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Cloud Computing – Fundamentals

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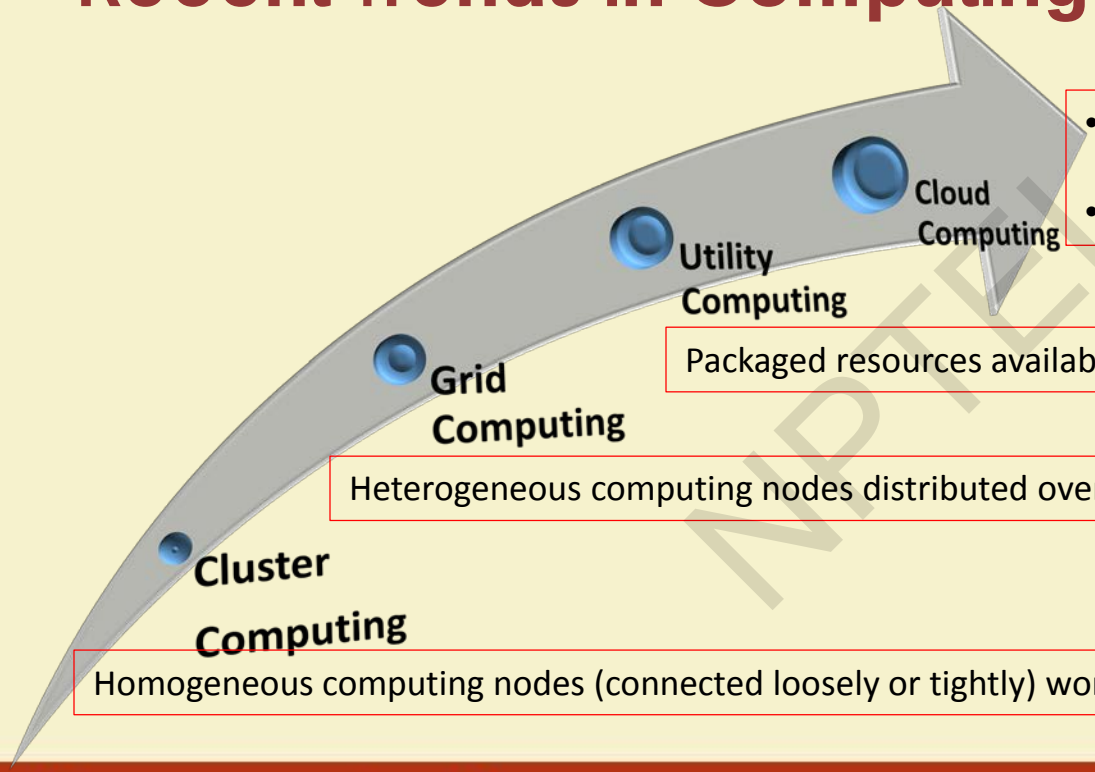
Recent Trends in Computing



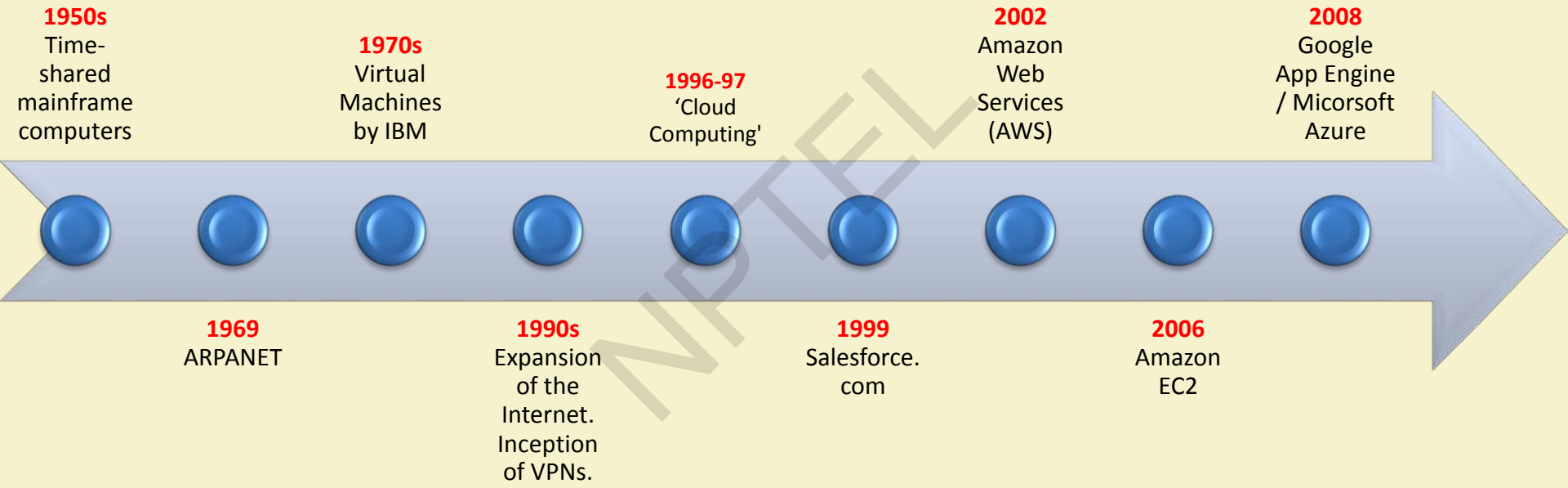
- Shared pool of configurable computing resources
- Ubiquitous, dynamic & on-demand access

Packaged resources available for computing and storage

Heterogeneous computing nodes distributed over a wide area to perform very large tasks

Homogeneous computing nodes (connected loosely or tightly) working together

Evolution of Cloud Computing



Cloud Computing

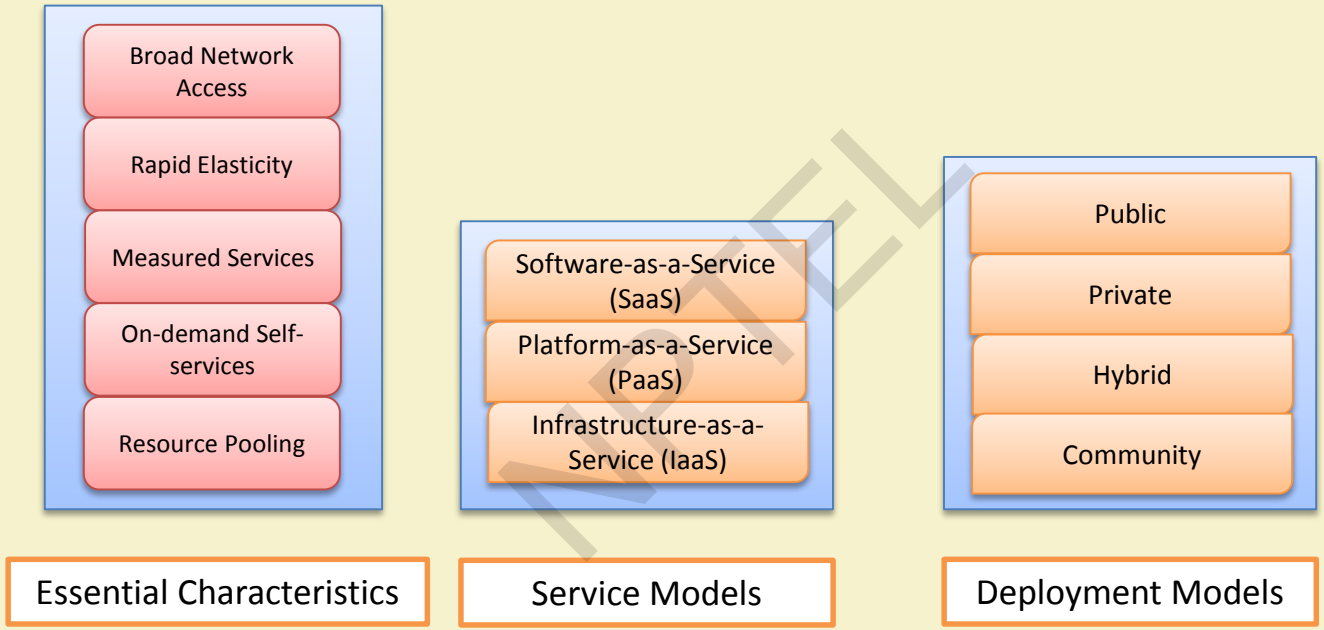
"Cloud computing is a model for enabling convenient, *on-demand network access to a shared* pool of *configurable computing resources* (e.g., network infrastructures, servers, storage, applications, etc.)" – NIST

Source: P Mell & T Grance, "A NIST Notional Definition of Cloud Computing", version 15, 2009.

- It can be envisioned as step on from Utility Computing
- It provides *high level generalization (abstraction)* of computation and storage model
- It can be *rapidly allocated* and *released* with low management effort
- It has some essential **characteristics, service models**, and **deployment models**
- It provides on-demand services, that can be accessed from any place and at anytime

Source: Rajkumar Buyya, "Mastering Cloud Computing: Foundations and Applications Programming", Tata McGraw-Hill Education, 2013

NIST Visual Model of Cloud Computing



Source: NIST

Business Advantages

- ✓ Nearly zero cost for upfront infrastructure investment
- ✓ Real-time Infrastructure availability
- ✓ More efficient resource utilization
- ✓ Usage-based costing
- ✓ Reduced time to market

General Characteristics

- ✓ Improved **agility** in resource provisioning.
- ✓ **Ubiquitous** – independent of device or location
- ✓ **Multitenancy** – sharing of resources and costs across a large pool of users
- ✓ Dynamic load balancing
- ✓ Highly **reliable** and **scalable**
- ✓ Low cost and low maintenance
- ✓ Improved security and access control

Essential Characteristics

- ✓ **Broad network access**
  - Cloud resources should be available over the network
  - Should support standard mechanisms for information retrieval using traditional interfaces
  - Supported clients: heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs)

Source: P Mell & T Grance, “A NIST Notional Definition of Cloud Computing”, version 15, 2009.

Essential Characteristics

- ✓ **Rapid elasticity**
  - Cloud resource allocation should be rapid, elastic and automatic
  - Dynamic allocation/release facility for scale-out and scale-in
  - Consumers should feel infinite resources
  - Facility for add/remove of quantity should be there

Source: P Mell & T Grance, “A NIST Notional Definition of Cloud Computing”, version 15, 2009.

Essential Characteristics

- ✓ **Measured service**
  - Resource usage should be recorded and monitored
  - Facility to dynamically control and optimize the resource usage
  - This facility should be transparent between the service provider and consumer.

Source: P Mell & T Grance, “A NIST Notional Definition of Cloud Computing”, version 15, 2009.

Essential Characteristics

- ✓ **On-demand self-service**
  - Provide server time and network storage to users automatically
  - This facility should be available as a self-service

Source: P Mell & T Grance, “A NIST Notional Definition of Cloud Computing”, version 15, 2009.

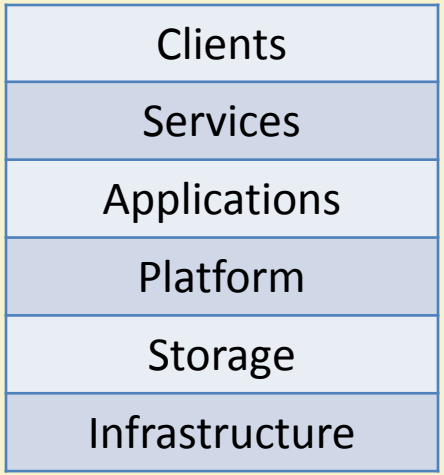
Essential Characteristics

- ✓ **Resource pooling**
  - Automatically pool the whole available resources
  - Serve multiple end-users using a multi-tenant model
  - Resources should be allocated according to user's demand

Source: P Mell & T Grance, "A NIST Notional Definition of Cloud Computing", version 15, 2009.

Components of Cloud Computing

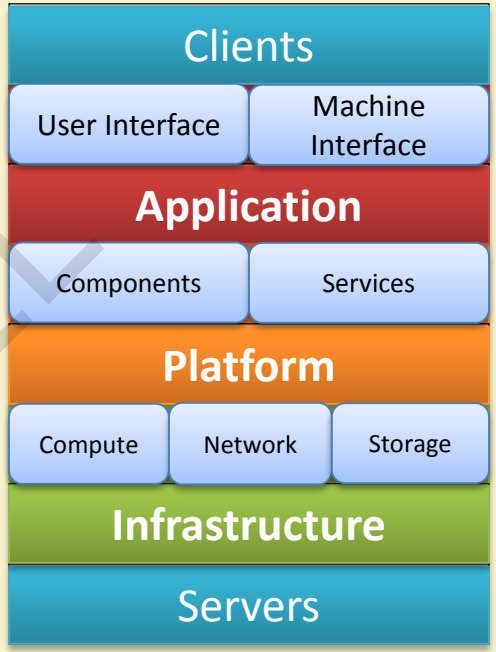
- ✓ **Clients /end-users:** Thick, Thin, Mobile
- ✓ **Services:** Products & solutions (Identity, Mapping, Search, etc.)
- ✓ **Applications:** Web apps, SaaS, etc.
- ✓ **Platform:** Apps/Web hosting using PaaS
- ✓ **Storage:** Database, Data-Storage-as-a-Service (DSaaS)
- ✓ **Infrastructure:** Virtualization, IaaS, EC2



Source: Wikipedia

Service Models

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



Source: Wikipedia

Software-as-a-Service (SaaS)

- ✓ Facility to execute service provider's applications at user's end
- ✓ Applications are available as 'services'
- ✓ Services can be accessed via different types of client devices (e.g. web browser, app)
- ✓ End-users do not posses the control of the cloud infrastructure

Examples: Google Apps, Salesforce, Learn.com.

Source: P Mell & T Grance, "A NIST Notional Definition of Cloud Computing", version 15, 2009.

Platform-as-a-Service (PaaS)

- ✓ Facility for the consumer to execute *consumer-created* or *acquired applications* onto cloud infrastructure
- ✓ Support for deployment of such applications
- ✓ The user does not control the cloud infrastructure
- ✓ User can control the deployed applications using given configurations

Examples: Windows Azure, Google App Engine

Source: P Mell & T Grance, "A NIST Notional Definition of Cloud Computing", version 15, 2009.

Infrastructure-as-a-Service (IaaS)

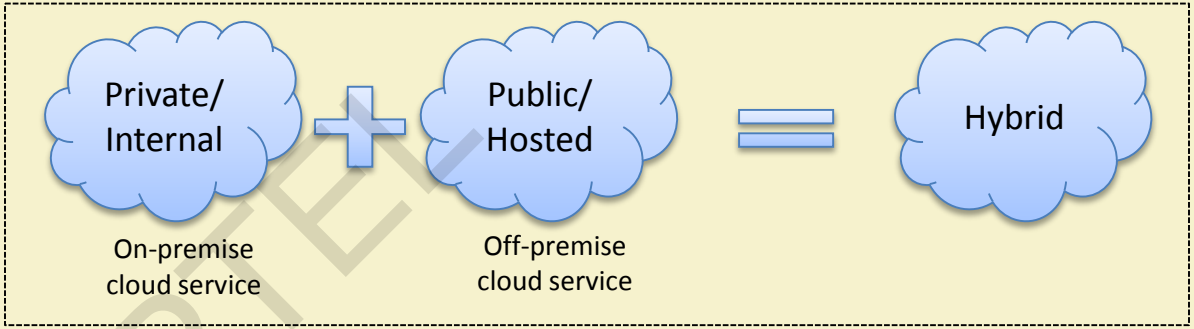
- ✓ Facility to access computing resources such as network, storage, and operating system
- ✓ User can deploy, execute and control any software (O*perating systems* and *other applications*)
- ✓ In some case, the user can control selected networking components (e.g., host firewalls).

Examples: Amazon EC2, GoGrid, iland, Rackspace Cloud Servers.

Source: P Mell & T Grance, "A NIST Notional Definition of Cloud Computing", version 15, 2009.

Deployment Models

- ✓ Public cloud
- ✓ Private cloud
- ✓ Hybrid cloud
- ✓ Others:
  - Community cloud
  - Distributed cloud
  - Multi-cloud
  - Inter-cloud



Source: https://en.wikipedia.org/wiki/Cloud_computing

Public Cloud

- ✓ Cloud set-up for the use of any person or industry
- ✓ Typically owned by an organization who offers the cloud service.
- ✓ Examples: Amazon Web Service (AWS), Google Compute Engine, Microsoft Azure
- ✓ Advantages:
  - Easy to set-up at low cost, as provider covers the hardware, application and bandwidth costs.
  - Scalability to meet needs.
  - Pay-per-use ensures that from user's perspective no resources wasted.

Source: Christian Baun and Marcel Kunze, "A Taxonomy Study on Cloud Computing Systems and Technologies", Cloud Computing - Methodology, Systems, and Applications, L Wang et al. (Eds), CRC Press, 2012

Private Cloud

- ✓ Cloud set-up functioned only for a single organization
- ✓ Typically managed by the organization itself (on-premises) or a third party (off-premises)
- ✓ Advantages:
  - Total control over the system and data
  - Minimum security concerns
- ✓ Disadvantages:
  - Regular maintenance

Source: Christian Baun and Marcel Kunze, "A Taxonomy Study on Cloud Computing Systems and Technologies“, Cloud Computing - Methodology, Systems, and Applications, L Wang et al. (Eds), CRC Press, 2012

Public Cloud vs Private Cloud

	Public Cloud	Private Cloud
Virtualized resources	Publicly shared	Privately shared
Customer types	Multiple	Limited
Connectivity	Over Internet	Over Internet/private network
Security	Low	High

Source: Christian Baun and Marcel Kunze, "A Taxonomy Study on Cloud Computing Systems and Technologies“, Cloud Computing - Methodology, Systems, and Applications, L Wang et al. (Eds), CRC Press, 2012

Hybrid Cloud

- ✓ Cloud set-up constructed by two or more unique cloud set-up (private, community, or public)
- ✓ Pooled together by standardized tools
- ✓ Supports data and application portability (e.g., facility for load-balancing between clouds)
- ✓ Provides multiple deployment models

Source: Christian Baun and Marcel Kunze, "A Taxonomy Study on Cloud Computing Systems and Technologies“, Cloud Computing - Methodology, Systems, and Applications, L Wang et al. (Eds), CRC Press, 2012

Other Types of Cloud

- ✓ **Community cloud**
  - Shared set-up between several organizations having common concerns (security, compliance, jurisdiction, etc.)
  - Managed by internally or by third party
- ✓ **Distributed Cloud**
  - Collection of scattered set of computing devices in different locations, however, connected to a single network
  - Two types – *Public-resource Computing* and *Volunteer Cloud*.

Source: Christian Baun and Marcel Kunze, "A Taxonomy Study on Cloud Computing Systems and Technologies“, Cloud Computing - Methodology, Systems, and Applications, L Wang et al. (Eds), CRC Press, 2012

Other Types of Cloud

- ✓ **Multi-cloud**
  - Multiple cloud computing services offered via single heterogeneous architecture
  - Increases fault-tolerance and flexibility
- ✓ **Inter-cloud**
  - Unified global *'cloud of clouds'* based on the Internet
  - Supports interoperability between cloud service providers

Source: Christian Baun and Marcel Kunze, "A Taxonomy Study on Cloud Computing Systems and Technologies", Cloud Computing - Methodology, Systems, and Applications, L Wang et al. (Eds), CRC Press, 2012

Comparison of Different Deployment Models

	On-premise	Off-premise
Dedicated Access	Private cloud	Hosted private cloud
Shared Access	Community cloud	Public cloud

Source: Christian Baun and Marcel Kunze, "A Taxonomy Study on Cloud Computing Systems and Technologies“, Cloud Computing - Methodology, Systems, and Applications, L Wang et al. (Eds), CRC Press, 2012

Thank You!!

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Cloud Computing – Service Models

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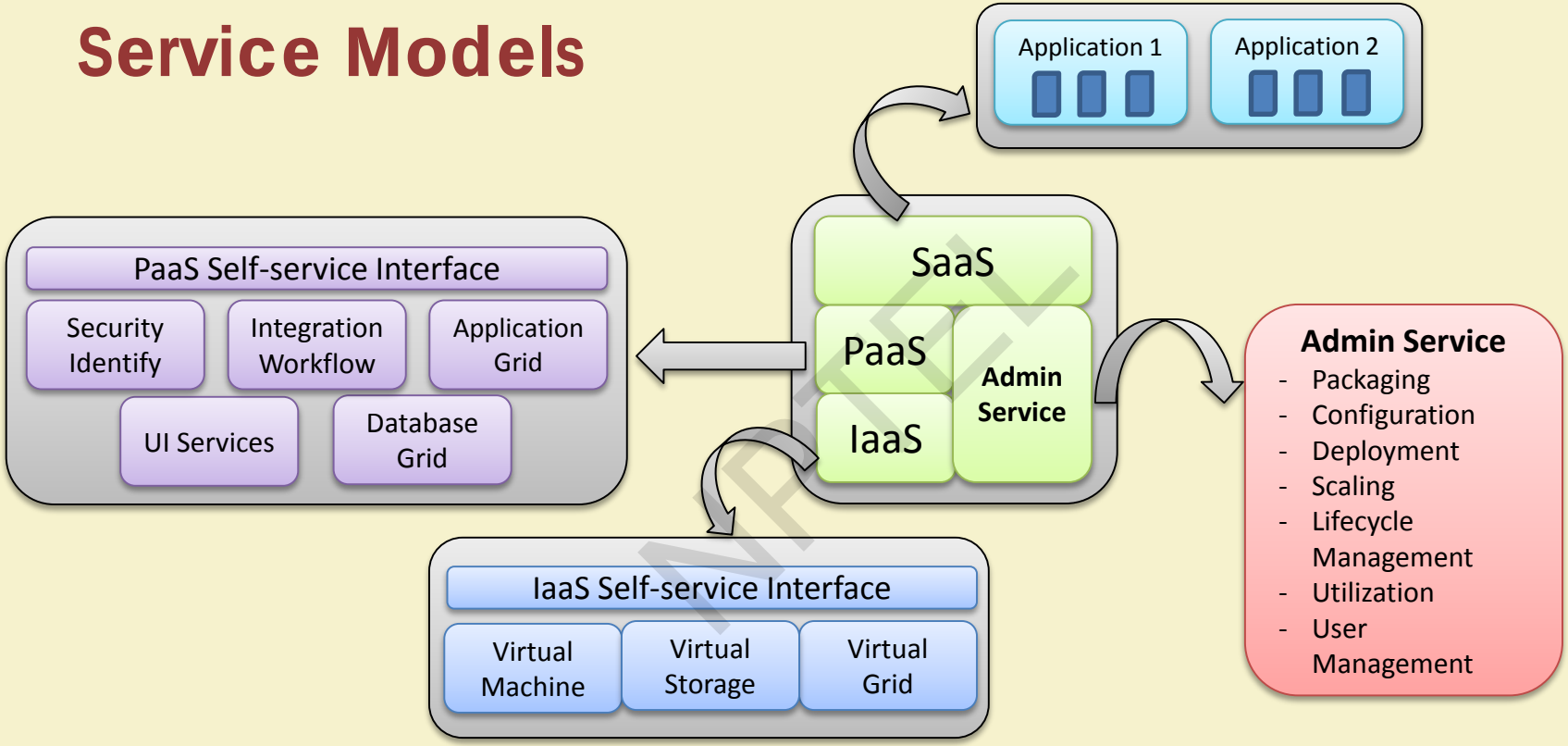
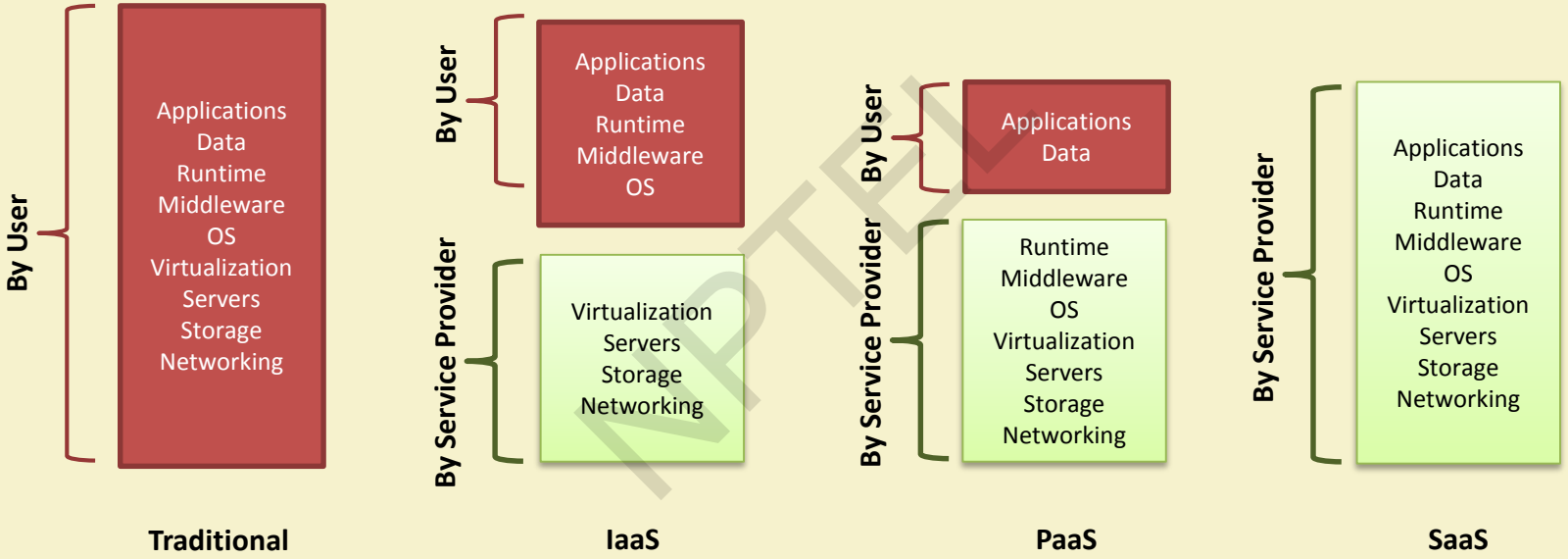
Service Models



Source: NIST (2011)

Comparison of Different Service Models



Source: NIST (2011)

Infrastructure-as-a-Service (IaaS)

"Infrastructure-as-a-Service, abbreviated as IaaS, contains the basic building blocks for cloud IT and typically provide access to networking features, computers (virtual or dedicated hardware), and data storage space." – Amazon

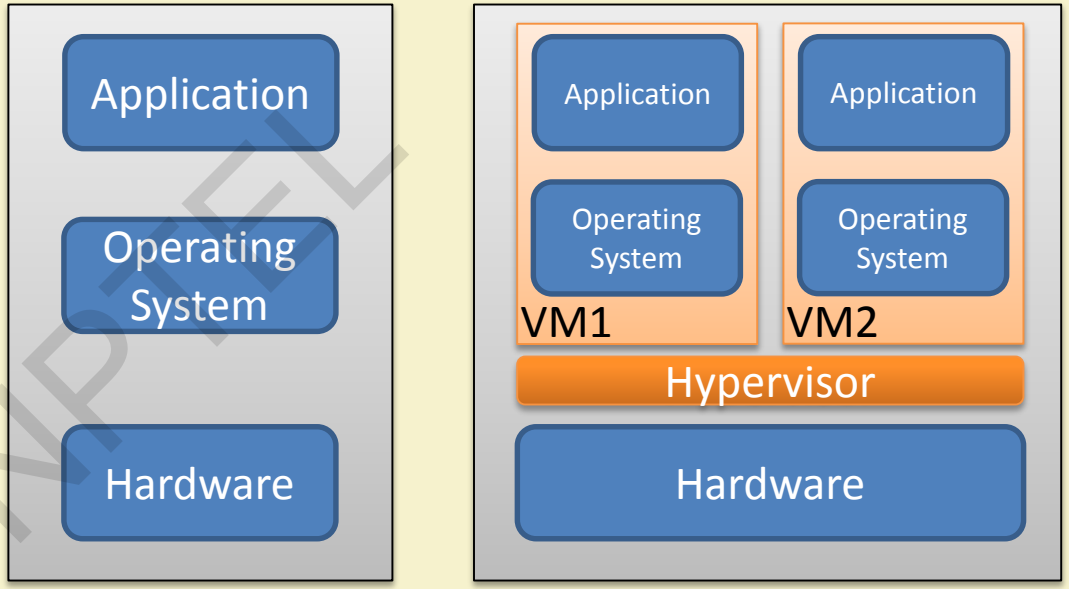
Source: https://aws.amazon.com/types-of-cloud-computing/

- ✓ On-demand delivery of **computing infrastructure**
- ✓ IaaS provides the following:
  - Servers- Compute, machines
  - Storage
  - Network
  - Operating system

Source: Rajkumar Buyya, "Mastering Cloud Computing: Foundations and Applications Programming", Tata McGraw-Hill Education, 2013

Working Methodology

- The user rents servers, software, **data center space** or network equipment
- Cloud service provider offers resource management
- Outsourced service on-demand model



Source: Wikipedia, Hardware Virtualization

Why IaaS?

- ✓ New businesses can operate without investing on computer hardware.
- ✓ Scalable for rapidly growing businesses. (Organizations that experience huge success immediately)
- ✓ Suitable for serving fluctuating computing demands. (Ex. Flipkart, Amazon during festival seasons)
- ✓ Suitable for new business model trials.
- ✓ Helps in minimizing the capital expenses. (entrepreneurs starting on a shoestring budget)

Essential Characteristics

- ✓ **Scalability and elasticity:**
  - Dynamic scaling of required infrastructure resources
  - Large amount of resource allocation/release in a short span of time
  - No variation in system performance while scale in or out

Essential Characteristics

- ✓ **Manageability and interoperability**
  - Clients have total control of the virtualized infrastructure resources
  - Pre-configured facility for allocation of virtualized resources
  - The virtualized resources are to be monitored for their running status
  - The Usage and Billing system records the use of infrastructure resources and accordingly calculate payment

Essential Characteristics

- ✓ **Availability and reliability**
  - Stored data can be retrieved at any time without failure
  - The clients should be able to access the computational resources without failure
  - Uninterrupted facility for computation and communication

Essential Characteristics

- ✓ **Performance and optimization**
  - High utilization of physical resources among different clients
  - To enable high computing power with the large pool of physical resources using parallel processing
  - To optimize the deployment of physical resources by dynamic configuration of virtual infrastructure resources

Essential Characteristics

- ✓ **Accessibility and portability**
  - Facility for client to ease various tasks – control, manage and access infrastructure resources
  - To facilitate easy reallocation and duplication of allocated infrastructure resources

IaaS Categories

- ✓ IaaS can be obtained as:
  - **Public Cloud**
    - Shared infrastructure resources
    - Available for self-service basis
  - **Private Cloud**
    - Private infrastructure resources
    - Access control
  - **Hybrid Cloud:** A blend of public and private

IaaS – Challenges and Limitations

- ✓ Sometimes the **regulatory approval** does not allow **outsourcing the storage and processing** of sensitive data.(Ex.: Medical records)
- ✓ **Network latency** may degrade the level of expected performance

IaaS – Challenges and Limitations (contd.)

- ✓ Users may require **automated decision making** of job scheduling to available resources
- ✓ **Seamless scaling** of services independent of traffic variation
- ✓ Developers have to focus on **low level system details**

Platform-as-a-Service (PaaS)

"Platform-as-a-service remove the need for organizations to manage the underlying infrastructure (usually hardware and operating systems) and allow you to focus on the deployment and management of your applications." – Amazon

Source: https://aws.amazon.com/types-of-cloud-computing/

- ✓ PaaS provides the **platform** which allows developers to create applications which can be offered as services via Internet
- ✓ Simplifies the application development and deploy providing the **cloud-aware** feature
- ✓ PaaS is an **application middleware** offered as a service to developers
- ✓ Provides **abstraction and security** for deployed applications.

Source: Rajkumar Buyya, "Mastering Cloud Computing: Foundations and Applications Programming", Tata McGraw-Hill Education, 2013

PaaS (contd.)

- ✓ Facilitates **development and managing applications** without the complexity of maintaining the underlying infrastructure
- ✓ Allows customers to **rent virtualized servers** and associated services
- ✓ Provides **elastic scaling** of the user's deployed application

Features of PaaS Offering

- ✓ Operating system
- ✓ Server-side scripting environment
- ✓ Database management system
- ✓ Server Software
- ✓ Support
- ✓ Storage
- ✓ Network access
- ✓ Tools for design and development
- ✓ Hosting

PaaS Working Model

- ✓ Allows users to create software applications using offered tools
- ✓ Provides **preconfigured features** that customers can subscribe
- ✓ Support available for managing the infrastructure and applications for customers
- ✓ Services are regularly updated with new features

Business Advantages

- ✓ Facility for accessing key **middleware services** without worrying about the underlying complexities of managing individual hardware and software elements
- ✓ Ease of access for the **development and deployment tools**
- ✓ Freedom from managing development and deployment tools individually

Software-as-a-Service (SaaS)

"Software as a Service provides you with a completed product that is run and managed by the service provider. In most cases, people referring to Software as a Service are referring to end-user applications." – Amazon

Source: https://aws.amazon.com/types-of-cloud-computing/

- ✓ SaaS is a **simplified model of software delivery** over Internet
- ✓ Operation, maintenance and technical support is provided by the service provider
- ✓ Typically offered via web browser working as a **thin-client**
- ✓ Supports a fully **pay-as-you-go** model

Source: Software Services for e-Business and e-Society: Proceedings of 9th IFIP WG 6.1 Conference on e-Business, e-Services and e-Society, I3E 2009, Nancy, France, September 23-25, 2009.

SaaS (contd.)

- ✓ Remote access of software via Internet where web-browser acts as a thin-client
- ✓ Facility for access and control of commercial software via Internet
- ✓ Multi-tenant application delivery in a one-to-many model

Advantages

Traditional Software	SaaS
Customers install, manage & maintain	Customers uses over the Internet
Runs on individual organization on dedicated instantiation	Runs on multiple customers simultaneously
Cross platform support required	No concerns for cross platform support
Less frequent version updates & purchased separately	More frequent updates for enhanced user satisfaction
Separate costs incurred for upgrades	No separate cost
Vulnerable to software piracy	Less vulnerable to software piracy

Source: Software Services for e-Business and e-Society: Proceedings of 9th IFIP WG 6.1 Conference on e-Business, e-Services and e-Society, I3E 2009, Nancy, France, September 23-25, 2009.

SaaS Architecture

- ✓ **Scalability**
  - To maximize application concurrency
  - To optimize the shared pool of resources such as threads and network connections
- ✓ **Multi-tenancy**
  - Important architectural shift from designing isolated, single-tenant applications
  - Ability to accommodate users from multiple companies at the same time
  - Transparency to all the users
  - Maximize the sharing of resources across tenants while distinguishing user's individual data

SaaS Architecture (contd.)

- ✓ **Configurability**
  - To facilitate parallel allocation of a single application on a single server to several users
  - To customize the application for one customer will change the application for other customers as well
  - Separate data space for different users

Limitations of SaaS

- ✓ Centralized control
- ✓ Switching cost
- ✓ Limited flexibility
- ✓ Data security and privacy

Thank You!!

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Cloud Computing – Service Management and Security

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Introduction

- ✓ Deals with the world of cloud computing and service management, ensuring **optimal performance** and efficiency in **on-demand, virtual** environments
- ✓ Aims to provide equal importance to desired outcomes of customers
- ✓ Management of services at no cost and risk

Objectives

- ✓ To provide **standard services**
- ✓ Clear & complete description of services
- ✓ Usage monitoring and billing
- ✓ High availability of networks and connectivity
- ✓ Ease of access
- ✓ Portals for service selection
- ✓ Rapid fulfillment/decommissioning of resources
- ✓ Service guarantees
- ✓ Secure computing and storage

Source : IBM Global Technology, Integrated Service Management and Cloud Computing: More than Just Technology Best Friends, White Paper, IBM Global Technology Services, 2010

Service Level Agreement

- ✓ Defines the non functional requirements expected from the service provider
- ✓ Provides a **roadmap** with clearly defined deliverables
- ✓ Describes the **quality, utility and warranty** of services expected by the customer

Note: Depending on the service provider exact metric for each SLA varies, however areas covered remain unchanged like volume and quality of work, speed, efficiency

Source: K.T. Kearney, F. Torelli, "The SLA Model". In Wieder, P.; Butler, J.M.; Theilmann, W.; Yahyapour, R. Service Level Agreements for Cloud Computing. Springer Science+Business Media, LLC. pp. 43–68, 2011. ISBN 9781461416142.

Accounting and Billing

- ✓ Service Accounting
  - Aims to obtain resource usage information, typically in the form of records
  - Depends on infrastructure and service monitoring, as usage information is obtained from metric measurements
- ✓ Billing
  - Service provider calculates billing information using
    - Accounting records
    - Resource prices
    - Billing rules

Source : M. Lindner, F. Marquez, C. Chapman, S. Clayman, D. Henriksson, and E. Elmroth. The cloud supply chain: A framework for information, monitoring, accounting and billing. In 2nd International ICST Conference on Cloud Computing (CloudComp 2010). Springer Verlag, 2010

Comparing Scaling Hardware: Traditional vs. Cloud

- ✓ Traditional data centers
  - Heterogeneous hardware
  - Networked computing
  - Remote server
- ✓ Cloud Computing
  - Off-premises
  - Virtual hosting solution
  - Heterogeneous hardware, software and networks on the cloud

Source : *Wikipedia – Cloud Computing*

Comparison between Traditional vs. Cloud (contd.)

- ✓ Major differences include
  - Resilience and Elasticity
  - Flexibility and Scalability
  - Automation
  - Running Costs
  - Security

Source : *Wikipedia – Cloud Computing*

Economics of scaling: Benefitting enormously

- ✓ Economics depends on four customer population metrics
  - Number of unique customer sets
  - Duty cycles of customer set
  - Relative displacement duty cycle
  - Load of customer set

Source : Kevin L. Jackson, 2011, "The Economic Benefit of Cloud Computing", Forbes

Economics of scaling (contd.)

- ✓ Economic incentives
  - Lower cost
  - Cap-Ex free Computing
  - Deploy projects faster; foster innovation
  - Scale as needed
  - Lower maintenance costs
  - Resiliency and redundancy

Source : Jackson, Kevin L., 2011, "The Economic Benefit of Cloud Computing", Forbes

Managing Data in Cloud

- ✓ Steps in evaluating database manager
  - Define the type of application that will be served like data asset protection, business intelligence, e-commerce
  - Determine how suitable these apps are for public or private clouds
  - Factors affecting easy development process

Managing Data in Cloud (Contd.)

- ✓ Demands of cloud database management system
  - Efficiency
  - Fault-Tolerance
  - Adaptive to heterogeneity
  - Operational comfort on encrypted data
  - Capable of interfacing with other products/solutions

Source : D. Abadi. Data management in the cloud: Limitations and opportunities. IEEE Data Eng. Bull., 32(1):3–12, 2009.

Managing Data in Cloud (Contd.)

- ✓ Database-as-a-Service (DBaaS)
  - MicrosoftAzure/SQLDatabase
  - AmazonWebServices/DynamoDB/RelationalDatabaseService
  - GoogleCloudSQL/GoogleAppEngine Datastore
  - ClearDB
  - Database.com

Source : *Wikipedia – Cloud Database*

Cloud Security - Introduction

- ✓ **Problem:** User loses control of information available on public cloud
- ✓ **Security concerns:**
  - Loss of data
  - Account seizing
  - Service traffic hindrance
  - Vulnerable APIs
- ✓ **Solution:** Protection from theft, leakage and deletion by providing secure policies

Source: D.Velev and P.Zlateva "Cloud infrastructure security" in Open Research Problems in Network Security vol.6555 J.Camenisch V.Kisimov and M.Dubovitskaya Eds.Berlin Heidelberg: Springer 2011 pp.140-148.

Infrastructure Security

- ✓ Security of cloud infrastructure must be implicitly assured
  - For public or private cloud
  - For services SaaS, PaaS, IaaS
- ✓ Building Levels for viewing, evaluating and executing infrastructure security are
    - Network level security
    - Host level security
    - Application level security

Source: D.Velev and P.Zlateva "Cloud infrastructure security" in Open Research Problems in Network Security vol.6555 J.Camenisch V.Kisimov and M.Dubovitskaya Eds.Berlin Heidelberg: Springer 2011 pp.140-148.

Network Level Security

- ✓ Public clouds
  - Small change severely affects the network topology
  - Proper access control for using resources
- ✓ Achieving **confidentiality and integrity** of data-in-transit to and from the cloud service provider
- ✓ **Availability** of internet resources correctly to **genuine** users from cloud service provider

Source: D.Velev and P.Zlateva "Cloud infrastructure security" in Open Research Problems in Network Security vol.6555 J.Camenisch V.Kisimov and M.Dubovitskaya Eds.Berlin Heidelberg: Springer 2011 pp.140-148.

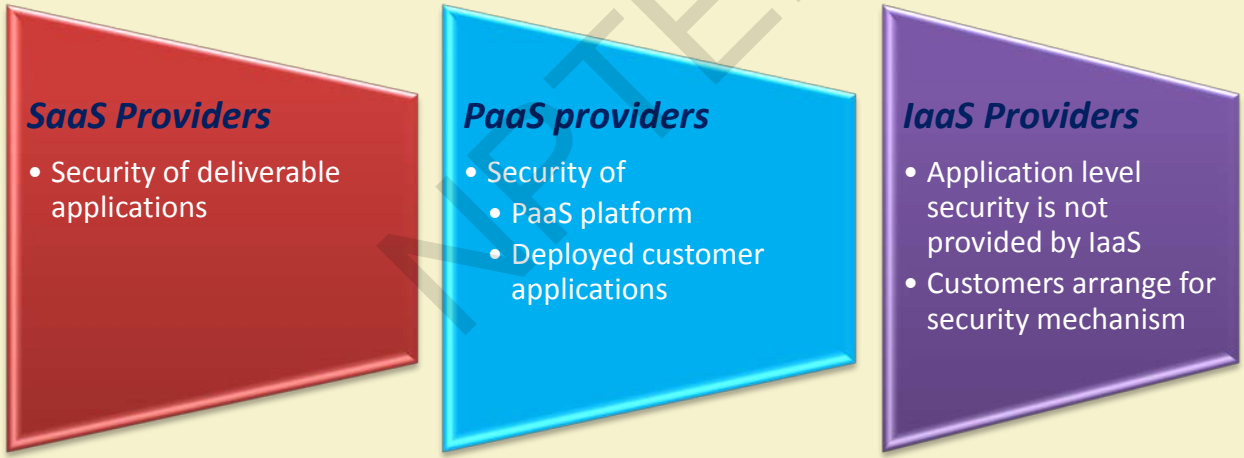
Host Level Security

- ✓ Host security at PaaS and SaaS Level:
  - Hide the host operating system from end-users
  - Security responsibilities are transferred to Cloud service providers
- ✓ Host security at IaaS Level:
  - Primary objective is to secure the allocated hosts
  - Example of threats: Blue Pill attack on hypervisor

Source: D.Velev and P.Zlateva "Cloud infrastructure security" in Open Research Problems in Network Security vol.6555 J.Camenisch V.Kisimov and M.Dubovitskaya Eds.Berlin Heidelberg: Springer 2011 pp.140-148.

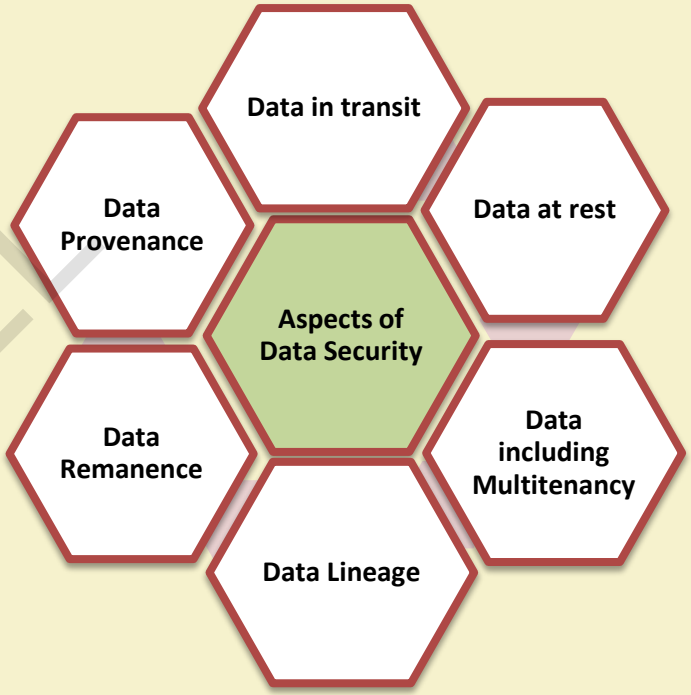
Application Level Security

- ✓ Both CSP and the customer are responsible for security at application level



Data Security

- ✓ Objectives:
  - Confidentiality
  - Integrity
  - Availability
- ✓ Solution:
  - Identity management
  - Encryption
  - Access control



Source: L. Grandinetti; O. Pisacane; M. Sheikhalishahi; "Cloud Security" in 1st Edition, Pervasive Cloud Computing Technologies: Future Outlooks and Interdisciplinary Perspectives, IGI Global, 31-Oct-2013.

Identity and Access Management (IAM)

- ✓ A branch of cloud security that allows the **legitimate persons** to retrieve the **legitimate resources** at the **legitimate time** for the **legitimate reasons**
- ✓ User identities and access permissions are instigated, caught, administered and recorded by IAM
- ✓ **Authentication**, **authorization** and **evaluation** of all users are done according to the terms and conditions and the roles of users

Source: Wikipedia – Identity Management

Features of IAM

- ✓ Single Access Control Interface
- ✓ Increased security
- ✓ Access Control over Resource-level
- ✓ Improvement of operational efficiency
- ✓ Organizations attain access control and operational security using IAM
- ✓ Improvement of regulatory compliance management

Source: Wikipedia – Identity Management

Access Control

- ✓ Access control layers in cloud include:
  - Cloud access
  - Server access
  - Service access
  - Database access (direct and queries via web services)
  - VM access
  - Access to objects within a VM
- ✓ Management of these layers depends on provider or consumer, based on the deployment model

Trust and Reputation

- ✓ **Trust:** Independent expectancy between two entities for any specific context at a given time
- ✓ **Reputation:** Belief of an entity's standing by the community
- ✓ These concepts are needed by the customer to select appropriate cloud provider

Source: Z. Raghebi and M. R. Hashemi, "A New Trust Evaluation Method based on Reliability of Customer Feedback for Cloud Computing", in Proc. Information Security and Cryptology Conference, pp. 1-6, Iran, 2013.

Source: S. M. Habib; S. Hauke; S. Ries; M. Muhlhauser , "Trust as a facilitator in cloud computing: a survey", Journal of Cloud Computing, vol. 1 (1), pp. 1-18, 2012.

Trust and Reputation Contd.

- ✓ Different **modes** of trust establishment include
  - Accomplishment of Service Level Agreement
  - Application of audit standards
  - Measuring and ratings
  - Questionnaires for self-assessment

Source: Z. Raghebi and M. R. Hashemi, "A New Trust Evaluation Method based on Reliability of Customer Feedback for Cloud Computing", in Proc. Information Security and Cryptology Conference, pp. 1-6, Iran, 2013.

Source: S. M. Habib; S. Hauke; S. Ries; M. Muhlhauser , "Trust as a facilitator in cloud computing: a survey", Journal of Cloud Computing, vol. 1 (1), pp. 1-18, 2012.

Risk Assessment

- ✓ Categorization of different assessment methodology
  - Formal versus informal procedures
  - Qualitative (high/moderate/low) versus quantitative (numbers) techniques
  - Consequence versus cause analysis
  - Inductive versus deductive techniques

Source: E. Cayirci, A. Garaga, A. S. De Oliveira, Y. Roudier, "A Cloud Adoption Risk Assessment Model", IEEE/ACM International Conference on Utility and Cloud Computing (UCC), 8-11 Dec. 2014, London, UK, pp. 908 – 913.

Authentication in Cloud Computing

- ✓ User Authentication
  - **What:** User authentication process between **new users** and **service provider**
  - **When:** During the authentication, the properties and safety of process can be invaded by attack causing severe damages
  - **Where:** User authentication is done at PaaS layer
  - **Consequence:** Threat to authentication process can lead to divulge of confidential data to a fake user

Source: H. Chang; E. Choi ,"User authentication in cloud computing" ,Proc. UCMA CCIS,vol. 151 pp. 338-342 2011

Thank You!!

IIT KHARAGPUR

NPTEL ONLINE CERTIFICATION COURSES

Cloud Computing – Case Studies

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Introduction

- ✓ Simulation tools provide reliable, scalable and repeatable environment for performance evaluation
- ✓ The simulators facilitate pre-deployment tests of services
- ✓ As the demand of cloud computing is growing everyday, the simulators and technologies are needed to be studied

Introduction (contd.)

- ✓ Cloud simulators allow customers to
  - Evaluate the services
  - Testing at no cost
  - Enable repeatable evaluation
  - Control the environment
  - Pre-detection of issues affecting performance
  - Design of countermeasures

Cloud Simulators

- ✓ Different Cloud Simulators are:
  - CloudSim
  - CloudAnalyst
  - GreenCloud
  - iCanCloud
  - GroudSim
  - DCSim

CloudSim

- ✓ A simulation framework
  - Models cloud computing environments – Data Center, VM, applications, users, network topology
  - Written on Java-based environment
  - Allows to examine the performance of application services
  - Dynamic addition/removal of resources during simulation
  - Developed at CLOUDS Lab. of University of Melbourne

Source : Calheiros RN, Ranjan R, Beloglazov A, Rose CAFD, Buyya R. CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. Software: Practice and Experience 2011; 41(1):23–50

Advantages of CloudSim

- ✓ **Time effectiveness**: Cloud-based application implementation in
  - Minimum time
  - Minimum effort
- ✓ **Flexibility and applicability**:
  - Support for diverse cloud environments
  - Enables modelling of application services in any environment

Source : Calheiros RN, Ranjan R, Beloglazov A, Rose CAFD, Buyya R. CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. Software: Practice and Experience 2011; 41(1):23–50

Features of CloudSim

- ✓ Various cloud computing data centers
- ✓ Different data center network topologies
- ✓ Message-passing applications
- ✓ Virtualization of server hosts
- ✓ Allocation of virtual machines (VMs)
- ✓ User defined policies for allocation of host resources to VMs
- ✓ Energy-aware computational resources
- ✓ Dynamic addition/removal of simulation components
- ✓ Stop and resume of simulation

Source : Calheiros RN, Ranjan R, Beloglazov A, Rose CAFD, Buyya R. CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. Software: Practice and Experience 2011; 41(1):23–50

CloudSim Architecture

- ✓ User Code: **Top most** layer
  - Presents different machine and application specifications
- ✓ CloudSim: **Middle** layer
  - Provides cloud environment
  - Enables modelling and simulation
- ✓ Core Simulation Engine: **Bottom** most layer
  - Event scheduling
  - Entity creation
  - Interaction between components
  - Clock management

Source : Calheiros RN, Ranjan R, Beloglazov A, Rose CAFD, Buyya R. CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. Software: Practice and Experience 2011; 41(1):23–50

Top Layer: User Code

- ✓ Basic entities:
  - Users
  - Physical Machines
  - Virtual Machines
  - Applications & services
  - Scheduling policies

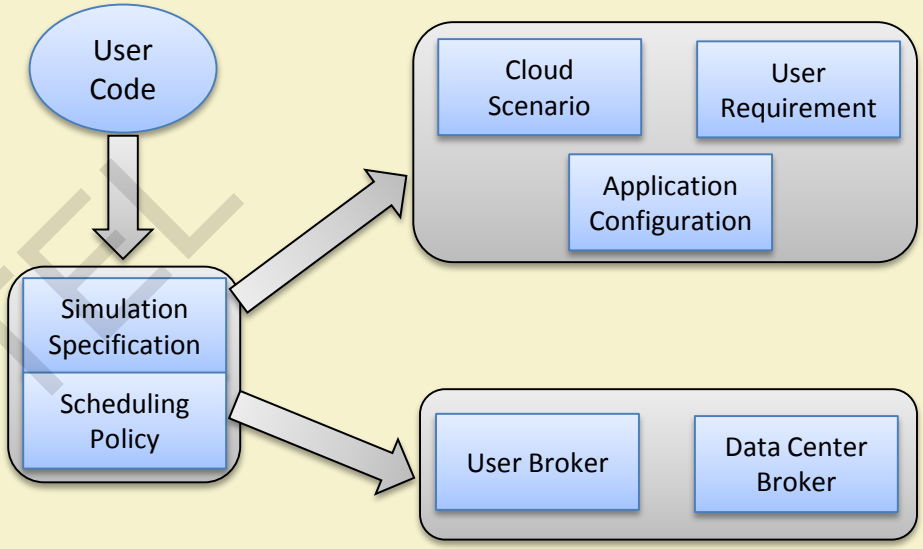


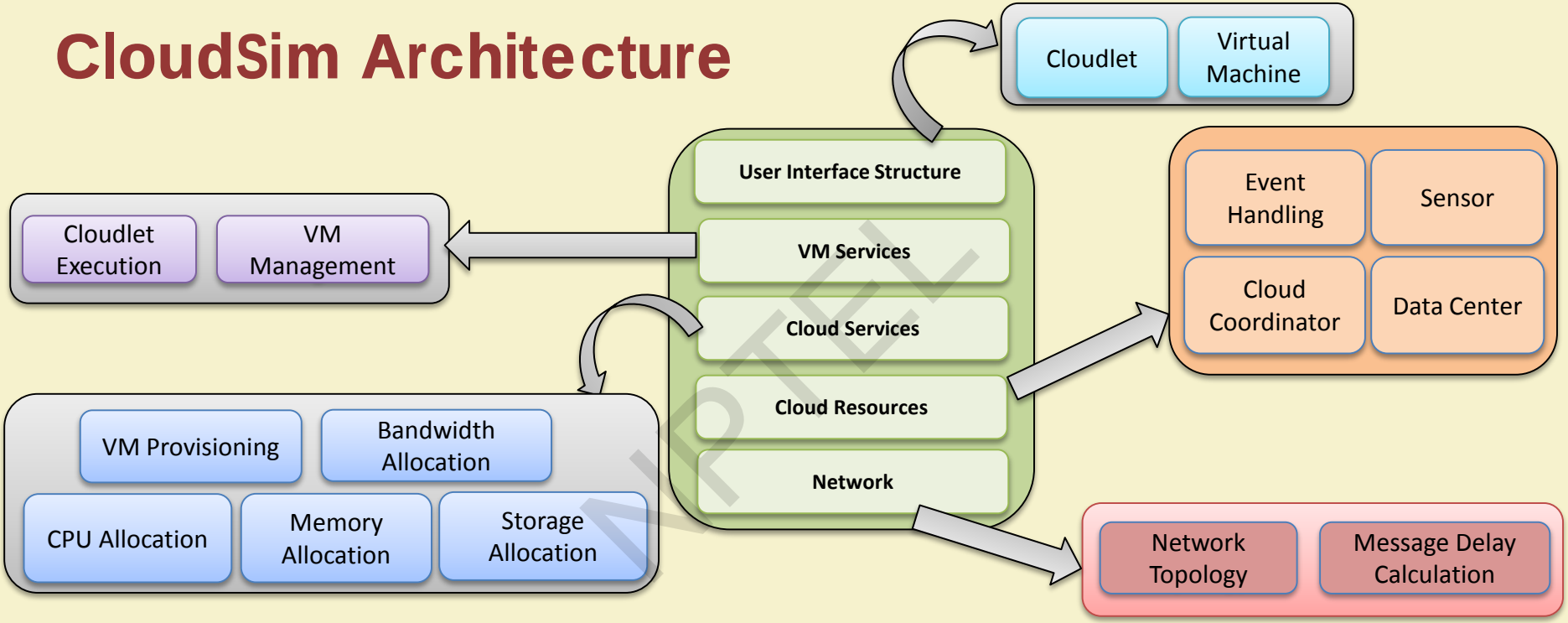
Fig: Functionalities at top layer

Source : Calheiros RN, Ranjan R, Beloglazov A, Rose CAFD, Buyya R. CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. Software: Practice and Experience 2011; 41(1):23–50

Middle Layer: CloudSim

- ✓ Creation and simulation of
  - Dedicated management interfaces
  - Memory, storage, bandwidth and VMs
- ✓ Helps in solving issues like
  - Hosts provisioning to VMs
  - Application execution management
  - Dynamic system state monitoring
- ✓ Allows a cloud service provider to
  - Implement customized strategies
  - Evaluating the efficiency of different policies in VM provisioning

CloudSim Architecture



Source : Calheiros RN, Ranjan R, Beloglazov A, Rose CAFD, Buyya R. CloudSim: A toolkit for modeling and simulation of cloud computing environments and evaluation of resource provisioning algorithms. Software: Practice and Experience 2011; 41(1):23–50

CloudAnalyst

- ✓ Simulation tool designed based on CloudSim
- ✓ Provides GUI
- ✓ Supports geographically distributed large-scale Cloud applications
- ✓ The purpose is to study the behavior of such applications under various deployment configurations

Source: B. Wickremasinghe, R. N. Calheiros, R. Buyya, "CloudAnalyst: A CloudSim-Based Visual Modeller for Analysing Cloud Computing Environments and Applications", in Proc. of IEEE Intl. Conf. on Advanced Information Networking and Applications (AINA), pp. 446-452, Perth, 2010.

Features of CloudAnalyst

- ✓ Easy to use due to Graphical User Interface (GUI)
- ✓ High level of configurability
- ✓ Flexibility of adding components
- ✓ Repeatability of experiments
- ✓ Graphical output (e.g. charts, tables)
- ✓ Easy to extend (Java Swing) and uses blended technology

Source: B. Wickremasinghe, R. N. Calheiros, R. Buyya, "CloudAnalyst: A CloudSim-Based Visual Modeller for Analysing Cloud Computing Environments and Applications", in Proc. of IEEE Intl. Conf. on Advanced Information Networking and Applications (AINA), pp. 446-452, Perth, 2010.

CloudAnalyst Design

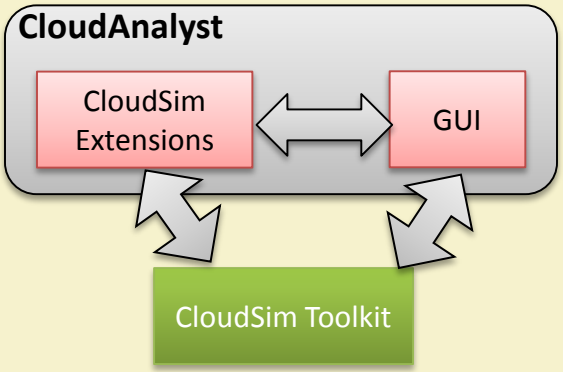


Fig: CloudAnalyst Architecture

Main components

- ***GUI Package***: Front end
- ***Simulation***: Create, execute, hold
- ***UserBase***: User traffic generation
- ***DataCenterController***: Events of data center
- ***Internet***: Internetworking & routing
- ***InternetCharacteristics***: Properties of Internet (delay, Bandwidth, throughput, etc.)
- ***VmLoadBalancer***: Policies for load balancing
- ***CloudAppServiceBroker***: Entities for routing between *UserBase* & data center.

Source: R. Buyya, CloudAnalyst: A CloudSim-based Tool for Modelling and Analysis of Large Scale Cloud Computing Environments, Distributed computing project, CSSE Dept., University of Melbourne, 433-659, Jun 22, 2009

GreenCloud

- ✓ **Why:**
  - The computing capacity has increased the cost and operational expenses of data centers
  - Energy consumption by data center is the major factor driving the operational expense
- ✓ **What:**
  - Operational cost is the energy utilized by computing and communication units within a data center
- ✓ **How:**
  - GreenCloud monitors the energy consumption of servers, switches, etc.
  - Developed as an extension of a packet-level network simulator NS2

Source: D. Kliazovich, P. Bouvry, S. U. Khan, "GreenCloud: A packet-level simulator of energy-aware cloud computing data centers", J. Supercomput., vol. 62, no. 3, pp. 1263-1283, Dec. 2012

Features of GreenCloud

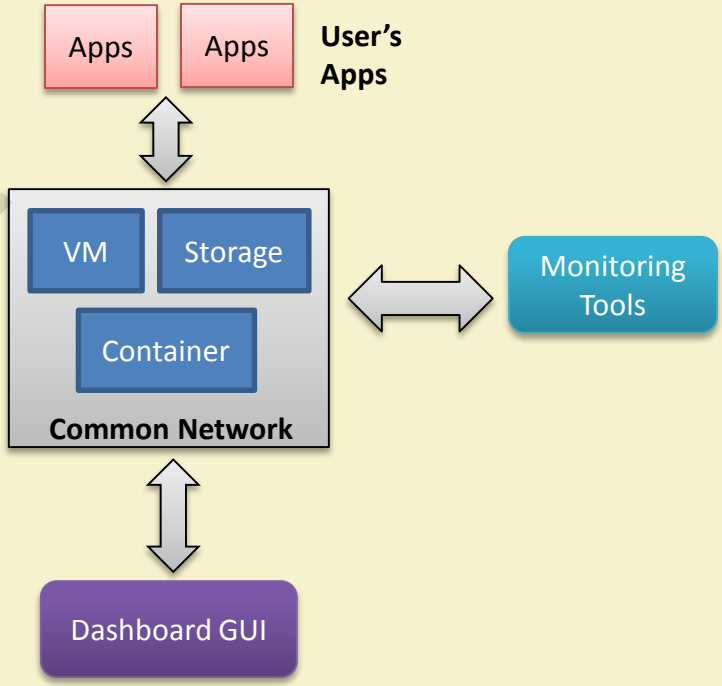
- ✓ User-friendly GUI
- ✓ Open source
- ✓ Facility for monitoring energy consumption of network & devices
- ✓ Supports simulation of cloud network components
- ✓ Supports monitoring of energy consumption of individual components
- ✓ Enables improved power management schemes
- ✓ Dynamic management and configuration of devices

Open Source and Commercial Clouds

	Open Source Clouds	Commercial Clouds
Examples	OpenStack, CloudStack, Eucalyptus	Amazon Web Services (AWS), Microsoft Azure, Google App Engine
Facility	Mostly offers IaaS	IaaS, PaaS, SaaS Services on subscription
Security	Implemented by user	Implemented by service provider
Type	Private/On-premise	Public/Off-premise/Hosted-private

OpenStack

- ✓ Collection of open source technologies
- ✓ Managed by the OpenStack Foundation
- ✓ Supports vastly scalable cloud system
- ✓ Preconfigured software suit
- ✓ Different services available for users
- ✓ Considered Infrastructure as a Service (IaaS).
- ✓ Ease of use: add new instances quickly to run other cloud components
- ✓ Provides a platform to create software applications
- ✓ Developed software applications can be used by the end users



Source: OpenStack Website www.openstack.org/software

OpenStack Components and Features

- ✓ Components:
  - Compute (Nova)
  - Networking (Neutron)
  - Block storage (Cinder)
  - Identity (Keystone)
  - Image (Glance)
  - Object storage (Swift)
  - Dashboard (Horizon)
  - Database (Trove)
  - Elastic map reduce (Sahara)
  - Shared file system (Manila)
  - DNS (Designate)
  - Search (Searchlight)
  - Key manager (Barbican)

- ✓ Features
  - Allows users to create and deploy virtual machines
  - Allows set up of cloud management environment
  - Supports easy horizontal scaling – dynamic addition/removal of instances to support more users in real-time
  - Open source software – free to access the source code and share their own code to community

Source : opensource.com Website www.openstack.org/software/

Microsoft Azure

- ✓ Previously Windows Azure
- ✓ Supports Iaas and PaaS
- ✓ Supports extensive set of services to quickly create, deploy and manage applications
- ✓ Many programming languages and frameworks are supported
- ✓ Available across a worldwide Microsoft-managed datacenters

Source URL: https://azure.microsoft.com/en-in/overview/what-is-azure

Azure Services

- ✓ Compute
- ✓ Mobile services
- ✓ Storage services
- ✓ Data management
- ✓ Messaging
- ✓ Media services
- ✓ Content Delivery Network (CDN)
- ✓ Developer
- ✓ Management
- ✓ Machine Learning

Azure as PaaS (Platform as a Service)

- ✓ Platform is provided to clients to develop and deploy software
- ✓ Clients **focus on application development** rather than worry about hardware and infrastructure
- ✓ Low Cost
- ✓ less vulnerable to security attacks
- ✓ Ease to move on to new tools
- ✓ Solves the issues related to most of the operating systems, servers and networking.

Source URL : https://azure.microsoft.com/en-in/overview/what-is-paas/

Azure as IaaS (Infrastructure as a Service)

- ✓ Offers total control of the OS and application stack
- ✓ Features to access, manage and monitor the data centers
- ✓ Ideal for the application where complete control is required
- ✓ Facility for loading of custom configurations

Source URL: https://blogs.msdn.microsoft.com/hanuk/2013/12/03/which-windows-azure-cloud-architecture-paas-or-iaas

Amazon Elastic Compute Cloud (EC2)

- ✓ A web service for users to **launch and manage** server instances in Amazon's data centers
- ✓ Provides various **APIs**, **tools** and **utilities**
- ✓ Facilitate dynamic computation **scaling** in the Amazon Web Services (AWS) cloud
- ✓ Supports **pay-per-use billing** rather than making large and expensive hardware purchases

Source: amazon web services Website https://aws.amazon.com/ec2/

Amazon EC2 Instances

- ✓ Virtual computing environments
- ✓ Instance templates of different configurations – CPU, memory, storage, networking capacity
- ✓ Dynamic instance allocation by AWS according to user demand
- ✓ Instance types
  - General purpose: T2, M4, M3
  - Compute optimized: C4, C3
  - Memory optimized: X1, R4, R3
  - Accelerated computing instances: P2, G2, F1

Source URL: https://aws.amazon.com/ec2/

Features of Amazon EC2

- ✓ **Operating system**:
  - Supports all OS types
  - Custom distribution: Amazon Linux AMI/**Amazon Machine Images**
- ✓ **Persistent storage**:
  - Temporary: Local 'Instance Store'
  - Amazon Elastic Block Store (EBS)
  - Simple Storage Service (S3)
- ✓ **Automated scaling**: Rule based / Schedule based
- ✓ Different **"availability zones"** in data centers increases fault-tolerance

Features of Amazon EC2

- ✓ **Firewall Rules/Security Groups**: Only predefined protocols, ports, and source IP ranges reach the instances
- ✓ **Elastic IP address**: Mapping between IP and any VM of user
- ✓ **Amazon CloudWatch**: CPU, disk, network resource utilization monitoring
- ✓ **Enhanced security** for instances using public-private key pair
- ✓ **Virtual private clouds (VPCs)**:
  - Logically separate from the rest of the AWS cloud
  - Optionally connected to user's own network

Thank You!!