Cloud computing

- Syllabus
- Case study
- Assignment
- Lab exercise
- Research on cloud
- Masters level thesis on cloud- guidelines
- Opportunities

Chapter 1 – Introduction to Cloud Computing

Contents

- Defining the Cloud.
- Types of cloud computing.
- Delivery models and services.
- Ethical issues in cloud computing.
- Components of Cloud Computing.
- Cloud vulnerabilities.
- Characteristic of Cloud Computing.

History

- The actual term "cloud" borrows from telephony in that telecommunications companies, who until the 1990s offered primarily dedicated point-to-point data circuits, began offering Virtual Private Network (VPN) services with comparable quality of service but at a much lower cost.

Cloud computing

- Uses Internet technologies to offer scalable and elastic services.
  The term “elastic computing” refers to the ability of *dynamically acquiring computing resources* and supporting a variable workload.

- The resources used for these services can be metered and the *users can be charged only for the resources they used*.

- The maintenance and security are ensured by service providers.

- The service providers can operate more efficiently due to specialization and centralization.

Cloud computing (cont'd)

- Lower costs for the cloud service provider are past to the cloud users.
- Data is stored:
  - closer to the site where it is used.
  - in a device and in a location-independent manner.
- The data storage strategy can increase reliability, as well as security, and can lower communication costs.

Cloud computing (cont'd)

- In addition, the platform provides on demand services, that are always on, anywhere, anytime and any place.
- Pay for use and as needed, elastic
  - scale up and down in capacity and functionalities
- The hardware and software services are available to
  - general public, enterprises, corporations and businesses markets

Cloud computing (Summary)

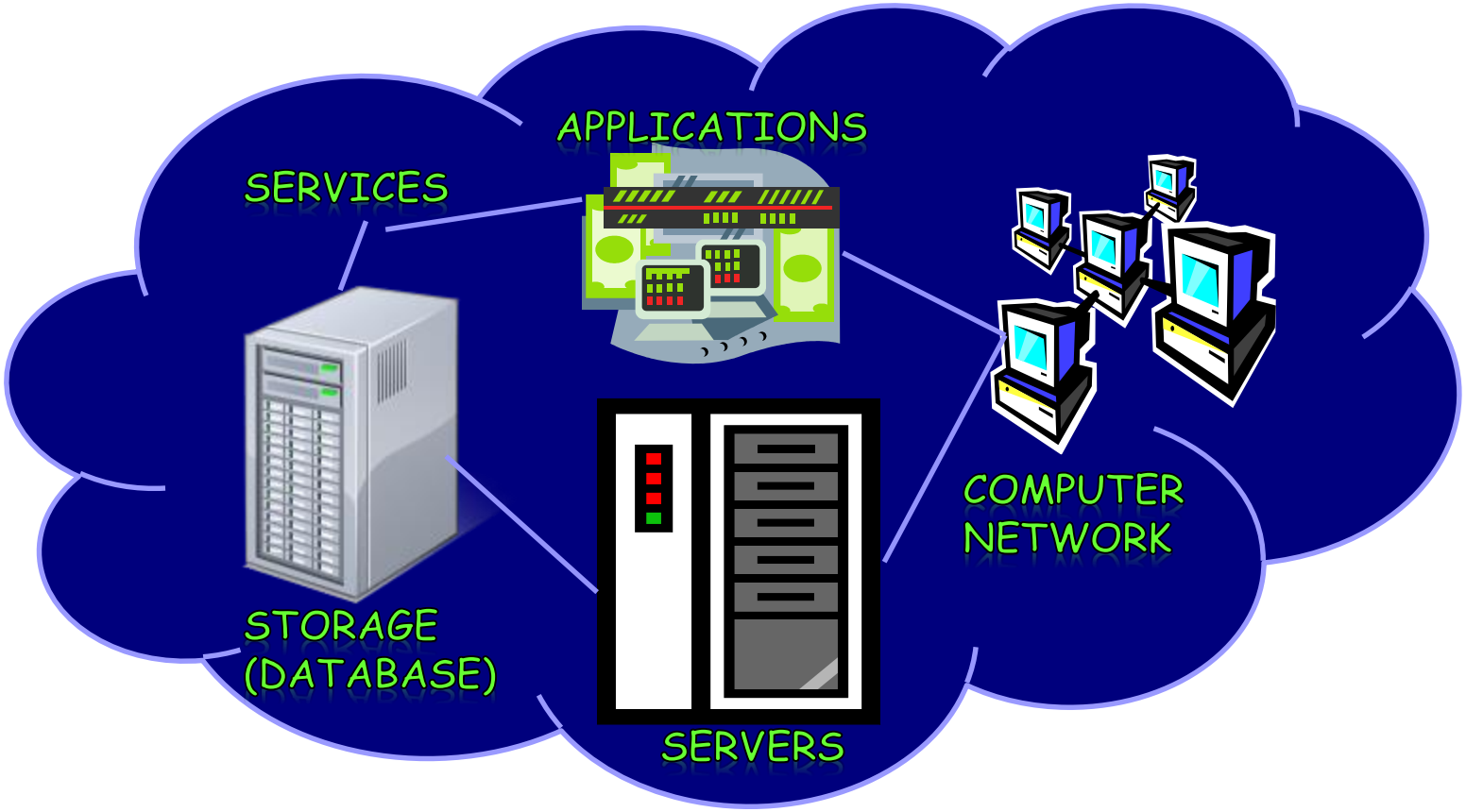
- Cloud computing is an umbrella term used to refer to Internet based development and services

- A number of characteristics define cloud data, applications services and infrastructure:
  - **Remotely hosted**: Services or data are hosted on remote infrastructure.
  - **Ubiquitous**: Services or data are available from anywhere.
  - **Commodified**: The result is a utility computing model similar to traditional that of traditional utilities, like gas and electricity - you pay for what you would want!

What is Cloud Computing

- Cloud computing is a model for enabling convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.
- Cloud computing users avoid capital expenditure (CapEx) on hardware, software, and services when they pay a provider only for what they use.
- Low shared infrastructure and costs, low management overhead, and immediate access to a broad range of applications

What is Cloud Computing



- Shared pool of configurable computing resources
- On-demand network access
- Provisioned by the Service Provider

Emergence of Cloud Computing

- Cloud computing is becoming the latest disruptive force for supplier or a consumer of technology services.
- Cloud computing is going to change the landscape of IT and how services are provided.
- Cloud computing is in your best interest to understand the impact on technology service.

Emergence of CC

Question: *what is this cloud computing thing anyway?*

- Cloud computing:
  - Is available through a well-defined interface
  - Is available everywhere and for many devices
  - Scales on demand
  - Is reliable
  - Has a low capital expenditure for consumers
  - means you only pay for what you use.

Emergence of CC

- Think of cloud computing as a utility service.
- Hydropower providing electricity.
  - Electricity: is accessed through a well-defined interface, can be used everywhere and for many devices,
  - Power can be increased as required, is reliable and for the consumer, and you only pay for what you use.

Let us review the trend of traditional service as a utility service….

Essential Utilities and Delivery Networks

(1) Water

→

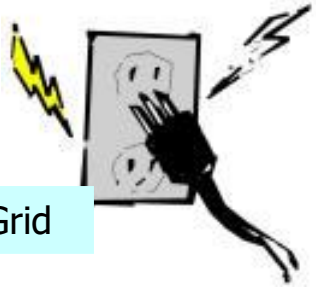
Water Distribution Network

→

(2) Electricity

→

Power Grid



(3) Gas

→

(4) Telephone

Telecom Networks

Next Revolution in IT

- Classical Computing
  - Buy & Own
    - Hardware, System Software, Applications often to meet peak needs.
  - Install, Configure, Test, Verify, Evaluate
  - Manage
  - ..
  - Finally, use it
  - $$$$....$(High CapEx)

Every 36 months?

Cloud Computing

- Subscribe
- Use

Cloud Motivation

- **Capital Expenses (CAPEX)**
  - Expenditures creating future benefits.
  - Incurred when a business spends money either to buy fixed assets
  - CAPEX is a cost which cannot be deducted in the year in which it is paid or incurred and must be capitalized
- Examples
  - acquiring fixed, and in some cases, intangible assets
  - repairing an existing asset so as to improve its useful life
  - upgrading an existing asset if its results in a superior fixture
  - starting or acquiring a new business

Cloud Motivation

- **Operational Expenses (OPEX)**
  - Ongoing cost for running a product, business, or system
  - Day-to-day expense
  - Operating expenses is the sum of a operating expenses for a period of time (e.g. month or year)
- Examples
  - license fees and / or rental fees
  - maintenance and repairs
  - attorney fees and legal fees
  - utilities, such as telephone, subscriptions, etc
  - Insurance, property management, including a resident manager
  - travel and vehicle expenses

Cloud Motivation

- Total Cost of Ownership (TCO)
  - TCO= CAPEX + OPEX

- **ICT related CAPEX**
  - Computer hardware and programs
  - Network hardware and software
  - Server hardware and software
  - Workstation hardware and software
  - Installation and integration of hardware and software
  - Purchasing research
  - Maintenance, warranties and support licenses

- **ICT related OPEX**
  - Rented space (hosting, data center)
  - Electricity (for related equipment, cooling, backup power)
  - Testing costs, downtime, outage and failure expenses
  - Backup and recovery process
  - Technology training
  - Audit (internal and external)
  - Information technology personnel

Cloud Consideration

- How much ICT do we need?
  - Knowledge, skill, ability, capability, capacity, ...
  - Hardware, Infrastructure, Platform, Application, …
- Can I consume ICT when we needed it?
  - Now, tomorrow, in one year, ...
- Does ICT grow with our demands?
  - From start-up, to SME, to enterprise, ...
- Does ICT shrink with our demands?
  - Seasons, financial crisis, retirement, ...
- Can I pay for only those ICT I actually use?
  - Per day, per hour, per KByte, per Mbit/sec, ...

Use service from ICT provider/expert

On-demand, self-service

Elasticity

Elasticity

Metered service, pay-as-you-go

Defining Clouds: There are many views for what is cloud computing?

Over 20 definitions:

- http://cloudcomputing.sys-con.com/read/612375_p.htm
- Renting “remote storage” → backup
- Renting “remote server” → hosting Web server
- Renting “remote more servers” → to manage large workload

- Buyya’s Scientific definition of Cloud Computing ☺
  - “Cloud is a **market-oriented** distributed computing system consisting of a collection of inter-connected and **virtualized** computers that are **dynamically provisioned** and presented as one or more unified computing resources based on **service-level agreements (SLA)** established through **negotiation** between the service provider and consumers.”
  - SLA = {negotiated and agreed QoS parameters + rewards + penalties for violation of agreement....}

Distributed Computing Systems

- **Observation**

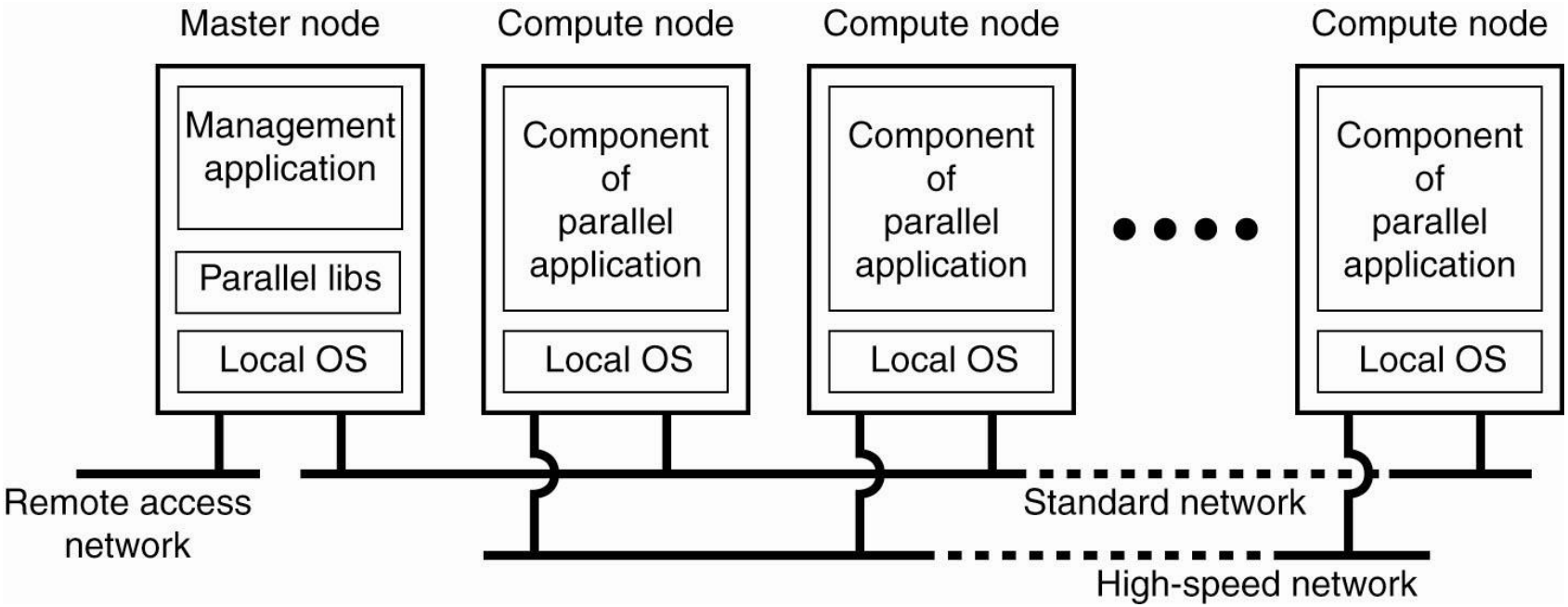
Many distributed systems are configured for High-Performance Computing

- **Cluster Computing**

Essentially a group of high-end systems connected through a LAN:

  - Homogeneous: same OS, near-identical hardware
  - Single managing node

Distributed Computing Systems : Cluster Computing



- Figure - An example of a cluster computing system.

Distributed Computing Systems

- **Grid Computing**
- The next step: lots of nodes from everywhere:
  - Heterogeneous
  - Dispersed across several organizations
  - Can easily span a wide-area network
- **Note**
- To allow for collaborations, grids generally use virtual organizations. In essence, this is a grouping of users
- (or better: their IDs) that will allow for authorization on resource allocation.

Distributed Computing Systems: Cloud Computing

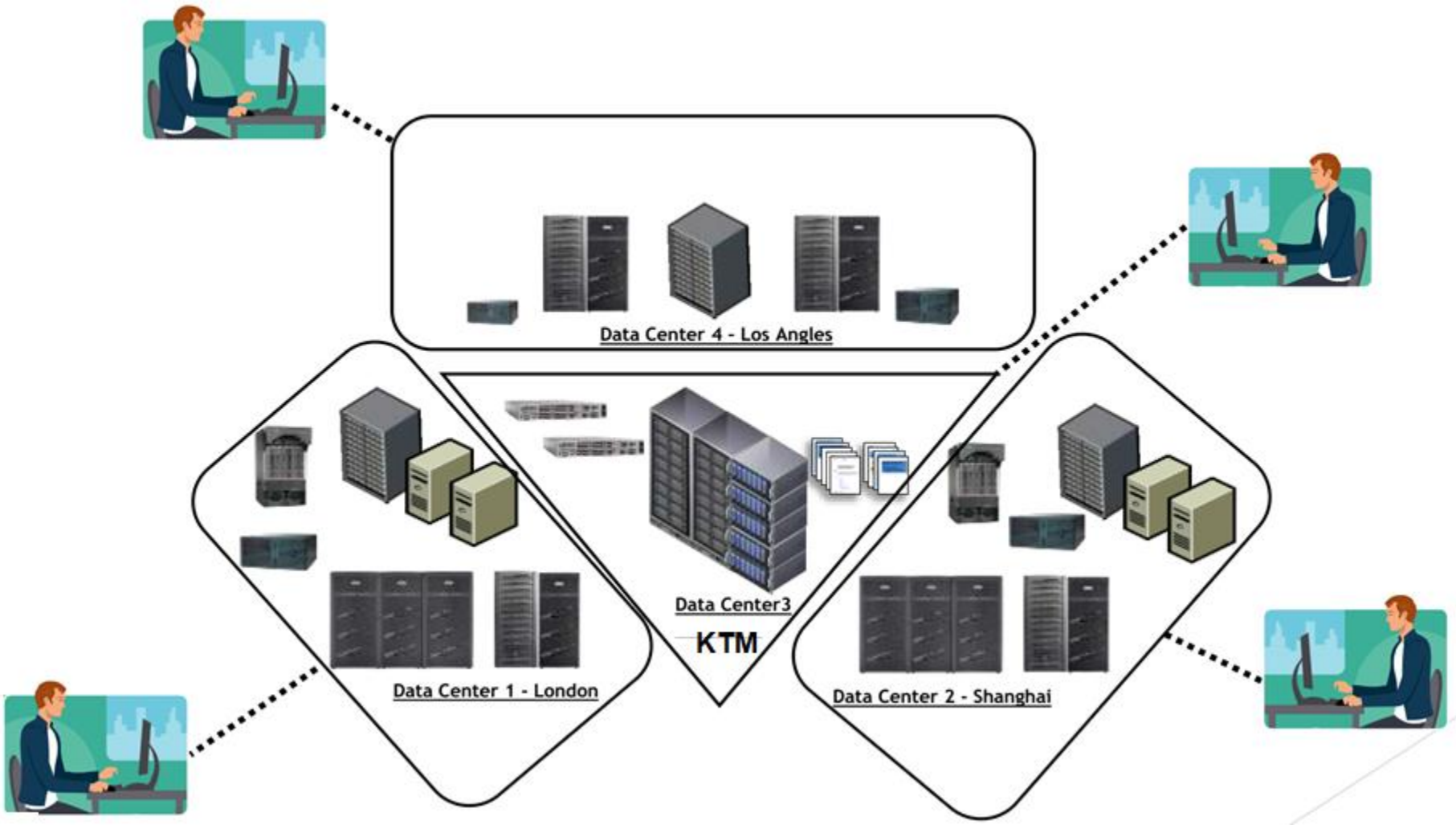
- **Cloud Computing** is a general term used to describe a new class of network based computing that takes place over the Internet,
  - basically a step on from Utility Computing
  - a collection/group of integrated and networked hardware, software and Internet infrastructure (called a platform).
- Using the Internet for communication and transport provides hardware, software and networking services to clients
- These platforms hide the complexity and details of the underlying infrastructure from users and applications by providing very simple graphical interface or API (Applications Programming Interface).

Cloud Services and Data Centre

Typical data centre:

- Requires hardware, space, electricity and cooling;
- Requires that someone manage the operating system, applications and updates;
- Requires software licensing;
- Is difficult to scale, with either too much or too little capacity;
- Has high upfront capital costs; and
- Provides a location where you have complete control (and responsibility).

Conventional Data centers

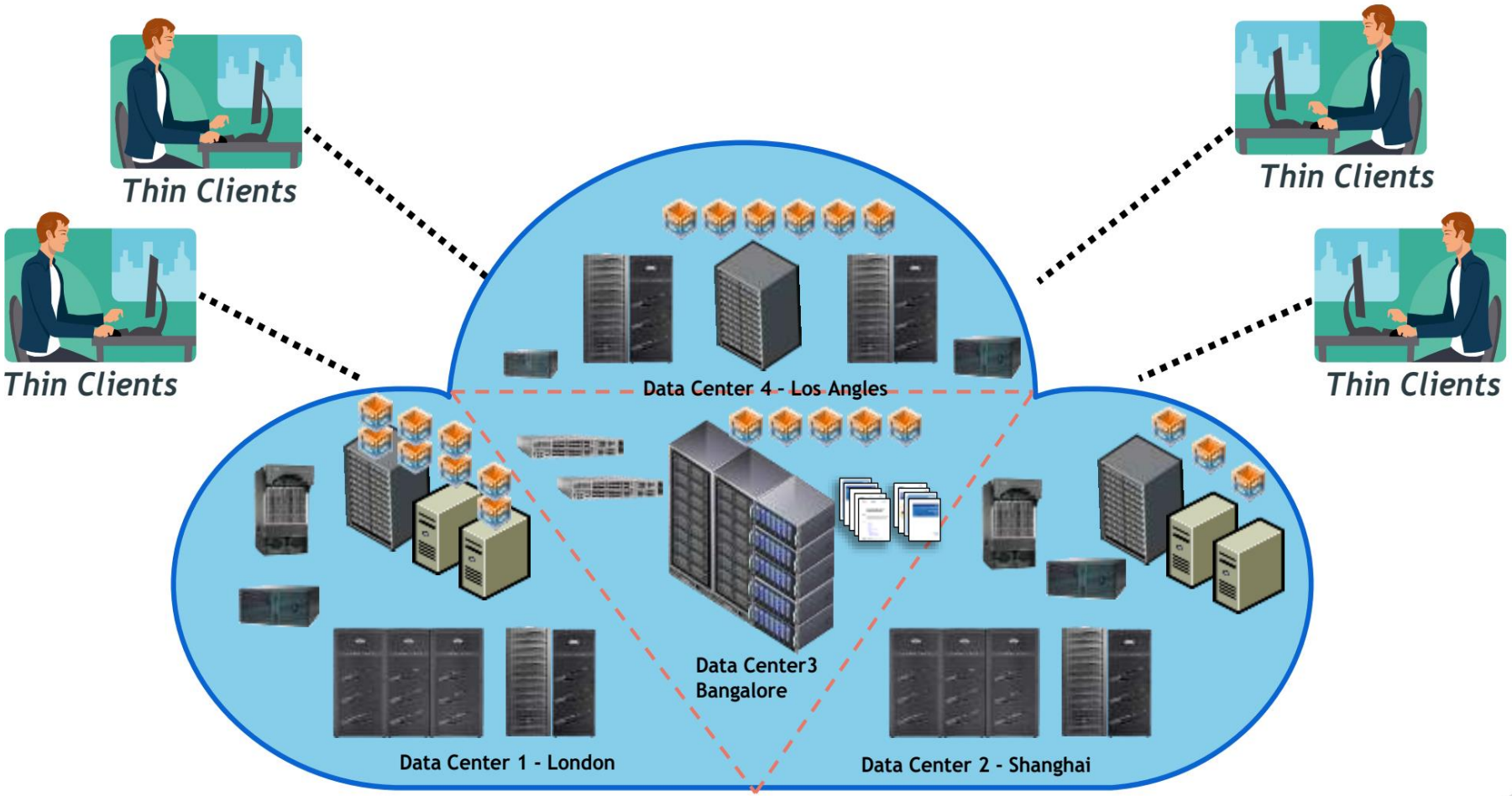


Cloud Services and Data Centre

Cloud computing models:

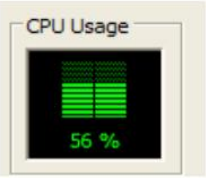
- Consist, typically, of a shared, multi-tenant environment
- Have pools of computing resources
- Have resources that can be requested as required
- Are available via the Internet (or available as a private cloud and connection)
- Provide for a “pay as you go” model

Cloud computing – Virtual Data Center



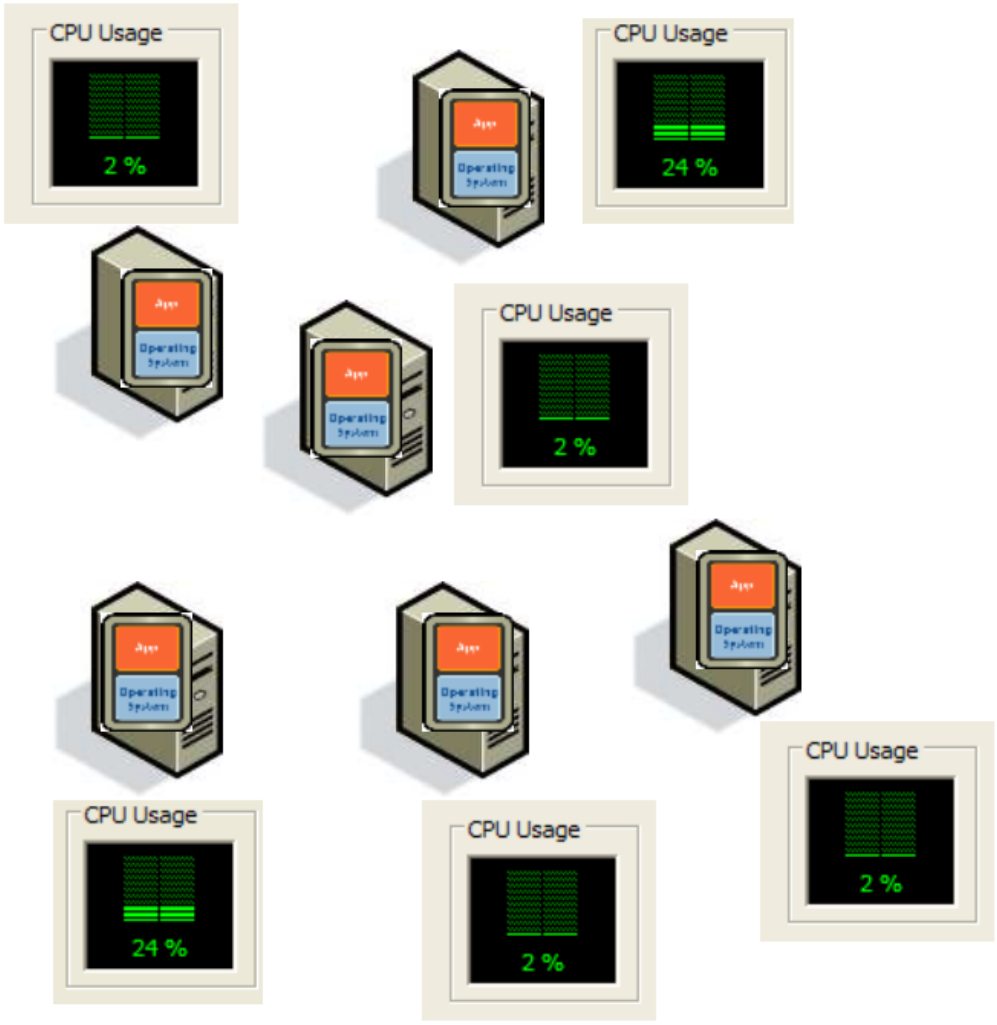
With Virtualization

- Flexibility
- Rapid provisioning
- Disaster Recovery
- High Availability
- Automation
- Systems Management integration
- Adaptive Data Center



Without Virtualization

- All require same power
- All emit same heat
- All require physical space
- Setup, (re-configuration Maintenance, support…



Types of clouds

- Public Cloud - the infrastructure is made available to the general public or a large industry group and is owned by the organization selling cloud services.
- Private Cloud – the infrastructure is operated solely for an organization.
- Community Cloud - the infrastructure is shared by several organizations and supports a community that has shared concerns.
- Hybrid Cloud - composition of two or more clouds (public, private, or community) as unique entities but bound by standardized technology that enables data and application portability.

The “good” about cloud computing

- Resources, such as CPU cycles, storage, network bandwidth, are shared.
- When multiple applications share a system, their peak demands for resources are not synchronized thus, *multiplexing leads to a higher resource utilization*.
- Resources can be aggregated to support data-intensive applications.
- Data sharing facilitates collaborative activities. Many applications require multiple types of analysis of shared data sets and multiple decisions carried out by groups scattered around the globe.

More “good” about cloud computing

- Eliminates the initial investment costs for a private computing infrastructure and the maintenance and operation costs.
- Cost reduction: concentration of resources creates the opportunity to pay as you go for computing.
- Elasticity: the ability to accommodate workloads with very large peak-to-average ratios.
- User convenience: virtualization allows users to operate in familiar environments rather than in idiosyncratic ones.

Why cloud computing could be successful when other paradigms have failed?

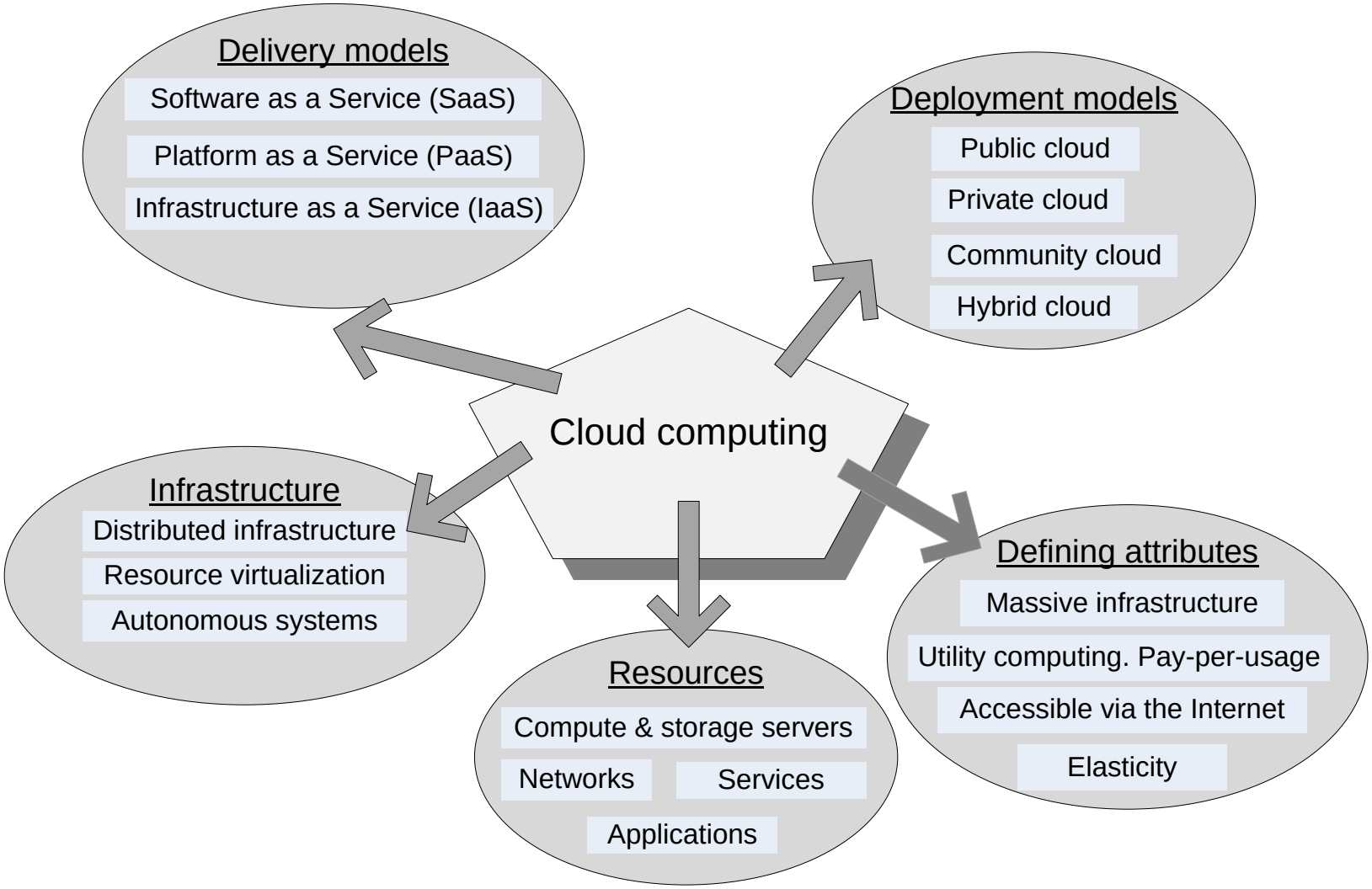
- It is in a better position to exploit recent advances in software, networking, storage, and processor technologies promoted by the same companies who provide cloud services.
- It is focused on enterprise computing; its adoption by industrial organizations, financial institutions, government, and so on could have a huge impact on the economy.
- A cloud consists of a homogeneous set of hardware and software resources.
- The resources are in a single administrative domain (AD). Security, resource management, fault-tolerance, and quality of service are less challenging than in a heterogeneous environment with resources in multiple ADs.

Challenges for cloud computing

- Availability of service; what happens when the service provider cannot deliver?
- Diversity of services, data organization, user interfaces available at different service providers limit user mobility; once a customer is hooked to one provider it is hard to move to another. Standardization efforts at NIST!
- Data confidentiality and auditability, a serious problem.
- Data transfer bottleneck; many applications are data-intensive.

More challenges

- Performance unpredictability, one of the consequences of resource sharing.
  - How to use resource virtualization and performance isolation for QoS guarantees?
  - How to support elasticity, the ability to scale up and down quickly?
- Resource management; are self-organization and self-management the solution?
- Security and confidentiality; major concern.
- Addressing these challenges provides good research opportunities!!


Delivery models
Software as a Service (SaaS)
Platform as a Service (PaaS)
Infrastructure as a Service (IaaS)
Deployment models
Public cloud
Private cloud
Community cloud
Hybrid cloud
Cloud computing
Infrastructure
Distributed infrastructure
Resource virtualization
Autonomous systems
Defining attributes
Massive infrastructure
Utility computing. Pay-per-usage
Accessible via the Internet
Elasticity
Resources
Compute & storage servers
Networks
Services
Applications

Cloud delivery models

- Software as a Service (SaaS)
- Platform as a Service (PaaS)
- Infrastructure as a Service (IaaS)

Software-as-a-Service (SaaS)

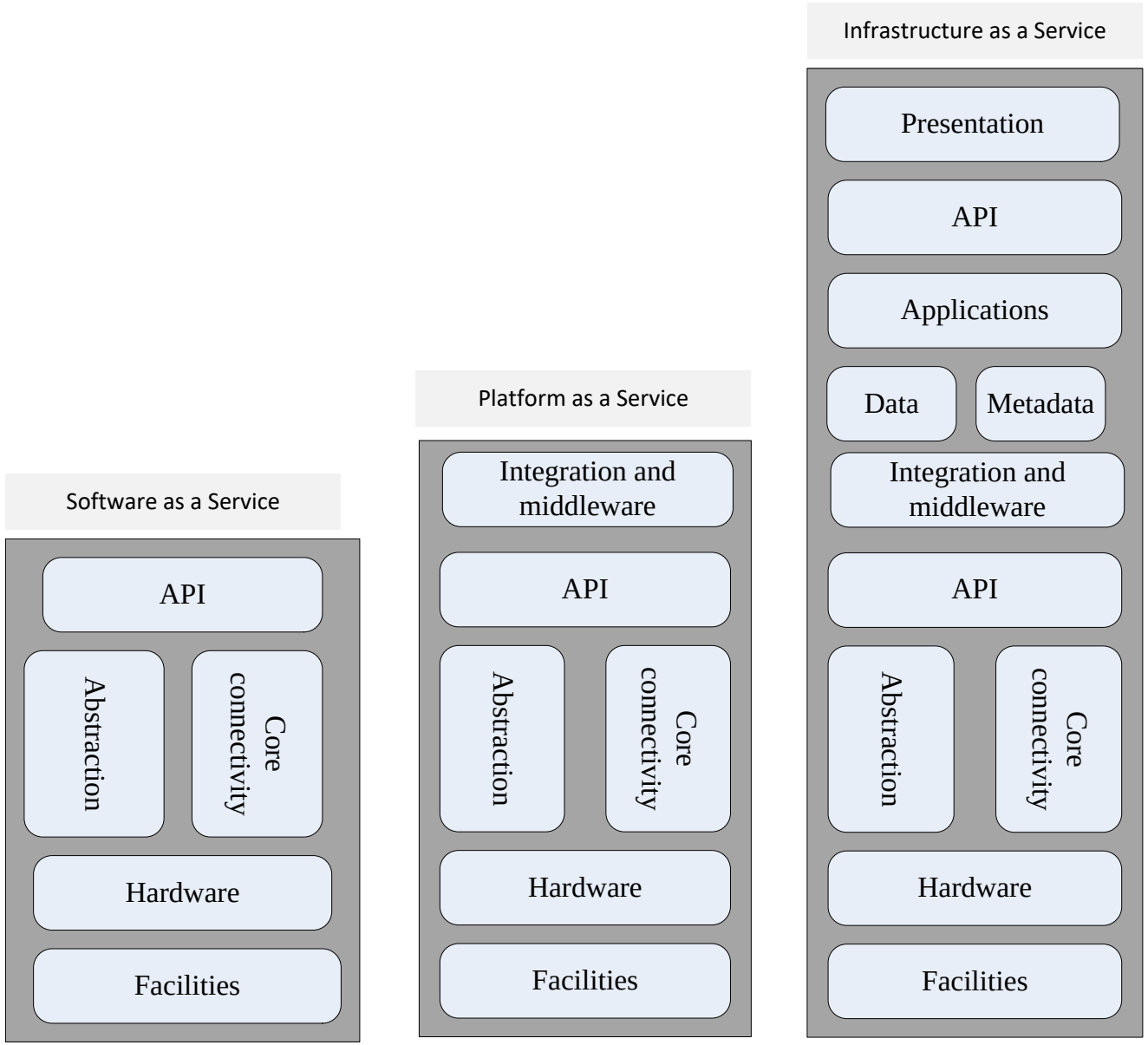
- Applications are supplied by the service provider.
- The user does not manage or control the underlying cloud infrastructure or individual application capabilities.
- Services offered include:
  - Enterprise services such as: workflow management, group-ware and collaborative, supply chain, communications, digital signature, customer relationship management (CRM), desktop software, financial management, geo-spatial, and search.
  - Web 2.0 applications such as: metadata management, social networking, blogs, wiki services, and portal services.
- Not suitable for real-time applications or for those where data is not allowed to be hosted externally.
- Examples: Gmail, Google search engine.

Platform-as-a-Service (PaaS)

- Allows a cloud user to deploy consumer-created or acquired applications using programming languages and tools supported by the service provider.
- The user:
  - Has control over the deployed applications and, possibly, application hosting environment configurations.
  - Does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage.
- Not particularly useful when:
  - The application must be portable.
  - Proprietary programming languages are used.
  - The hardware and software must be customized to improve the performance of the application.

Infrastructure-as-a-Service (IaaS)

- The user is able to deploy and run arbitrary software, which can include operating systems and applications.
- The user does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of some networking components, e.g., host firewalls.
- Services offered by this delivery model include: server hosting, Web servers, storage, computing hardware, operating systems, virtual instances, load balancing, Internet access, and bandwidth provisioning.


Infrastructure as a Service
Presentation
API
Applications
Data
Metadata
Integration and middleware
API
Abstraction
Core connectivity
Hardware
Facilities
Platform as a Service
Integration and middleware
API
Abstraction
Core connectivity
Hardware
Facilities
Software as a Service
API
Abstraction
Core connectivity
Hardware
Facilities

Cloud activities

- Service management and provisioning including:
  - Virtualization.
  - Service provisioning.
  - Call center.
  - Operations management.
  - Systems management.
  - QoS management.
  - Billing and accounting, asset management.
  - SLA management.
  - Technical support and backups.

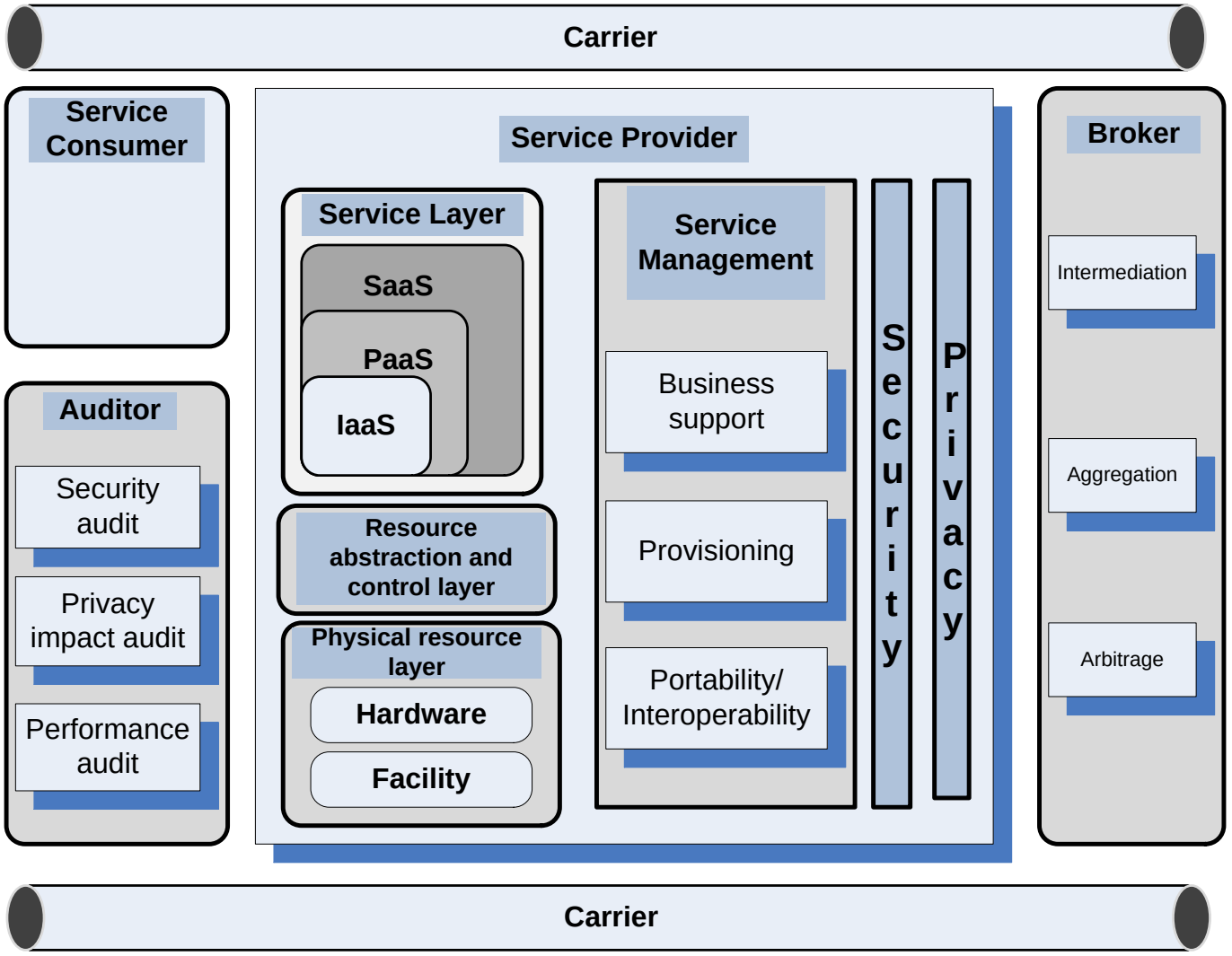
Cloud activities (cont'd)

- Security management including:
  - ID and authentication.
  - Certification and accreditation.
  - Intrusion prevention.
  - Intrusion detection.
  - Virus protection.
  - Cryptography.
  - Physical security, incident response.
  - Access control, audit and trails, and firewalls.

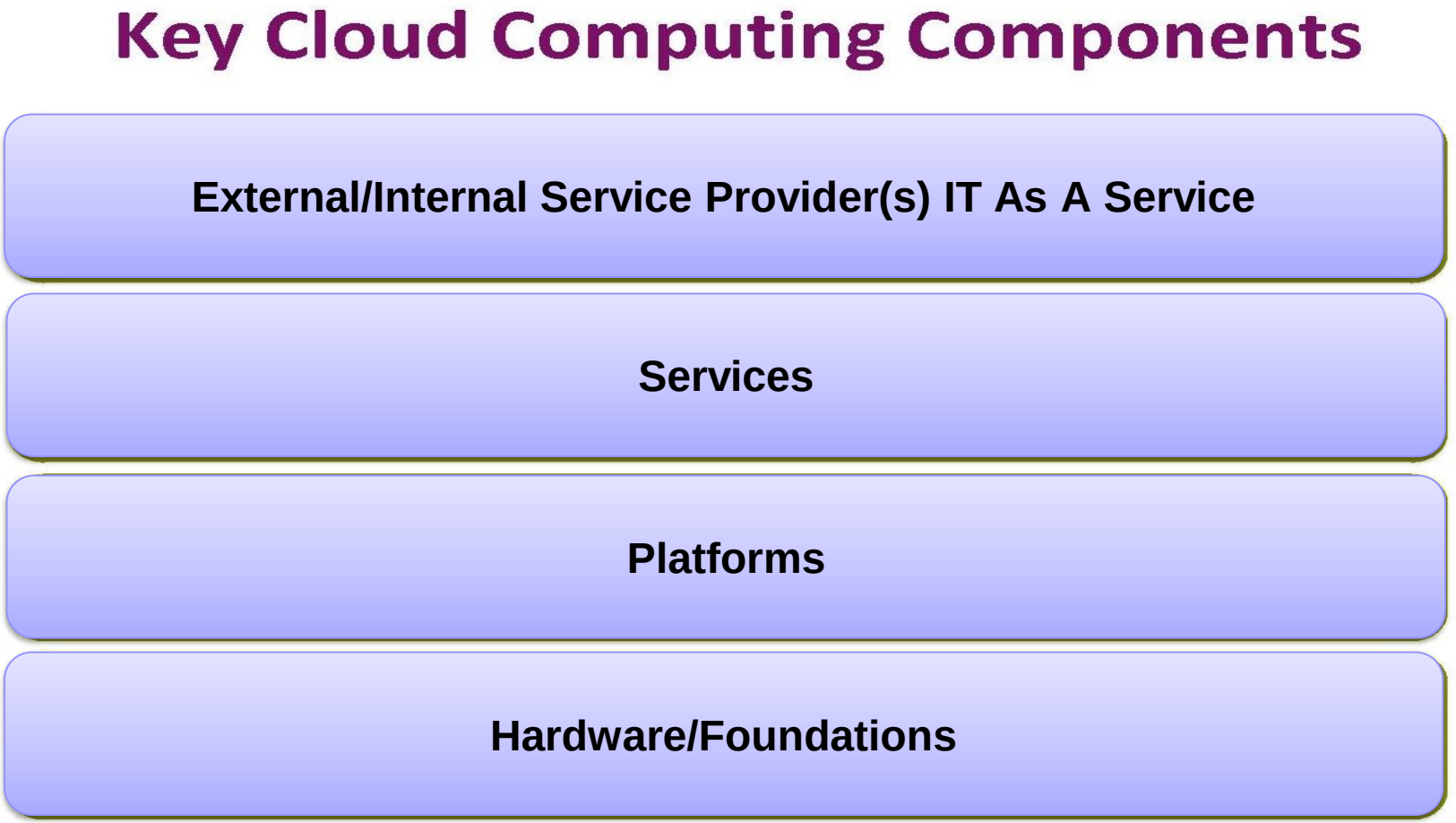
Cloud activities (cont'd)

- Customer services such as:
  - Customer assistance and on-line help.
  - Subscriptions.
  - Business intelligence.
  - Reporting.
  - Customer preferences.
  - Personalization.
- Integration services including:
  - Data management.
  - Development.

NIST cloud reference model



Components of Cloud Computing



Ethical issues

- Paradigm shift with implications on computing ethics:
  - The control is relinquished to third party services.
  - The data is stored on multiple sites administered by several organizations.
  - Multiple services interoperate across the network.
- Implications
  - Unauthorized access.
  - Data corruption.
  - Infrastructure failure, and service unavailability.

Deperimeterization

- Systems can span the boundaries of multiple organizations and cross the security borders.
- The complex structure of cloud services can make it difficult to determine who is responsible in case something undesirable happens.
- Identity fraud and theft are made possible by the unauthorized access to personal data in circulation and by new forms of dissemination through social networks and they could also pose a danger to cloud computing.

Privacy issues

- Cloud service providers have already collected petabytes of sensitive personal information stored in data centers around the world. The acceptance of cloud computing therefore will be determined by privacy issues addressed by these companies and the countries where the data centers are located.

- Privacy is affected by cultural differences; some cultures favor privacy, others emphasize community. This leads to an ambivalent attitude towards privacy in the Internet which is a global system.

Cloud vulnerabilities

- Clouds are affected by malicious attacks and failures of the infrastructure, e.g., power failures.

- Such events can affect the Internet domain name servers and prevent access to a cloud or can directly affect the clouds:
  - in 2004 an attack at Akamai caused a domain name outage and a major blackout that affected Google, Yahoo, and other sites.
  - in 2009, Google was the target of a denial of service attack which took down Google News and Gmail for several days;
  - in 2012 lightning caused a prolonged down time at Amazon.

Cloud Computing Characteristics

Common Characteristics:

- Massive Scale
- Resilient Computing
- Homogeneity
- Geographic Distribution
- Virtualization
- Service Orientation
- Low Cost Software
- Advanced Security

Essential Characteristics:

- On Demand Self-Service
- Broad Network Access
- Rapid Elasticity
- Resource Pooling
- Measured Service

cloud computing characteristics(cont'd)

- **Scalability:** Infrastructure capacity allows for traffic spikes and minimizes delays.
- **Resiliency:** Cloud providers have mirrored solutions to minimize downtime in the event of a disaster. This type of resiliency can give businesses the sustainability they need during unanticipated events.
- **Homogeneity:** No matter which cloud provider and architecture an organization uses, an open cloud will make it easy for them to work with other groups, even if those other groups choose different providers and architectures.

cloud computing characteristics(cont'd)

- ***On-demand self-service****:* A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service's provider.

- ***Broad network access****:* Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous **thin or thick client** platforms (e.g., mobile phones, laptops, and PDAs).

cloud computing characteristics(cont'd)

- ***Resource pooling**:* In cloud computing, service providers serve multiple clients, customers or "tenants" with provisional and scalable services.
- There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources.
- But may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, network bandwidth, and virtual machines.

cloud computing characteristics(cont'd)

- ***Rapid elasticity:*** Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.
- ***Measured Service****:* Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts).

Assignment

- **Problem:** An IT industries (say AWS) decides to provide free access to a public cloud dedicated to higher education. Which one of the three cloud computing delivery models, *SaaS, PaaS, or IaaS, should it embrace, and why? What applications would be most beneficial for the* students?