UNIVERSIDADE
BEIRA INTERIOR

# System Models, Cloud Types and Ecosystem

Computação na Nuvem

Mestrado em Engenharia Informática

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Ano Letivo 2023/2024

# Credits

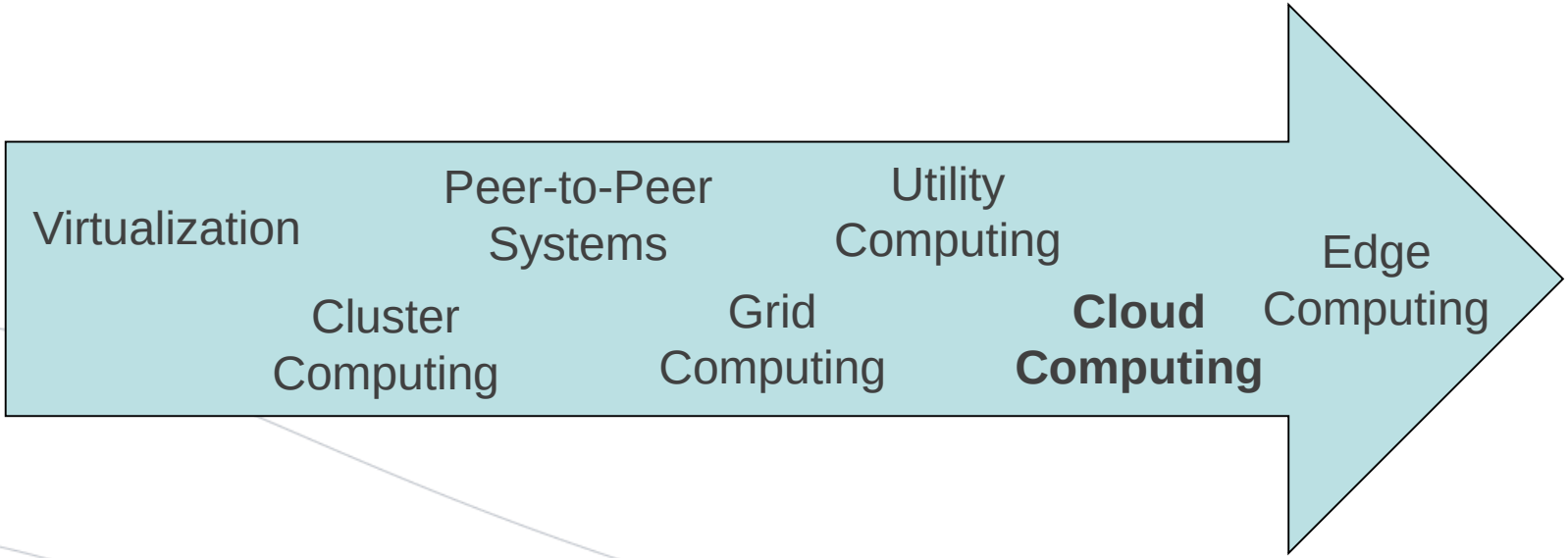
- These slides are partly based on the following:
- Distributed and Cloud Computing: From Parallel Processing to the Internet of Things, Kai Hwang, Jack Dongarra, Geoffrey C. Fox (Authors), Morgan Kaufmann, 1st edition, 2011, ISBN-13: 978-0123858801, 672 pages.
- utility computing, SearchDataCenter, TechTarget, https://searchdatacenter.techtarget.com/definition/utility-computing
- What is edge computing and why it matters, Keith Shaw, Network World, Nov 13, 2019, https://www.networkworld.com/article/3224893/what-is-edge-computing-and-how-it-s-changing-the-network.html
- What Is Edge Computing?, Cloudflare, 2020 https://www.cloudflare.com/learning/serverless/glossary/what-is-edge-computing/
- NIST Cloud Computing Reference Architecture, Recommendations of the National Institute of Standards and Technology, Sept 2011, https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication500-292.pdf
- Cloud Computing – Types of Cloud, July 6, 2018, https://www.esds.co.in/blog/cloud-computing-types-cloud/#sthash.QsyM2lKU.FGfJPmd0.dpbs
- The Different Types of Cloud Computing and How They Differ, Blair Felter, February 6th, 2020, https://www.vxchnge.com/blog/different-types-of-cloud-computing

# Agenda

- System Models for Distributed and Cloud Computing
- What is Cloud Computing?
- Public, Private, and Hybrid Clouds
- Cloud Ecosystem and Enabling Technologies

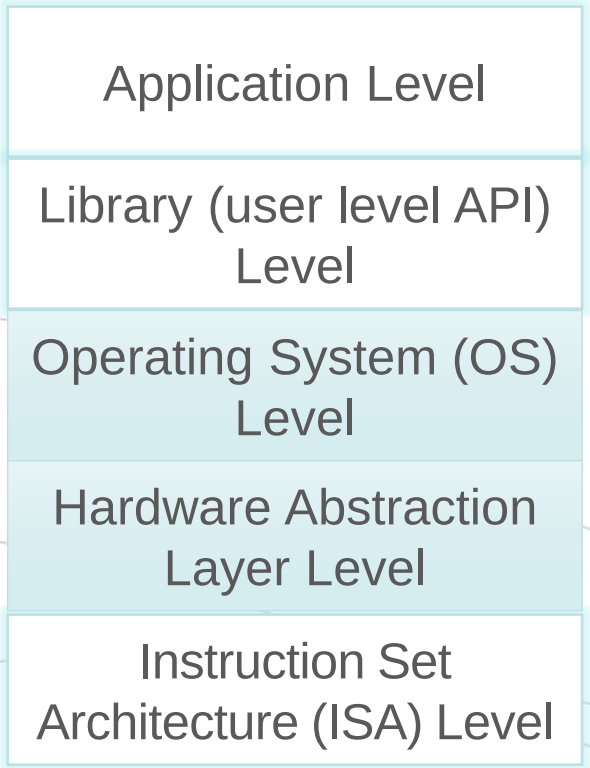
# System Models for Distributed and Cloud Computing

## Evolution of Computing Paradigms



# System Models for Distributed and Cloud Computing

**Virtualization**
in 5 abstraction layers




- The main function of the software layer for hardware level virtualization, known as hypervisor, is to virtualize the physical hardware of a host machine into virtual resources to be used by the VMs.
- The purpose of a virtual machine (VM) is to enhance resource sharing by many users and improve resource utilization and application flexibility.
- OS-level virtualization creates isolated containers on a single physical server and the OS instances to utilize the hardware and software. The containers behave like real servers.

# System Models for Distributed and Cloud Computing

**Table 1.2** Classification of Parallel and Distributed Computing Systems

| Functionality, Applications | Computer Clusters [10,28,38] | Peer-to-Peer Networks [34,46] | Data/ Computational Grids [6,18,51] | Cloud Platforms [1,9,11,12,30] |
|---|---|---|---|---|
| Architecture, Network Connectivity, and Size | Network of compute nodes interconnected by SAN, LAN, or WAN hierarchically | Flexible network of client machines logically connected by an overlay network | Heterogeneous clusters interconnected by high-speed network links over selected resource sites | Virtualized cluster of servers over data centers via SLA |
| Control and Resources Management | Homogeneous nodes with distributed control, running UNIX or Linux | Autonomous client nodes, free in and out, with self-organization | Centralized control, server-oriented with authenticated security | Dynamic resource provisioning of servers, storage, and networks |
| Applications and Network-centric Services | High-performance computing, search engines, and web services, etc. | Most appealing to business file sharing, content delivery, and social networking | Distributed supercomputing, global problem solving, and data center services | Upgraded web search, utility computing, and outsourced computing services |
| Representative Operational Systems | Google search engine, SunBlade, IBM Road Runner, Cray XT4, etc. | Gnutella, eMule, BitTorrent, Napster, KaZaA, Skype, JXTA | TeraGrid, GriPhyN, UK EGEE, D-Grid, ChinaGrid, etc. | Google App Engine, IBM Bluecloud, AWS, and Microsoft Azure |

# System Models for Distributed and Cloud Computing

- **Utility Computing** is a service provisioning model in which a service provider makes computing resources and infrastructure management available to the customer as needed, and charges them for specific usage rather than a flat rate.
- As in other types of on-demand computing (such as grid computing), the utility model seeks to maximize the efficiency use of resources and/or maximize associated costs.

# System Models for Distributed and Cloud Computing

- With deployments of Internet of Things (IoT) devices and the arrival of 5G fast wireless, placing compute and analytics close to where data is created is making the case for **edge computing**.
- **Edge computing** is a new paradigm focused on bringing computing as close to the source of data as possible in order to reduce latency and bandwidth use.
- In simpler terms, edge computing means running fewer processes in the cloud and moving those processes to local places, such as on a user's computer, an IoT device, or an edge server.
- Bringing computation to the network's edge minimizes the amount of long-distance communication that has to happen between a client and server.

# System Models for Distributed and Cloud Computing

- Edge computing is transforming the way data is being handled, processed, and delivered from millions of devices around the world. The explosive growth of internet-connected devices – the IoT – along with new applications that require real-time computing power, continues to drive edge-computing systems.

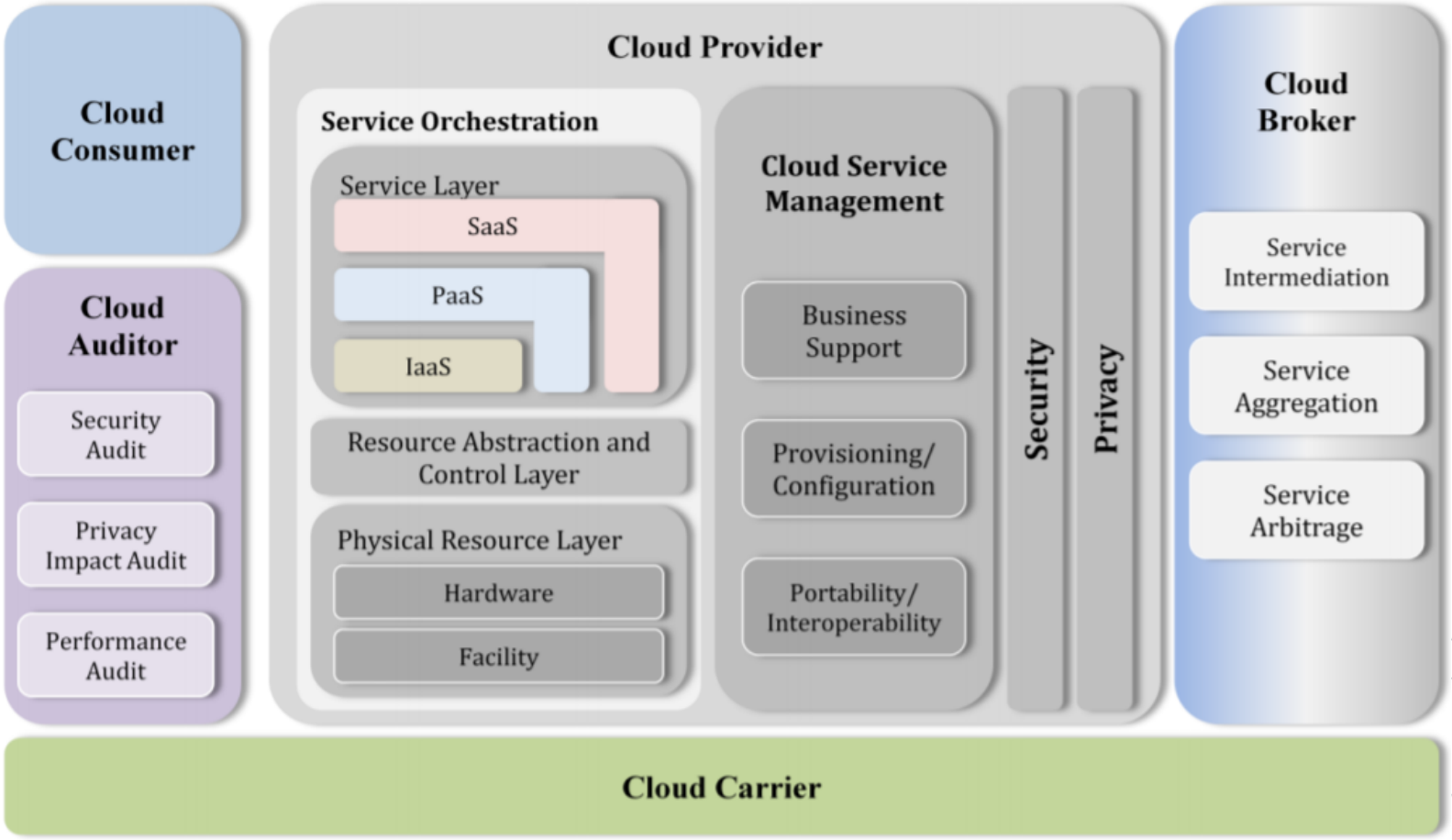
- Faster networking technologies, such as 5G wireless, are allowing for edge computing systems to accelerate the creation or support of real-time applications, such as video processing and analytics, self-driving cars, artificial intelligence and robotics, to name a few.

# What is Cloud Computing?

- **Cloud computing** is the delivery of computing services like servers, storages and more over the Internet. The companies that offer these computing services are called cloud (service) providers. They charge for cloud computing services based on usage.
- **Cloud computing** is usually classified on the basis of location (Public, Private, Hybrid, Community Cloud), or on the service (IaaS - Infrastructure as a Service, PaaS - Platform as a Service, SaaS - Software as a Service, or, Storage, Database, Information, Process, Application, Integration, Security, Management or Testing as a service) that the cloud is offering.

# What is Cloud Computing?

NIST (National Institute of Standards and Technology) Conceptual Reference Model



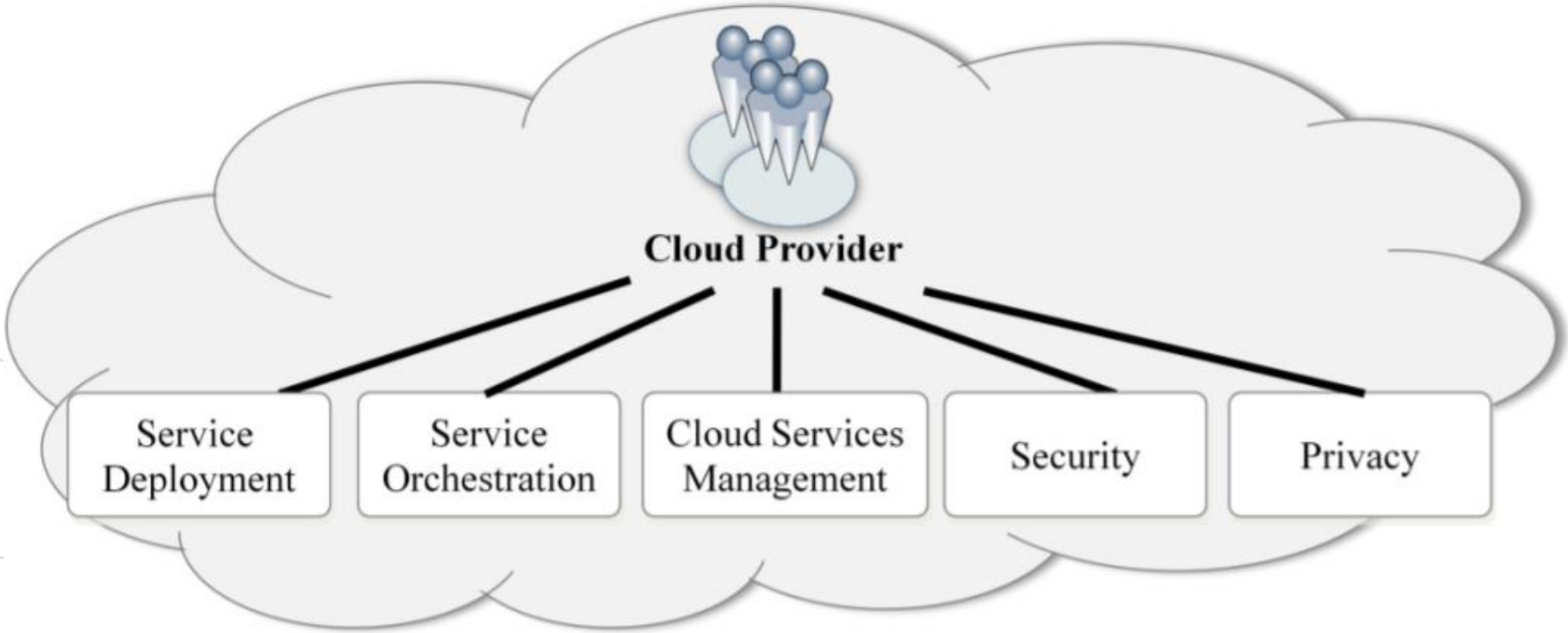
# What is Cloud Computing?

## Actors in Cloud Computing

| Actor | Definition |
|---|---|
| **Cloud Consumer** | A person or organization that maintains a business relationship with, and uses service from, *Cloud Providers*. |
| **Cloud Provider** | A person, organization, or entity responsible for making a service available to interested parties. |
| **Cloud Auditor** | A party that can conduct independent assessment of cloud services, information system operations, performance and security of the cloud implementation. |
| **Cloud Broker** | An entity that manages the use, performance and delivery of cloud services, and negotiates relationships between *Cloud Providers* and *Cloud Consumers*. |
| **Cloud Carrier** | An intermediary that provides connectivity and transport of cloud services from *Cloud Providers* to *Cloud Consumers*. |

# What is Cloud Computing?

Major Activities of a Cloud Provider



# Public, Private, and Hybrid Clouds

- **Cloud Types**
  - Public Clouds
  - Private Clouds
  - Hybrid Clouds
  - Community Clouds
  - Multi-cloud Models

# Public, Private, and Hybrid Clouds

- There is no consensus about the number of cloud types:
  - **Tree Cloud Types** (Public Clouds, Private Clouds, Hybrid Clouds)
  - **Four Cloud Types** (Public Clouds, Private Clouds, Hybrid Clouds, Community Clouds)
  - **Five Cloud Types** (Public Clouds, Private Clouds, Hybrid Clouds, Community Clouds, Multi-cloud Models)

# Public, Private, and Hybrid Clouds

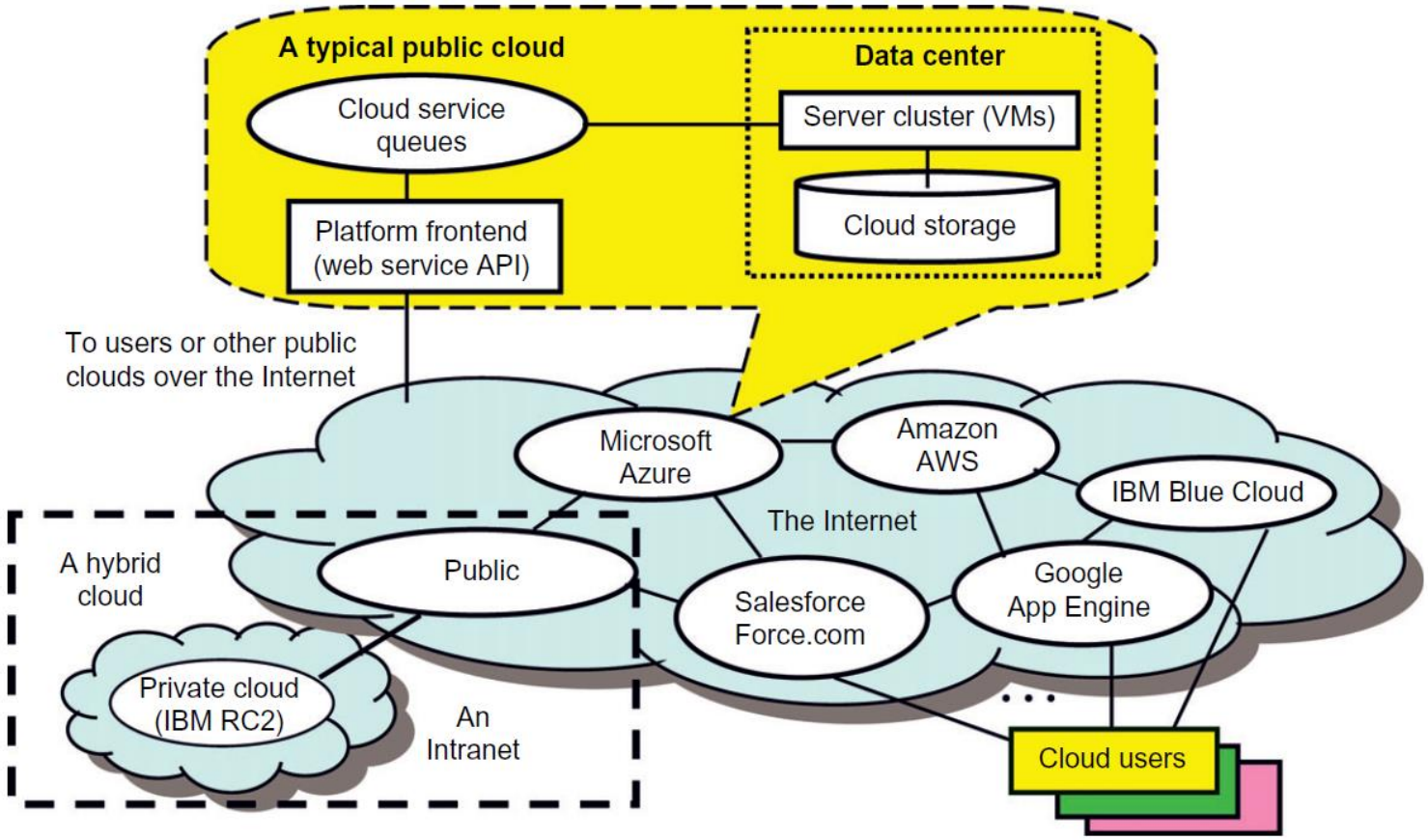
- **Public Clouds**
- Cloud platforms are systems distributed through virtualization and may be distributed geographically.
- A public cloud is built over the Internet and can be accessed by subscription by any user.
- Many public clouds are available, including Google Cloud Platform, Amazon Web Services (AWS), Microsoft Azure, IBM Cloud, and Salesforce.com's Force.com.
- Cloud service commercial providers offer a publicly accessible remote interface for creating and managing VM instances within their proprietary infrastructure.
- The application and infrastructure services are offered on a flexible price-per-use basis.

# Public, Private, and Hybrid Clouds

- **Private Clouds**
- A private cloud is built within the domain of an intranet owned by a single organization.
- it is client owned and managed, and its access is limited to the owning clients and their partners.
- Private clouds give local users a flexible and agile private infrastructure to run service workloads within their administrative domains.
- A private cloud is supposed to deliver more efficient and convenient cloud services.
- It may impact the cloud standardization, while retaining greater customization and organizational control.

# Public, Private, and Hybrid Clouds

Public, private, and hybrid clouds illustrated by functional architecture and connectivity of representative clouds



# Public, Private, and Hybrid Clouds

- **Hybrid Clouds**
- A hybrid cloud is built with both public and private clouds.
- Private clouds can also support a hybrid cloud model by supplementing local infrastructure with computing capacity from an external public cloud.
- A hybrid cloud provides access to clients, the partner network, and third parties. In summary, public clouds promote standardization, preserve capital investment, and offer application flexibility. Private clouds attempt to achieve customization and offer higher efficiency, resiliency, security, and privacy.
- Hybrid clouds operate in the middle, with many compromises in terms of resource sharing.

# Public, Private, and Hybrid Clouds

- **Community Clouds**
- A community cloud is shared between organizations with a common goal or that fit into a specific community (professional community, geographic community, etc.).
- Community cloud shares infrastructure between several organizations from a specific community with common concerns (security, compliance, jurisdiction, etc.), whether managed internally or by a third-party, and either hosted internally or externally.
- The costs are spread over fewer users than a public cloud (but more than a private cloud), so only some of the cost savings potential of cloud computing are realized.

# Public, Private, and Hybrid Clouds

- **Multi-cloud Model**
- In some cases, a single public cloud isn't enough to meet an organization's computing needs.
- They turn instead to multi-clouds, a more complex hybrid cloud example that combines a private cloud with multiple public cloud services.
- While a hybrid cloud always consists of a public and private cloud, a multi-cloud environment is a bit more varied on a case-to-case basis.
- In this arrangement, an organization's IT infrastructure consists of multiple public clouds from multiple providers, although it may access those clouds through a single software-defined network.

# Public, Private, and Hybrid Clouds

- A private cloud could certainly be part of a multi-cloud architecture, but it is usually more isolated from its public cloud counterparts.
- The purpose of a multi-cloud model is versatility and specialization. In enterprise-level organizations, for example, not every department has the same cloud needs. A marketing department, for instance, needs different types of cloud computing tools than a research or human resources department.
- Rather than trying to create a one-size-fits-all solution, companies can pick and choose from existing public cloud providers to ensure that each department has a solution catered to its specific needs.

# Public, Private, and Hybrid Clouds

- Multi-cloud models also offer reassurance because they don’t leave organizations dependent upon a single cloud provider.
- This can decrease costs and increase flexibility in the long run while also avoiding the problem of vendor lock-in.
- When combined with private cloud assets, multi-cloud deployments allow organizations to accomplish multiple goals at one time without having to radically expand or rethink their existing infrastructure.

# Public, Private, and Hybrid Clouds

- **Hybrid Cloud vs Multi-Cloud**
- The **key differentiator** to keep in mind is that **multi-cloud** models involve using **separate cloud** environments to perform **separate tasks**.
- If an organization needs its IT infrastructure to be able to accommodate the conflicting demands of different departments, then it probably needs to pursue a multi-cloud deployment.
- The sales team may need the CRM features offered by a specific cloud provider, while software programmers may favor different types of cloud computing environments that offer superior storage and processing capacity.

# Cloud Ecosystem and Enabling Technologies

Classical computing versus cloud computing. The experts at IBM have estimated that an 80 percent to 95 percent saving results from cloud computing, compared with the conventional computing paradigm.

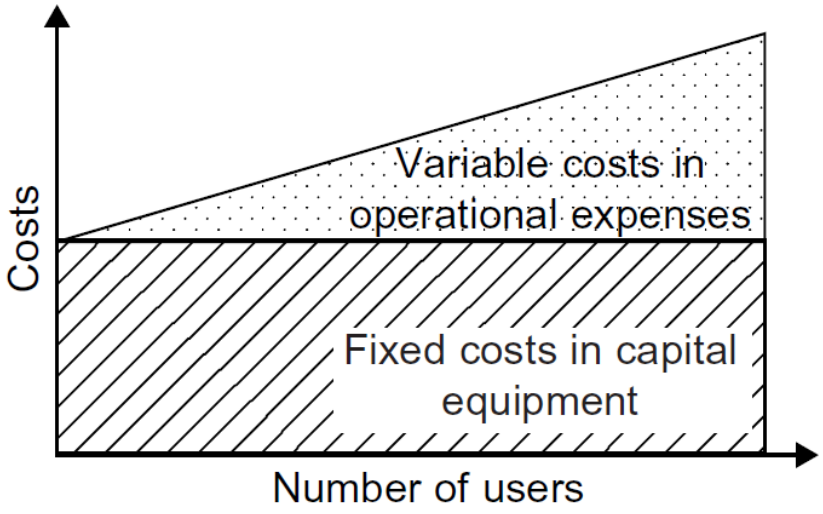
| **Classical Computing** | **Cloud Computing** |
|---|---|
| (Repeat the following cycle every 18 months) | (Pay as you go per each service provided) |
| **Buy and own** | **Subscribe** |
| Hardware, system software, applications to meet peak needs | - - - - |
| **Install, configure, test, verify, evaluate, manage** | **Use** (Save about 80-95% of the total cost) |
| - - - - | - - - - |
| **Use** | (Finally) |
| - - - - | **$ - Pay for what you use** |
| **Pay $$$$$** (High cost) | based on the QoS |

# Cloud Ecosystem and Enabling Technologies

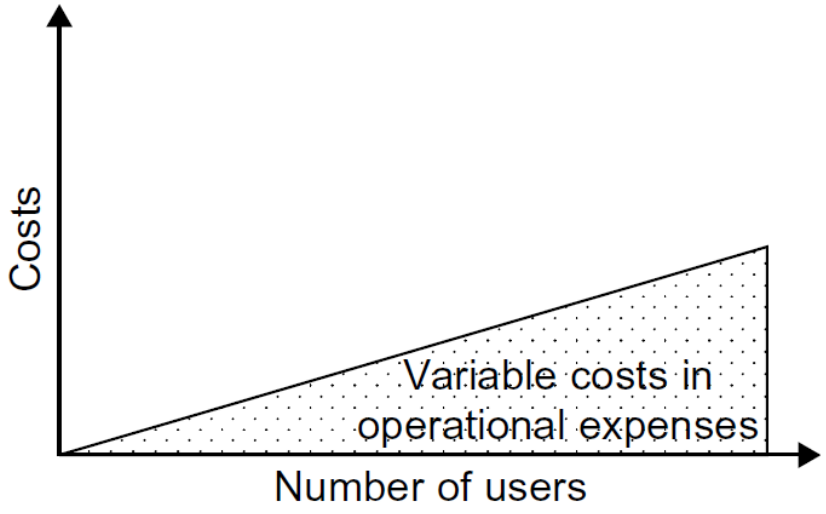
- **Cost Model**
- In traditional IT computing, users must acquire their own computer and peripheral equipment as capital expenses. In addition, they have to face operational expenditures in operating and maintaining the computer systems, including personnel and service costs.
- The fixed cost is the main cost, and it could be reduced slightly as the number of users increases. Operational costs may increase sharply with a larger number of users.
- Cloud computing applies **a pay-per-use business model**, in which user jobs are outsourced to data centers.
- To use the cloud, there is no up-front cost in hardware acquisitions. Only variable costs are experienced by users.

# Cloud Ecosystem and Enabling Technologies

Computing economics between traditional IT users and cloud users




(a) Traditional IT cost model




(b) Cloud computing cost model

# Cloud Ecosystem and Enabling Technologies

- **Cloud Design Objectives**
- **Shifting computing from desktops to datacenters**: Computer processing, storage, and software delivery is shifted away from desktops and local servers toward data centers over the Internet.
- **Service provisioning and cloud economics**: Providers supply cloud services by signing SLAs with consumers and end users. The services must be efficient in terms of computing, storage, and power consumption. Pricing is based on a pay-as-you-go policy.
- **Scalability in performance**: The cloud platforms and software and infrastructure services must be able to scale in performance as the number of users increases.

# Cloud Ecosystem and Enabling Technologies

- **Cloud Design Objectives (2)**
- **Data privacy protection**: Can you trust data centers to handle your private data and records? This concern must be addressed to make clouds successful as trusted services.
- **High quality of cloud services**: The QoS of cloud computing must be standardized to make clouds interoperable among multiple providers.
- **New standards and interfaces**: This refers to solving the data lock-in problem associated with data centers or cloud providers. Universally accepted APIs and access protocols are needed to provide high portability and flexibility of virtualized applications.

# Cloud Ecosystem and Enabling Technologies

- **Cloud Ecosystems**
- An ecosystem was suggested for building private clouds with four levels of ecosystem development.
- At the user end, consumers demand a flexible platform. At the **cloud management level**, the cloud manager provides **virtualized resources** over an **IaaS platform**.
- At the **virtual infrastructure (VI) management level**, the manager allocates **VMs over multiple server clusters**.
- At the **VM management level**, the VM managers handle **VMs installed on individual host machines**.
- An **ecosystem of cloud tools** attempts to span both **cloud management** and **VI management**. Integrating these two layers is difficult due to the lack of open and standard interfaces between them.

# Cloud Ecosystem and Enabling Technologies

- **Cloud Ecosystems (2)**
- It is desired a flexible and open architecture that enables organizations to build private/hybrid clouds. VI management is aimed at this goal.
- VI tools include: **oVirt**, **vSphere** from **VMWare**, and **VM Orchestrator** from **Platfom Computing**. These tools support dynamic placement and VM management on a pool of physical resources, automatic load balancing, server consolidation, and dynamic infrastructure resizing and partitioning.
- Besides public clouds such as **Amazon EC2**, **Eucalyptus**, **OpenStack**, and **Globus Nimbus** are **open source tools** for **virtualization** of **cloud infrastructure**. To access these **cloud management tools**, one can use the **Amazon EC2WS, Nimbus WSRF**, and **ElasticHost REST** cloud interfaces. **For VI management**, **OpenNebula** and **VMware vSphere** can be used to manage all VM generation including Xen, KVM, and VMware tools.

# Cloud Ecosystem and Enabling Technologies

Cloud ecosystem for building private clouds: **(a)** Consumers demand a flexible platform; **(b)** Cloud manager provides virtualized resources over an IaaS platform; **(c)** VI manager allocates VMs; **(d)** VM managers handle VMs installed on servers