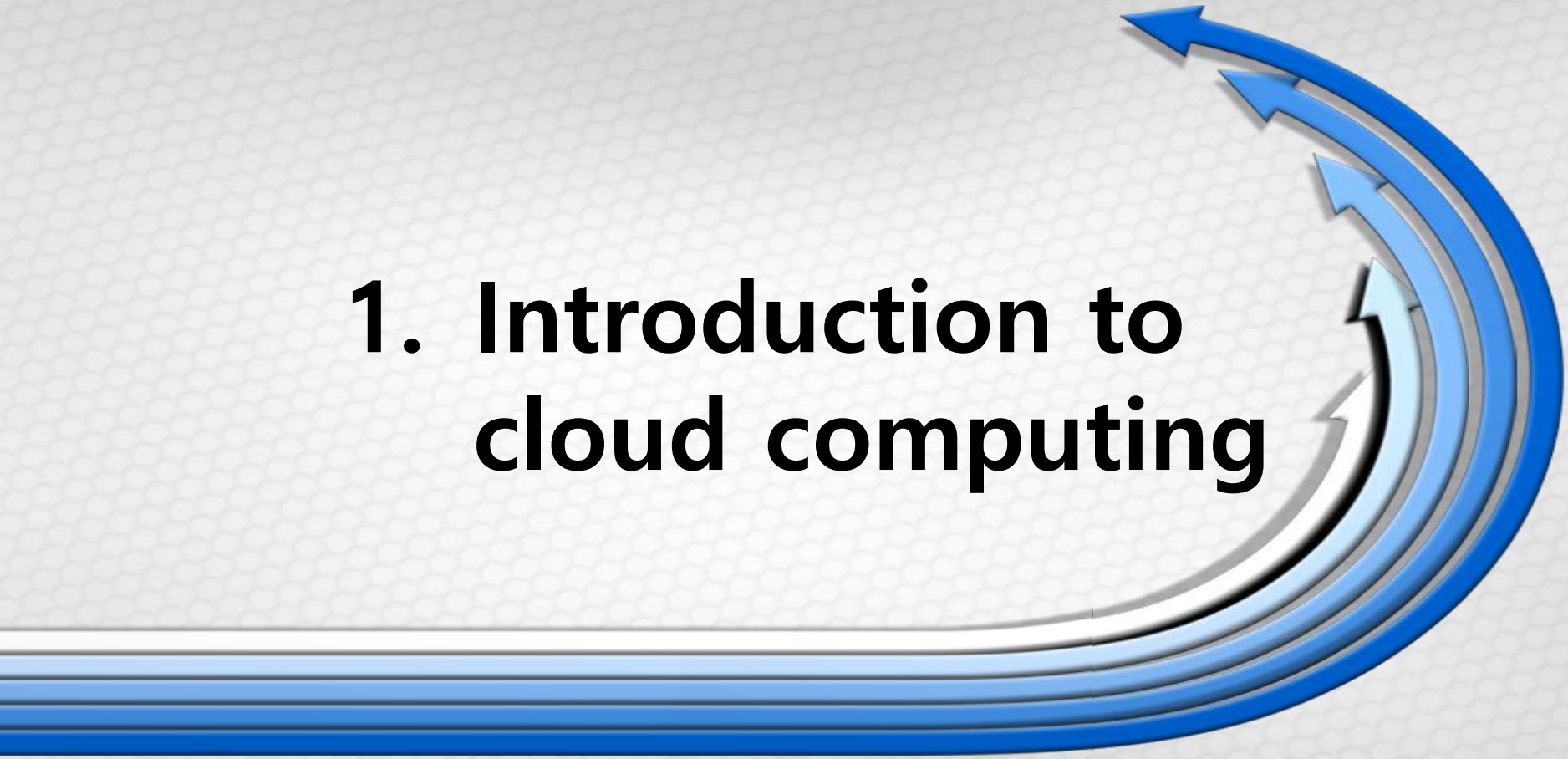
# 1. Introduction to cloud computing



# Why Cloud Computing?

- Web-scale problems
- Large data centers
- Different models of computing
- Highly-interactive Web applications

# Web-Scale Problems

## Characteristics

- Definitely data-intensive
- May also be processing intensive

## Examples

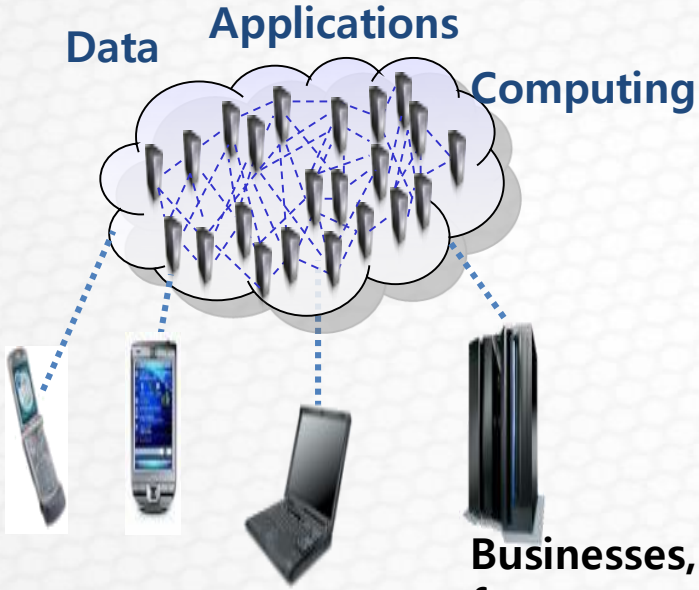
- Crawling, indexing, searching, mining the Web
- “Post-genomics” life sciences research
- Other scientific data (physics, astronomers, etc.)
- Sensor networks
- Web 2.0 applications
- …

# How much data?

- Wayback Machine (WWW pages) has 2 PB + 20 TB/month (2006)
- Google processes 20 PB a day (2008)
- “all words ever spoken by human beings” ~ 5 EB
- NOAA has ~1 PB climate data (2007)
- CERN’s LHC will generate 15 PB a year (2008)


Wayback Machine: History archiving of Homepages

# Cloud Computing Definition




4+ billion phones by 2010 [Source: Nokia]

Businesses, from startups to enterprises

- Cloud computing can be defined as "a new style of computing in which dynamically scalable and often virtualized resources are provided as a services with pay-as-you-go manner over the Internet"
- Can be ubiquitously accessed from any connected devices (PCs, laptops, smart phones, and PDAs) over the internet
- Emerging Cloud applications include - social networking, gaming portals, business applications, media content delivery, and scientific workflows

# Cloud Computing Definition

It is a scalable and flexible distributed computing environment

It consists of a collection of interconnected and virtualized computers that are dynamically provisioned and presented as one or more unified computing resources to consumers

It delivers different levels of services (e.g, SaaS, PaaS, IaaS) to customers anywhere, anytime via Internet

It is driven by economies of scale that is the services can be dynamically configured and delivered “on-demand”

It provides the ability to pay for use of computing resources as needed

It benefits to consumers by freeing them from the low level task of setting up basic hardware (servers) and soft-ware infrastructures and thus reduce the cost of ‘in-house’ provisioning of these services

# “The Cloud”: What’s New?

A style of computing where massively scalable (and elastic) IT-related capabilities are provided “as a service” to external customers using Internet technologies.

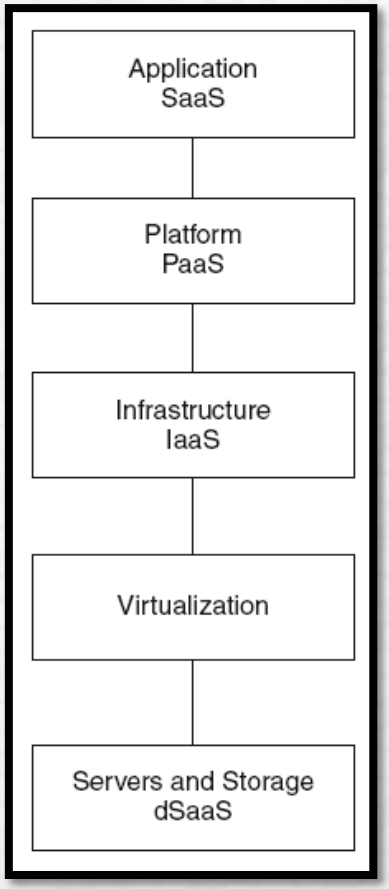
**What’s new?**

| Acquisition Model : Based on purchasing of services | Business Model : Based on pay for use | Access Model: Over the Internet to ANY device | Technical Model: Scalable, elastic, dynamic, multi-tenant, & sharable |
|---|---|---|---|

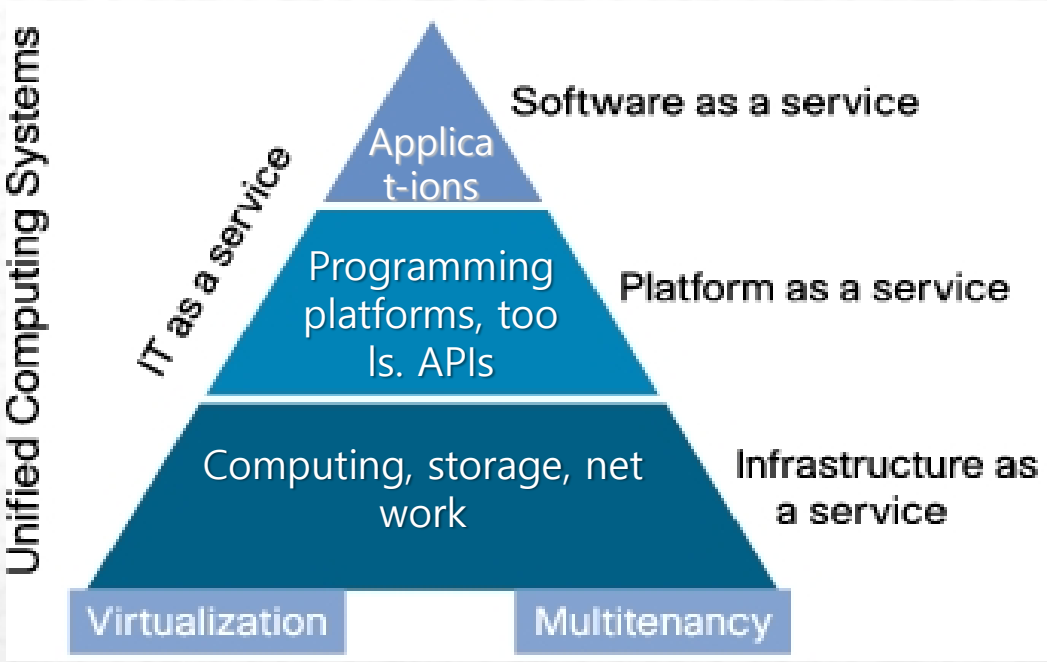
# Business Benefits

- Cost efficient model for creating and acquiring information services
- Removes or reduces IT management complexity
- Increases business responsiveness with real-time capacity reallocation
- Powers rich internet applications

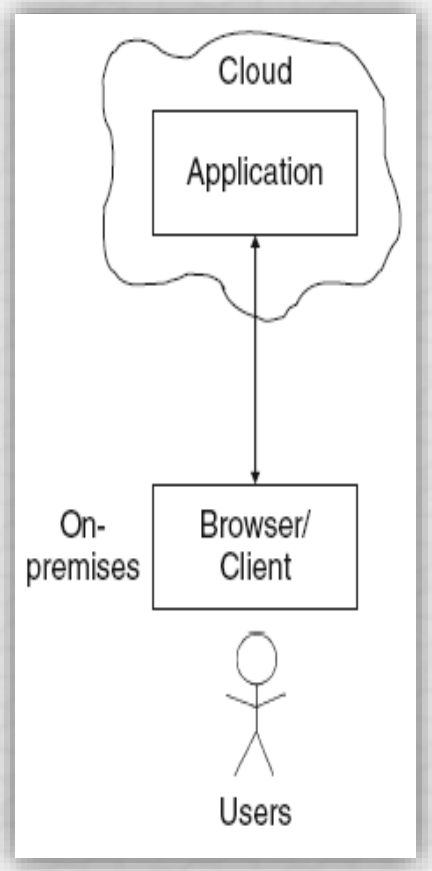
# Layers of Cloud Computing




**Cloud computing can be viewed as a collection of services (XaaS), which can be presented as a layered cloud computing architecture**



# Software-as-a-Service (SaaS)




- In this case, applications are exposed as a service running on a cloud infrastructure
- The client contains a simple browser to access the application
- A well-known example of SaaS is salesforce.com
- Others example include Google Apps, blist, slide rocket ,Microsoft Office Online etc.

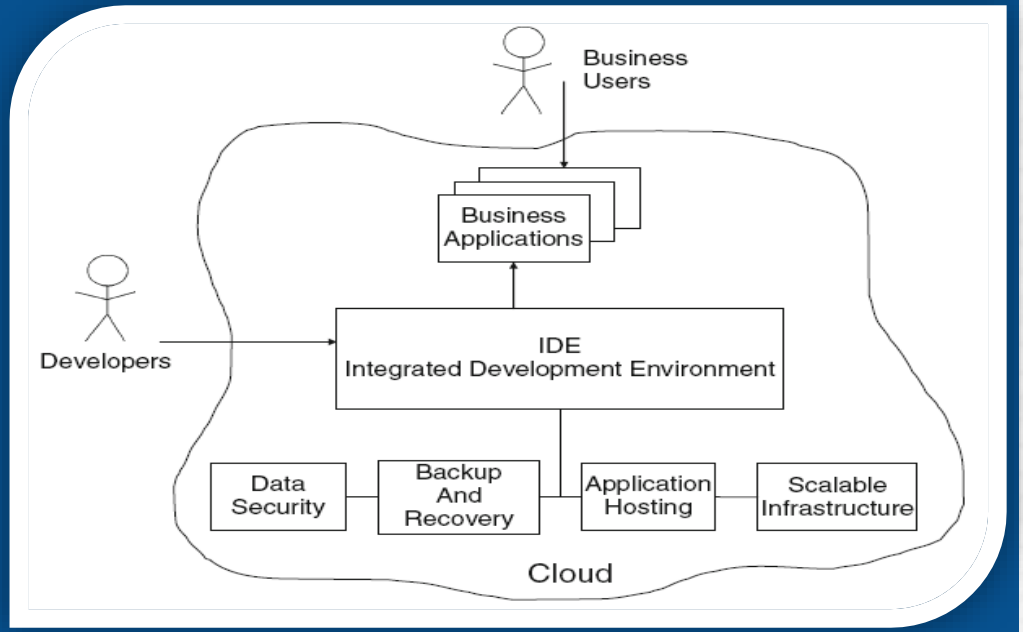
◀ Software-as-a-Service

# Infrastructure-as-a-Service (IaaS)

- Infrastructure-as-a-service (IaaS) refers to computing resources as a service
- This includes virtualized computers with guaranteed processing power and reserved bandwidth for storage and Internet access
- Instead of owning, managing or controlling the underlying infrastructure, the infrastructure is rented as a service
- Examples include Amazon Elastic Cloud Compute (EC2), Sun Microsoft's Nework.com, IBM Blue Cloud, 3Tera etc.

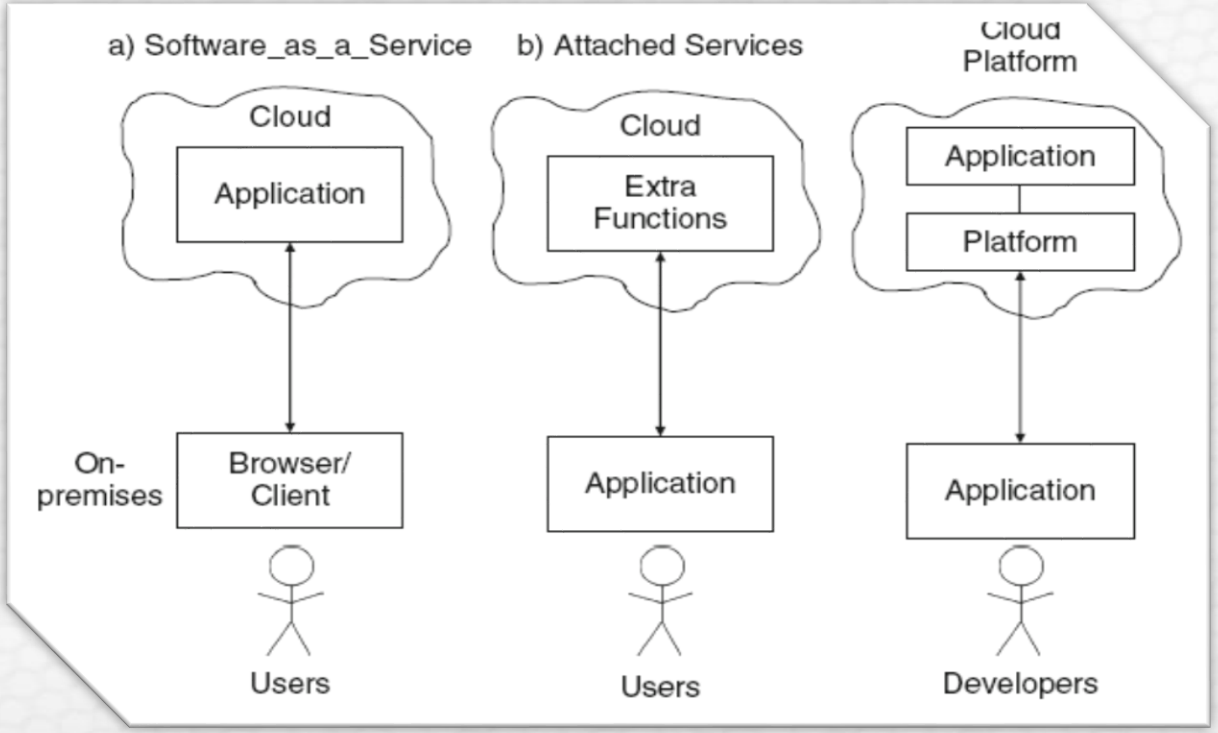
# Platform-as-a-Service (PaaS)

- PaaS is similar to IaaS, but also includes operating systems and required services for a particular application
- In other words, PaaS is IaaS with a custom software stack for the given application
- The PaaS provides Integrated Development Environment (IDE) including
  - data security,
  - backup and recovery
  - application hosting and
  - scalable architecture



# Three Categories of Cloud Services

- According to Chappell (2008) there are three categories of cloud services, as follows
- SaaS
- Attached services
- Cloud Platform



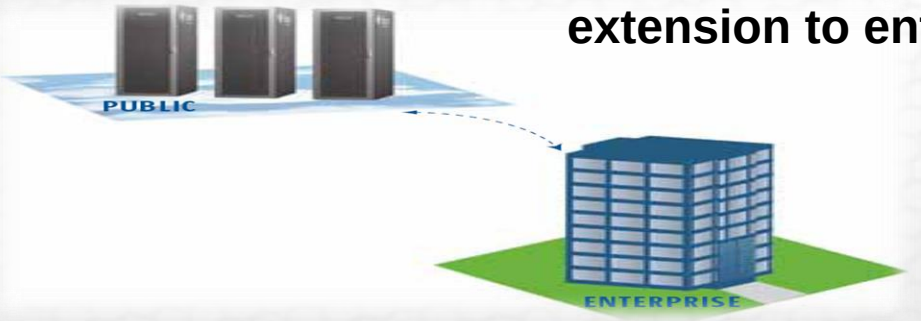
# Types of Cloud Computing

**Public Cloud** ⟷

**Private Cloud**

**Hybrid Cloud**

- **Public clouds are run by third parties, and applications from different customers are likely to be mixed together on the cloud's servers, storage systems, and networks**
- **Public clouds are most often hosted away from customer premises, and they provide a way to reduce customer risk and cost by providing a flexible, even temporary extension to enterprise infrastructure**



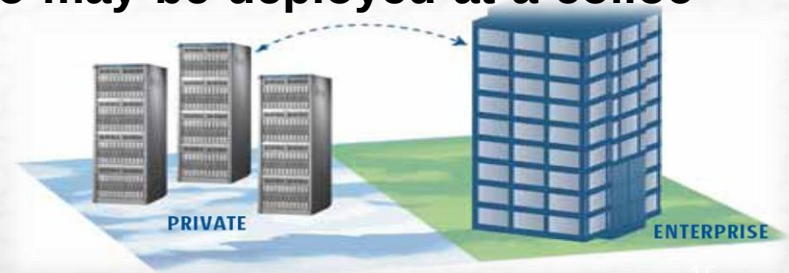
# Types of Cloud Computing

Public Cloud

Private Cloud

Hybrid Cloud

- Private clouds are built for the exclusive use of one client, providing the utmost control over data, security, and quality of service
- The company owns the infrastructure and has control over how applications are deployed on it
- Private clouds may be deployed in an enterprise datacenter, and they also may be deployed at a collocation facility



# Types of Cloud Computing

Public Cloud

Private Cloud

Hybrid Cloud

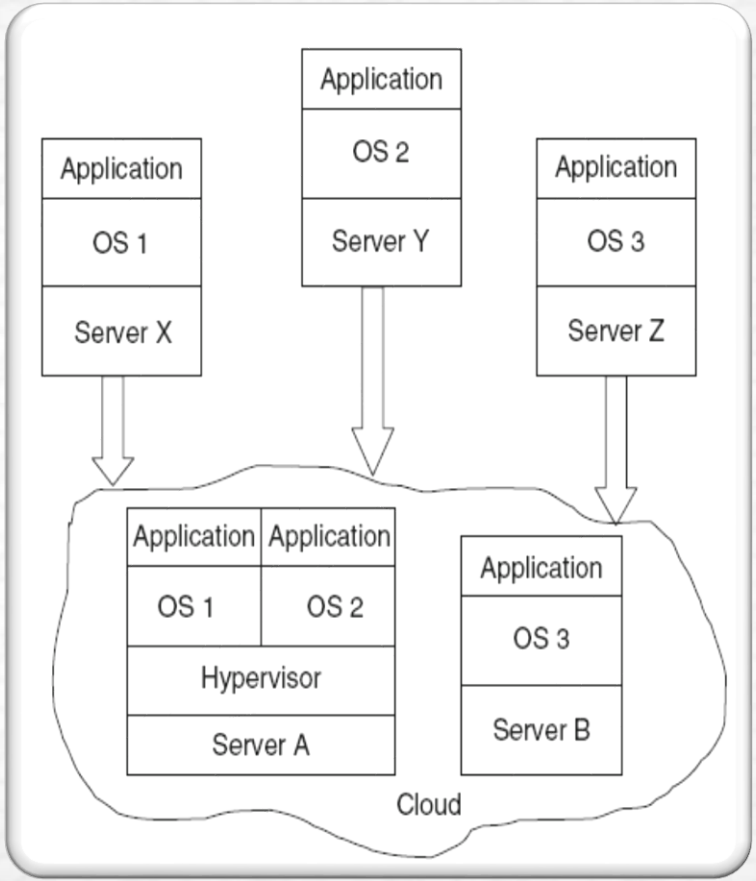
- Hybrid clouds combine both public and private cloud models
- They can help to provide on-demand, externally provisioned scale
- The ability to augment a private cloud with The resources of a public cloud can be used to maintain service levels in the face of rapid workload fluctuations


Example: This is most often seen with the use of storage clouds to support Web 2.0 applications

# 2. Enabling technologies

# Virtualization

- Virtualize and share resources among different applications with the objective for better server utilization
- Virtualization technologies include virtual machine techniques such as VMwareand Xen, and virtual networks, such as VPN
- Virtual machines provide virtualized IT-infrastructures on-demand
- Virtual networks support users with a customized network environment to access cloud resources.



# Web Service and SOA

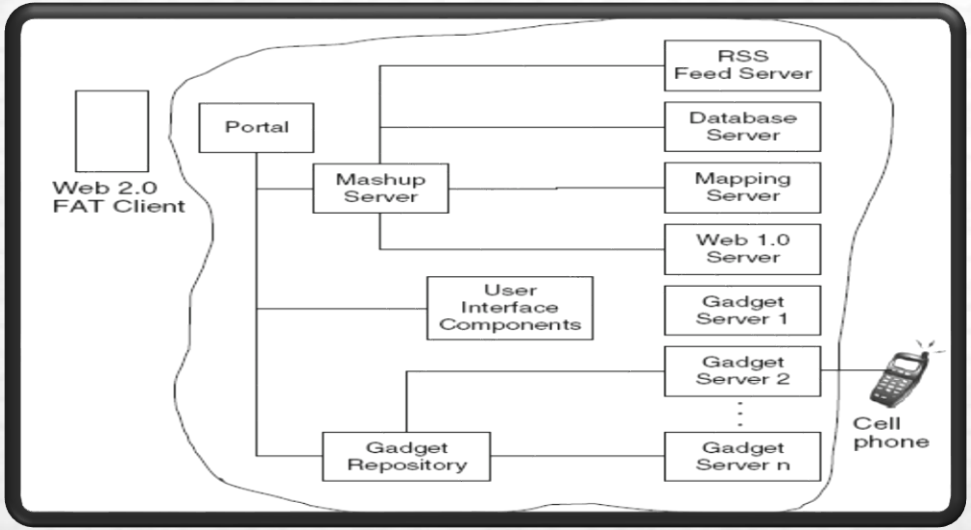
- Cloud services are typically designed as Web services, which follow industry standards including WSDL, SOAP, and UDDI
- A Service Oriented Architecture organizes and manages Web services inside clouds
- A SOA also includes a set of cloud services, which are available on various distributed platforms

## Service Flow and Workflows

The concept of service flow and workflow refers to an integrated view of service based activities provided in clouds

# Web 2.0 and Mashup

- **Web 2.0 enhances creativity, information sharing, and collaboration among users on the Web**
- **Mashup is a web application that combines data from more than one source into a single integrated storage tool**
- **Both technologies are very beneficial for cloud computing**




**A cloud computing architecture, in which an application reuses various components**

# 3. Cloud computing features

# Cloud computing features

## Scalability and on-demand services

- Provides resources and services for users on demand

## User-centric interface

- Location independent and can be accessed by any device

## Guaranteed Quality of Service (QoS)

- Guarantee QoS for users in terms of hardware/CPU
- performance, bandwidth, and memory capacity

## Autonomous system

- Managed transparently to users

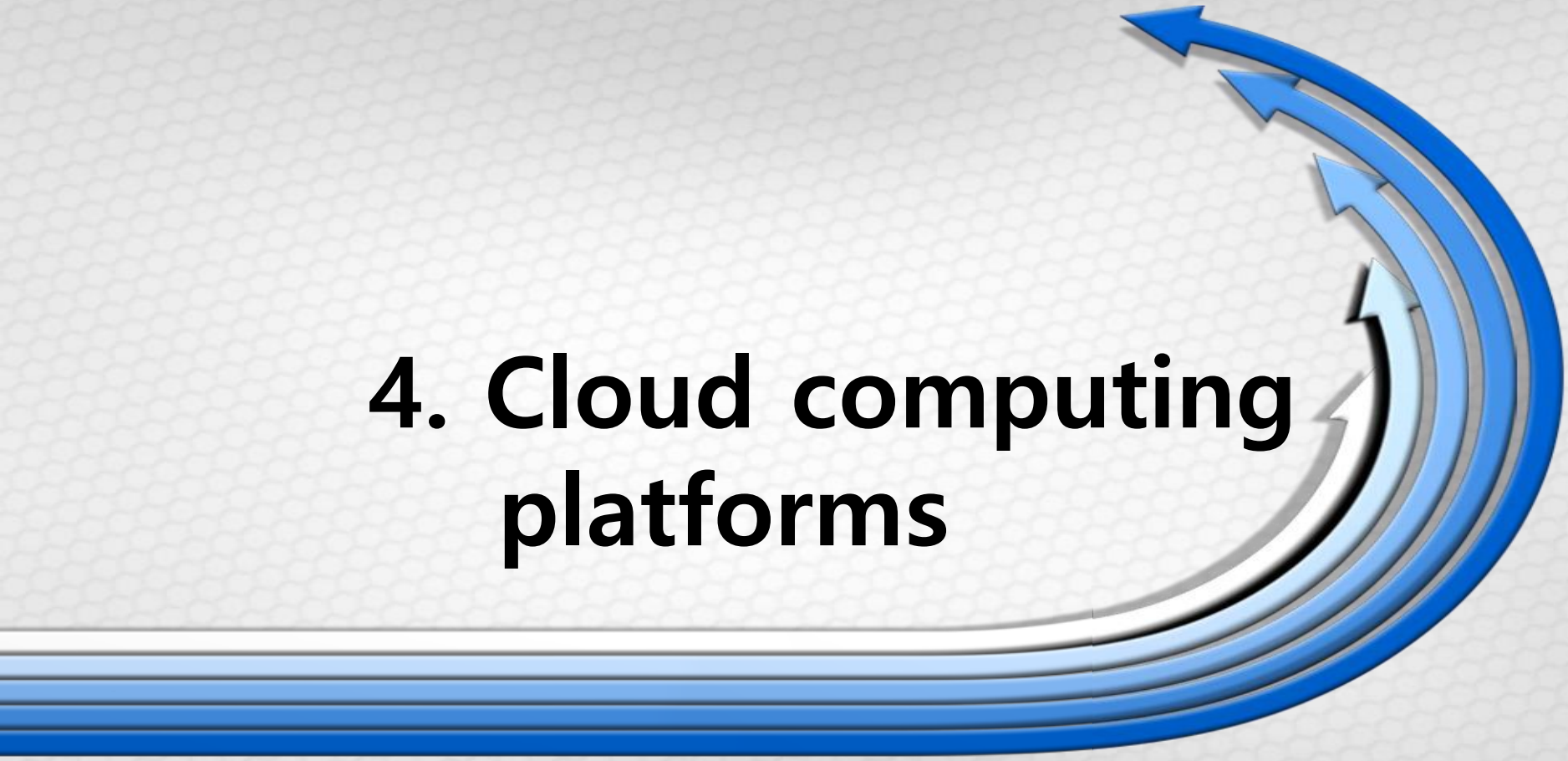
## Pricing

- No capital expenditure is required
- Users pay for services and capacity as they need them

# Cloud Computing Security

- One of the critical issues in implementing cloud computing is taking virtual machines, which contain critical applications and sensitive data, to public and shared cloud environments.
- Therefore, potential cloud computing users are concerned about the following security issues

  - Will the users still have the same security policy control over their applications and services?
  - Can it be proved to the organization that the system is still secure and meets SLAs?
  - Is the system complaint and can it be proved to company's auditors?



# 4. Cloud computing platforms

# Cloud Computing Platforms

## Key Players in Cloud Computing Platforms (adapted from Lakshmanan(2009))

| Company | Cloud computing platform | Year of launch | Key offerings |
|---|---|---|---|
| Amazon. com | AWS (Amazon Web Services) | 2006 | Infrastructure as a service (Storage, Computing, Message queues, Datasets, Content distribution) |
| Microsoft | Azure | 2009 | Application platform as a service (.Net, SQL data services) |
| Google | Google App. Engine | 2008 | Web Application Platform as a service (Python run time environment) |
| IBM | Blue Cloud | 2008 | Virtualized Blue cloud data center |
| Salesforce.com | Force.com | 2008 | Proprietary 4GL Web application framework as an on Demand platform |

# Pricing

**Pricing for cloud platforms and services is based on three key dimensions:**

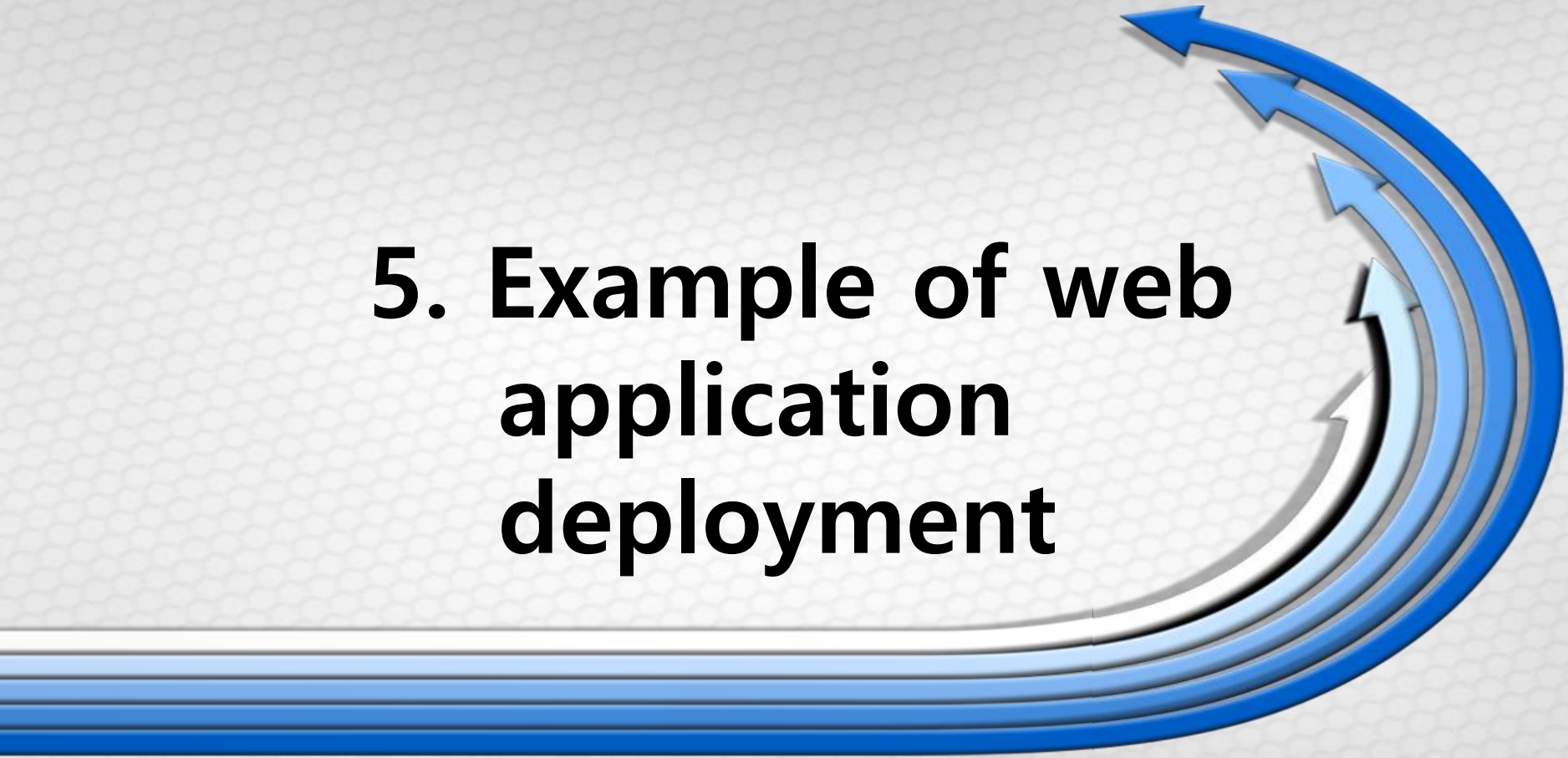
- **Storage**
  - It is typically measured as average daily amount of data stored in GB over a monthly period
- **Bandwidth**
  - It is measured by calculating the total amount of data transferred in and out of platform service through transaction and batch processing
- **Compute**
  - It is measured as the time units needed to run an instance, or application, or machine to servicing requests

# Pricing comparison for Cloud computing

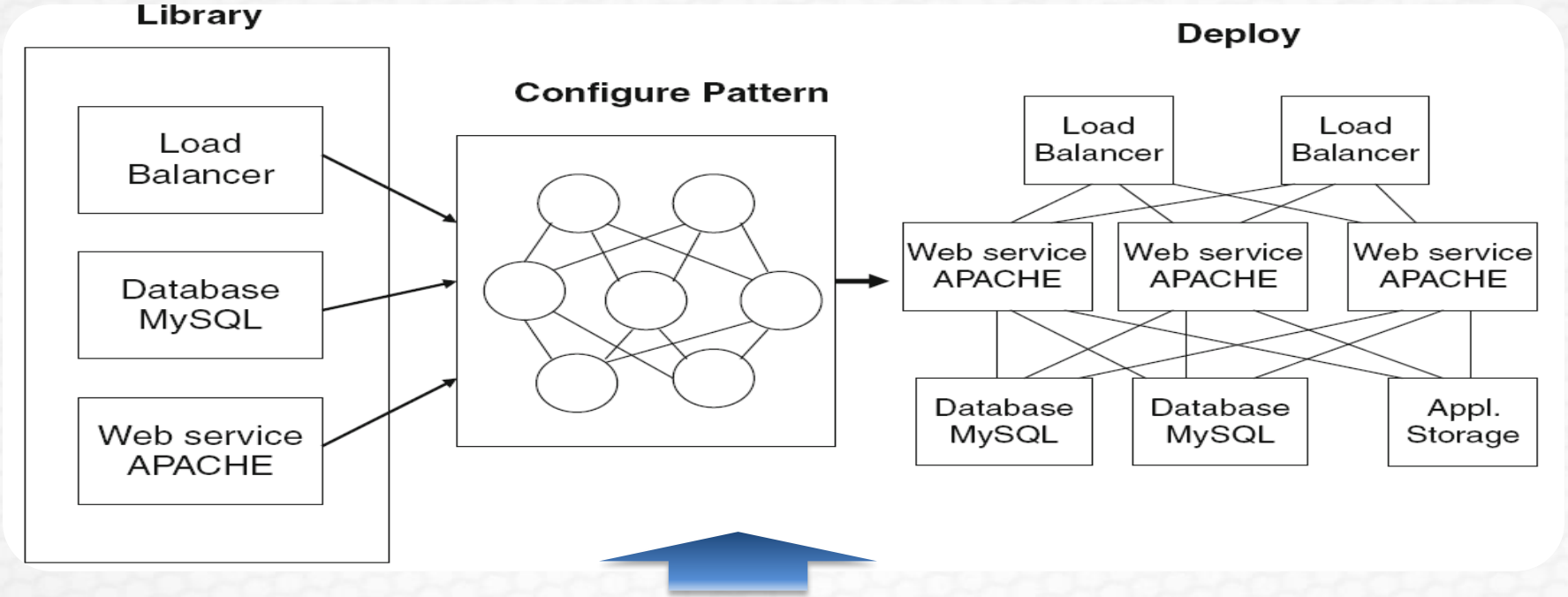
## Pricing comparison for cloud computing

| Resource | UNIT | Amazon | Google | Microsoft |
|---|---|---|---|---|
| Stored data | GB per month | $0.10 | $0.15 | $0.15 |
| Storage transaction | Per 10 K requests | $0.10 | | $0.10 |
| Outgoing bandwidth | GB | $0.10 – $0.17 | $0.12 | $0.15 |
| Incoming bandwidth | GB | $0.10 | $0.10 | $0.10 |
| Compute time | Instance Hours | $0.10 – $1.20 | $0.10 | $0.12 |

# 5. Example of web application deployment



# Example of web application deployment



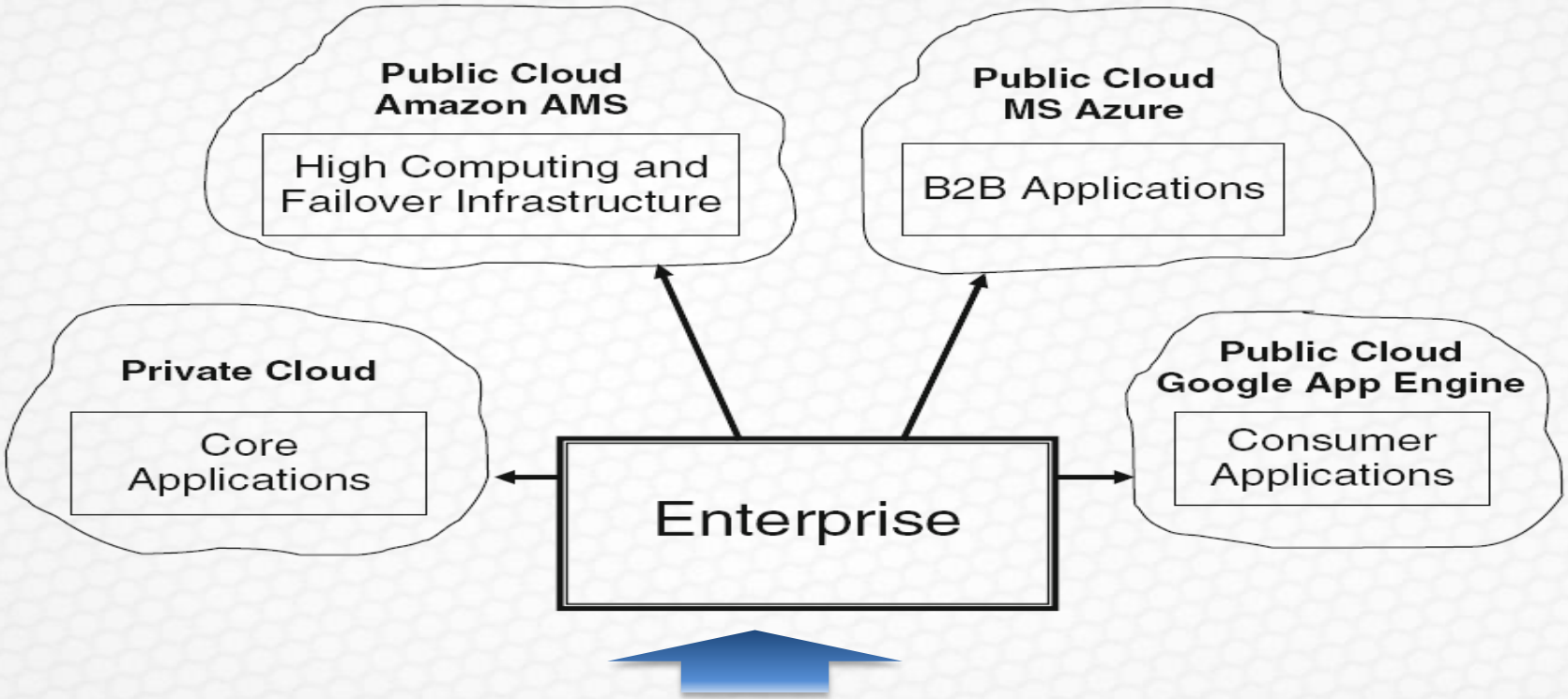

**An example of the deployment of an application into a two-tier Web server architecture using cloud computing**

# 6. Cloud computing challenges

# Cloud computing challenges

- Performance
- Security and Privacy
- Control
- Bandwidth Costs
- Reliability

# Cloud Computing in the Future




**Distributed hybrid Cloud architecture**