RV College of Engineering
Autonomous Institution Affiliated to Visvesvaraya Technological University, Belagavi
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Cloud Computing and Architecture

Virtualization and Cloud Architecture

UNIT 2

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Virtualization

- Virtualization technology is one of the fundamental components of cloud computing, especially in regard to infrastructure-based services. Virtualization allows the creation of a secure, customizable, and isolated execution environment for running applications, even if they are untrusted, without affecting other users' applications.
- Virtualization is a large umbrella of technologies and concepts that are meant to provide an abstract environment—whether virtual hardware or an operating system—to run applications.

Virtualization

Virtualization technologies have gained renewed interested recently due to the confluence of several phenomena:

Increased performance and computing capacity

Underutilized hardware and software resources

Lack of space

Greening initiatives

Rise of administrative costs

Virtualization

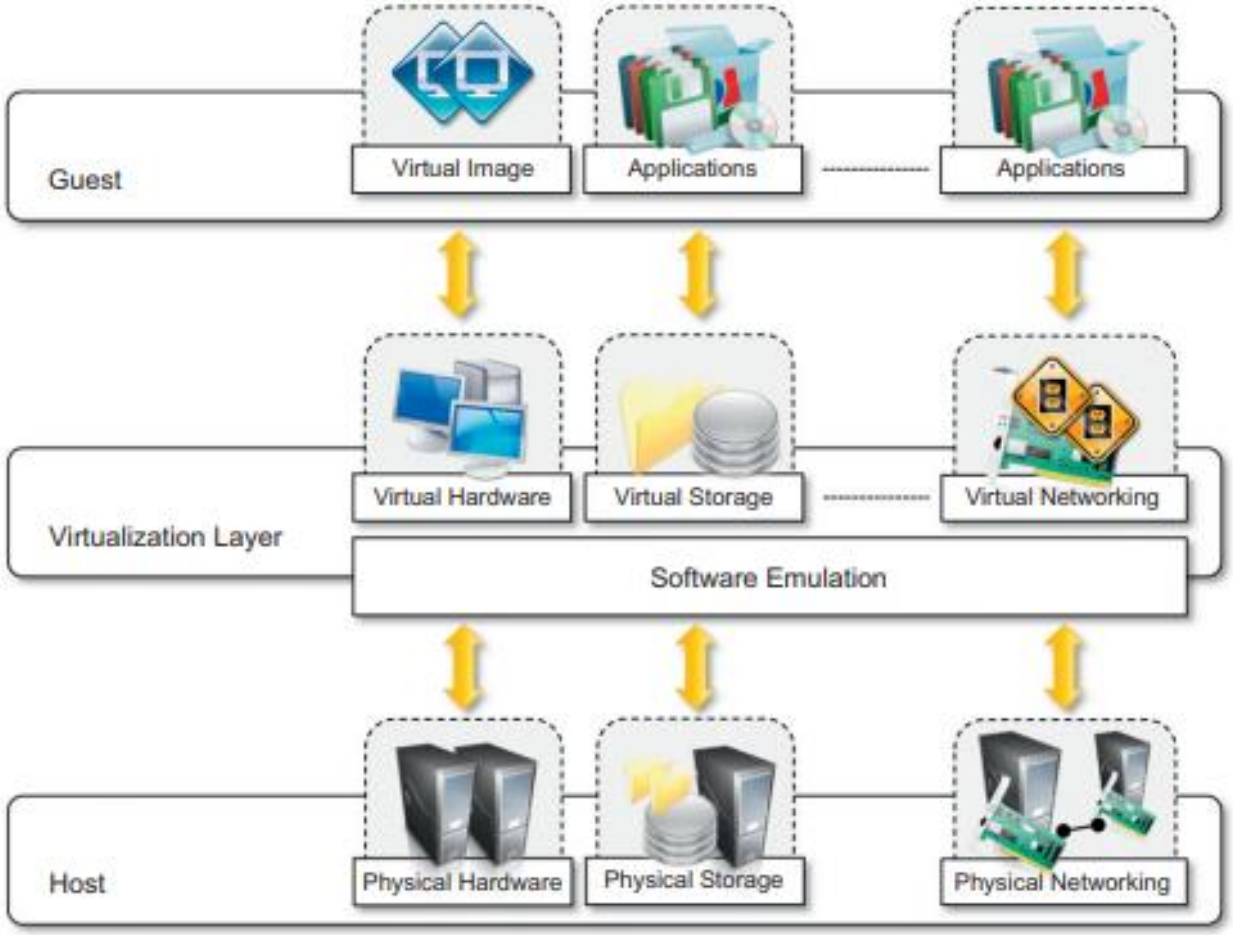
The virtualization reference model.

In a virtualized environment there are three major components:

The guest represents the system component that interacts with the virtualization layer rather than with the host, as would normally happen.

The virtualization layer is responsible for recreating the same or a different environment where the guest will operate

The host represents the original environment where the guest is supposed to be managed.



Virtualization

The virtualization reference model.

In the case of **hardware virtualization**, the guest is represented by a system image comprising an operating system and installed applications.

These are installed on top of virtual hardware that is controlled and managed by the virtualization layer, also called the **virtual machine manager.**

Virtualization

Characteristics of virtualized environments

Increased security

Managed execution

Portability

Virtualization

Characteristics of virtualized environments

Increased security

The ability to control the execution of a guest in a completely transparent manner opens new possibilities for delivering a secure, controlled execution environment.

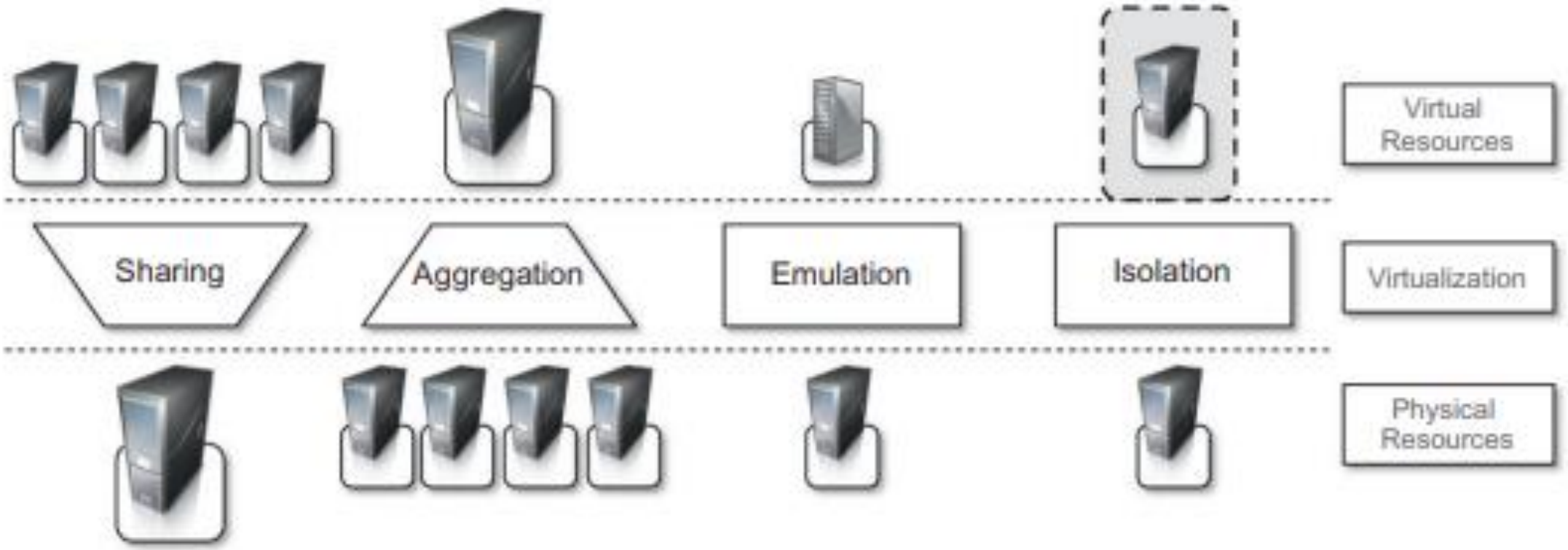
- The virtual machine represents an emulated environment in which the guest is executed
- All the operations of the guest are generally performed against the virtual machine, which then translates and applies them to the host. This level of indirection allows the virtual machine manager to control and filter the activity of the guest, thus preventing some harmful operations from being performed.

Virtualization

Characteristics of virtualized environments

2. Managed execution

Virtualization of the execution environment not only allows increased security, but a wider range of features also can be implemented. In particular, sharing, aggregation, emulation, and isolation are the most relevant features

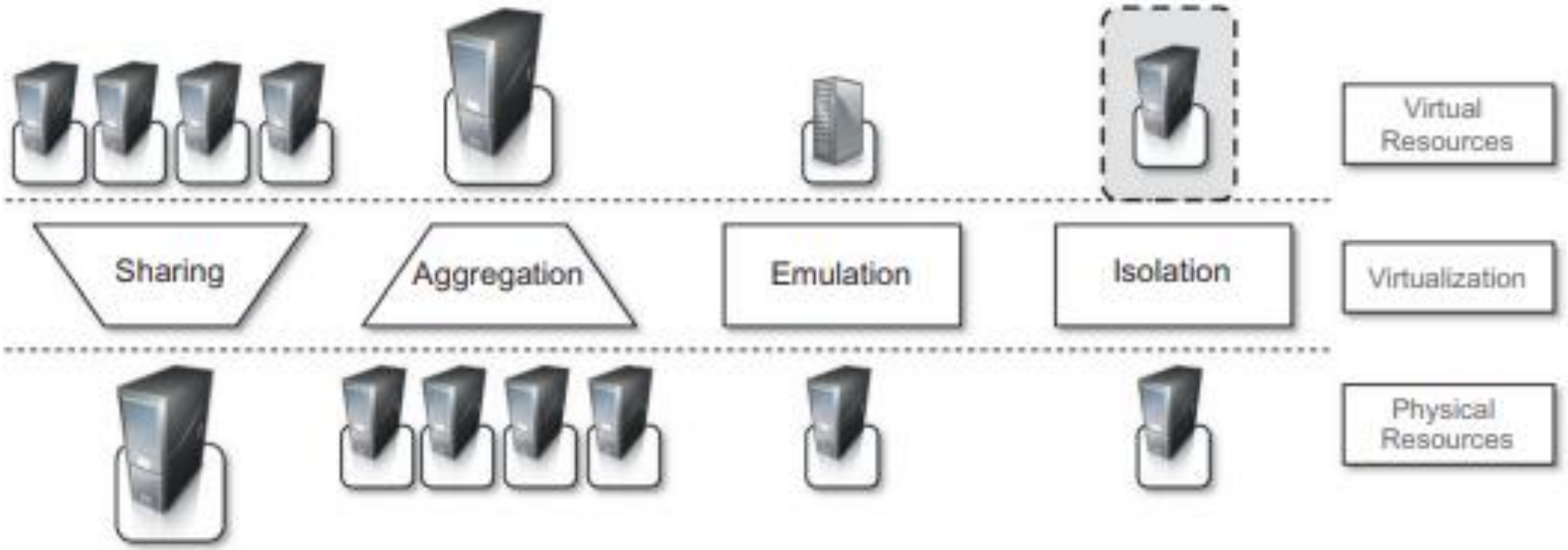


Virtualization

Characteristics of virtualized environments

2. Managed execution

• **Sharing.** Virtualization allows the creation of a separate computing environments within the same host. In this way it is possible to fully exploit the capabilities of a powerful guest, which would otherwise be underutilized.



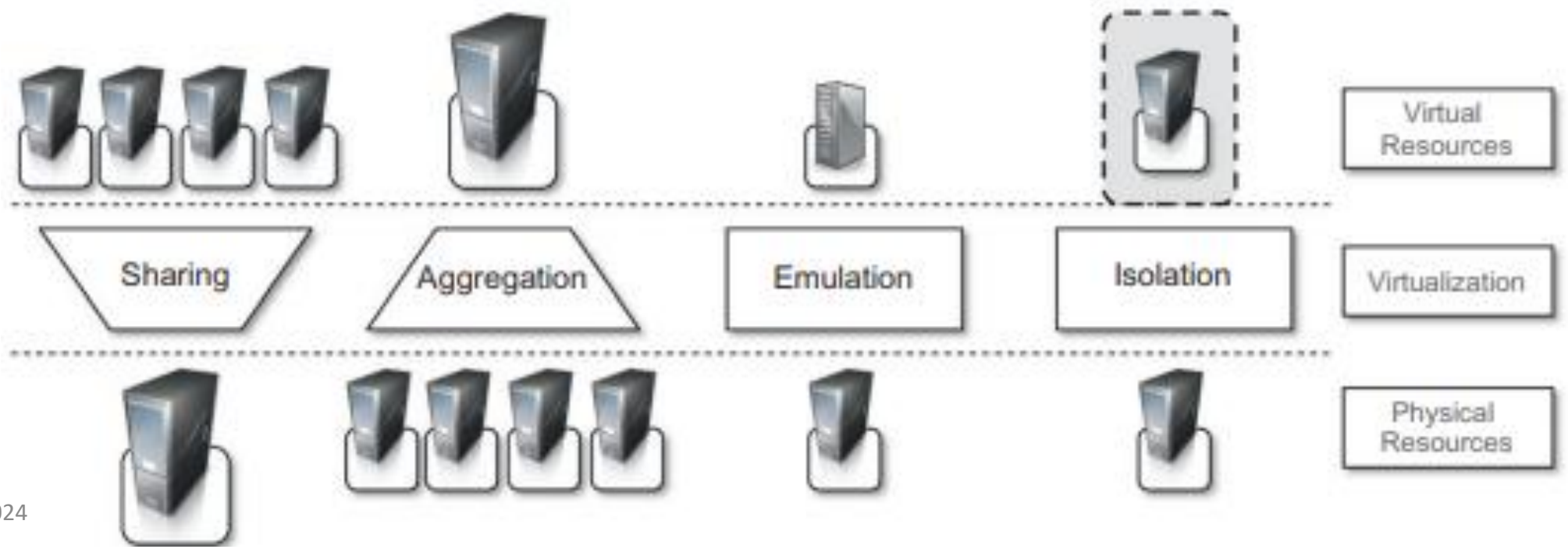
Virtualization

Characteristics of virtualized environments

2. Managed execution

Emulation. Guest programs are executed within an environment that is controlled by the virtualization layer, which ultimately is a program. This allows for controlling and tuning the environment that is exposed to guests

hardware virtualization solutions are able to provide virtual hardware and emulate a particular kind of device such as Small Computer System Interface (SCSI) devices for file I/O, without the hosting machine having such hardware installed.

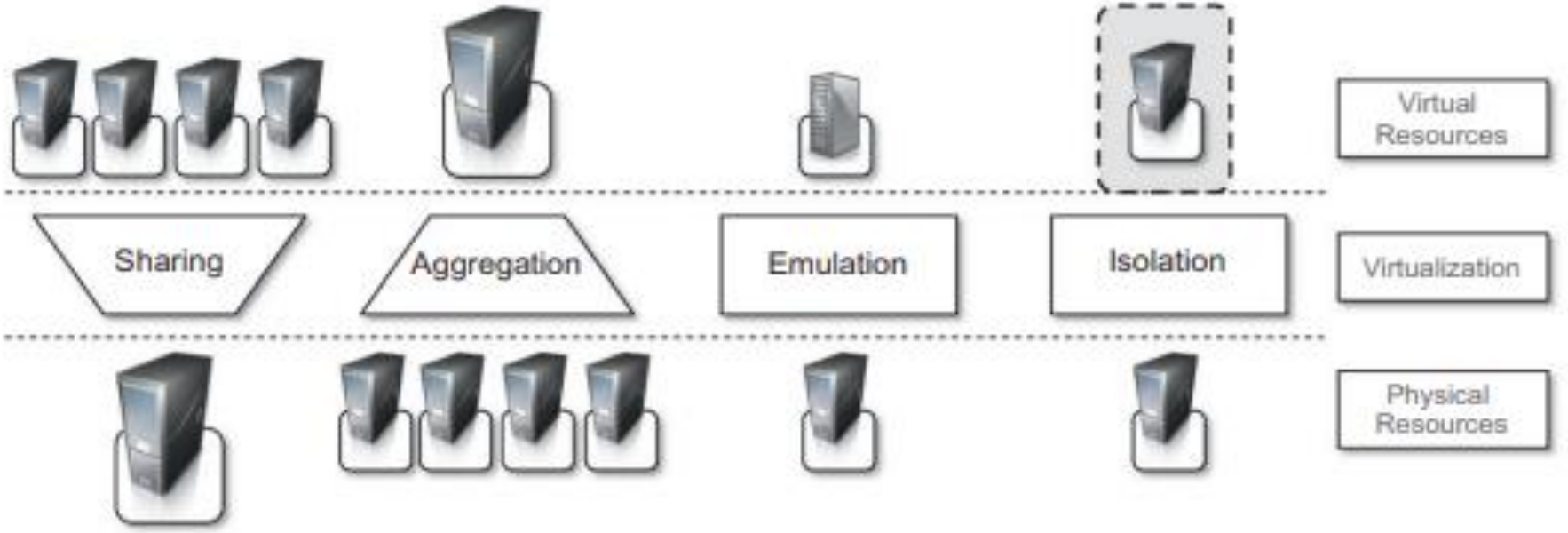


Virtualization

Characteristics of virtualized environments

2. Managed execution

Isolation. Virtualization allows providing guests—whether they are operating systems, applications, or other entities—with a completely separate environment, in which they are executed.



Virtualization

Characteristics of virtualized environments

2. Managed execution

Another important capability enabled by virtualization is **performance tuning.**

This capability provides a means to effectively implement

Quality-of-Service (QoS)

Service Level Agreement (SLA

Virtualization

Characteristics of virtualized environments

3. Portability

The concept of portability applies in different ways according to the specific type of virtualization considered.

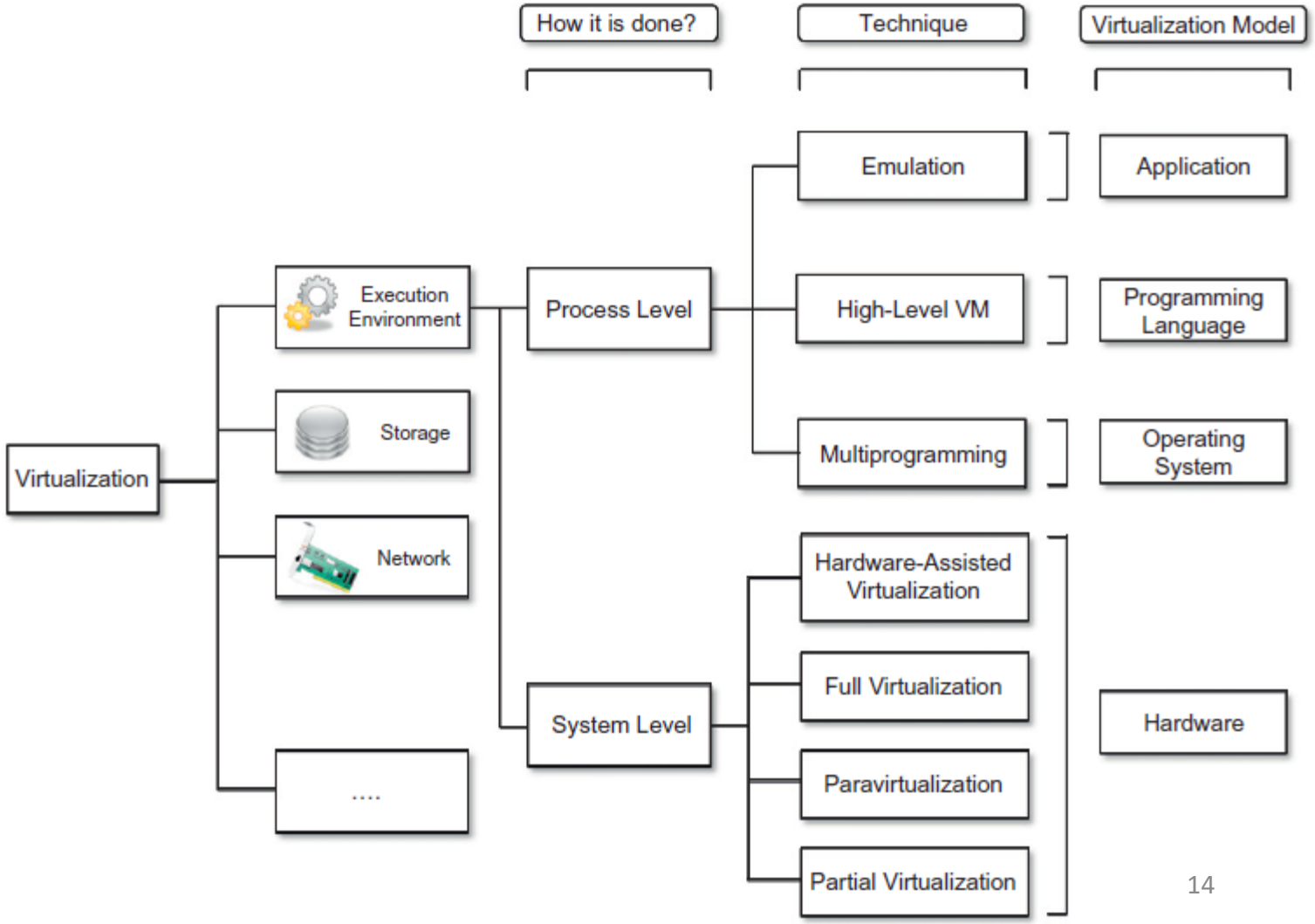
In the case of a hardware virtualization solution, the guest is packaged into a virtual image that, in most cases, can be safely moved and executed on top of different virtual machines.

Virtualization

Taxonomy of virtualization techniques

Virtualization covers a wide range of emulation techniques that are applied to different areas of computing.

1. Execution environments
2. Storage
3. Networks.

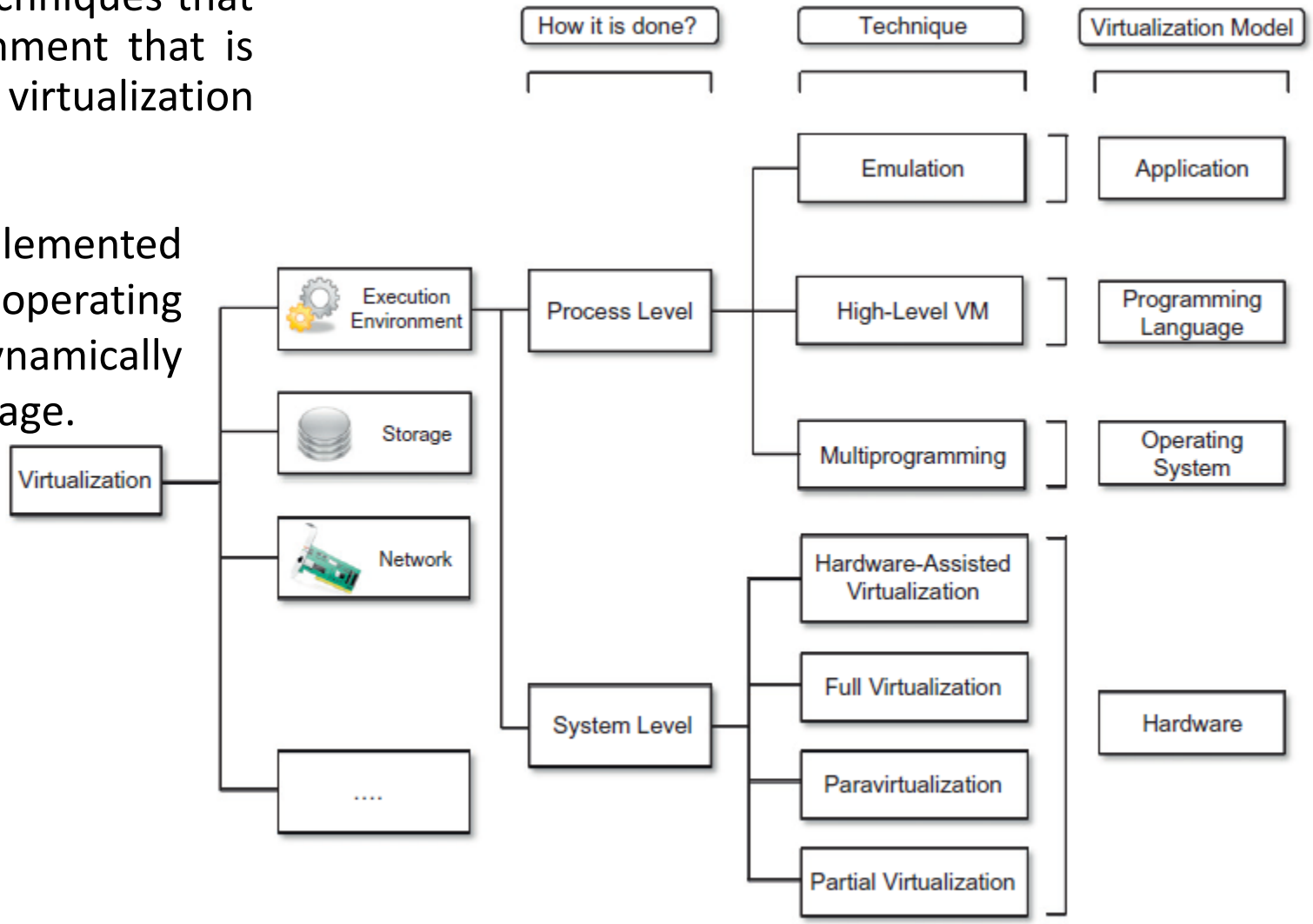


Virtualization

1. Execution environments

Execution virtualization includes all techniques that aim to emulate an execution environment that is separate from the one hosting the virtualization layer.

execution virtualization can be implemented directly on top of the hardware by the operating system, an application, or libraries dynamically or statically linked to an application image.



Virtualization

- **Different Models of Execution Environments**
- Machine reference model
- Hardware-level virtualization
- Programming language-level virtualization
- Application-level virtualization

Virtualization

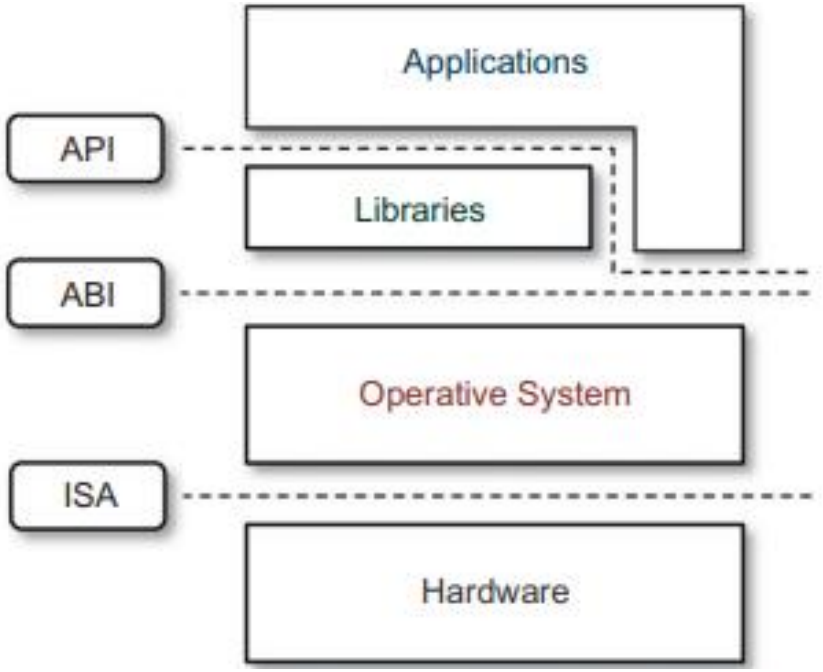
Machine reference model

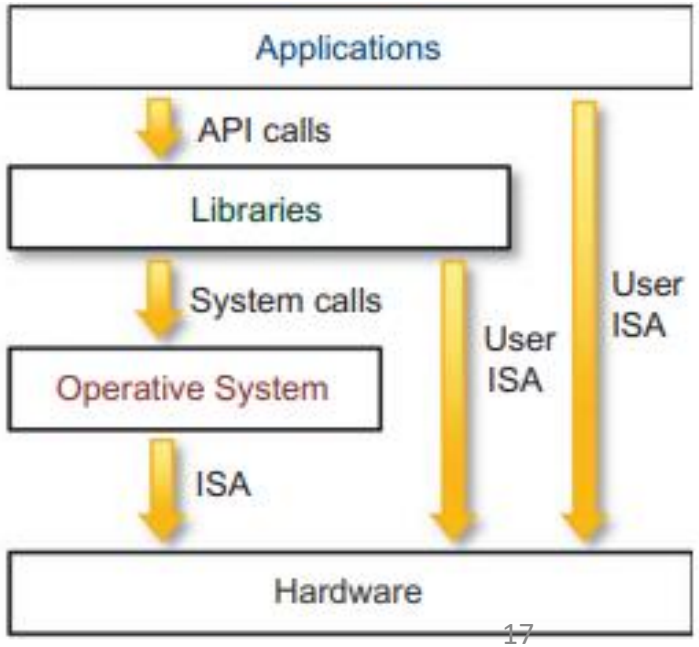
The model for the hardware is expressed in terms of the **Instruction Set Architecture** (ISA), which defines the instruction set for the processor, registers, memory, and interrupt management.

ISA is the interface between hardware and software, and it is important to the operating system (OS) developer (System ISA) and developers of applications that directly manage the underlying hardware (User ISA)

The **application binary interface (ABI)** separates the operating system layer from the applications and libraries, which are managed by the OS

The highest level of abstraction is represented by the **application programming interface (API),** which interfaces applications to libraries and/or the underlying operating system.



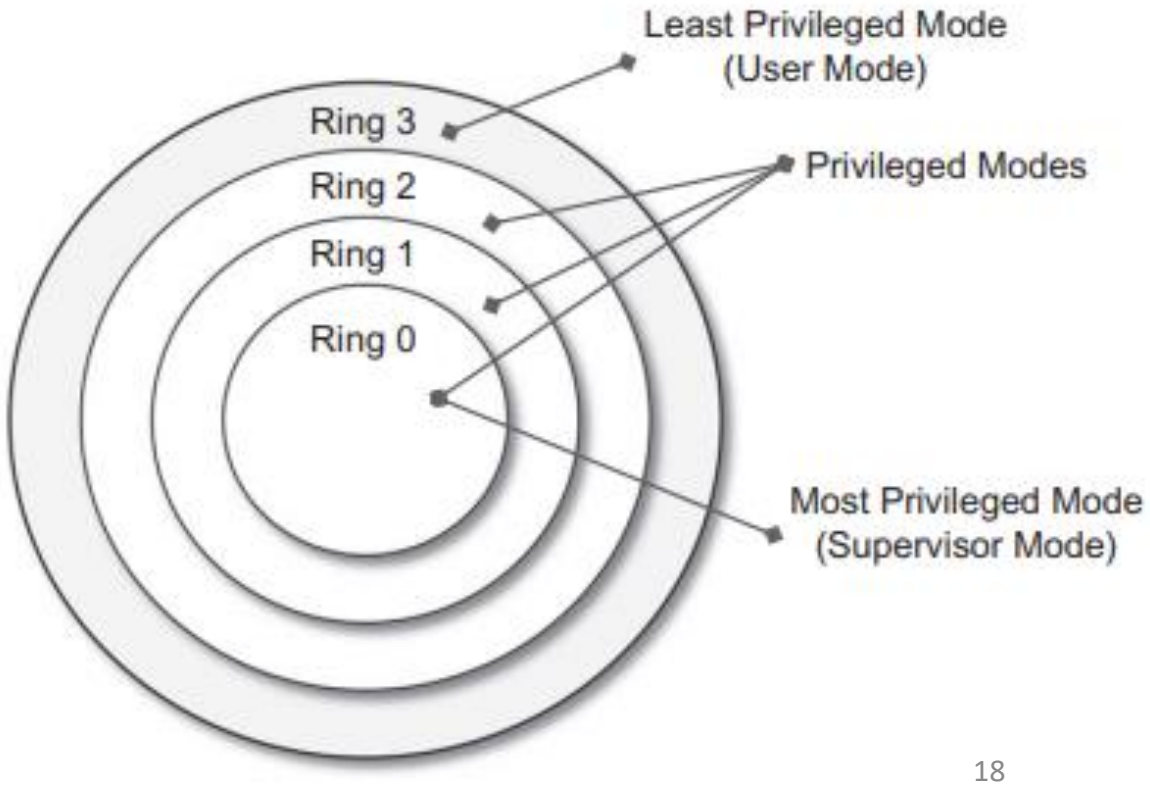


Virtualization

Machine reference model

The instruction set exposed by the hardware has been divided into different security classes that define who can operate with them.

The first distinction can be made between privileged and nonprivileged instructions



Virtualization

Hardware-level virtualization

Virtualization

Other types of virtualization

- Storage virtualization
- Network virtualization
- Desktop virtualization
- Application server virtualization

Virtualization

Other types of virtualization

Storage virtualization

- Storage virtualization is a system administration practice that allows decoupling the physical organization of the hardware from its logical representation
- There are different techniques for storage virtualization, one of the most popular being network-based virtualization by means of **storage area networks (SANs).** SANs use a network-accessible device through a large bandwidth connection to provide storage facilities.

Virtualization

Other types of virtualization

Network virtualization

- Network virtualization combines hardware appliances and specific software for the creation and management of a virtual network.
- Network virtualization can aggregate different physical networks into a single logical network (external network virtualization) or provide network-like functionality to an operating system partition (internal network virtualization).
- The result of external network virtualization is generally a virtual LAN (VLAN). A VLAN is an aggregation of hosts that communicate with each other as though they were located under the same broadcasting domain.

Virtualization

Other types of virtualization

Desktop virtualization

- Desktop virtualization abstracts the desktop environment available on a personal computer in order to provide access to it using a client/server approach
- desktop virtualization makes accessible a different system as though it were natively installed on the host, but this system is remotely stored on a different host and accessed through a network connection.
- The basic services for remotely accessing a desktop environment are implemented in software components such as

Windows Remote Services, VNC(Virtual Network Computing), and X Server.

Infrastructures for desktop virtualization based on cloud computing solutions include Sun **Virtual Desktop Infrastructure (VDI), Parallels Virtual Desktop Infrastructure (VDI)**

Virtualization

Other types of virtualization

Application server virtualization

- Application server virtualization abstracts a collection of application servers that provide the same services as a single virtual application server.
- It uses load-balancing strategies and providing a high-availability infrastructure for the services hosted in the application server.

Virtualization

Technology Examples of Virtualization

Xen: paravirtualization

VMware: full virtualization

Microsoft Hyper-V

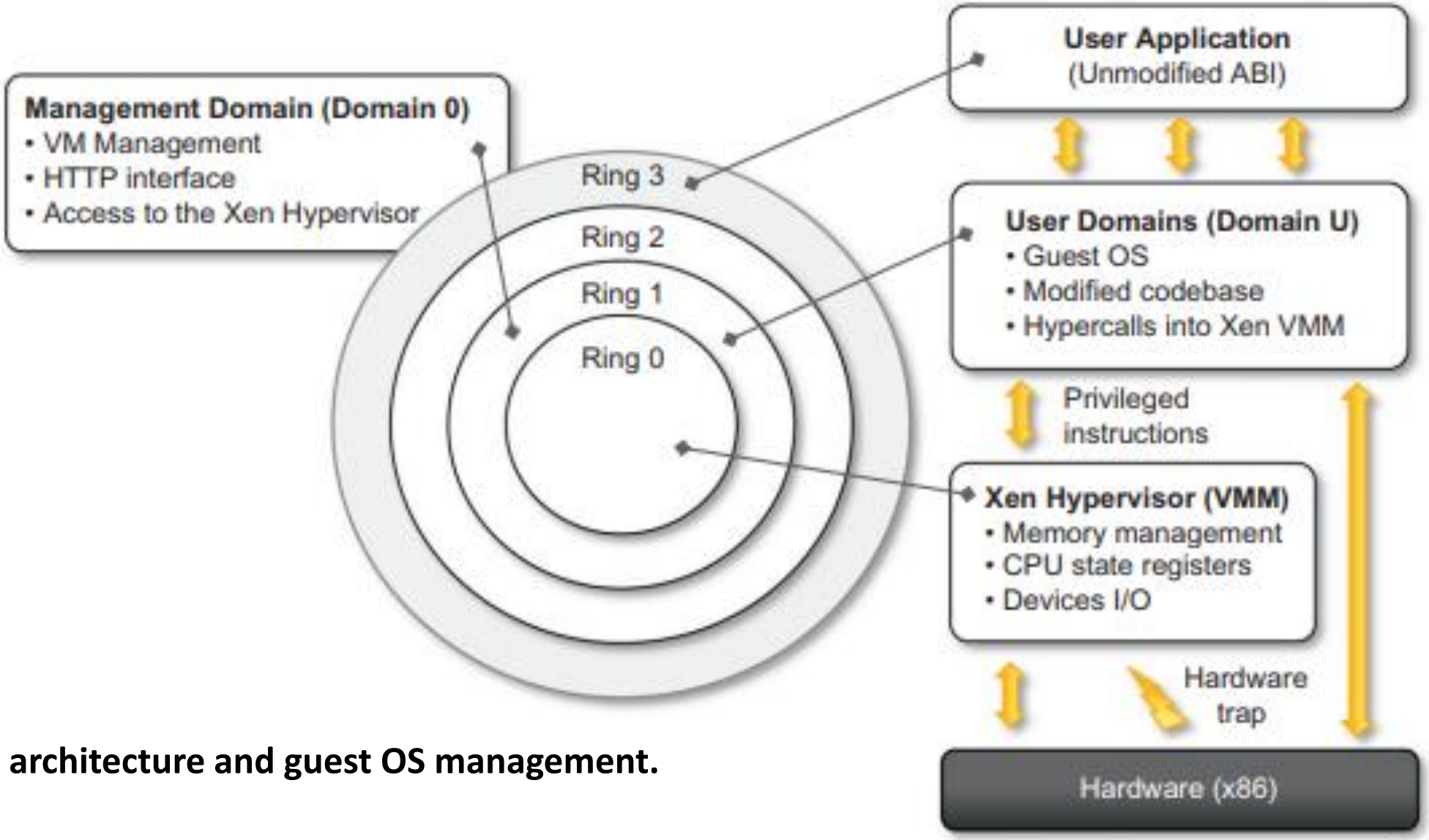
Xen: Paravirtualization

- Xen is an open-source initiative implementing a virtualization platform based on paravirtualization.
- Xen-based technology is used for either desktop virtualization or server virtualization, and recently it has also been used to provide cloud computing solutions by means of Xen Cloud Platform (XCP)
- Xen is the most popular implementation of paravirtualization, which, in contrast with full virtualization, allows high-performance execution of guest operating systems.
- This is done by modifying portions of the guest operating systems run by Xen with reference to the execution of such instructions.

Paravirtualization is an enhancement of virtualization technology in which a guest operating system (OS) is modified prior to installation inside a virtual machine (VM).

Virtualization

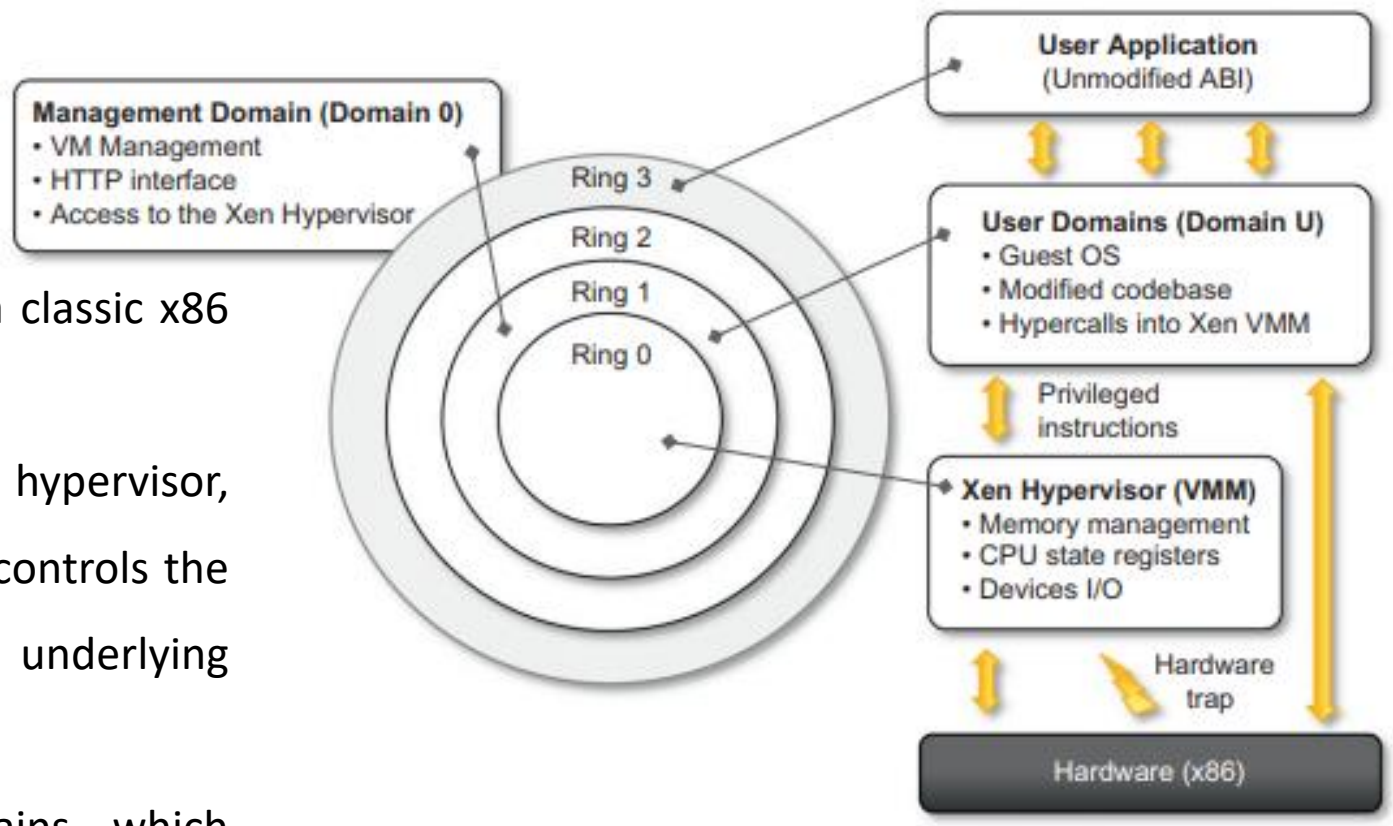
Xen: Paravirtualization



Xen architecture and guest OS management.

Virtualization

Xen: Paravirtualization

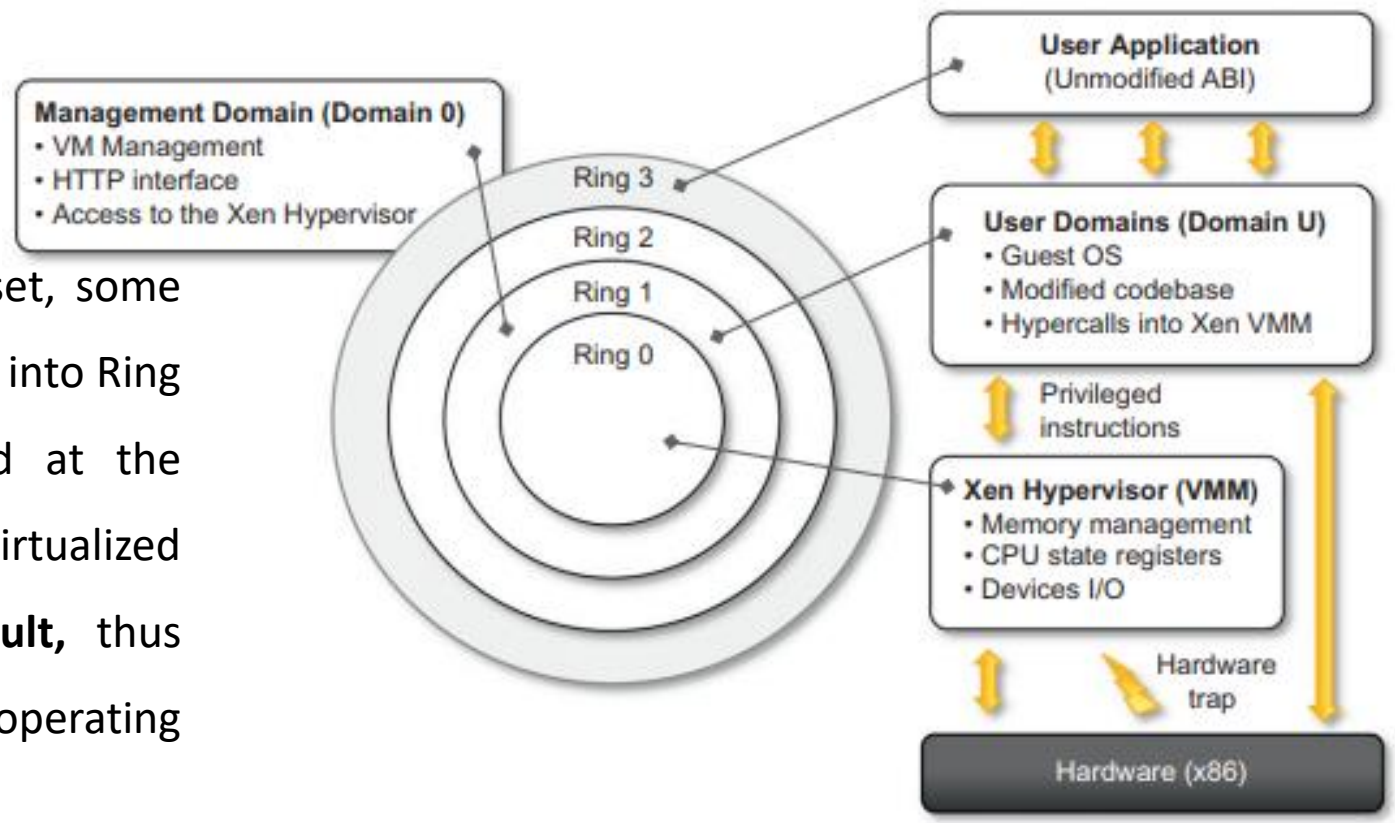


- The architecture of Xen and its mapping onto a classic x86 privilege model.
- A Xen-based system is managed by the Xen hypervisor, which runs in the highest privileged mode and controls the access of guest operating system to the underlying hardware
- operating systems are executed within domains, which represent virtual machine instances. Moreover, specific control software, which has privileged access to the host and controls all the other guest operating systems, is executed in a special domain called **Domain 0**.

Many of the x86 implementations support four different security levels, called rings, where Ring 0 represent the level with the highest privileges and Ring 3 the level with the lowest ones

Virtualization

Xen: Paravirtualization



- Because of the structure of the x86 instruction set, some instructions allow code executing in Ring 3 to jump into Ring 0 (kernel mode). Such operation is performed at the hardware level and therefore within a virtualized environment will result in a **trap or silent fault,** thus preventing the normal operations of the guest operating system
- To avoid this situation, operating systems need to be changed in their implementation, and the sensitive system calls need to be reimplemented with **hypercalls**

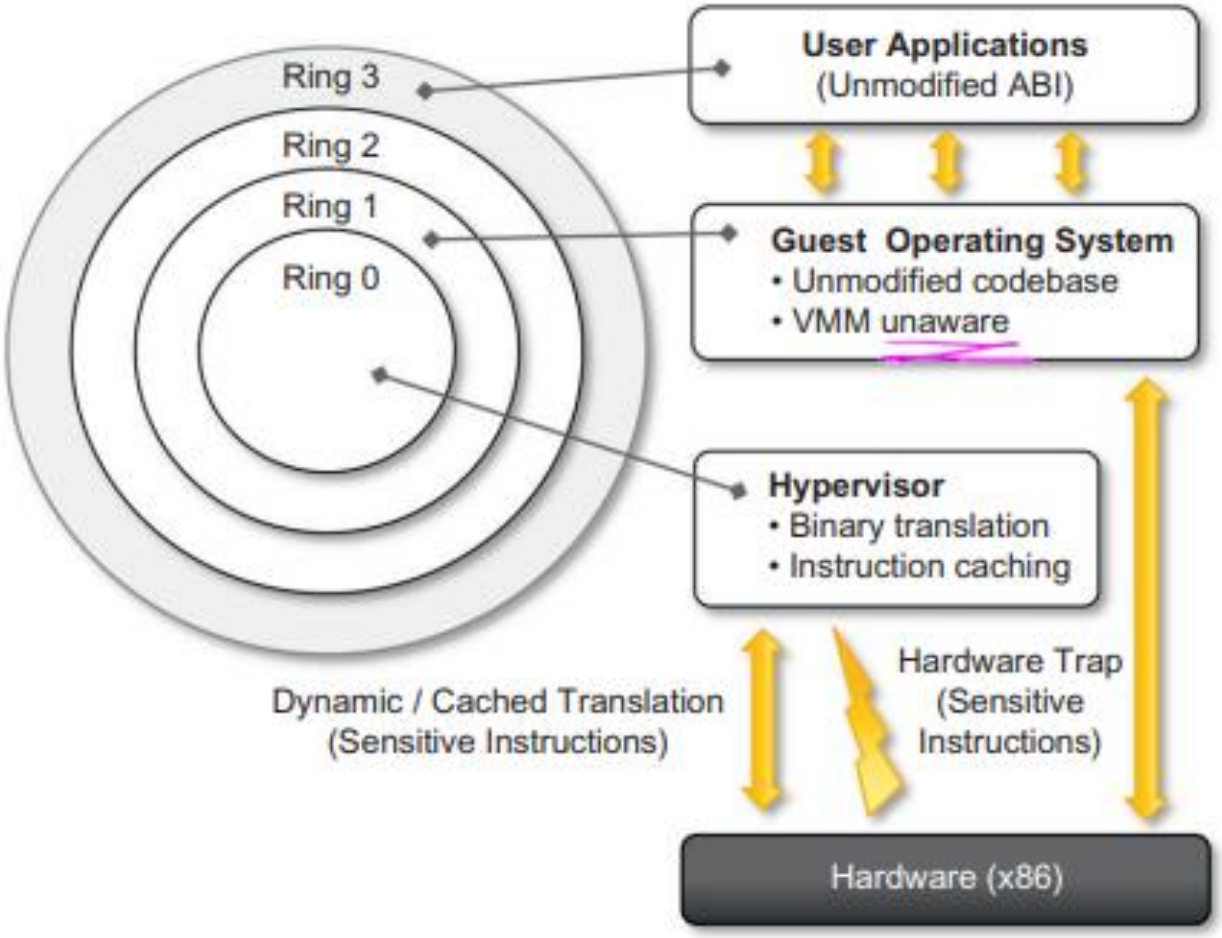
Xen exhibits some limitations in the case of legacy hardware and legacy operating systems

The hypervisor provides a calling mechanism for guests. Such calls are referred to as hypercalls. Each hypercall defines a set of input and/or output parameters. These parameters are specified in terms of a memory-based data structure

Virtualization

VMware: full virtualization

- VMware's technology is based on the concept of full virtualization, where the underlying hardware is replicated and made available to the guest operating system.
- VMware implements full virtualization either in the **desktop environment**, by means of **Type II hypervisors**, or in the **server environment**, by means of **Type I hypervisors.**
- In both cases, full virtualization is made possible by means of **direct execution** (for nonsensitive instructions) and **binary translation** (for sensitive instructions)



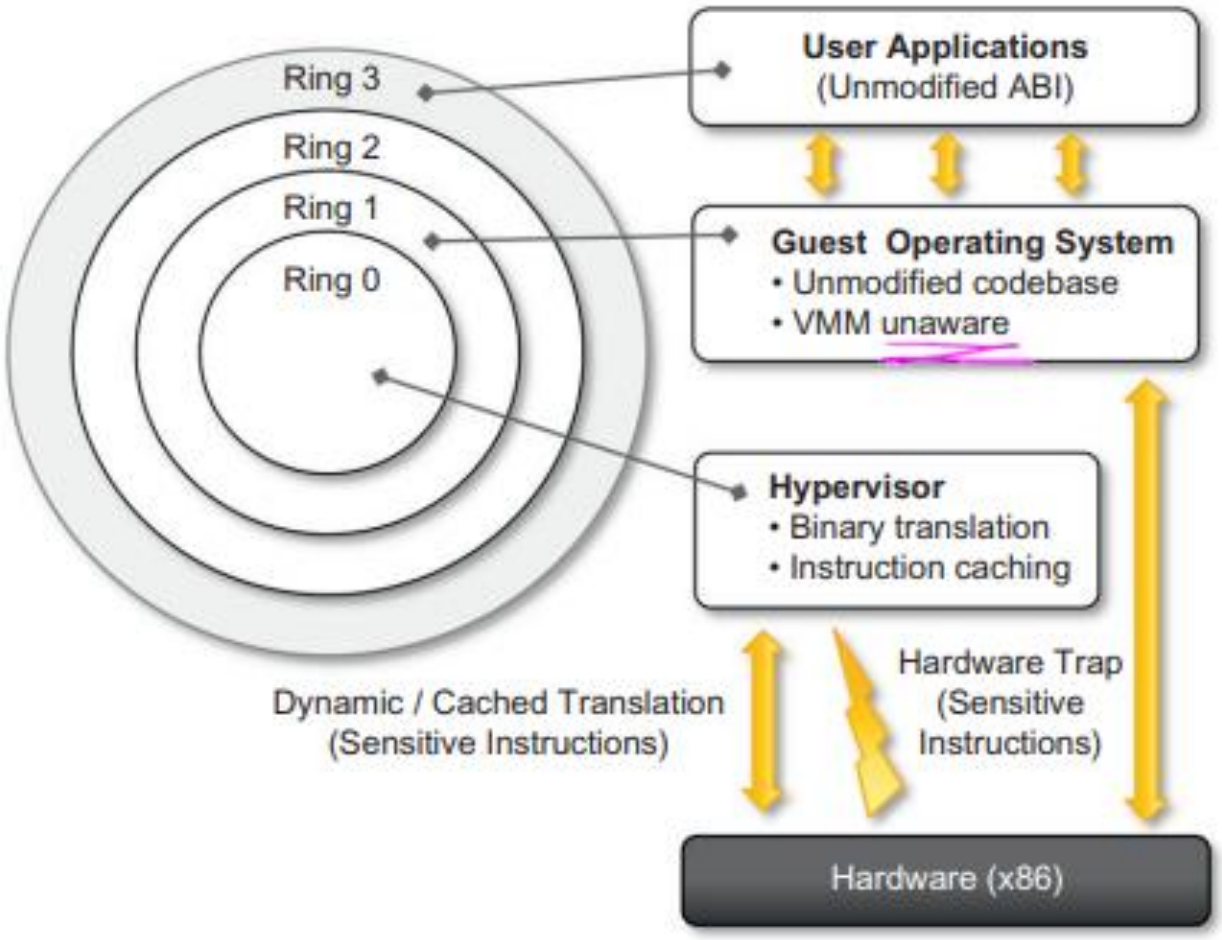
A full virtualization reference model.

Virtualization

VMware: full virtualization

Full virtualization and binary translation

- VMware is well known for the capability to virtualize x86 architectures, which runs unmodified on top of their hypervisors.
- With the new generation of hardware architectures and the introduction of hardware-assisted virtualization.
- **Dynamic binary translation** is the only solution to implement full virtualization

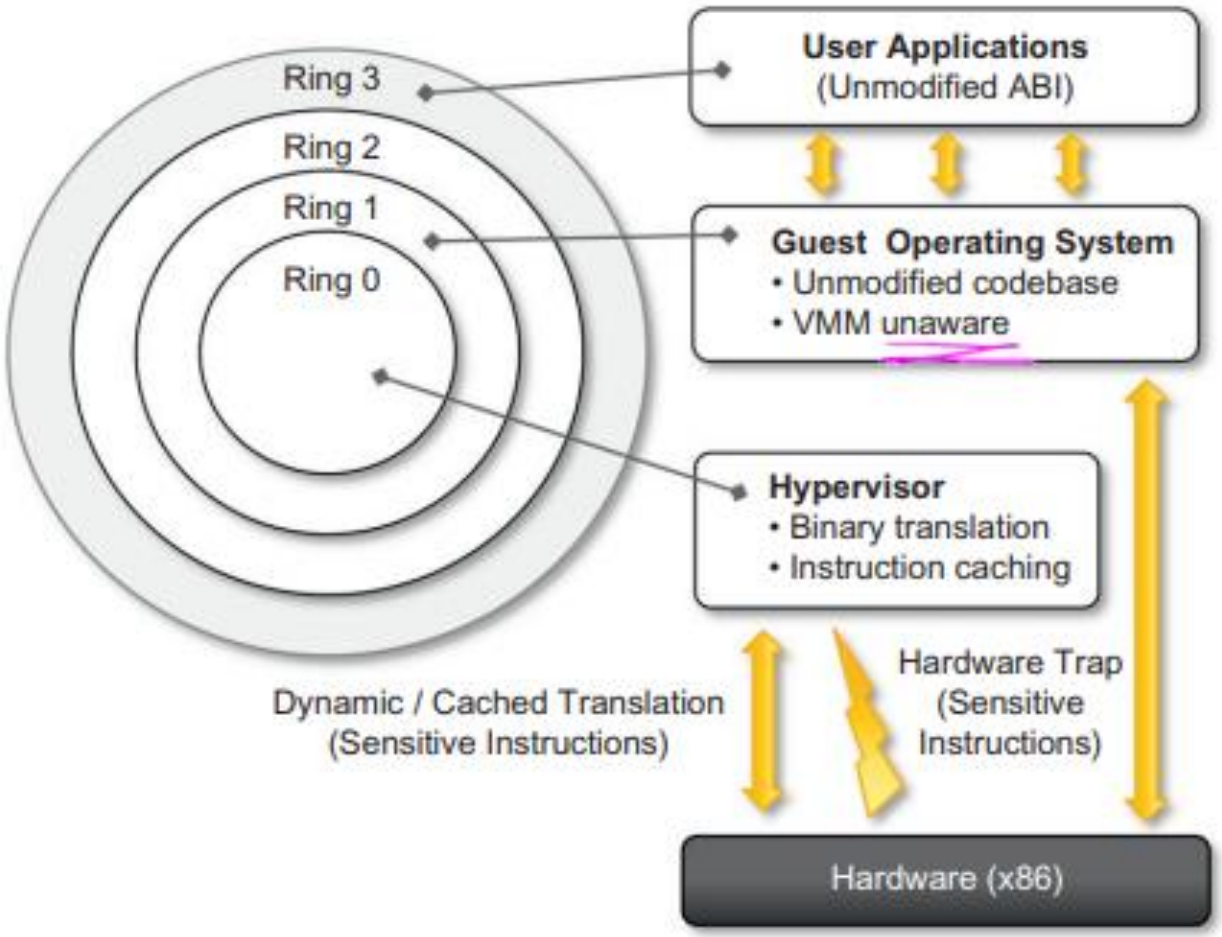


Generally, a trap is generated and the way it is managed differentiates the solutions in which virtualization is implemented for x86 hardware. In the case of dynamic binary translation, the trap triggers the translation of the offending instructions into an equivalent set of instructions that achieves the same goal without generating exceptions.

Virtualization

VMware: full virtualization

- **CPU virtualization** is only a component of a fully virtualized hardware environment. VMware achieves full virtualization by providing virtual representation of memory and I/O devices.
- Memory virtualization constitutes another challenge of virtualized environment



Virtualization

VMware: full virtualization

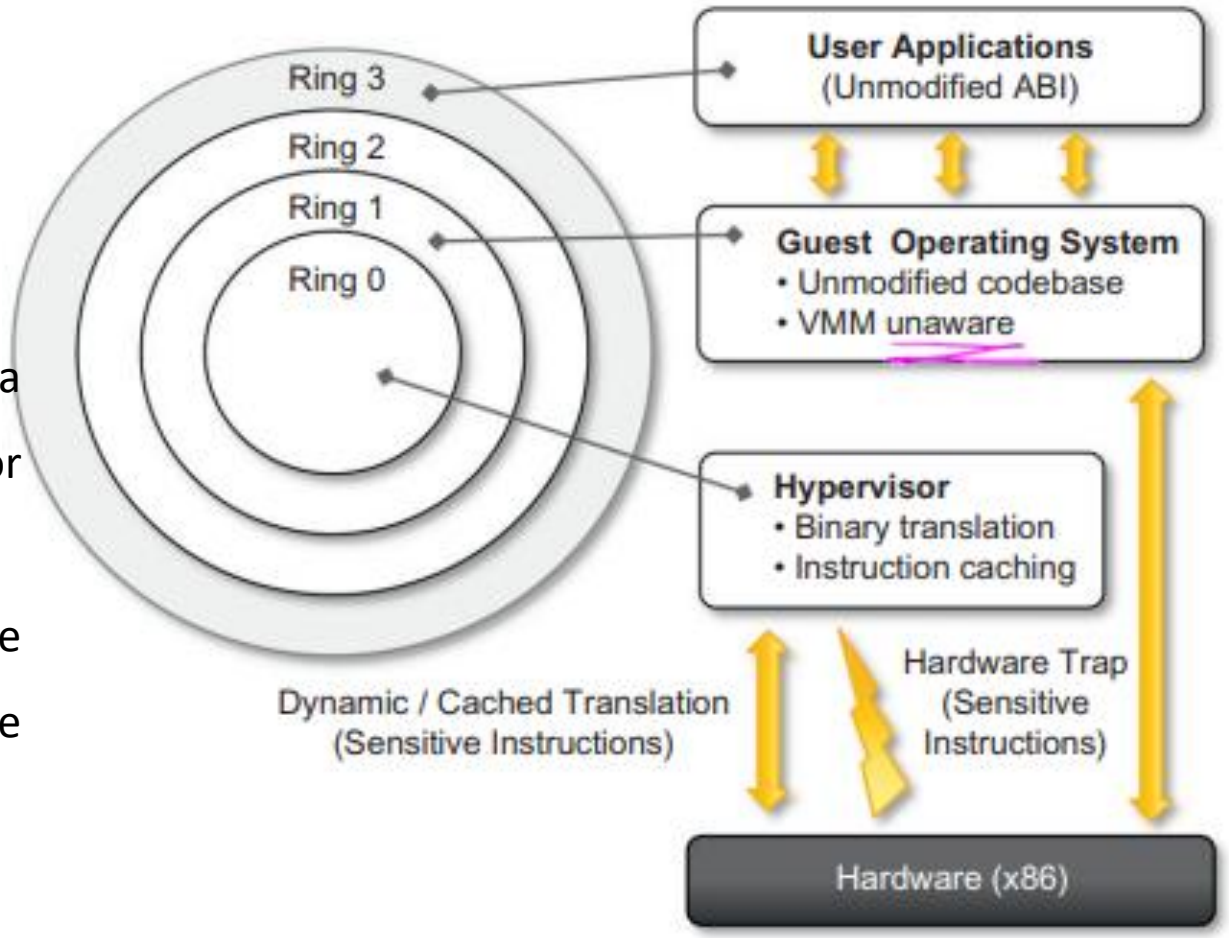
This approach has both advantages and disadvantages.

Advantages

- The major advantage is that guests can run unmodified in a virtualized environment, which is a crucial feature for operating systems for which source code is not available.
- This is the case, for example, of operating systems in the Windows family. Binary translation is a more portable solution for full virtualization.

Disadvantages

- On the other hand, translating instructions at runtime introduces an additional overhead that is not present in other approaches



VMware: full virtualization

Virtualization solutions

- End-user (desktop) virtualization
- Server virtualization
- ~~Infrastructure virtualization and cloud computing solutions (X)~~

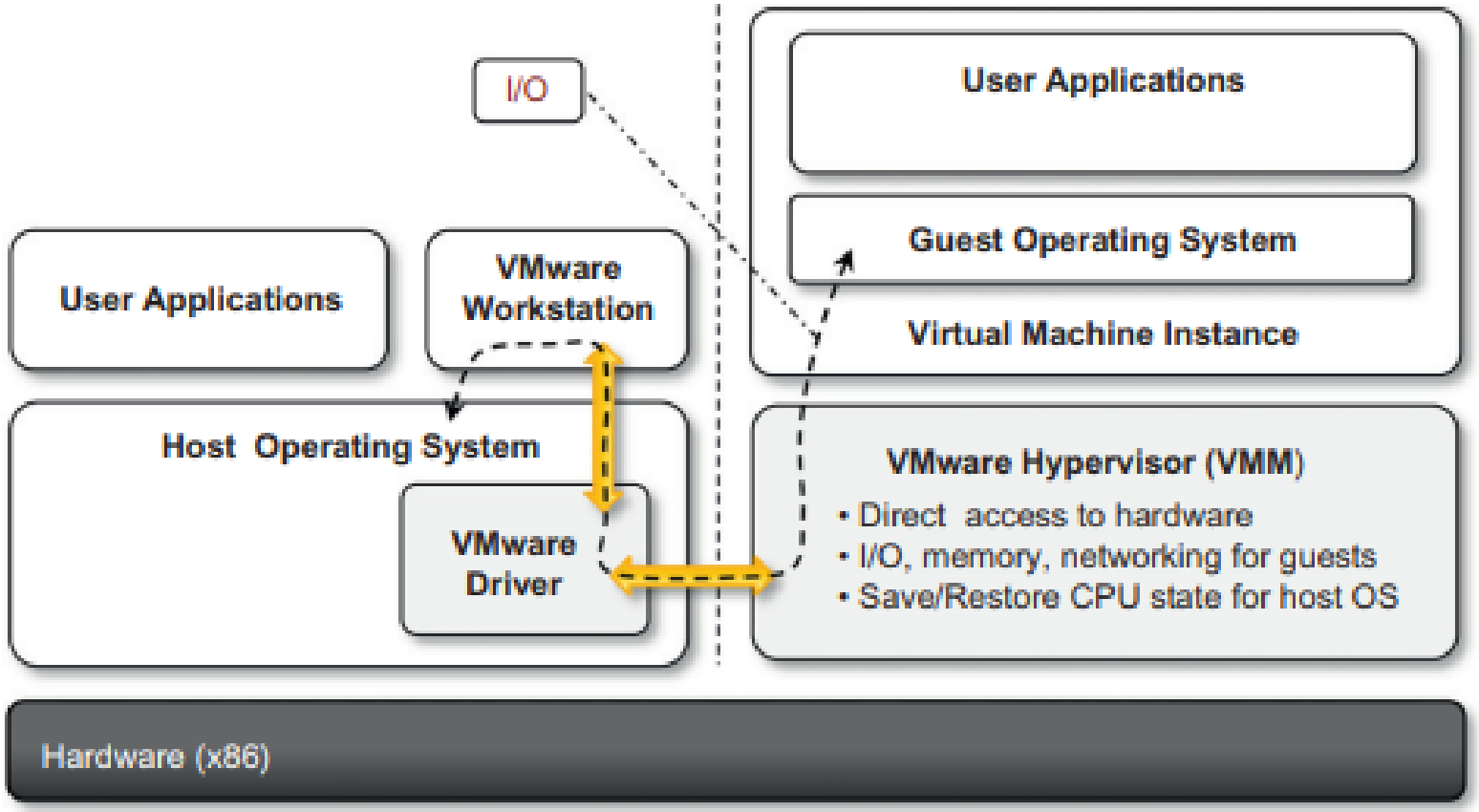
Virtualization

VMware: full virtualization

Virtualization solutions

End-user (desktop) virtualization

- VMware supports virtualization of operating system environments and single applications on enduser computers.
- VMware software—VMware Workstation, for Windows operating systems, and VMware Fusion, for Mac OS X environments—is installed in the host operating system to create virtual machines and manage their execution



VMware workstation architecture.

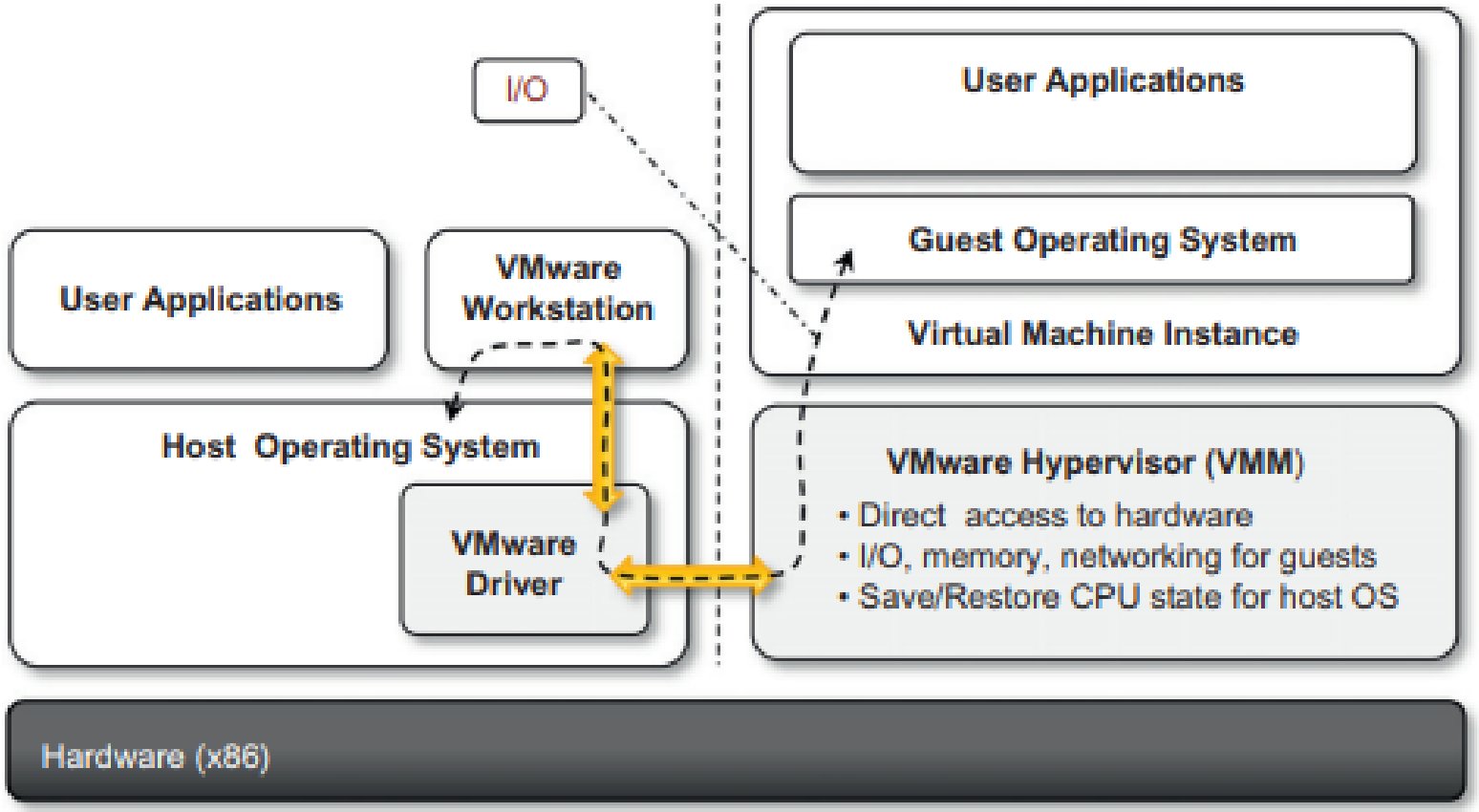
Virtualization

VMware: full virtualization

Virtualization solutions

End-user (desktop) virtualization

- The virtualization environment is created by an application installed in guest operating systems, which provides those operating systems with full hardware virtualization.
- VM Ware driver in the host operating system that provides two main services:



VMware workstation architecture.

- It deploys a virtual machine manager that can run in privileged mode.
- It provides hooks for the VMware application to process specific I/O requests eventually by relaying such requests to the host operating system via system calls.

Virtualization

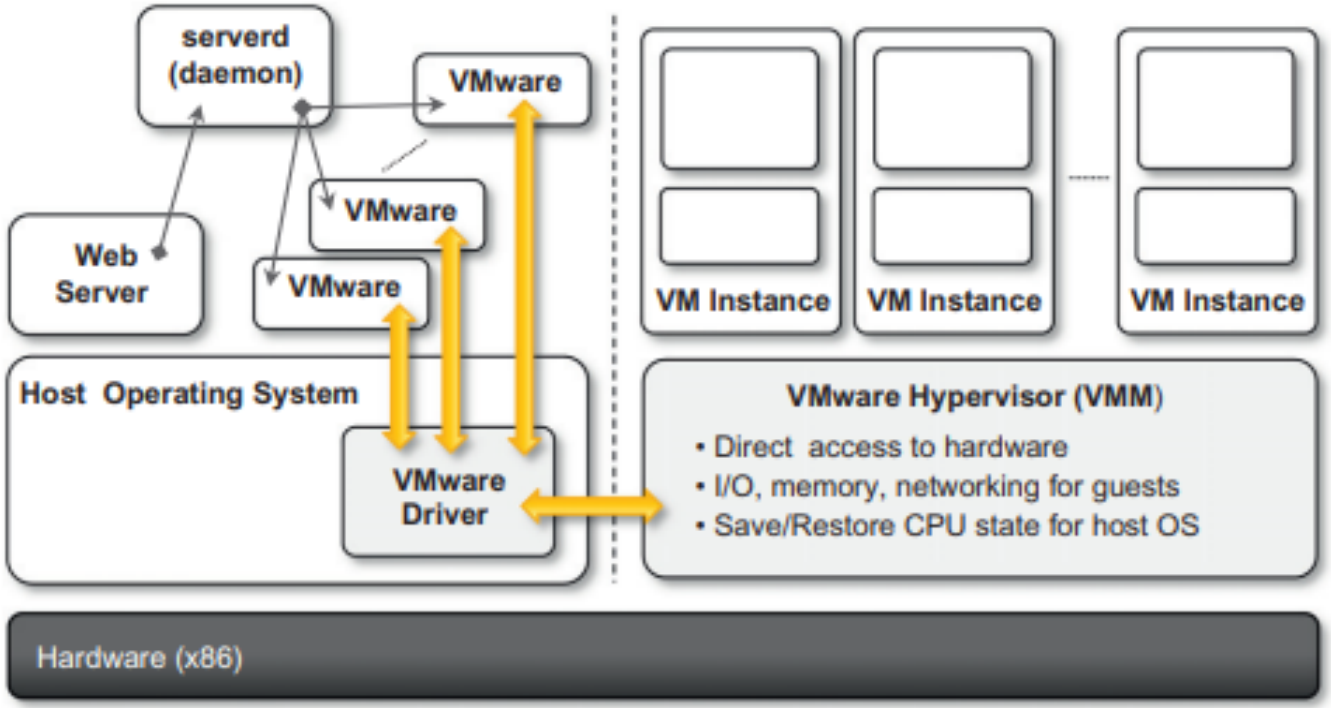
VMware: full virtualization

Virtualization solutions

Server virtualization

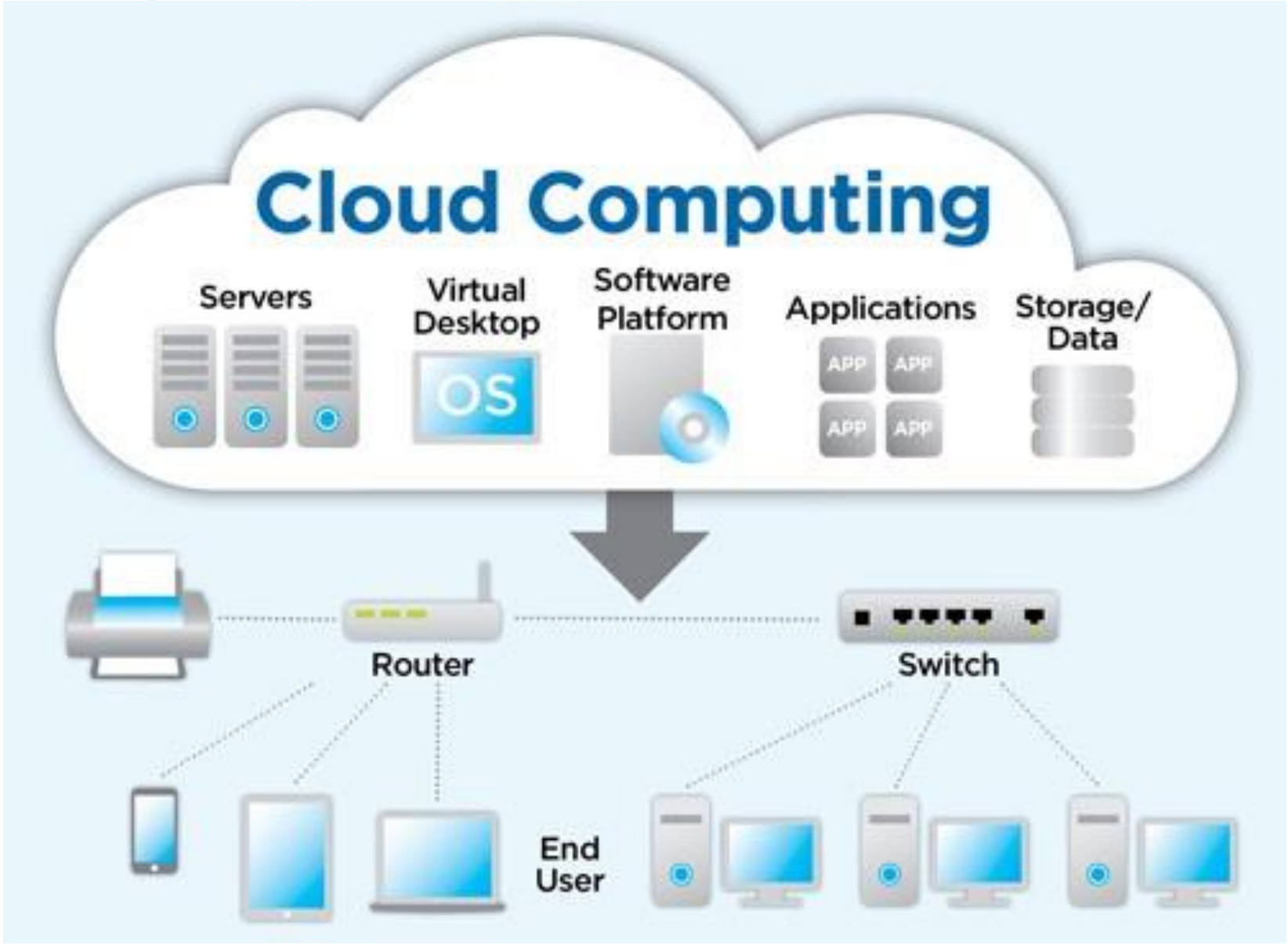
- The architecture is mostly designed to serve the virtualization of Web servers. A daemon process, called serverd, controls and manages VMware application processes.

- These applications are then connected to the virtual machine instances by means of the VMware driver installed on the host operating system. Virtual machine instances are managed by the VMM as described previously. User requests for virtual machine management and provisioning are routed from the Web server through the VMM by means of serverd



VMware GSX server architecture.

Cloud Computing Architecture



Scenario

A smart city is an urban area that uses different types of electronic data collection sensors to supply information which is used to manage assets and resources efficiently. This includes data collected from citizens, devices, and assets that is processed and analysed to monitor and manage traffic and transportation systems, power plants, water supply networks, waste management, law enforcement, information systems, schools, libraries, hospitals, and other community services. Imagine yourself as a cloud service provider, who provides all three service models, propose a cloud-based system to support the smart cities.

- **Platform-as-a-Service (PaaS)** solutions provide a development and deployment platform for running applications in the cloud.
- Application management is the core functionality of the middleware. PaaS implementations provide applications with a runtime environment and do not expose any service for managing the underlying infrastructure
- They automate the process of deploying applications to the infrastructure, configuring application components, provisioning and configuring supporting technologies such as load balancers and databases, and managing system change based on policies set by the user

Cloud Computing Architecture

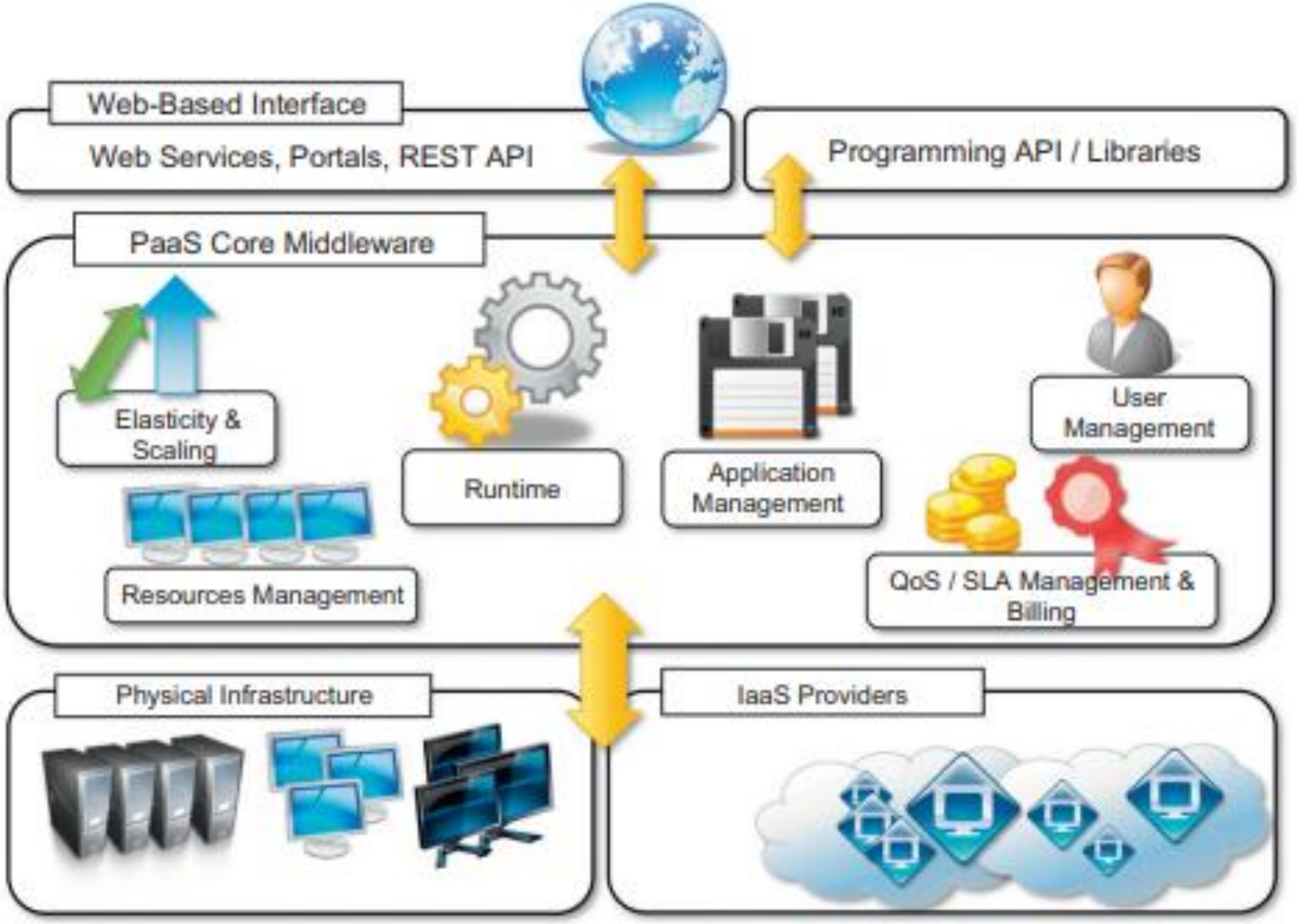


Table 4.2 Platform-as-a-Service Offering Classification

Category	Description	Product Type	Vendors and Products
PaaS-I	Runtime environment with Web-hosted application development platform. Rapid application prototyping.	Middleware + Infrastructure Middleware + Infrastructure	Force.com Longjump
PaaS-II	Runtime environment for scaling Web applications. The runtime could be enhanced by additional components that provide scaling capabilities.	Middleware + Infrastructure Middleware Middleware + Infrastructure Middleware + Infrastructure Middleware + Infrastructure Middleware	Google AppEngine AppScale Heroku Engine Yard Joyent Smart Platform GigaSpaces XAP
PaaS-III	Middleware and programming model for developing distributed applications in the cloud.	Middleware + Infrastructure Middleware Middleware Middleware Middleware Middleware	Microsoft Azure DataSynapse Cloud IQ Manjrasof Aneka Apprenda SaaSGrid GigaSpaces DataGrid

Software as a service Software-as-a-Service (SaaS)

The acronym SaaS was then coined in 2001 by the Software Information & Industry Association (SIIA) with the following connotation:

In the software as a service model, the application, or service, is deployed from a centralized datacentre across a network—Internet, Intranet, LAN, or VPN—providing access and use on a recurring fee basis. Users “rent,” “subscribe to,” “are assigned,” or “are granted access to” the applications from a central provider. Business models vary according to the level to which the software is streamlined, to lower price and increase efficiency, or value-added through customization to further improve digitized business processes.

Software as a service Software-as-a-Service (SaaS) is a software delivery model that provides access to applications through the Internet as a Web-based service.

- It provides a means to free users from complex hardware and software management by offloading such tasks to third parties, which build applications accessible to multiple users through a Web browser.

- **Multitenancy,** which is a feature of SaaS compared to traditional packaged software, allows providers to **centralize** and **sustain** the effort of **managing large hardware infrastructures**, **maintaining** and **upgrading** applications transparently to the users, and optimizing resources by sharing the costs among the large user base

The core characteristics of SaaS:

- The product sold to customer is application access.
- The application is centrally managed.
- The service delivered is one-to-many.
- The service delivered is an integrated solution delivered on the contract, which means provided as promised.

Benefits of SAAS

Software cost reduction and total cost of ownership (TCO) were paramount

Service-level improvements

Rapid implementation

Standalone and configurable applications

Rudimentary application and data integration

Subscription and pay-as-you-go (PAYG) pricing

Types of clouds

Public clouds. The cloud is open to the wider public.

Private clouds. The cloud is implemented within the private premises of an institution and generally made accessible to the members of the institution or a subset of them.

Hybrid or heterogeneous clouds. The cloud is a combination of the two previous solutions and most likely identifies a private cloud that has been augmented with resources or services hosted in a public cloud.

Community clouds. The cloud is characterized by a multi-administrative domain involving different deployment models (public, private, and hybrid), and it is specifically designed to address the needs of a specific industry.

Types of clouds

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Public clouds

These services offered are made available to anyone, from anywhere, and at any time through the Internet.

From a structural point of view they are a distributed system, most likely composed of one or more datacenters connected together, on top of which the specific services offered by the cloud are implemented

They have become an interesting option for small enterprises, which are able to start their businesses without large up-front investments by completely relying on public infrastructure for their IT needs

A fundamental characteristic of public clouds is **multitenancy**

Private clouds

Public clouds are appealing and provide a viable option to cut IT costs and reduce capital expenses, but they are not applicable in all scenarios.

For example, a very common critique to the use of cloud computing in its canonical implementation is the **loss of control**.

Fair management and respect of the customer's privacy

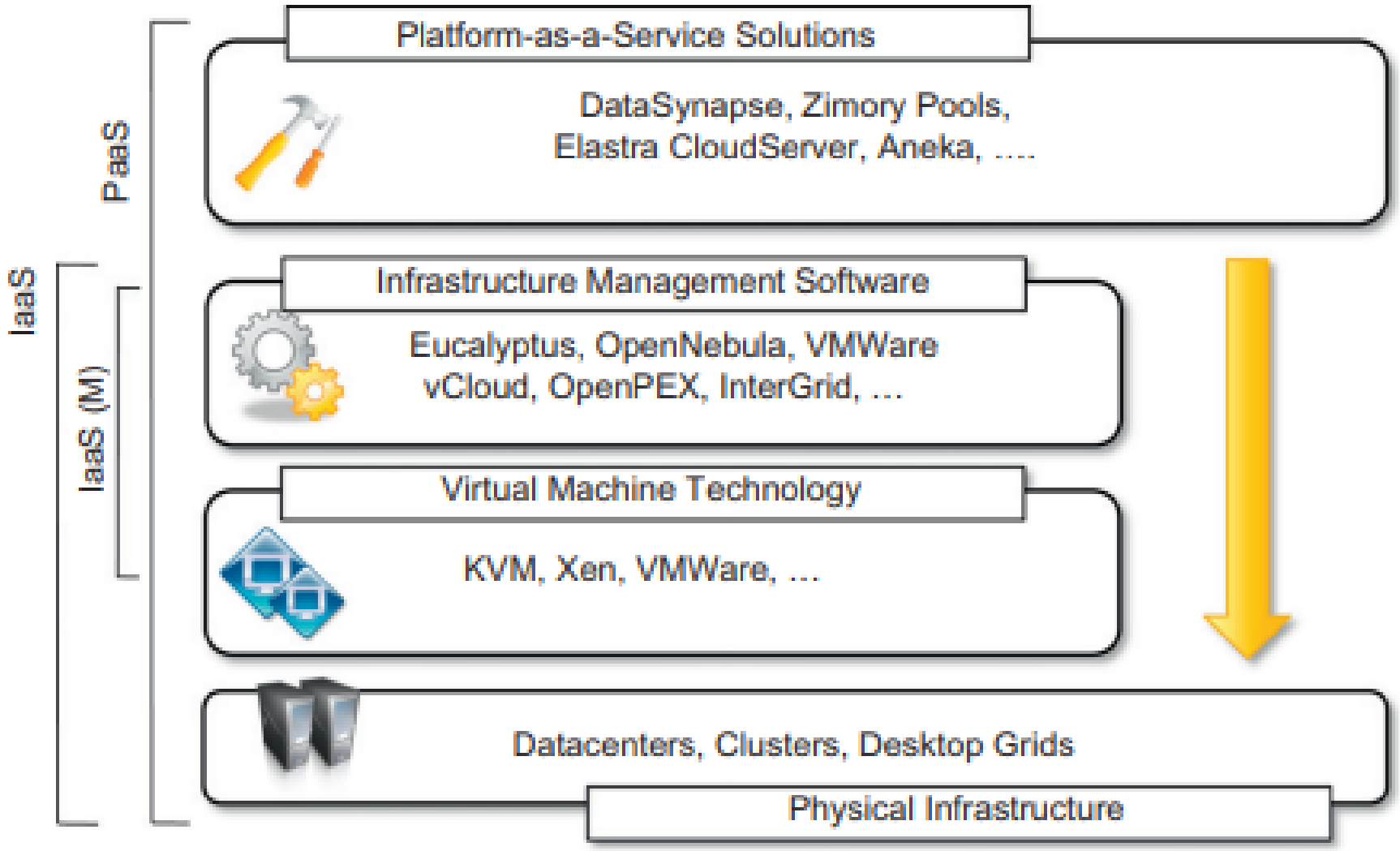
Private clouds are virtual distributed systems that rely on a private infrastructure and provide internal users with dynamic provisioning of computing resources.

Cloud Computing Architecture

key advantages of using a private cloud computing infrastructure:

- Customer information protection.
- Infrastructure ensuring SLAs.
- Compliance with standard procedures and operations.

Cloud Computing Architecture



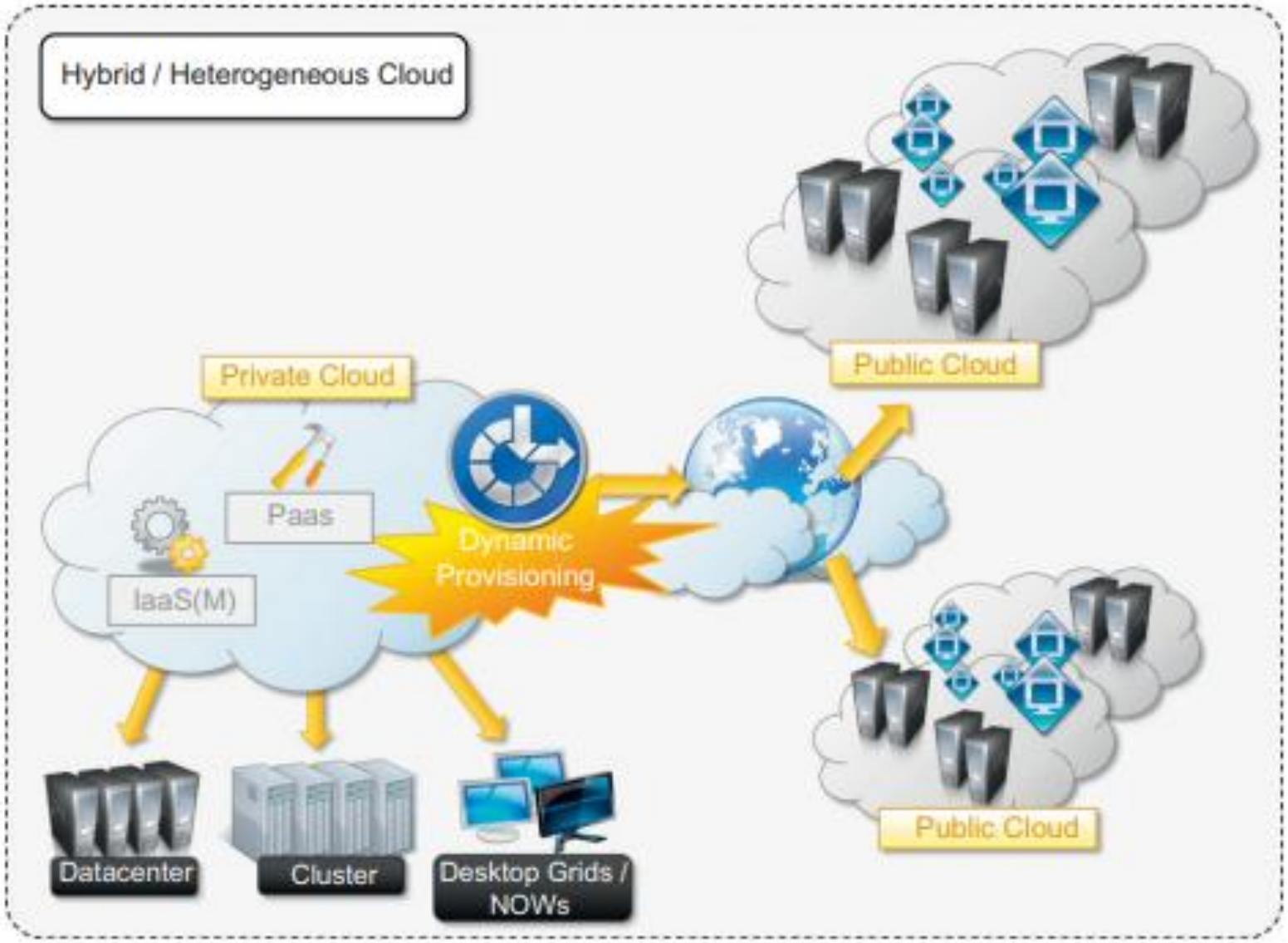
Private clouds hardware and software stack.

hybrid clouds.

- Hybrid clouds allow enterprises to exploit existing IT infrastructures, maintain sensitive information within the premises, and naturally grow and shrink by provisioning external resources and releasing them when they're no longer needed.
- Hybrid clouds address scalability issues by leveraging external resources for exceeding Datacenter Public Cloud Cluster Desktop Grids / NOWs Public Cloud Dynamic Provisioning IaaS(M) Paas Private Cloud Hybrid / Heterogeneous Cloud capacity demand.

- These resources or services are temporarily leased for the time required and then released. This practice is also known as **cloudbursting**.

Cloud Computing Architecture



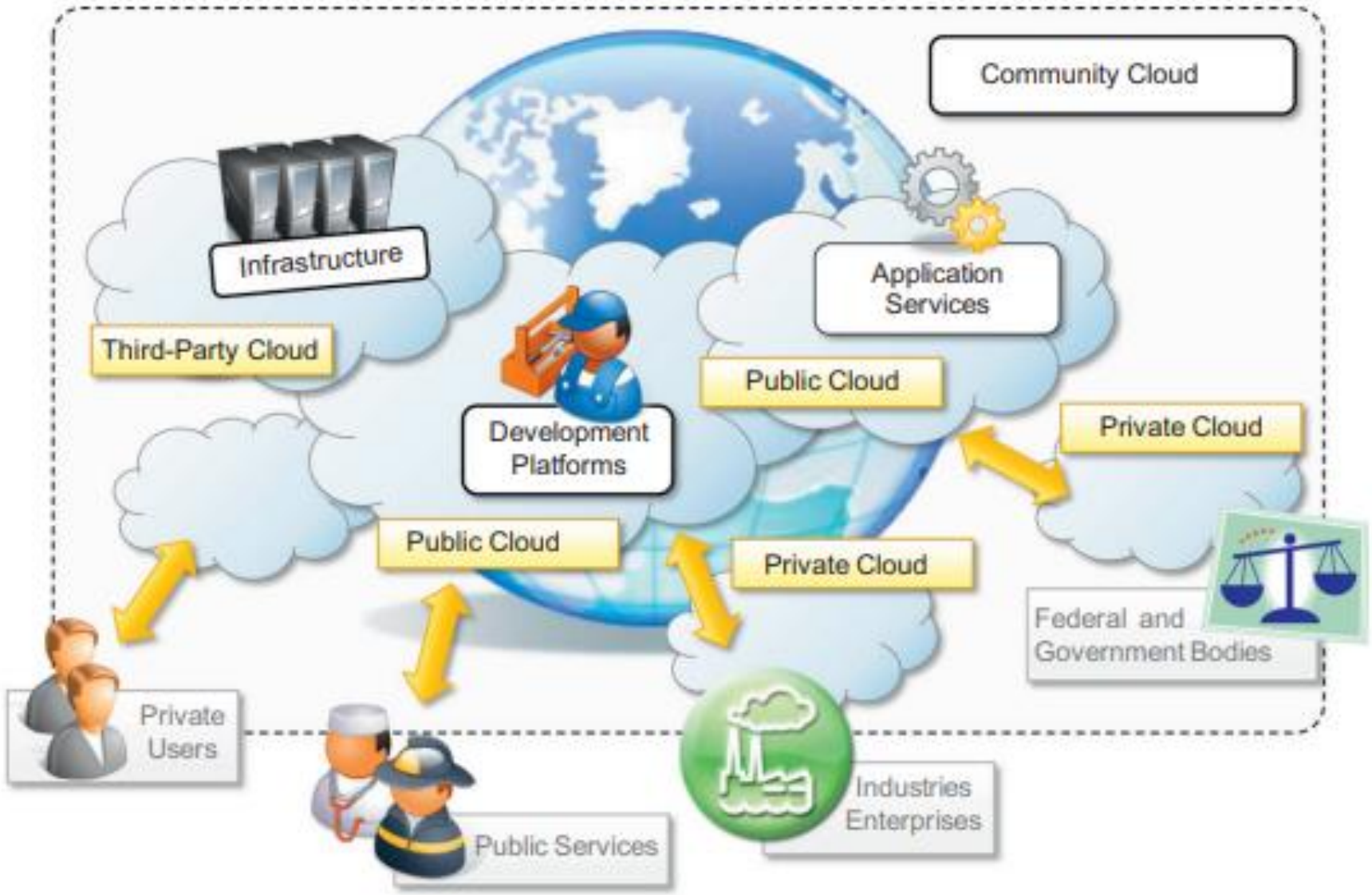
Community clouds

Community clouds are distributed systems created by integrating the services of different clouds to address the specific needs of an industry, a community, or a business sector.

The National Institute of Standards and Technologies (NIST) characterizes community clouds as follows:

The infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on premise or off premise

Cloud Computing Architecture



A community cloud.

Candidate sectors for community clouds are as follows:

- Media industry.
- Healthcare industry.
- Energy and other core industries
- Public sector.
- Scientific research.

Cloud Computing Architecture

The benefits of these community clouds are the following:

- Openness.
- Community.
- Graceful failures.
- Convenience and control.
- tic process. •
- Environmental sustainability.