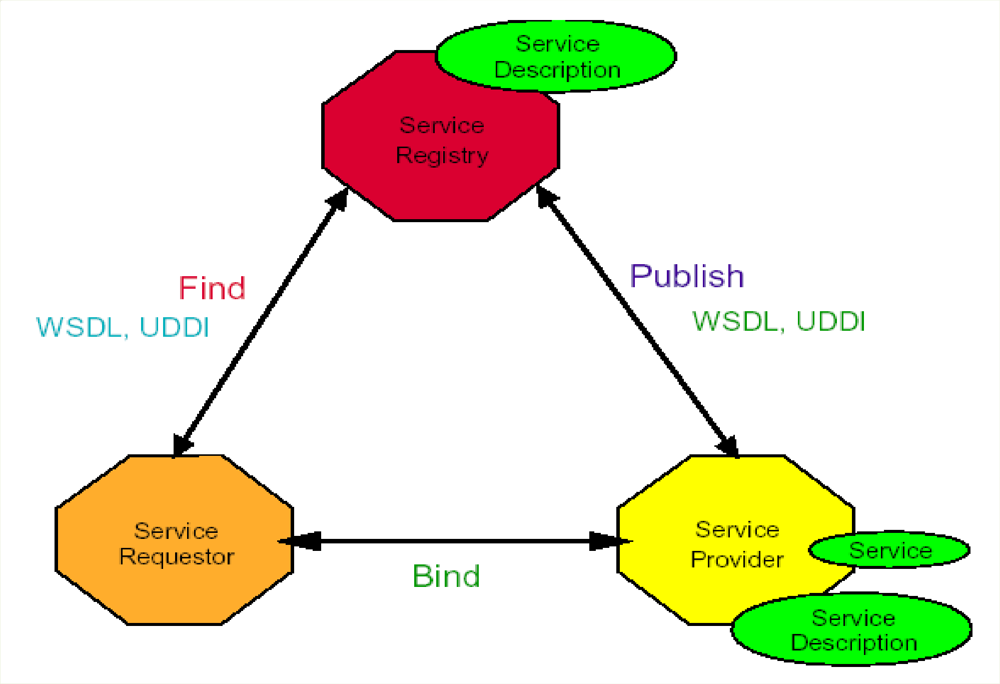
Inventory Service

Figure Taken from Oracle Session id: 40024

Service Oriented Architecture (SOA)

- IBM has created a model to show Web services interactions which is referred to as a Service-Oriented Architecture (SOA) consisting of relationships between three entities:
  - A service provider;
  - A service requestor;
  - A service broker
- IBM's SOA is a generic model describing service collaboration, not just specific to Web services.
  - See: http://www-106.ibm.com/developerworks/webservices/

Web Service Model



Analogous to telephone directory: yellow pages, white pages..

Web Service Model *(contd…)*

- Roles in Web Service architecture
  - Service provider
    - Owner of the service
    - Platform that hosts access to the service
  - Service requestor
    - Business that requires certain functions to be satisfied
    - Application looking for and invoking an interaction with a service
  - Service registry
    - Searchable registry of service descriptions where service providers publish their service descriptions

Web Service Model *(contd…)*

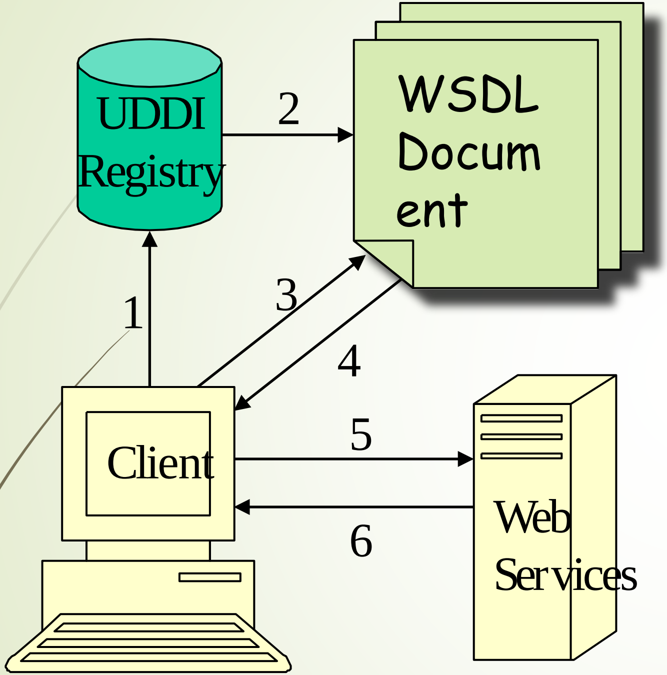
- Operations in a Web Service Architecture
  - Publish
    - Service descriptions need to be published in order for service requestor to find them
  - Find
    - Service requestor retrieves a service description directly or queries the service registry for the service required
  - Bind
    - Service requestor invokes or initiates an interaction with the service at runtime

Web Service Components

- **XML** – eXtensible Markup Language
  - A uniform data representation and exchange mechanism.
- **SOAP** – Simple Object Access Protocol
  - A standard way for communication.
- **WSDL** – Web Services Description Language
  - A standard meta language to described the services offered.
- **UDDI** – Universal Description, Discovery and Integration specification
  - A mechanism to register and locate WS based application.

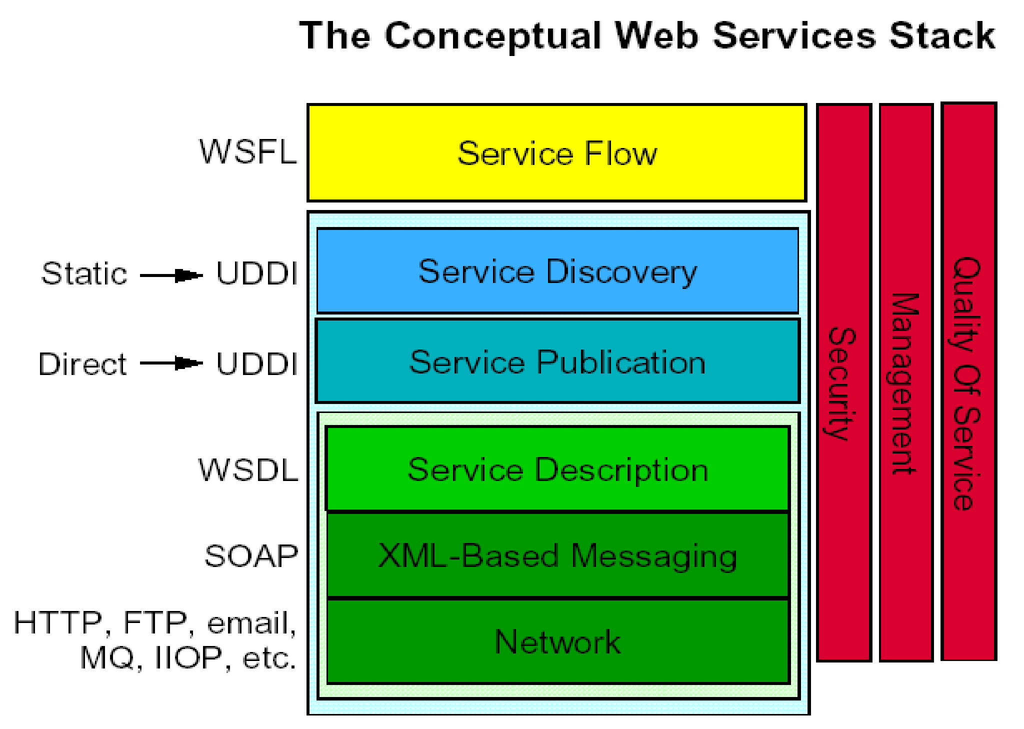
SOAP (Simple Object Access Protocol) is a message protocol that enables the distributed elements of an application to communicate.

Steps of Operation



1. Client queries registry to locate service.
2. Registry refers client to WSDL document.
3. Client accesses WSDL document.
4. WSDL provides data to interact with Web service.
5. Client sends SOAP-message request.
6. Web service returns SOAP-message response.

Web Service Stack



XML

- Developed from Standard Generalized Markup Method (SGML)
- Widely supported by W3C
- Essential characteristic is the separation of content from presentation
- Designed to describe **data**
- XML document can optionally reference a *Document Type Definition (DTD),* also called a *Schema*
  - XML parser checks syntax
  - If an XML document adheres to the structure of the schema it is *valid*

Separation of Content from Presentation

- Cascading Style Sheets (**CSS**)

- There are a number of good reasons for doing this. The first is that these elements are often changed independently. For example, you may want to present the same web content, with the same business logic, but with a different style. Or, you may want to present different content, but with the same style and logic.

XML *(contd…)*

- XML tags are not predefined
  - You must **define your own tags.**
- Enables cross-platform data communication in Web Services

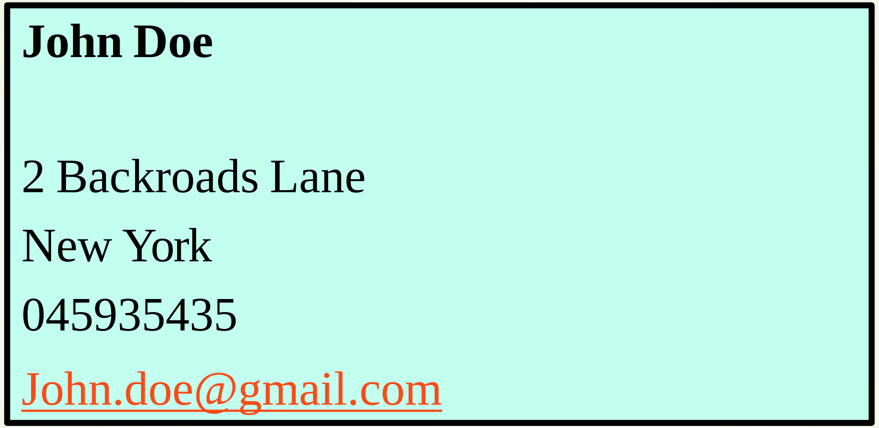
XML vs HTML

An HTML example:

```
<html>
<body>
    <h2>John Doe</h2>
    <p>2 Backroads Lane<br>
          New York<br>
          045935435<br>
          john.doe@gmail.com<br>
          </p>
</body>
</html>
```

XML vs HTML *(contd…)*

- This will be displayed as:



John Doe

2 Backroads Lane

New York

045935435

John.doe@gmail.com

- HTML specifies how the document is to be displayed, and not what information is contained in the document.
- Hard for machine to extract the embedded information. Relatively easy for human.

XML vs HTML *(contd…)*

- Now look at the following:

```
<?xml version=1.0?>
<contact>
  <name>John Doe</name>
  <address>2 Backroads Lane</address>
  <country>New York</country>
  <phone>045935435</phone>
  <email>john.doe@gmail.com</email>
</contact>
```

- In this case:
  - The information contained is being marked, but not for displaying.
  - Readable by both human and machines.

SOAP

- **S**imple **O**bject **A**ccess **P**rotocol
- Format for sending messages over Internet between programs
- XML-based
- W3C compliant
- Platform and language independent
- Simple and extensible
- Uses mainly HTTP as a transport protocol
  - HTTP message contains a SOAP message as its payload section
- Stateless, one-way
  - But applications can create more complex interaction patterns

The World Wide Web Consortium is the main international standards organization for the World Wide Web.

Stateful and Stateless

- A stateless system sends a request to the server and relays the response (or the state) back without storing any information.
- On the other hand, stateful systems expect a response, track information, and resend the request if no response is received.

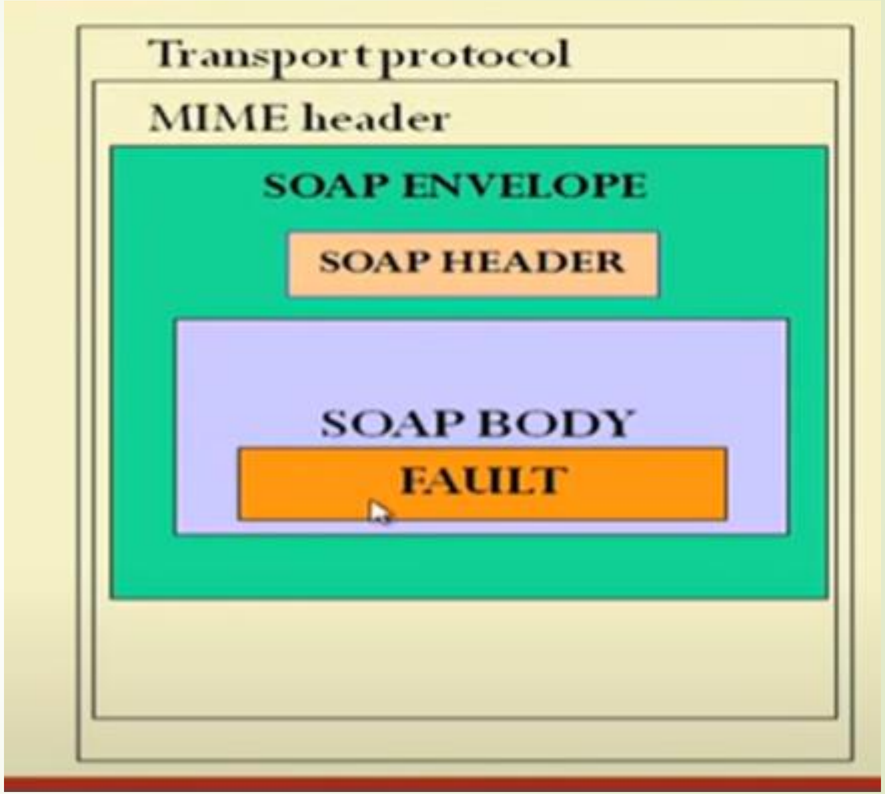
SOAP Building Blocks

- Envelope (required) – identifies XML document as SOAP message

- Header (optional) – contains header information

- Body (required) –call and response information

- Fault (optional) – errors that occurred while processing message



MIME

- **Multipurpose Internet Mail Extension (MIME)** is a standard that was proposed by Bell Communications in 1991 in order to expand the limited capabilities of email.
  MIME is a kind of add-on *or a supplementary protocol* that allows non-ASCII data to be sent through SMTP. It allows the users to exchange different kinds of data files on the Internet: audio, video, images, application programs as well.

- **Why do we need MIME?**
  Limitations of Simple Mail Transfer Protocol (SMTP):

1. SMTP has a very simple structure
2. Its simplicity however comes with a price as it only sends messages in NVT 7-bit ASCII format.
3. It cannot be used for languages that do not support 7-bit ASCII format such as French, German, Russian, Chinese and Japanese, etc. so it cannot be transmitted using SMTP. So, in order *to make SMTP more broad*, *we use MIME*.
4. It cannot be used to send binary files or video or audio data.

SOAP Message Structure

- Request and Response messages
  - Request invokes a method on a remote object
  - Response returns result of running the method
- SOAP specification defines an “envelop”
  - “envelop” wraps the message itself
  - Message is a different vocabulary
  - Namespace prefix is used to distinguish the two parts

message
SOAP envelope

SOAP Envelop vocabulary

SOAP Request

```
POST /InStock HTTP/1.1
Host: www.stock.org
Content-Type: application/soap+xml; charset=utf-8 Content-Length: 150

<?xml version="1.0"?>
<soap:Envelope
xmlns:soap="http://www.w3.org/2001/12/soap-envelope"
soap:encodingStyle=http://www.w3.org/2001/12/soap-encoding”>

    <soap:Body xmlns:m="http://www.stock.org/stock">
            <m:GetStockPrice>
                  <m:StockName>IBM</m:StockName>
            </m:GetStockPrice>
    </soap:Body>
</soap:Envelope>
```

SOAP Response

```
HTTP/1.1 200 OK
Content-Type: application/soap; charset=utf-8
Content-Length: 126

<?xml version="1.0"?>
<soap:Envelope xmlns:soap="http://www.w3.org/2001/12/soap-envelope"
soap:encodingStyle="http://www.w3.org/2001/12/soap-encoding">

    <soap:Body xmlns:m="http://www.stock.org/stock">
        <m:GetStockPriceResponse>
                <m:Price>34.5</m:Price>
        </m:GetStockPriceResponse>
    </soap:Body>
</soap:Envelope>
```

Why SOAP?

- Other distributed technologies failed on the Internet
  - Unix RPC – requires binary-compatible Unix implementations at each endpoint
  - CORBA – requires compatible ORBs
  - RMI – requires Java at each endpoint
  - DCOM – requires Windows at each endpoint
- SOAP is the platform-neutral choice
  - Simply an XML wire format
  - Places no restrictions on the endpoint implementation technology choices

Remote Procedure Call (RPC) is used to call other processes on the remote systems like a local system.
Unix: family of multitasking, multi-user computer operating systems that derive from the original AT&T Unix, whose development started in 1969 at the Bell Labs research center.
ORB: Object Request Broker manages the interaction between clients and servers, using the Internet InterORB Protocol (IIOP)
CORBA: Common Object Request Broker Architecture

SOAP Characteristics

- SOAP has three major characteristics:
  - Extensibility - security and Web service -routing are among the extensions under development.
  - Neutrality - SOAP can be used over any transport protocol such as HTTP, SMTP or even TCP.
  - Independent - SOAP allows for any programming model.

SOAP Usage Models

- RPC-like message exchange
  - Request message bundles up method name and parameters
  - Response message contains method return values
  - However, it isn’t required by SOAP
- SOAP specification allows any kind of body content
  - Can be XML documents of any type
  - Example:
    - Send a purchase order document to the inbox of B2B partner
    - Expect to receive shipping and exceptions report as response

SOAP Security

- SOAP uses HTTP as a transport protocol and hence can use HTTP security mainly HTTP over SSL.
- But, since SOAP can run over a number of application protocols (such as SMTP) security had to be considered.
- The *WS-Security specification* defines a complete encryption system.

WSDL - Web Service Definition Language

- WSDL : XML vocabulary standard for describing Web services and their capabilities
- Contract between the XML Web service and the client
- Specifies what a request message must contain and what the response message will look like in unambiguous notation
- Defines where the service is available and what communications protocol is used to talk to the service.

WSDL Document Structure

- A WSDL document is just a simple XML document.
- It defines a web service using these major elements:
  - **port type** - The operations performed by the web service.
  - **message -** The messages used by the web service.
  - **types -** The data types used by the web service.
  - **binding -** The communication protocols used by the web service.

A Sample WSDL

```
<message name="getTermRequest">
  <part name="term" type="xs:string"/>
</message>

<message name="getTermResponse">
  <part name="value" type="xs:string"/>
</message>

<portType name="glossaryTerms">
  <operation name="getTerm">
    <input message="getTermRequest"/>
    <output message="getTermResponse"/>
  </operation>
</portType>
```

Binding to SOAP

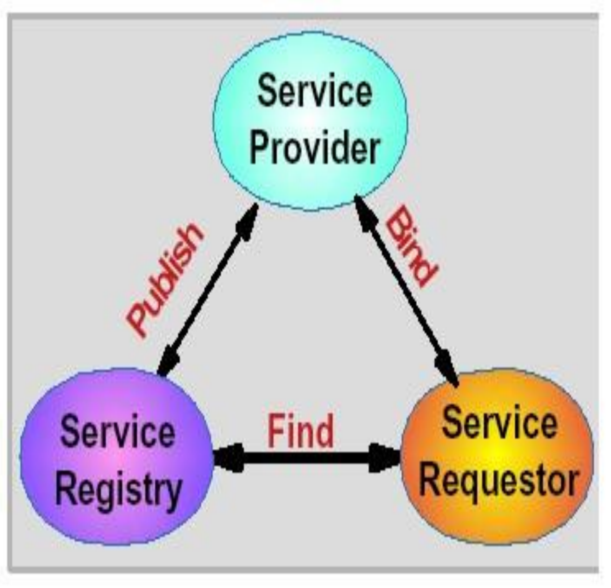
```
<message name="getTermRequest">
   <part name="term" type="xs:string"/>
</message>

<message name="getTermResponse">
   <part name="value" type="xs:string"/>
</message>

<portType  name="glossaryTerms">
  <operation name="getTerm">
      <input message="getTermRequest"/>
      <output message="getTermResponse"/>
  </operation>
</portType>

<binding type="glossaryTerms" name="b1">
<soap:binding style="document"
transport="http://schemas.xmlsoap.org/soap/http" />
  <operation>
    <soap:operation
     soapAction="http://example.com/getTerm"/>
    <input>
      <soap:body use="literal"/>
    </input>
    <output>
      <soap:body use="literal"/>
    </output>
  </operation>
</binding>
```

UDDI - Universal Description, Discovery, and Integration

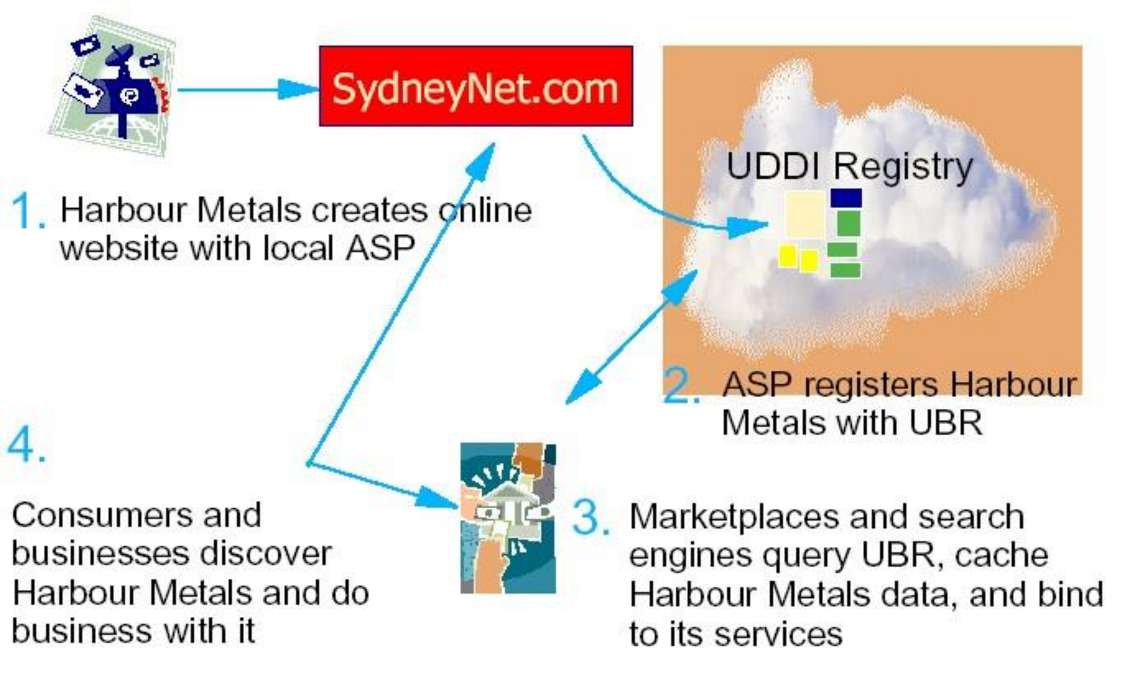
- A framework to define XML-based registries
- Registries are repositories that contain documents that describe business data and also provide search capabilities and programmatic access to remote applications
- Businesses can publish information about themselves and the services they offer
- Can be interrogated by SOAP messages and provides access to WSDL documents describing web services in its directory

UDDI Roles and Operations

- Service Registry
  - Provides support for publishing and locating services
  - Like telephone yellow pages
- Service Provider
  - Provides e-business services
  - Publishes these services through a registry
- Service requestor
  - Finds required services via the Service Broker
  - Binds to services via Service Provider



How can UDDI be Used?



1. Harbour Metals creates online website with local ASP

2. ASP registers Harbour Metals with UBR

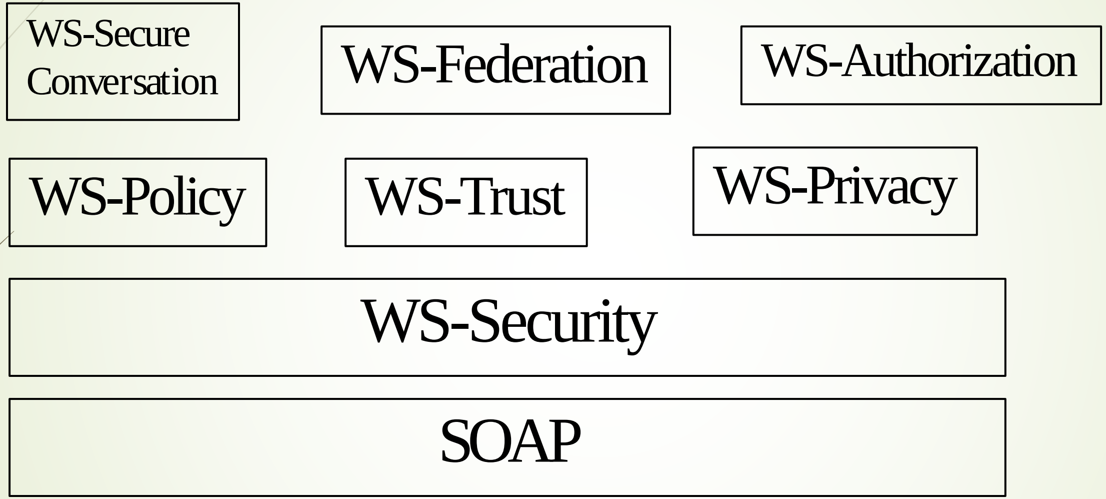
3. Marketplaces and search engines query UBR, cache Harbour Metals data, and bind to its services

4. Consumers and businesses discover Harbour Metals and do business with it

UDDI Benefits

- Making it possible to discover the right business from the millions currently online
- Defining how to enable commerce once the preferred business is discovered
- Reaching new customers and increasing access to current customers
- Expanding offerings and extending market reach

Web Services Security Architecture


WS-Secure Conversation
WS-Federation
WS-Authorization
WS-Policy
WS-Trust
WS-Privacy
WS-Security
SOAP