Cloud Computing

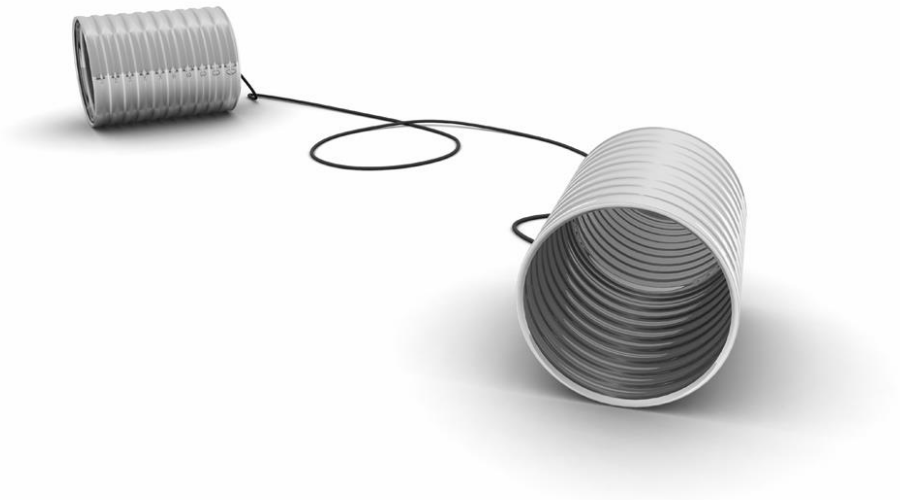
Tor Skeie

Based also on slides from
Professor Yogesh Simmhan, Indian Institute of Science



UiO : University of Oslo

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What do they say ?

WHAT IS CLOUD COMPUTING ?

Cloud Definitions

- Definition from ***NIST*** *(National Institute of Standards and Technology)*

Definition from ***NIST*** *(National Institute of Standards and Technology)*

  - 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.
  - This cloud model promotes **availability** and is composed of five essential characteristics, three service models, and four deployment models.

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.

This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models.

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

Cloud Definitions

- Definition from ***Wikipedia***
- Definition from ***Wikipedia***
  - Cloud computing is **Internet-based computing**, whereby **shared resources, software, and information** are provided to computers and other devices **on demand**, like the electricity grid.
  - Cloud computing is a style of computing in which **dynamically scalable** and often **virtualized resources** are provided as a **service** over the Internet.
  - Cloud computing is a style of computing in which dynamically scalable and often virtualized resources are provided over the Internet.



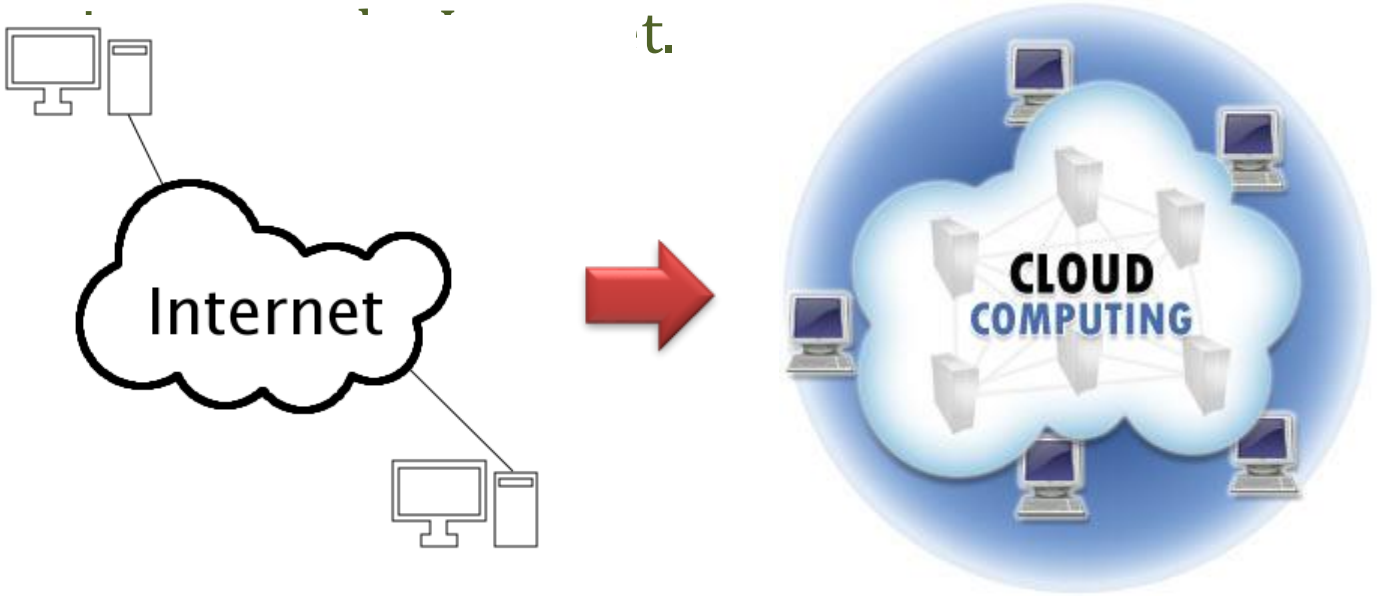


WIKIPEDIA
The Free Encyclopedia

Cloud Definitions

- Definition from *Whatis.com*
  - The name cloud computing was inspired by the cloud symbol that's often used to represent the Internet in flowcharts and diagrams.
  - Cloud computing is a general term for anything that involves **delivering hosted services over the Internet**.

Definition from *Whatis.com*
The name cloud computing was inspired by the cloud symbol that's often used to represent the Internet in flowcharts and diagrams. Cloud computing is a general term for anything that involves delivering hosted



Eye-Opening Facts About Cloud Computing

- 94% of companies are on the cloud
- Cloud data centers processed 94% of workloads in 2025
- Amazon Web Services is the leading cloud vendor with a 32% share
- Cost optimization is the primary reason for 47% of enterprises' cloud migration
- Amazon, Microsoft, and Google combined account for 63% of the global cloud computing market in 2026 (Synergy Research Group)
- Cloud Types – What's the Difference?
  - **Public cloud** – this refers to the model with which the services are delivered across the Internet
  - **Private cloud** – it's designed for internal use by a single organization
  - **Hybrid cloud** – this is when a company uses both a public and a private cloud

Source: hostingtribunal.com

Agenda

- What is Cloud Computing ?
  - Properties and characteristics
  - Benefits from cloud computing
- Service and deployment models
  - Three service models
  - Four deployment models



Properties and characteristics

WHAT IS CLOUD COMPUTING ?

In Our Humble Opinion

- Cloud computing is a paradigm of computing, a "new" way of thinking about IT industry, but not any specific technology as such
  - Central ideas
    - ***Utility Computing***
    - ***SOA*** - Service Oriented Architecture
    - ***SLA*** - Service Level Agreement
  - Properties and characteristics
    - High ***scalability*** and ***elasticity***
    - High ***availability*** and ***reliability***
    - High ***manageability*** and ***interoperability***
    - High ***accessibility*** and ***portability***
    - High ***performance*** and ***optimization***
  - Enabling techniques
    - Hardware virtualization
    - Parallelized and distributed computing
    - Web services / apps



Properties and Characteristics



Utility Computing
SOA + SLA

Central Ideas



DON'T TELL ME DETAILS!!

I DON'T CARE!!

Utility Computing
SOA + SLA

Central Ideas

- Perspective from user :
  - Users do not care about how the works are done
    - Instead, they only concern about what they can get
  - Users do not care about what the provider actually did
    - Instead, they only concern about their quality of service
  - Users do not want to own the physical infrastructure
    - Instead, they only want to pay as many as they used

- What does the user really care about?
  - They only care about the “Service” they get and the Cost



Utility Computing
SOA + SLA

Utility Computing

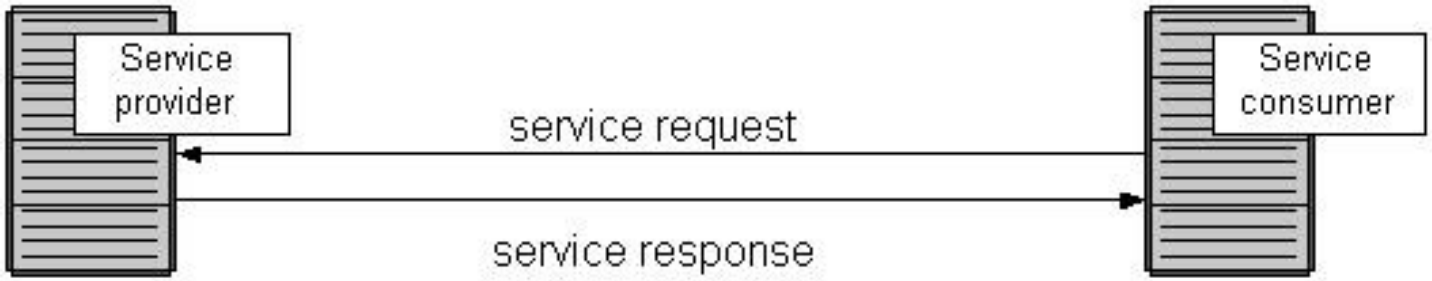


- One service provisioning model
  - Service provider makes computing resources and infrastructure management available to the customer as needed, and charges them for specific usage rather than a flat rate.
  - Like other types of on-demand computing, the utility model seeks to maximize the efficient use of resources and/or minimize associated costs.

Utility Computing
SOA + SLA

Service Oriented Architecture

- Definition
  - Service Oriented Architecture (SOA) is essentially a collection of services which communicate with each other over a network
  - Is a style of software design where services are provided to the other components as application components, through a communication protocol
  - The basic principles of service-oriented architecture are independent of vendors, products and technologies
- Approach
  - Usually implemented by Web Service model



Utility Computing
SOA + SLA

Service Level Agreement

- Definition
  - A service-level agreement (SLA) is a contract between a cloud service provider and a customer that specifies, usually in measurable terms (QoS), what services the cloud service provider will furnish

- Common content in contract
  - Performance guarantee metrics
    - Up-time and down-time ratio
    - System throughput
    - Response time
  - Problem management detail
  - Penalties for non-performance
  - Documented security capabilities



Scalability
Elasticity
- Dynamic provision
- Multi-tenant design

Scalability & Elasticity



Give me the world without limitation!!



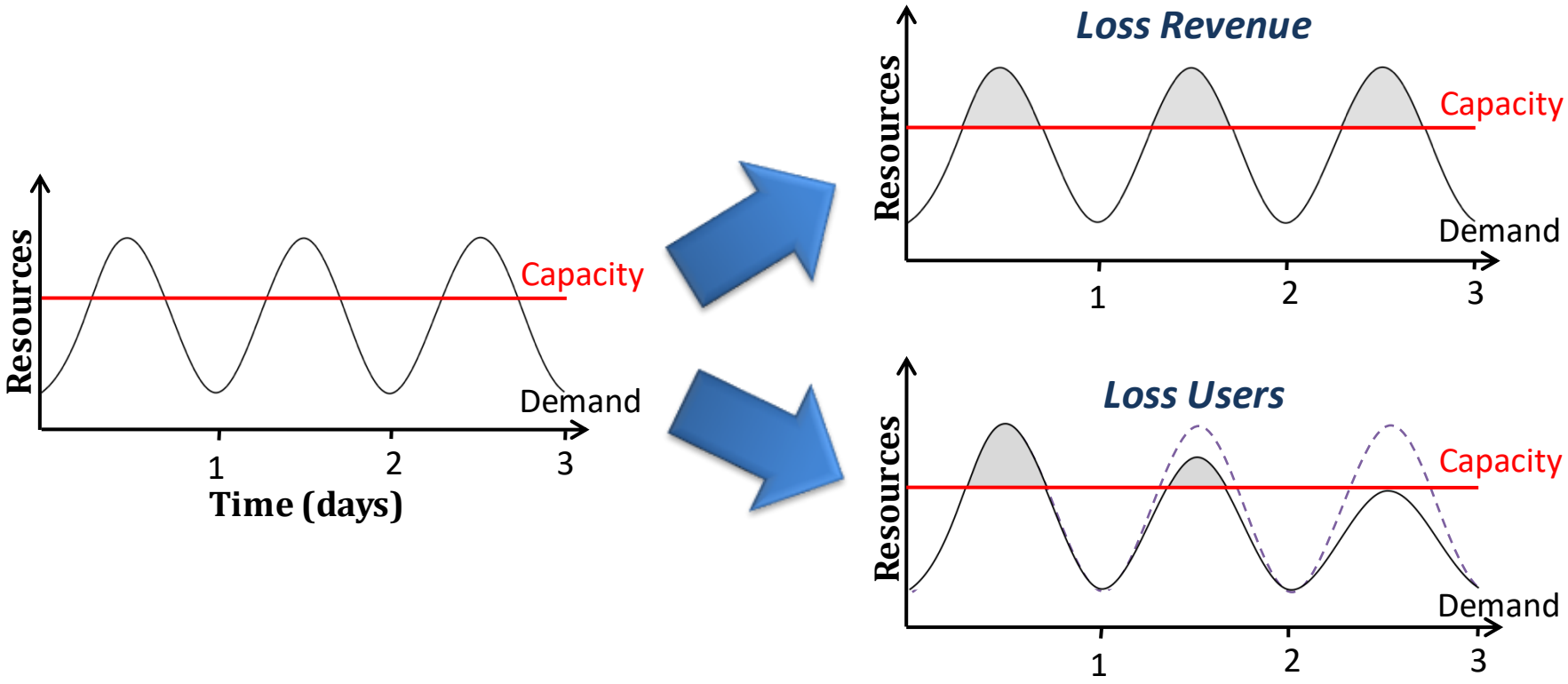
Scalability & Elasticity

- What is scalability ?
  - The ability to increase workload size within existing infrastructure (hardware, software, etc.) without impacting performance. The resources required to support this are usually pre-planned capacity with a certain amount of headroom built in to handle peak demand.
- What is elasticity ?
  - The ability to grow or shrink infrastructure resources dynamically as needed to adapt to workload changes in an autonomic manner, maximizing the use of resources. This can result in savings in infrastructure costs overall.
  - Cloud elasticity is a popular feature associated with scale-out solutions (horizontal scaling), which allows for resources to be dynamically added or removed when needed.
- But how to achieve these properties ?
  - Dynamic provisioning
  - Multi-tenant design

Scalability
Elasticity
• Dynamic provision
• Multi-tenant design

Static Provisioning

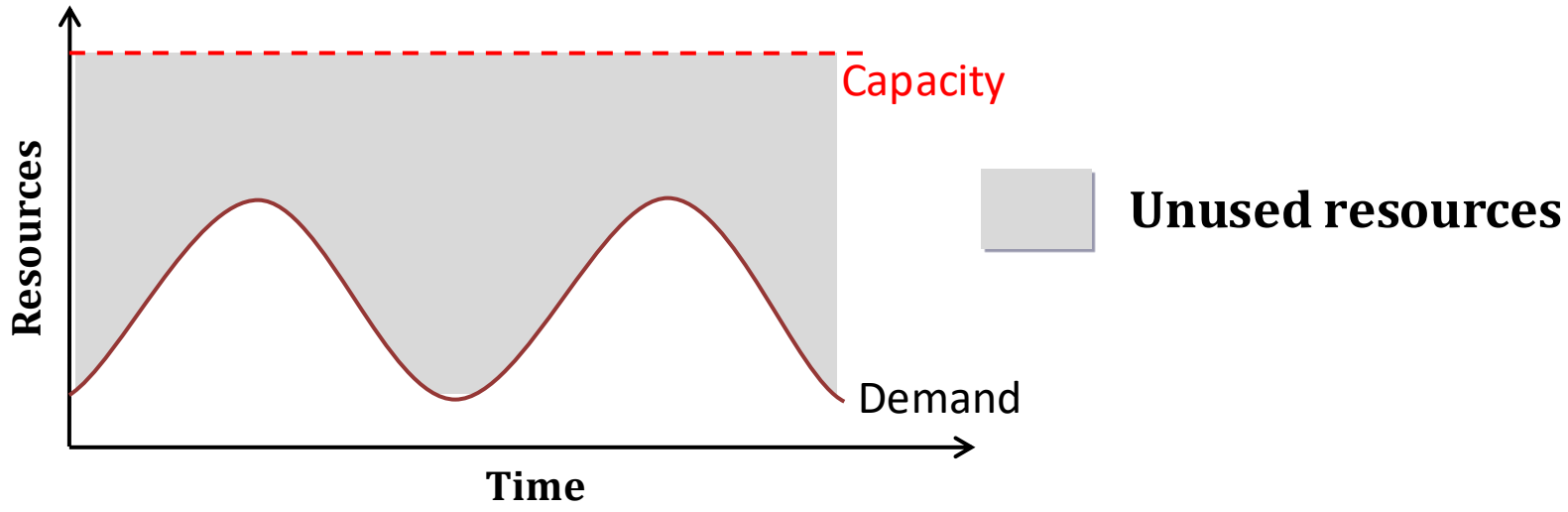
- In traditional computing model, two common problems :
  - Underestimate the system capacity which result in underprovision



Scalability
Elasticity
• Dynamic provision
• Multi-tenant design

Static Provisioning

- Overestimate system capacity which result in low utilization

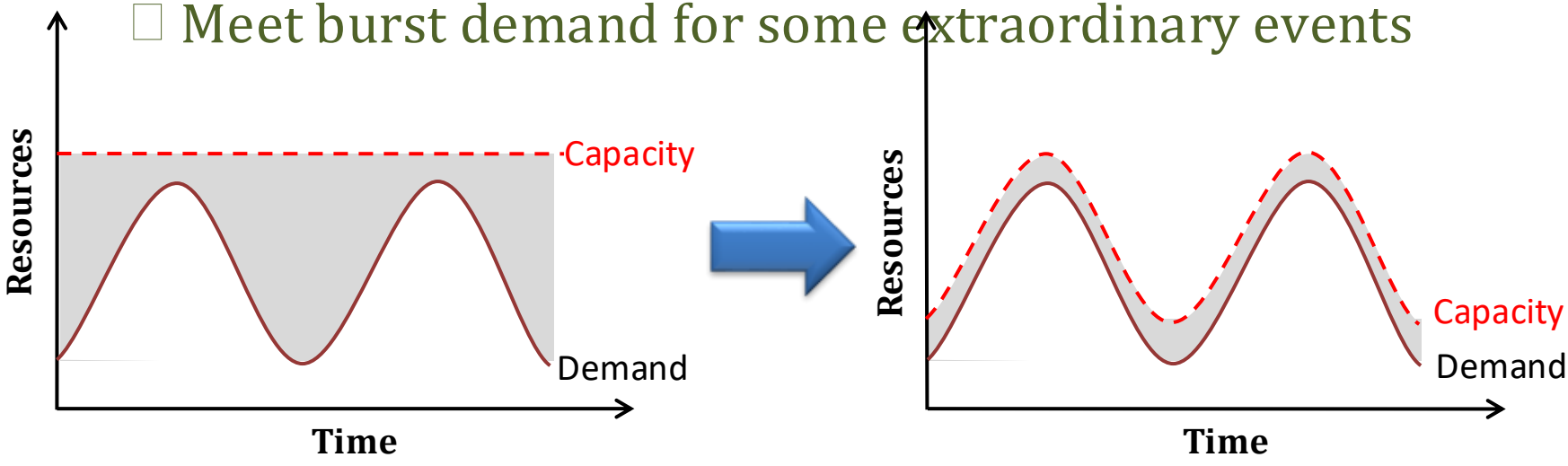


- How to solve this problem ??
  - Dynamically provision resources



Elasticity - Dynamic Provisioning

- Cloud resources should be provisioned dynamically
  - Meet seasonal demand variations
  - Meet demand variations between different industries
  - Meet burst demand for some extraordinary events





Multi-tenant Design

- What is multi-tenant design ?
  - Multi-tenant refers to a principle in software architecture where a single instance of the software runs on a server, serving multiple client organizations.
  - With a multi-tenant architecture, a software application is designed to virtually partition its data including configuration, thus each client organization works with a customized virtual application instance.

- Client oriented requirements :
  - Customization
    - Multi-tenant applications are typically required to provide a high degree of customization to support each target organization's needs.
  - Quality of service
    - Multi-tenant applications are expected to provide adequate levels of security and robustness.

Availability
Reliability

- Fault tolerance
- System resilience
- System security

Availability & Reliability



Data Never Lost

Machine Never Fail



Availability & Reliability

- What is availability ?
  - A measure of how prepared a system, subsystem, or equipment is to function properly when a mission begins, even if the mission start time is unpredictable.
  - Cloud systems usually require high availability
    - Ex. “Five Nines” system would statistically provide 99.999% availability
- What is reliability ?
  - The ability of a system or component to perform its required functions under stated conditions for a specified period of time.
- But how to achieve these properties ?
  - Fault tolerant system
  - Require system resilience
  - Reliable system security

Availability
Reliability
- Fault tolerance
- System resilience
- System security

Fault Tolerance

- Single Point Of Failure (SPOF)
  - A part of a system which, if it fails, will stop the entire system from working.
  - The assessment of a potentially single location of failure identifies the critical components of a complex system that would provoke a total system failure in case of malfunction.
- Preventing single point of failure
  - If a system experiences a failure, it must continue to operate without interruption during the repair process.





System Resilience

- What is resilience ?
  - Resilience is the ability to provide and maintain an acceptable level of service in the presence of faults that challenge normal operation.
  - Resiliency pertains to the system's ability to return to its original state after encountering trouble. In other words, if a risk event knocks a system offline, a highly resilient system will return back to work and function as planned as soon as possible.

- Examples of risk events
  - If power is lost at a plant for some time, can our system recover ?
  - If a key service is lost because a database corruption, can the business recover ?

Availability
Reliability
- Fault tolerance
- System resilience
- System security

System Resilience

- Disaster Recovery
  - Disaster recovery is the process, policies and procedures related to preparing for recovery or continuation of technology infrastructure critical to an organization after a natural or human-induced disaster.

- Some common strategies :
  - Backup
    - Make data off-site at regular interval
    - Replicate data to an off-site location
    - Replicate whole system
  - Preparing
    - Local mirror systems
    - Surge protector
    - Uninterruptible Power Supply (UPS)



Availability
Reliability
- Fault tolerance
- System resilience
- System security

System Security

- Security issue in Cloud Computing :
  - Cloud security is an evolving sub-domain of computer security, network security, and, more broadly, information security.
  - It refers to a broad set of policies and technologies to protect data, applications, and the associated infrastructure of cloud computing.





System Security

- Important security and privacy issues :
  - Data Protection
    - To be considered protected, data from one customer must be properly segregated from that of another.
  - Application Security
    - Cloud providers should ensure that applications available as a service via the cloud are secure.
  - Privacy
    - Cloud providers should ensure that all critical data are masked and that only authorized users have access to data in its entirety.

Manageability
Interoperability
- Control automation
- System monitoring
- Billing system

Billing System

- Billing System in Cloud
  - Users pay as many as many resources they used.
  - Cloud provider must first determine the list of service usage price.
  - Cloud provider must record the resource or service usage of each user and then charge users by these records.
- How can cloud provider know users' usage ?
  - Get those information by means of monitoring system.
  - Automatically calculate the total amount of money which user should pay. And automatically request money from use's banking account.



Performance Optimization

- Parallel processing
- Load balancing
- Job scheduling

Performance & Optimization



High Performance Improvement



Performance & Optimization

- Performance guarantees ??
  - Application performance should be guaranteed.
  - Cloud providers make use of powerful infrastructure or other underlining resources to build up a highly performed and highly optimized environment, and then deliver the complete services to cloud users.
- But how to achieve this property ?
  - Parallel computing
  - Load balancing
  - Job scheduling



Parallel Processing

- Parallel Processing
  - Parallel processing is a form of computation in which many calculations are carried out simultaneously, operating on the principle that large problems can often be divided into smaller ones, which are then solved concurrently.

- Parallelism in different levels :
  - Bit level parallelism
  - Instruction level parallelism
  - Data level parallelism
  - Task level parallelism

Performance Optimization
- Parallel processing
- Load balancing
- Job scheduling

Parallel Processing

- Hardware approaches
  - Multi-core computer
  - Symmetric multi-processor
  - Accelerators, e.g. general purpose graphic processing unit (GPUs)
  - Distributed heterogenous computing
    - High Performance Interconnects needed to offer HPC (as a service)
- Software approaches
  - Parallel programming language
  - Automatic parallelization



Performance Optimization
- Parallel processing
- Load balancing
- Job scheduling

Load Balancing

- What is load balancing ?
  - Load balancing is a technique to distribute workload evenly across two or more computers, network links, CPUs/GPUs, hard drives, or other resources, in order to get optimal resource utilization, maximize throughput, minimize response time, and avoid overload.

- Why load balancing ?
  - Improve resource utilization
  - Improve system performance
  - Improve energy efficiency

Unbalanced →



Accessibility
Portability
- Uniform access
- Thin client

Accessibility & Portability



Anyone !
Anytime !
Anywhere !



Accessibility & Portability

- What is accessibility ?
  - Accessibility is a general term used to describe the degree to which a product, device, service, or environment is accessible to as many people as possible.
- What is service portability ?
  - Service portability is the ability to access services using any device, anywhere, continuously with mobility support and dynamic adaptation to resource variations.
- But how to achieve these properties ?
  - Uniform access
  - Thin client

Accessibility
Portability
• Uniform access
• Thin client

Uniform Access

- How do users access cloud services ?
  - Cloud provider should offer their cloud service by means of widespread accessing media. In other words, users from different operating systems or other accessing platforms should be able to directly be served.
  - Nowadays, web browser technique is one of the most widespread platform in almost any intelligent electronic devices. Cloud service take this into concern, and delivery their services with web-based interface through the Internet.





What can we gain from cloud ?

WHAT IS CLOUD COMPUTING ?

Benefits From Cloud

- Cloud computing brings many benefits :
  - For the market and enterprises
    - Reduce initial investment
    - Reduce capital expenditure
    - Improve industrial specialization
    - Improve resource utilization
  - For the end user and individuals
    - Reduce local computing power
    - Reduce local storage power
    - Variety of thin client devices in daily life
  - And not least, being environmentally friendly 👍



For Market and Enterprises



Reduce Capital Expenditure

- Traditional capital expenditure of enterprises :
  - Each enterprise should establish its own IT department
  - IT department should handle the listed jobs
    - Manage and administrate hardware and software
    - Apply regular data backup and check point process
    - Purchase new infrastructure and eliminate outdated one
    - Always standby for any unexpected IT problems
- Some drawbacks :
  - Enterprise pays for IT investment which is not its business focus
  - Enterprise would need to take the risk of hardware/software malfunction
  - Replacing and updating infrastructure is time consuming and risky

Reduce Capital Expenditure

- Capital expenditure with Cloud Computing service :
  - Enterprise can almost dismiss its IT department
  - The jobs of IT department can be achieved by cloud provider
    - Dynamically update and upgrade hardware or software
    - Dynamically provision and deploy infrastructure for enterprise
    - Automatically backup data and check consistency
    - Self-recover from disaster or system malfunction
- Some benefits :
  - Enterprise can shift effort to its business focus
  - Enterprise can reconfigure its IT services in short time
  - Enterprise pays to cloud provider as many as the service used

Reduce Capital Expenditure

- What does cloud computing achieve ?

	Traditional	With Cloud Computing
Business focus	*Need to own its IT department*	*Cloud provider takes care everything*
Payment	*Pay for all investment and human resource*	*Enterprise pays as the service used*
Time duration	*Long establish time*	*Fast to business ready*



Improve Industrial Specialization

- What does cloud computing achieve ?

	Traditional	With Cloud Computing
Collaboration	*Enterprise needs to take care everything*	*Enterprise focuses on its own business*
Management	*Enterprise works with poor manageability*	*Cloud provider applies professional control*
Relationship	*Stand alone enterprise*	*Win-Win partnership*



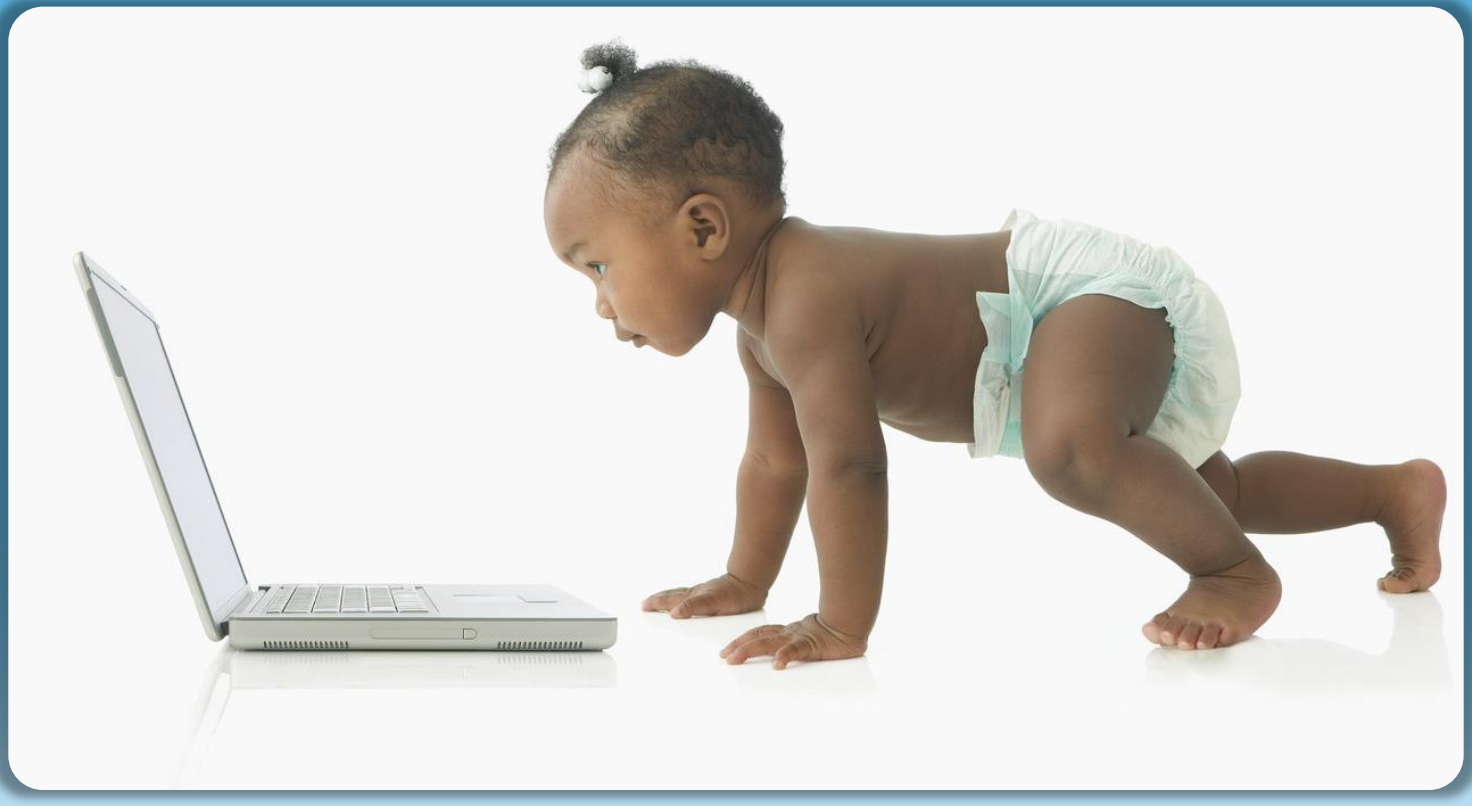
Improve Resource Utilization

- What does cloud computing achieve ?

	Traditional	With Cloud Computing
IT Resource Utilization	*IT resources under utilized most of time*	*Share to improve utilization of IT resources*
Power Consumption	*Waste power and cooling system*	*Cloud system should be global optimized*



For End User and Individual



Reduce Local Computing Power

- What does cloud computing achieve ?

	Traditional	With Cloud Computing
Hardware Requirement	*User needs to buy powerful hardware*	*Only basic hardware to connect to Internet*
Software Requirement	*Install application in local computer*	*No local installation requirement*
Portability	*Hard to be portable*	*Natively portable*



Reduce Local Storage Power

- What does cloud computing achieve ?

	Traditional	With Cloud Computing
Storage Space	*Limited to local disk, may be underutilized*	*Storage space dynamically allocated on demand*
Storage Data Consistency	*Difficult to maintain data consistency*	*Data consistency maintained by cloud*
Availability	*Regular user backup*	*Cloud service guarantee*



Variety of End Devices

- What does cloud computing achieve ?

	Traditional	With Cloud Computing
Computing Power	*Only accessed through desktop computer*	*Accessed through small smart devices*
Small Device Intelligence	*Functionalities were limited due to their power consumption*	*Shift computing intensive jobs into cloud, and then wait for results*



Agenda

- What is Cloud Computing ?
  - Properties and characteristics
  - Benefits from cloud computing
- Service and deployment models
  - Three service models
  - Four deployment models



Choose the service you need.

SERVICE MODELS

A Simple Analogy

Say, you just moved to a city and you are looking for a place to live.



What is your choice ?



Build a new house ?

Buy an empty house ?

Live in a hotel ?

Let’s build a new house !!

You can fully control everything you like your new house to have. But that is a hard work …



If you buy an empty house ?



You can customize some part of your house. But never change the original architecture.

How about live in a hotel ?

Live in a hotel will be a good idea if the only thing you care of is to enjoy your life!! There is nothing you can do with the “house” except living in it.

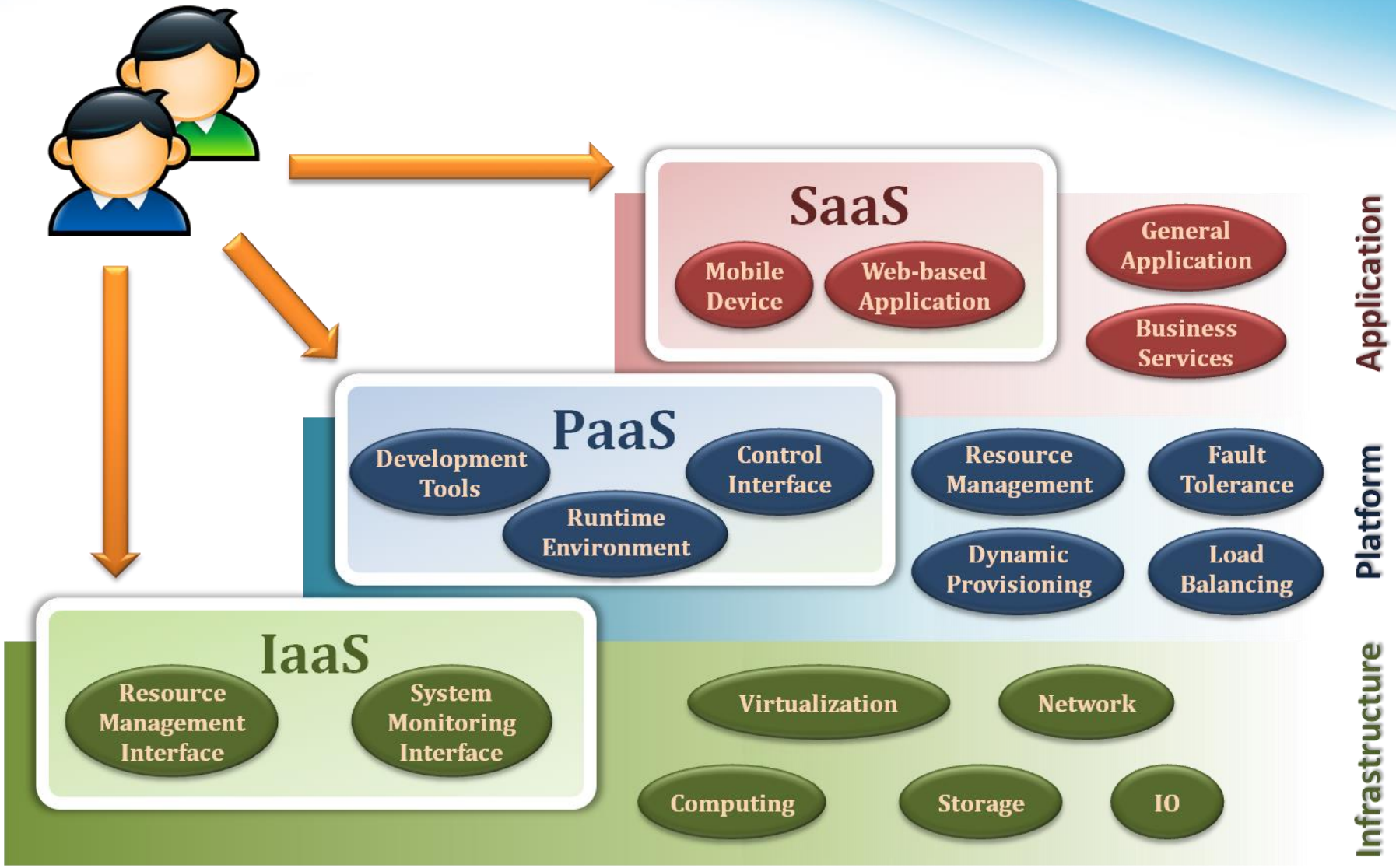


Let's translate this to Cloud Computing !!

Service Models Overview

- What if you want to have an IT “department” ?
  - Similar to ***build a new house*** in the previous analogy
    - You can rent some virtualized infrastructure and build up your own IT system among those resources, which may be fully controlled.
    - Technically speaking, use the ***Infrastructure as a Service (IaaS)*** solution.
  - Similar to ***buy an empty house*** in the previous analogy
    - You can directly develop your IT system through one cloud platform, and do not care about any lower-level resource management.
    - Technically speaking, use the ***Platform as a Service (PaaS)*** solution.
  - Similar to ***live in a hotel*** in the previous analogy
    - You can directly use some existing IT system solutions, which are provided by some cloud application service provider, without knowing any detail technique about how these service was achieved.
    - Technically speaking, use the ***Software as a Service (SaaS)*** solution.

Service Model Overview



Infrastructure as a Service

Platform as a Service

Software as a Service

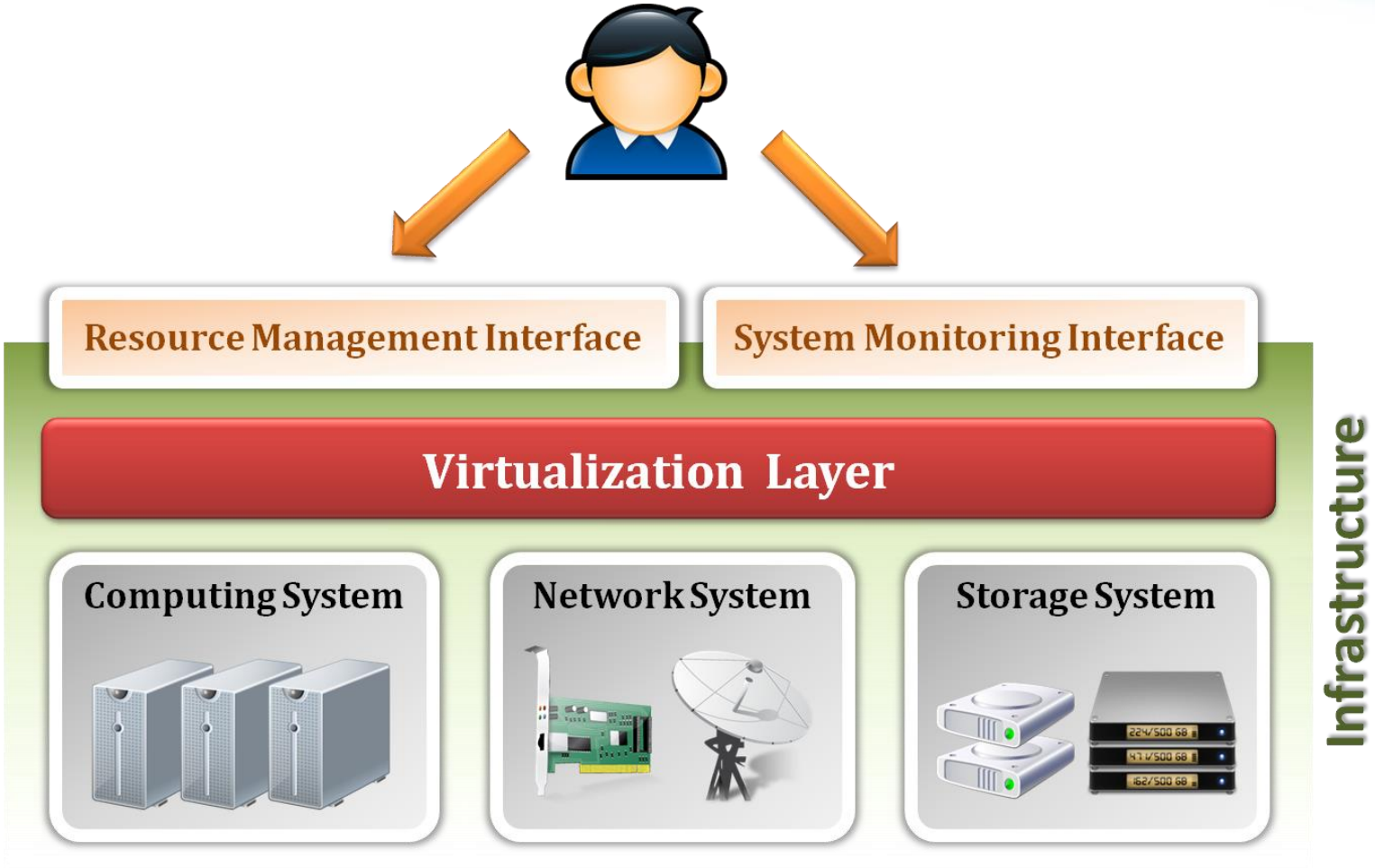
SERVICE MODELS

Infrastructure as a Service

- Infrastructure as a Service - IaaS
  - The capability provided to the consumer to provision processing, storage, networks, and other fundamental computing resources where the consumer can develop, deploy, and run arbitrary software, which can include operating systems and applications.
  - The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components.
- Examples :
  - Amazon EC2
  - Google Cloud
  - Microsoft Azure
  - OpenNebula
  - … etc

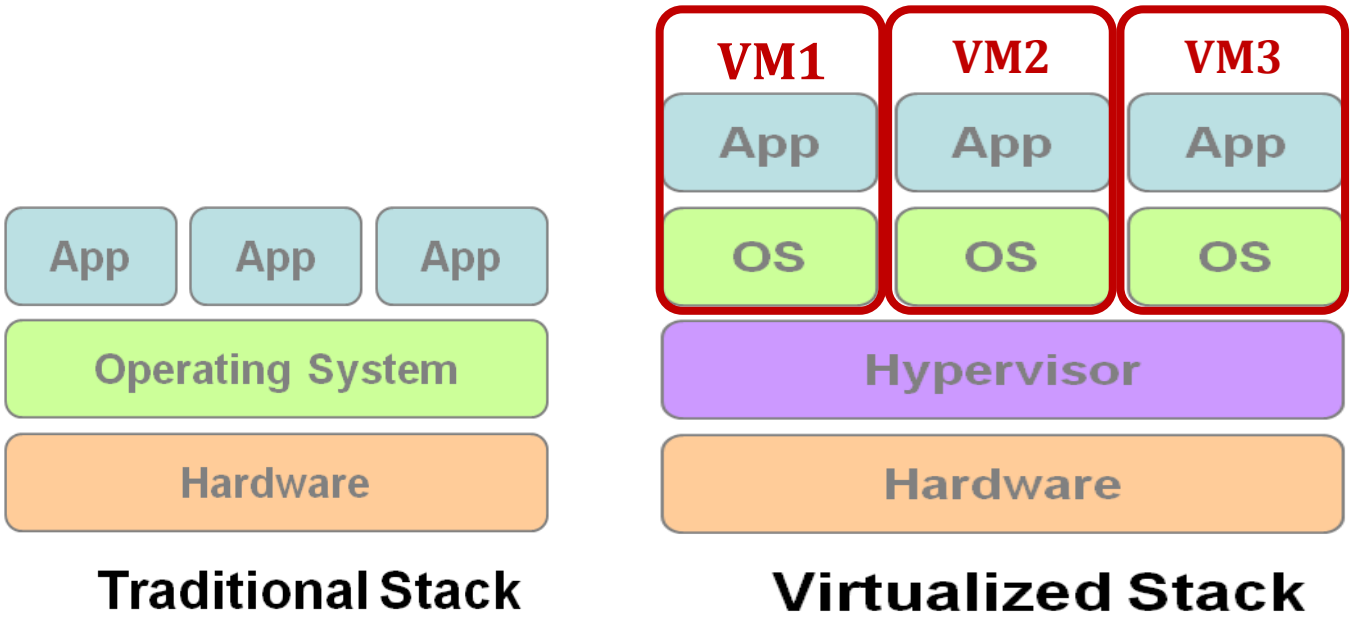
Infrastructure as a Service

- System architecture :



Infrastructure as a Service

- Enabling technique - ***Virtualization***
  - Virtualization is an abstraction of logical resources away from underlying physical resources.
    - Virtualization technique shifts OS onto hypervisor / virtual machines (VMs).
    - Multiple OS (VMs) share the physical hardware and provide different services and capabilities.
    - Improve utilization, availability, security and convenience.



Motivation for virtualization

- Cloud resource virtualization is important for:
  - Performance isolation
    - as we can dynamically assign and account for resources across different applications
  - System security:
    - as it allows isolation of services running on the same hardware
  - Performance and reliability:
    - as it allows applications to migrate from one platform to another
  - The development and management of services offered by a provider

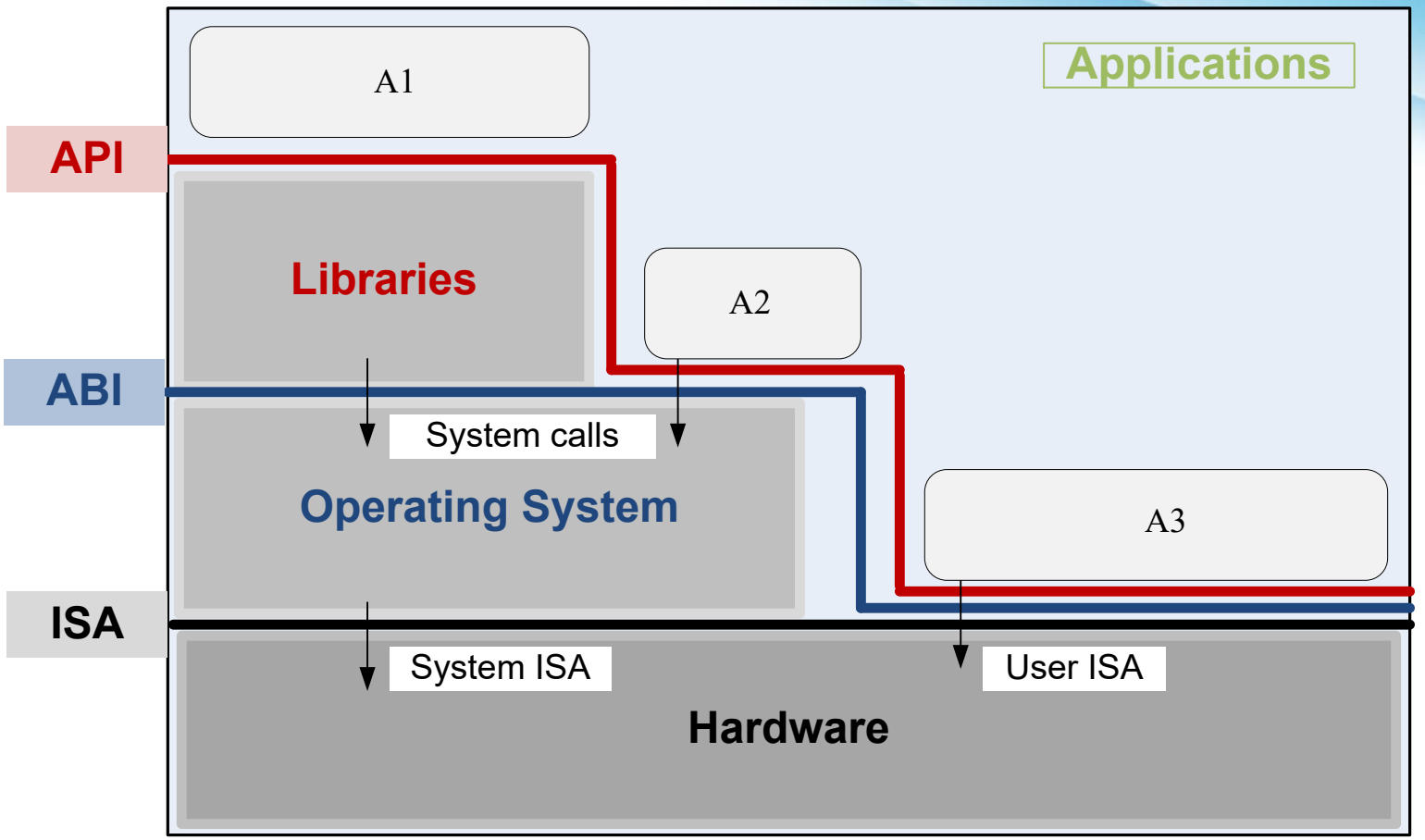
Virtualization

- Virtualization simulates the interface to a physical object by:
  - Multiplexing: creates multiple virtual objects from one instance of a physical object. Many virtual objects to one physical. Example: a processor is multiplexed among several processes or threads.
  - Aggregation: creates one virtual object from multiple physical objects. One virtual object to many physical objects. Example: a number of physical disks are aggregated into a RAID disk.
  - Emulation: constructs a virtual object of a certain type from a different type of a physical object. Example: a physical disk emulates a Random Access Memory (RAM).
  - Multiplexing and emulation. Examples: virtual memory with paging multiplexes real memory and disk; a virtual address emulates a real address.

Layering and Virtualization

- Layering – a common approach to manage system complexity:
  - Simplifies the description of the subsystems; each subsystem is abstracted through its *interfaces* with the other subsystems
  - Minimizes the interactions among the subsystems of a complex system
  - With layering we are able to design, implement, and modify the individual subsystems independently
- Layering in a computer system:
  - Hardware
  - Software
    - Operating system
    - Libraries
    - Applications

Layering and Interfaces

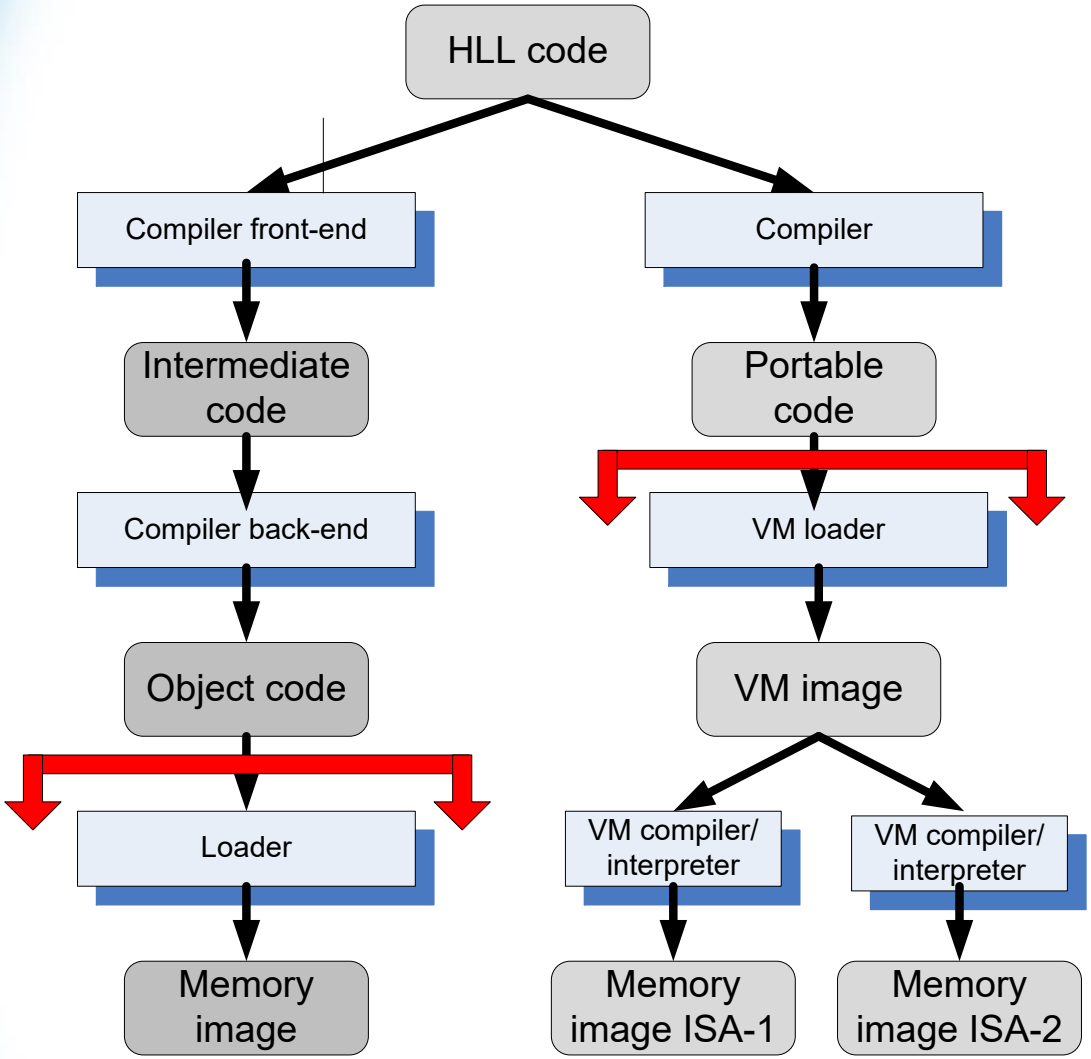


Application Programming Interface (API), Application Binary Interface (ABI), and Instruction Set Architecture (ISA). An application uses library functions (A1), makes system calls (A2), and executes machine instructions (A3)

Code portability

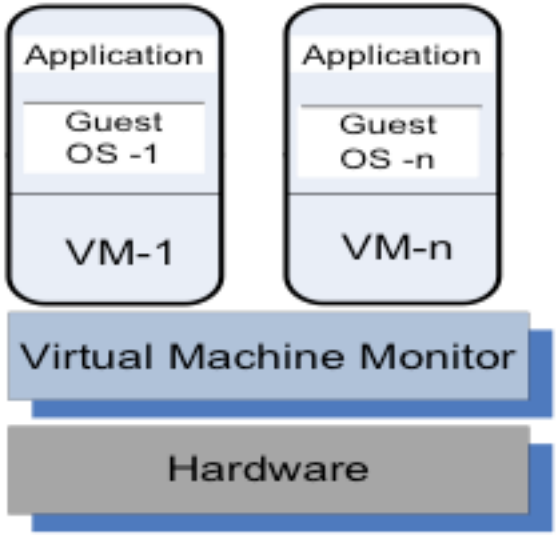
- Binaries created by a compiler for a specific ISA and a specific operating systems are not portable
- It is possible, though, to compile a HLL program for a virtual machine (VM) environment where portable code is produced and distributed, and then converted by binary translators to the ISA of the host system
- A **dynamic binary translation** converts blocks of guest instructions from the portable code to the host instruction and leads to a significant performance improvement, as such blocks are cached and reused

HLL Language Translations



Virtual Machine Monitor (VMM / Hypervisor)

- A **virtual machine monitor (VMM/hypervisor)** partitions the resources of computer system into one or more **virtual machines (VMs)**. Allows several operating systems to run concurrently on a single hardware platform
- A VM is an execution environment that runs an OS
- VM – an isolated environment that appears to be a whole computer, but actually only has access to a portion of the computer resources
- A VMM allows:
  - Multiple services to share the same platform
  - Live migration - the movement of a server from one platform to another
  - System modification while maintaining backward compatibility with the original system
  - Enforces isolation among the systems, thus security



- A **guest operating system** is an OS that runs in a VM under the control of the VMM.

IaaS - Summary

- **IaaS is the deployment platform that abstracts the infrastructure.**

- IaaS enabling technique
  - Virtualization
    - Server Virtualization
    - Storage Virtualization
    - Network Virtualization

- IaaS provided services
  - Resource Management Interface
  - System Monitoring Interface

Infrastructure as a Service

Platform as a Service

Software as a Service

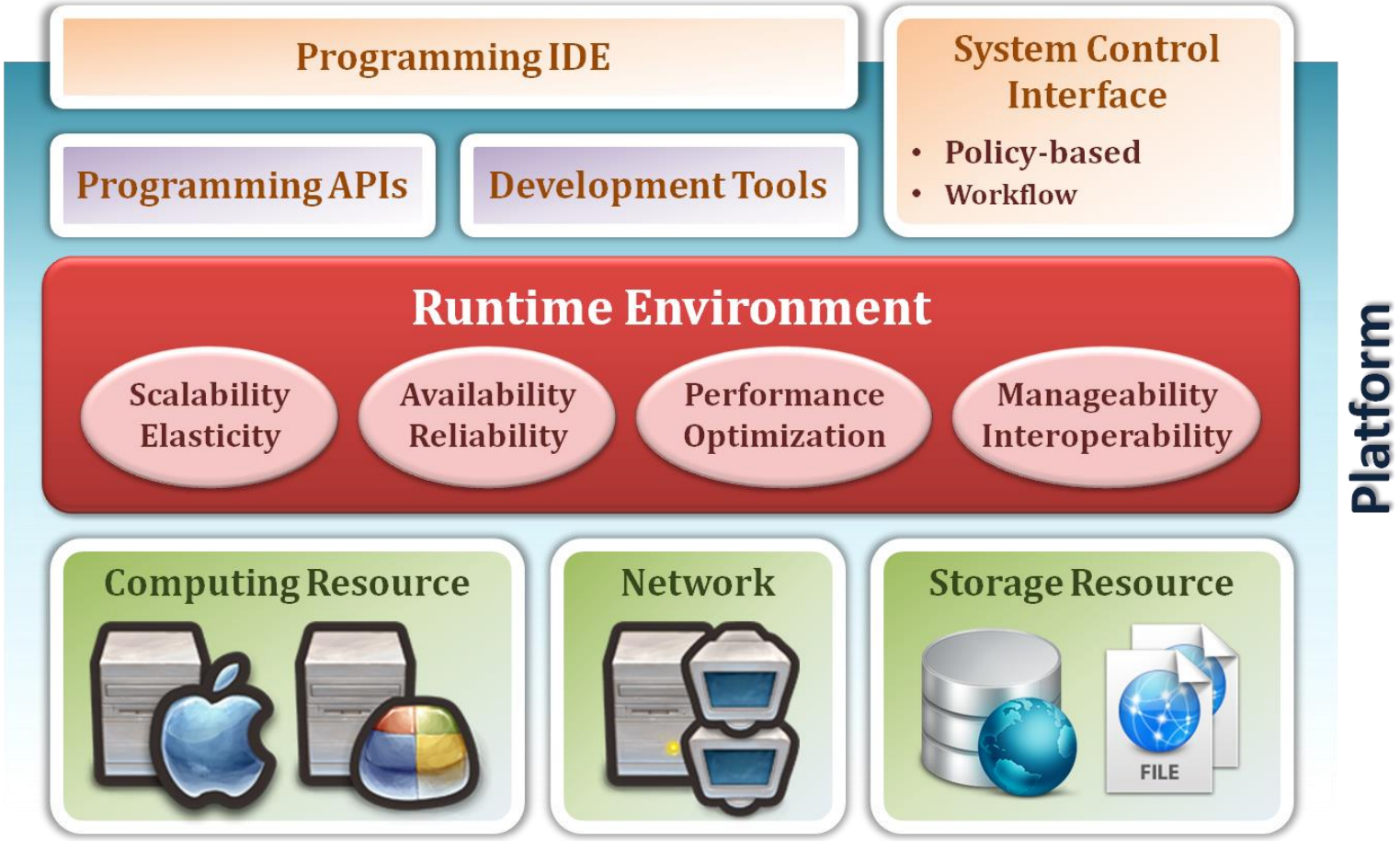
SERVICE MODELS

Platform as a Service

- Platform as a Service - PaaS
  - The capability provided to the consumer to deploy infrastructure functionality or applications created using programming languages and tools supported by the cloud provider.
  - The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.
- Examples :
  - Microsoft Windows Azure
  - Google App Engine
  - Hadoop
  - … etc

Platform as a Service

- System architecture :



Platform as a Service

- Enabling technique – **Runtime Environment Design**
  - Runtime environment refers to collection of software services available. Usually implemented by a collection of program libraries.

- Common properties in Runtime Environment :
  - Manageability and Interoperability
  - Performance and Optimization
  - Availability and Reliability
  - Scalability and Elasticity



Platform as a Service

- Provided service – **Programming IDE (Integrated Development Environment)**
  - Users make use of programming IDE to develop their service among PaaS.
    - This IDE should integrate the full functionalities which supported from the underling runtime environment.
    - This IDE should also provide some development tools, such as profiler, debugger and testing environment.
  - The programming APIs supported by the runtime environment may vary among different cloud providers, but there are still some common operating functions.
    - Computation, storage and communication resource operation

PaaS - Summary

- **PaaS is the development platform that abstracts the infrastructure, OS, and middleware to drive developer productivity.**
- PaaS enabling technique
  - Runtime Environment
- PaaS provide services
  - Programming IDE
    - Programming APIs
    - Development tools
  - System Control Interface
    - Policy based approach
    - Workflow based approach

Infrastructure as a Service

Platform as a Service

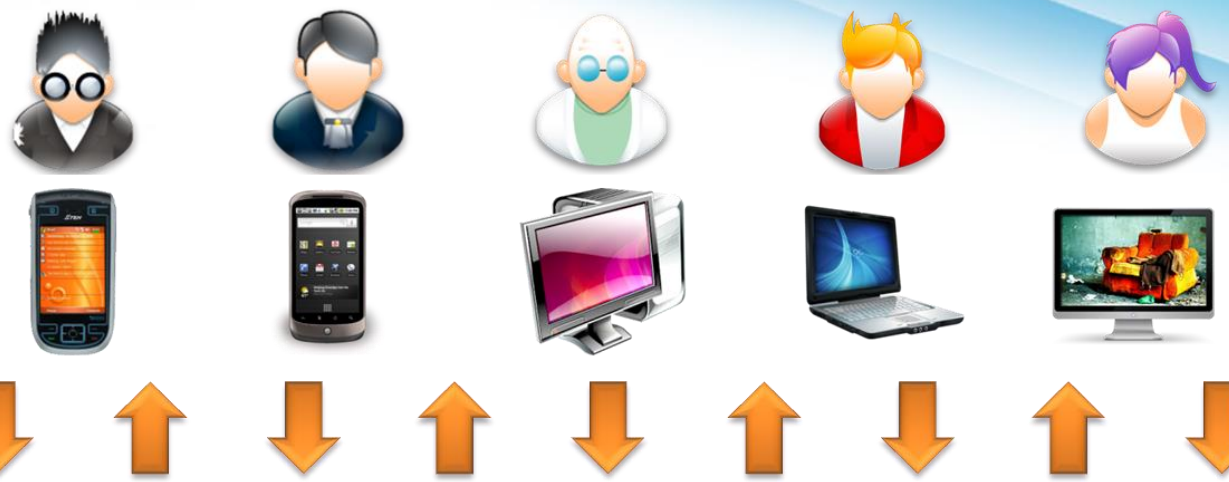
Software as a Service

SERVICE MODELS

Software as a Service

- Software as a Service - SaaS
  - The capability provided to the consumer to use the provider's applications running on a cloud infrastructure. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email).
  - The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.
- Examples :
  - Google Apps (e.g., Gmail, Google Docs, Google sites, …etc)
  - OpenAI, Microsoft Copilot, Google AI Studio, DeepSeek, …
  - SalesForce.com
  - EyeOS, etc.

Software as a Service



Web-base Applications

Web Portal

General Applications

Business Applications

Scientific Applications

Government Applications

Application

Commercial Platform



Open Source Platform



Other



Software as a Service

- Enabling Technique – **Web Service**
  - Web 2.0 is the trend of using the full potential of the web
    - Viewing the Internet as a computing platform
    - Running interactive applications through a web browser
    - Leveraging interconnectivity and mobility
    - Enhanced effectiveness with greater human participation
- Properties provided by Internet:
  - Accessibility and Portability



Software as a Service

- Provided service – **Web Portal**
  - Apart from the standard search engine feature, web portals offer other services such as e-mail, news, stock prices, information, databases and entertainment.
  - Portals provide a way for enterprises to provide a consistent look and feel with access control and procedures for multiple applications and databases, which otherwise would have been different entities altogether.
  - Some examples :
    - iGoogle
    - MSNBC
    - Netvibes
    - Yahoo!

SaaS - Summary

- **SaaS consists of "complete" applications that you rent and customize.**
- SaaS enabling technique
  - Web Service
- SaaS provide services
  - Web-based Applications
    - General applications
    - Business applications
    - Scientific applications
    - Government applications
  - Web Portal

How to deploy a cloud system ?

DEPLOYMENT MODELS

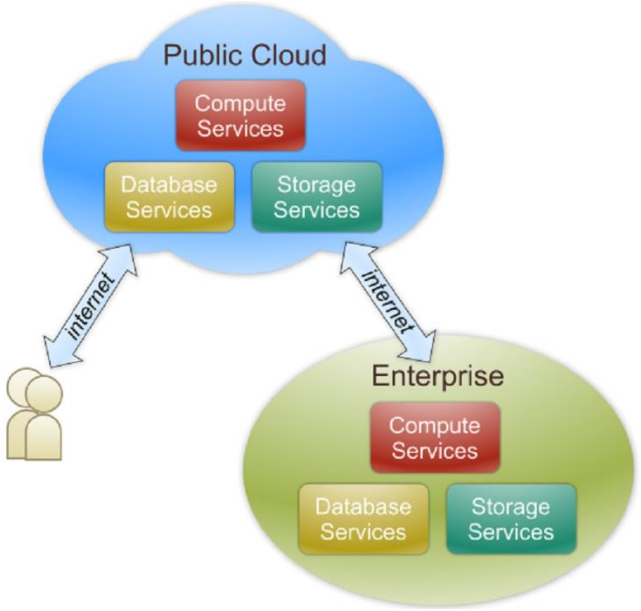


Deployment Model

- There are four primary cloud deployment models :
  - Public Cloud
  - Private Cloud
  - Community Cloud
  - Hybrid Cloud
- Each can exhibit the previously discussed characteristics; their differences lie primarily in the scope and access of published cloud services, as they are made available to service consumers.

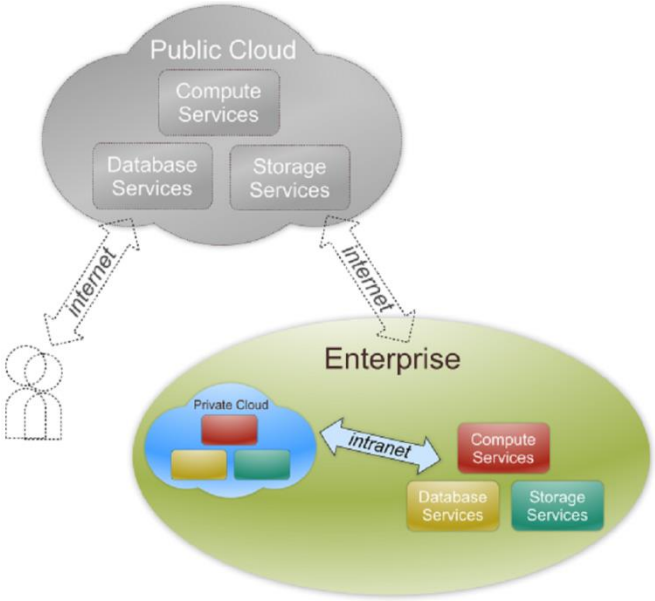
Public Cloud

- Public cloud definition
  - The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization offering cloud services.
  - Also known as external cloud or multi-tenant cloud, this model essentially represents a cloud environment that is openly accessible.
  - Basic characteristics :
    - Homogeneous infrastructure
    - Common policies
    - Shared resources and multi-tenant
    - Leased or rented infrastructure
    - Economies of scale



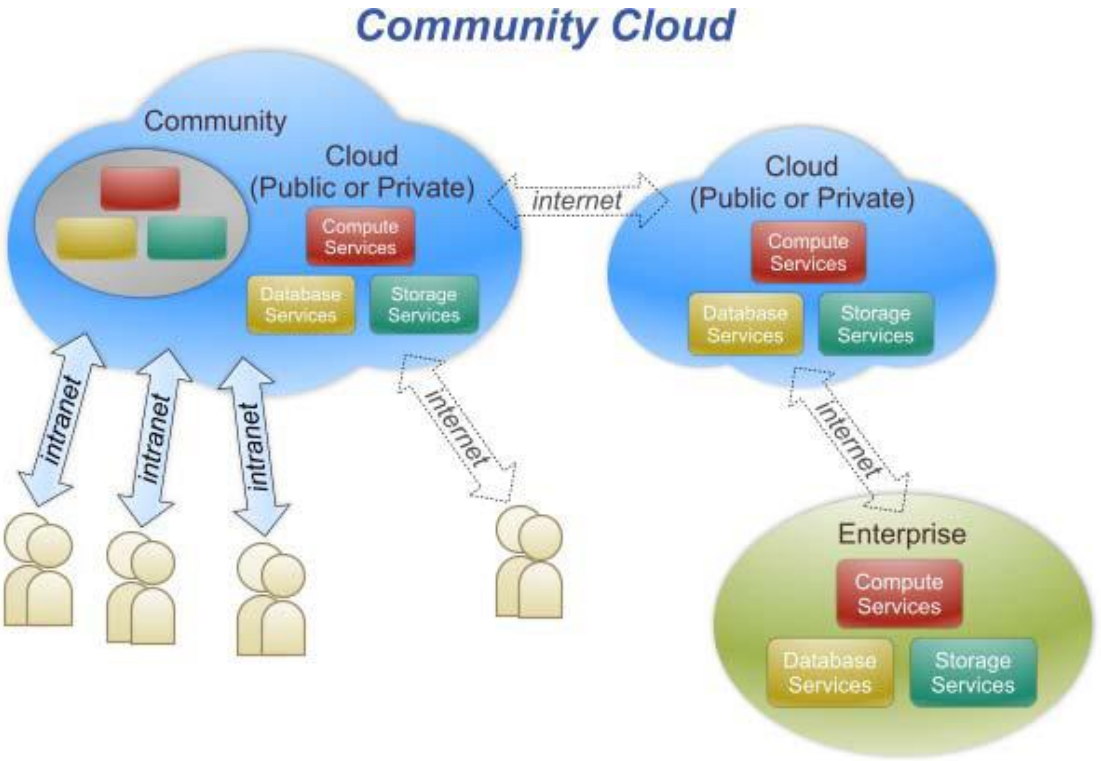
Private Cloud

- Private cloud definition
  - The cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on premise or off premise.
  - Also referred to as internal cloud or on-premise cloud, a private cloud intentionally limits access to its resources to service consumers that belong to the same organization that owns the cloud.
  - Basic characteristics :
    - Heterogeneous infrastructure
    - Customized and tailored policies
    - Dedicated resources
    - In-house infrastructure
    - End-to-end control



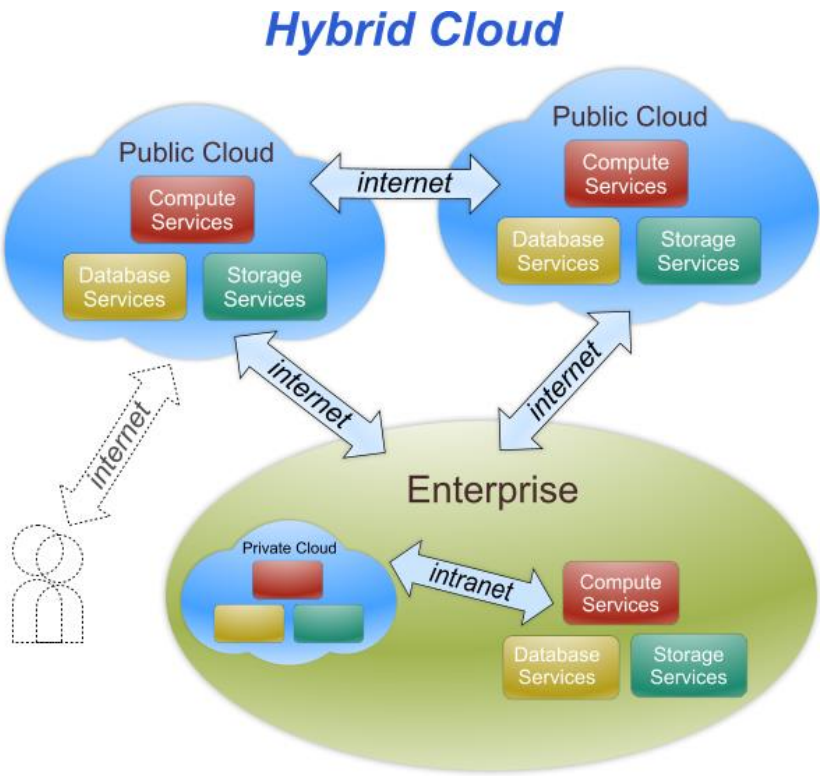
Community Cloud

- Community cloud definition
  - The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations).

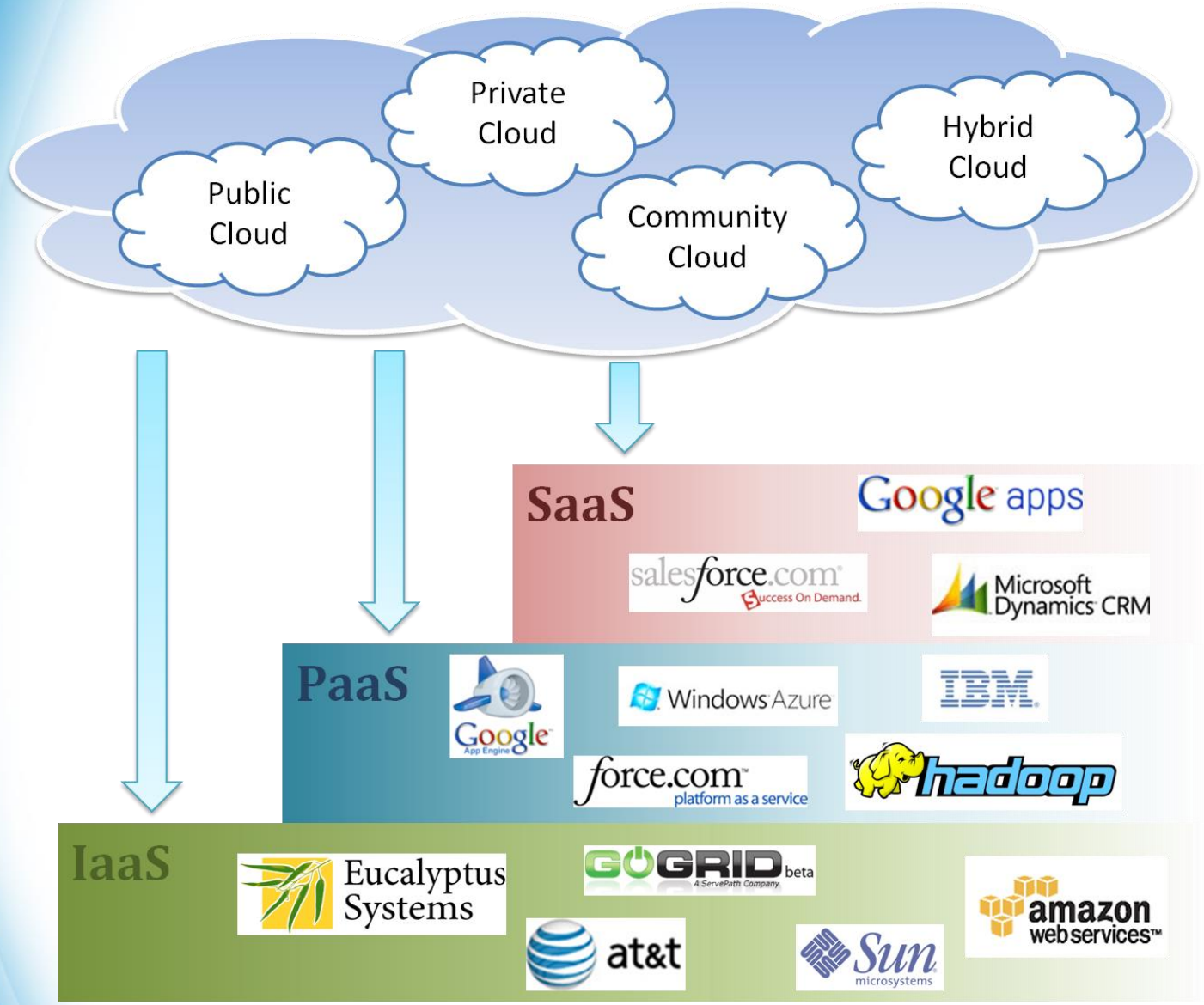


Hybrid Cloud

- Hybrid cloud definition
  - The cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load-balancing between clouds).



Cloud Ecosystem



Summary

- What is cloud computing in your mind
  - Clear or Cloudy?

- Cloud computing is a paradigm of computing, a way of thinking about IT industry, but not any specific technology as such
- Cloud computing can provide high quality of properties and characteristics based on essentially central ideas

- Service models and deployment models provide services that can be used to
  - Rent fundamental computing resources
  - Deploy and develop customer-created applications on clouds
  - Access provider's applications over network (wired or wireless)

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