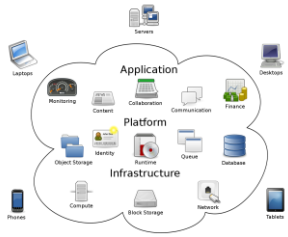


UNIT I

Cloud Computing

Introduction

The ACM Computing Curricula 2005 defined "computing" as

- Computing to mean any goal oriented activity requiring, benefiting from, or creating computers.
- Includes designing and binding hardware and software systems for a wide range of purposes:
  - Processing, structuring and managing various kind of information
    - scientific studies using computers
    - creating and using communication
    - entertainment media
    - finding and gathering information relevant to any particular purposes and so on

Overview

UNIT-1

- Introduction to Cloud Computing
  - Overview of Computing
  - Cloud Computing (NIST Model)
  - Properties of Cloud Computing
  - Open Standards of Cloud Computing
  - Service models of Cloud Computing (XaaS)
    - IaaS
    - PaaS
    - SaaS
  - Applications of Cloud computing
  - Cloud Computing Security Configurations
- Cloud Computing Architecture
  - Cloud Computing Stack
  - Deployment Models
    - Public
    - Private
    - Community
    - Hybrid

Overview (cont..)

UNIT-2

- Virtualization in Cloud
  - Virtualization
  - Applications and Advantages of Virtualization
  - Implement virtualization and Techniques of virtualizations
  - Middleware virtualization
  - Hardware Virtualizations
  - Types of Virtualization

- Security Issues in Cloud Computing
  - Security in cloud computing
  - Security Challenges in Cloud Computing
  - Information Security
  - Privacy and Trust in Cloud Computing

Overview (cont..)

UNIT-3

- Data Centre Architecture and Technologies
  - Architectural Building Blocks of Data Centre
  - Industry Direction and Operational and Technical Phasing

- Computing with Titans
  - Google
  - Microsoft
  - Amazon
  - IBM
  - Accessing the Cloud- Platforms through
    - Web Applications
    - Web API's
    - Web Browsers

Overview (cont..)

UNIT-4

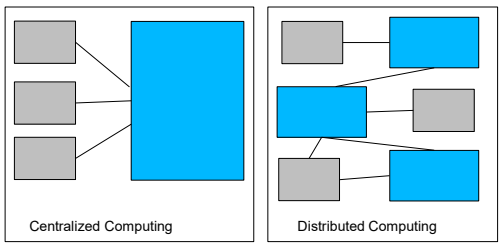
- Migrating to the Cloud
  - Cloud Services for Individuals
  - Cloud Services aimed at MidMarkets
  - Enterprise
  - Best Practices and Future of Cloud Computing

- Implementation of Cloud Using Any Cloud Platform
  - Introduction to Web Services
  - Structure, Objective, Cloud Portals, Groups, Mobile Apps, Setting up of Cloud Services
  - Containers
  - Handling Cloud Shell
  - Setting up of projects
  - Building Virtual Infrastructure,
  - Deployment of Virtual Machine
  - Configuring Load Balancing

Computing Trends

- Distributed Computing
- Grid Computing
- Cluster Computing
- Utility Computing
- Cloud Computing

Centralized vs. Distributed Computing



Distributed Computing

- Distributed Computing
  - A field of computing science
  - To solve more complex computational system
- IBM
  - A distributed computer system consists of *multiple software components* that are on *multiple computers*, *but run as a single system*. The computers that are in a distributed system can be physically close together and connected by a local network, or they can be geographically distant and connected by a wide area network.
- Wikipedia
  - A distributed system is a system whose *components are located on different networked computers, which communicate and coordinate* their actions by passing messages to one another from any system.

Distributed Computing- Examples

- ATM
- Bank Machines
- Internet (CDNs)
- Intranets/Workgroups

Distributed Computing- Computing Elements

- Computers (PCs)
- Workstations
- Server Systems

Distributed Computing- Properties

- Fault Tolerance
  - Node Failure
  - Check the status of each node
- Resource Sharing
- Load Sharing
- Scalable
  - Easy to add nodes
- Performance

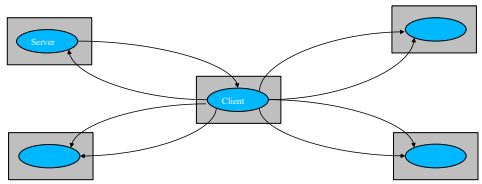
Distributed Computing-Need

- Application Nature or Architecture
- Performance of an Application
  - Computing Intensive-High end computing performance
  - Data Intensive-Large Datasets
- Sharing of the Resources
- Robustness
  - No Single point of Failure

Distributed Computing- Applications

- A set of process
  - Can be distributed across the network machines
  - Work together and ensemble to solve a common problem
- In the past, Client-Server
  - Resource Management centralized at the Server
- Peer-to-peer computing

Clients invokes individual Server

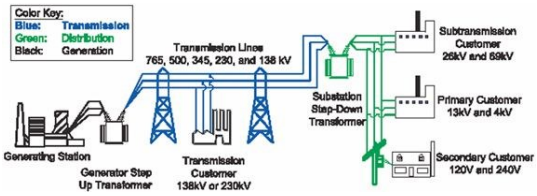


GRID COMPUTING

Grid Computing- Introduction

- IBM
  - Grid computing has emerged as a way to harness and take advantage of computing resources across geographies and organizations.
- AZURE
  - Grid computing is a group of networked computers which work together as a virtual supercomputer to perform large tasks, such as analysing huge sets of data or weather modeling.

Electrical Power Grid



- Electrical Power Grid
  - Users or electrical appliances get access the electricity through the wall socket without consideration about the originating location of electricity.
  - "The Power Grid" links together many different kinds of power plants i.e. Solar, Water, Coal etc.

Grid Computing- Introduction

- Grid Computing
  - Users/Applications access the computing resources
    - Processors
    - Storage
    - Data
    - Applications and so on
  - with little or no knowledge about the resources' location, underlying technologies, hardware, hosting OS, and so on.
- "The Grid"
  - links together the computing resources
  - Provides the mechanism to access those resources

Grid Computing- Introduction

- Sharing more than the information
  - Data
  - Computing Power
  - Applications in dynamic environment
  - Multi-institutional
  - virtual organizations
- Efficient uses of the resources
- Local communities of computing resources get together

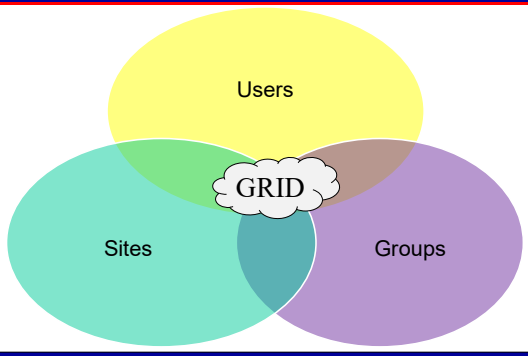
Grid Computing- Need

- Scientific / Complex Problem
- Simulations and Modelling
- Large Engineering Problems
- Data Visualization
- Exploiting under utilized resources

Grid Computing- Types

- Computational Grid
  - Provides secure access to huge shared computing resources
  - High throughput
  - Computation intensive application
- Data Grid
  - Data Storage, Data Discovery, Data handling, Data Publication
- Collaboration Grid
  - Different companies different people may work in collaborative environment via internet.
- Network Grid
  - Fault-tolerant and high performance communication services
- Utility Grid
  - Not only the data of computing resources. It shares any resources which is shared.

Grid Computing- Components



Grid Computing- Components

- Users
  - End Users with large population
  - End users' data (personal and confidential)
  - Different heterogeneous roles
  - Single sign in for multi purpose
- Groups
  - Data into groups
  - Access data as per group users privileges
- Sites
  - Heterogeneous rights for multiple users and groups
  - Different types of resources online
  - Local and global policies

CLUSTER COMPUTING

Cluster Computing- Introduction

- IBM
  - A cluster is a collection of one or more systems or logical partitions that work together as a single system. Use this information to understand the elements and their relationship to each other.
- Wikipedia
  - A computer cluster is a set of computers that work together so that they can be viewed as a single system. Unlike grid computers, computer clusters have each node set to perform the same task, controlled and scheduled by software.

Cluster Computing- Introduction

5	**Tianhe-2A** - TH-IVB-FEP Cluster, Intel Xeon E5-2692v2 12C 2.2GHz, TH Express-2, Matrix-2000, NUDT National Super Computer Center in Guangzhou China	4,981,760	61,444.5	100,678.7	18,482

resource: https://www.top500.org/lists/top500/2020/06/

- 5th Rank in Top 100 Supercomputers in the World
- 4 Supercomputers comes under top 200 Supercomputers
- 14 Supercomputers comes under top 300 Supercomputers
- HPC (High Performance Computing) Example:
  - https://www.ibm.com/docs/en/power-sys-solutions/0008-HPC?topic=overview-example-multiple-rack-maximum-compute-configuration

Cluster Computing- Introduction

- Microsoft Cluster Server(MSCS):
  - Microsoft Cluster Server (MSCS) is a computer program that allows server computers to work together as a computer cluster, to provide failover and increased availability of applications, or parallel calculating power in case of high-performance computing (HPC) clusters (as in supercomputing). [Wikipedia]
- Setup for Failover Clustering and Microsoft Cluster Service
  - https://docs.vmware.com/en/VMware-vSphere/6.5/vsphere-esxi-vcenter-server-651-setup-mscs.pdf

Cluster Computing- Planning

- Hardware requirements for clusters
  - To implement a high-availability solution, you need to plan and configure a cluster. A cluster groups systems and resources in a high availability environment.
- Software requirements for clusters
  - In order to use clustering, you must have the correct software and licenses.
- Communications requirements for clusters
  - Use any type of communications media in your clustering environment as long as it supports Internet Protocol (IP).
- Performance planning for clusters
  - When changes are made to a cluster, the overhead necessary to manage the cluster can be affected.

Cluster Computing- Planning

- Planning advanced node failure detection
  - Advanced node failure detection function can be used to reduce the number of failure scenarios which result in cluster partitions.
- Planning checklist for clusters
  - Complete the cluster configuration checklist to ensure that your environment is prepared properly before you begin to configure your cluster.
- Cluster applications
  - Application resilience is one of the key elements in a clustered environment. If you are planning to write and use highly available applications in your cluster you should be aware that these applications have specific availability specifications.
- Planning clusters
  - Before implementing a high-availability solution, you must ensure that you met all prerequisites for clusters.

Cluster Computing- Planning

- Planning data resiliency
  - Data resilience is the ability for data to be available to users or applications. You can achieve data resiliency by using IBM i cluster technology with PowerHA technologies or logical replication technologies.
- Planning environment resiliency
  - Environment resiliency ensures that your objects and attributes remain consistent among resources defined in the high-availability environment. You need to identity which resources require a consistent environment to function properly and create a cluster administrative domain that will ensure that these resource attributes remain consistent in your high availability solution.
- Security planning for high availability
  - Prior to configuring your high-availability solution, you should reassess the current security strategies in your environment and make any appropriate changes to facilitate high availability.

Cluster Computing- Configuring

- Creating cluster (IBM iCluster) : [https://www.ibm.com/docs/en/i/7.3?topic=clusters-creating-cluster]
  - Enabling nodes to be added to a cluster
    - Before you can add a node to a cluster, you need to set a value for the Allow add to cluster (ALWADDCLU) network attribute.
  - Adding nodes
    - The IBM i PowerHA graphical interface allows you to create a cluster with multiple nodes. After the cluster has been created you may add additional nodes through an active node in the cluster. A cluster can contain up to 128 nodes.
  - Starting nodes
    - Starting a cluster node activates clustering and cluster resource services on a node in an IBM i high availability environment.
  - Optional: Adding a node to a device domain
    - A device domain is a subset of nodes in a cluster that shares device resources.
  - Creating cluster resource groups (CRGs)
    - Cluster resource groups (CRGs) manage high availability resources, such as applications, data, and devices. Each CRG type manages the particular type of resource in a high-availability environment.
  - Starting a CRG
    - Starting a cluster resource group (CRG) enables resilience for the CRG.

Cluster Computing- Managing

- You may perform many tasks that are associated with the cluster technology that is the basis of your high availability solution.
- Example: https://www.ibm.com/docs/en/i/7.3?topic=powerha-managing-clusters

UTILITY COMPUTING

Utility Computing- Definition

- Wikipedia
  - Utility computing or The Computer Utility is a service provisioning model in which a service provider makes computing resources and infrastructure management available to the customer as needed, and charges them for specific usage rather than a flat rate. Like other types of on-demand computing (such as grid computing), the utility model seeks to maximize the efficient use of resources and/or minimize associated costs.
- Cloud computing is a practically implementation of Utility Computing
- It is an idea to acquire the computer resources on initial or low cost; the resources are essentially rented
- The word utility means:
  - Electrical power for computing
  - Fluctuating consumer needs or requirements
  - Charges based upon the usage of computing resource; no fixed or flat charge called *pay-per-use*

Utility Computing- Introduction

- "Utility Computing"
  - Form of virtualization
    - Amount of storage
    - Computing power
    - 24x7 sharing
  - Pay-for-use
  - Data center virtualization
  - Resource Utilization Problem Solved

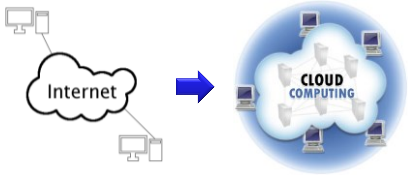
CLOUD COMPUTING

Cloud Computing- Introduction

- **Oxford Dictionary**
  - The practice of using a network of remote servers hosted on the internet to store, manage, and process data, rather than a local server or a personal computer.
- **Mircosoft AZURE**
  - cloud computing is the delivery of computing services—including servers, storage, databases, networking, software, analytics, and intelligence—over the Internet ("the cloud") to offer faster innovation, flexible resources, and economies of scale. You typically pay only for cloud services you use, helping lower your operating costs, run your infrastructure more efficiently and scale as your business needs change.
- **NIST (National Institute of Standards and Technology)**
  - cloud computing is a model for enabling ubiquitous, 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.
  - The NIST definition lists five essential characteristics of cloud computing: on-demand self-service, broad network access, resource pooling, rapid elasticity or expansion, and measured service.

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**

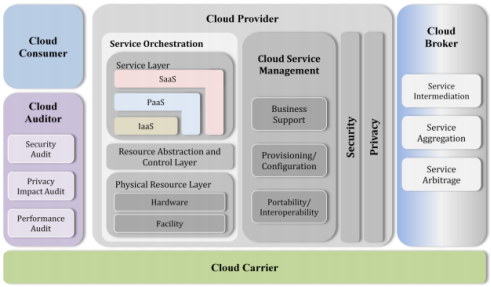


Cloud Computing- Characteristics

- Five essential characteristics of cloud computing
  - On-demand self-service:
    - Users are able to provision cloud computing resources without requiring human interaction, mostly done though a web-based self-service portal (management console).
  - Broad network access:
    - Cloud computing resources are accessible over the network, supporting heterogeneous client platforms such as mobile devices and workstations.
  - Resource pooling:
    - Service multiple customers from the same physical resources, by securely separating the resources on logical level.
  - Rapid elasticity:
    - Resources are provisioned and released on-demand and/or automated based on triggers or parameters. This will make sure your application will have exactly the capacity it needs at any point of time.
  - Measured service:
    - Resource usage are monitored, measured, and reported (billed) transparently based on utilization. In short, pay for use.

[source: IBM Cloud Computing]

Cloud Computing - Conceptual Reference Model



[source: NIST reference model]

Cloud Computing - Conceptual Reference Model

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

[source: NIST reference model]

Cloud Computing- Terms

- Terms used in Cloud Computing
  - Cloud Consumer
    - Person or organization that maintains a business relationship with, and uses service from, Cloud Service Providers.
  - Cloud Provider
    - Person, organization or entity responsible for making a service available to service consumers.
  - Cloud Carrier
    - The intermediary that provides connectivity and transport of cloud services between Cloud Providers and Cloud Consumers.
  - Cloud Broker
    - An entity that manages the use, performance and delivery of cloud services, and negotiates relationships between Cloud Providers and Cloud Consumers.
  - Cloud Auditor
    - A party that can conduct independent assessment of cloud services, information system operations, performance and security of the cloud implementation.

[source: NIST]

Cloud Computing- Terms

- Terms used in Cloud Computing
  - Cloud Distribution
    - The process of transporting cloud data between Cloud Providers and Cloud Consumers.
  - Cloud Access –
    - To make contact with or gain access to Cloud Services.
  - Service Deployment
    - All of the activities and organization needed to make a cloud service available
  - Service Orchestration
    - Refers to the arrangement, coordination and management of cloud infrastructure to provide different cloud services to meet IT and business requirements.
  - Cloud Service Management
    - Cloud Service Management includes all the service-related functions that are necessary for the management and operations of those services required by or proposed to customers.
  - Privacy
    - Information privacy is the assured, proper, and consistent collection, processing, communication, use and disposition of disposition of personal information (PI) and personally identifiable information (PII) throughout its life cycle. (Source: adapted from OASIS)

Cloud Computing- Terms

- Terms used in Cloud Computing
  - Security
    - Refers to information security. „information security" means protecting information and information systems from unauthorized access, use, disclosure, disruption, modification, or destruction in order to provide:
      - integrity, which means guarding against improper information modification or destruction, and includes ensuring information nonrepudiation and authenticity;
      - confidentiality, which means preserving authorized restrictions on access and disclosure, including means for protecting personal privacy and proprietary information;
      - availability, which means ensuring timely and reliable access to and use of information. (Source: [SOURCE: Title III of the E-Government Act, entitled the Federal Information Security Management Act of 2002 (FISMA)])
  - Service Consumption
    - A Cloud Broker in the act of using a Cloud Service.
  - Service Provision
    - A Cloud Broker in the act of providing a Cloud Service.
  - Security Audit
    - Systematic evaluation of a cloud system by measuring how well it conforms to a set of established security criteria.

Cloud Computing - Conceptual Reference Model

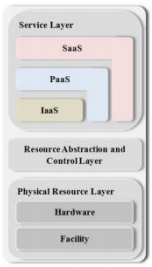
Example Usage Scenario 1: A cloud consumer may request service from a cloud broker instead of contacting a cloud provider directly. The cloud broker may create a new service by combining multiple services or by enhancing an existing service. In this example, the actual cloud providers are invisible to the cloud consumer and the cloud consumer interacts directly with the cloud broker.

Example Usage Scenario 2: Cloud carriers provide the connectivity and transport of cloud services from cloud providers to cloud consumers. As illustrated in Figure 4, a cloud provider participates in and arranges for two unique service level agreements (SLAs), one with a cloud carrier (e.g. SLA2) and one with a cloud consumer (e.g. SLA1). A cloud provider arranges service level agreements (SLAs) with a cloud carrier and may request dedicated and encrypted connections to ensure the cloud services are consumed at a consistent level according to the contractual obligations with the cloud consumers. In this case, the provider may specify its requirements on capability, flexibility and functionality in SLA2 in order to provide essential requirements in SLA1.

[source: NIST reference model; Link: https://bigdatawg.nist.gov/_uploadfiles/M0008_v1_7256814129.pdf]

Cloud Computing - Service Orchestration

- *Service Orchestration* refers to the composition of system components to support the Cloud Providers activities in arrangement, coordination and management of computing resources in order to provide cloud services to Cloud Consumers.



Cloud Computing – IaaS Services

- The capability provided to the consumer is to
  - provision processing
  - Storage
  - networks, and other fundamental computing resources
  - where the consumer is able to
    - 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 (e.g., host firewalls). (Source: NIST CC Definition).

Cloud Computing – IaaS Services

- *Backup and Recovery:* Services for backup and recovery of file systems and raw data stores on servers and desktop systems.
- *Compute:* Server resources for running cloud-based systems that can be dynamically provisioned and configured as needed.
- *Content Delivery Networks (CDNs):* CDNs store content and files to improve the performance and cost of delivering content for web-based systems.
- *Services Management:* Services that manage cloud infrastructure platforms. These tools often provide features that cloud providers do not provide or specialize in managing certain application technologies.
- *Storage:* Massively scalable storage capacity that can be used for applications, backups, archival, and file storage.

Cloud Computing – PaaS Services

- The capability provided to the consumer is
  - to deploy onto the cloud infrastructure consumer-created
  - or acquired applications created using programming languages and tools supported by the provider.
- The consumer does not manage or control
  - the underlying cloud infrastructure including
    - network,
    - servers
    - operating systems
    - storage,
  - but has control over the deployed applications and possibly application hosting environment configurations. (Source: NIST CC Definition)

Cloud Computing – PaaS Services

- *Business Intelligence:* Platforms for the creation of applications such as dashboards, reporting *systems, and data analysis.*
- *Database:* Services offering scalable relational database solutions or scalable non-SQL datastores.
- *Development and Testing:* Platforms for the development and testing cycles of application development, which expand and contract as needed.
- *Integration:* Development platforms for building integration applications in the cloud and within the enterprise.
- *Application Deployment:* Platforms suited for general purpose application development. These services provide databases, web application runtime environments, etc.

Cloud Computing – SaaS Services

- The capability provided to the consumer is
  - to use the provider's applications running on a cloud infrastructure.
  - 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
    - individual application capabilities, with the possible exception of limited user-specific application configuration settings. (Source: NIST CC Definition)

Cloud Computing – SaaS Services

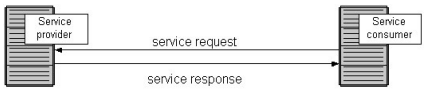
- *Email and Office Productivity:* Applications for email, word processing, spreadsheets, presentations, etc.
- *Billing:* Application services to manage customer billing based on usage and subscriptions to products and services.
- *Customer Relationship Management (CRM):* CRM applications that range from call center applications to sales force automation.
- *Collaboration:* Tools that allow users to collaborate in workgroups, within enterprises, and across enterprises.
- *Content Management:* Services for managing the production of and access to content for web-based applications.
- *Document Management:* Applications for managing documents, enforcing document production workflows, and providing workspaces for groups or enterprises to find and access documents.

Cloud Computing – SaaS Services

- *Financials:* Applications for managing financial processes ranging from expense processing and invoicing to tax management.
- *Human Resources:* Software for managing human resources functions within companies.
- *Sales:* Applications that are specifically designed for sales functions such as pricing, commission tracking, etc.
- *Social Networks:* Social software that establishes and maintains a connection among users that are tied in one or more specific types of interdependency.
- *Enterprise Resource Planning (ERP):* Integrated computer-based system used to manage internal and external resources, including tangible assets, financial resources, materials, and human resources.

Service Oriented Architecture

- Definition
  - Service Oriented Architecture (SOA) is essentially a collection of services which communicate with each other
  - Contain a flexible set of design principles used during the phases of systems development and integration
  - Provide a loosely-integrated suite of services that can be used within multiple business domains
- Approach
  - Usually implemented by Web Service model



Service Level Agreement

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

Cloud Computing – Security Configurations

- Cloud-based systems still need to address security requirements
  - *authentication, authorization, availability, confidentiality, identity management, integrity, audit, security monitoring, incident response, and security policy management.*.
- Cloud Service Model Perspectives
  - three service models: SaaS, PaaS, and IaaS, present consumers with different types of service management operations
  - expose different entry points into cloud systems (Attacks)
- Implications of Cloud Deployment Models
  - A private cloud is dedicated to one consumer organization, where as a public cloud could have unpredictable tenants co-existing with each other, therefore, workload isolation is less of a security concern in a private cloud than in a public cloud.

Cloud Computing – Advantages

- Accelerate the delivery of new apps
- Take advantage of cloud-native architecture such as Kubernetes to modernize applications and accelerate digital transformation.
- Ensure compliance with the latest regulations
- Deliver greater transparency into resources to cut costs and prevent data breaches
- Enable faster provisioning of resources
- Utilize hybrid cloud architecture to support real-time scalability for applications as business needs change
- Meet service targets consistently
- Leverage cloud reference architecture to gain insight into IT spending patterns and cloud utilization

Cloud Computing – Disadvantages

- Bandwidth requirement/ network connection dependency
- Privacy and security
- Recovery of data
- Dependency
- Agreement: SLA

Cloud Computing – Architecture

- Cloud architecture defines the technology components that are combined to build a cloud, where resources are pooled through virtualization technology and shared across a network. The components of a cloud architecture include:
  - A front-end platform (the client or device used to access the cloud)
  - One or more back-end platforms (servers and storage)
  - A cloud-based delivery methodology
  - A network to connect cloud clients, servers, and storage

Cloud Computing – Architecture Types

- *Public cloud architecture:*
  - *computing resources are owned and operated by a cloud services provider.*
  - *resources are shared and redistributed across multiple tenants via the Internet.*
  - *include reduced operating costs, easy scalability and little to no maintenance.*
- *Private cloud architecture:*
  - *owned and managed privately, usually in a company's own on-premises data center.*
  - *include multiple server locations or leased space in geographically scattered colocation facilities*
  - *typically more expensive than public cloud solutions, a private cloud architecture is more customizable and can offer stringent data security and compliance options.*

Cloud Computing – Architecture Types

- *Hybrid cloud architecture:*
  - *combines the operating efficiencies of the public cloud and data security capabilities of the private cloud*
  - *By utilizing both public and private cloud architectures, hybrid clouds help consolidate IT resources while enabling organizations to migrate workloads between environments depending on their IT and data security requirements.*
- *Multi-cloud architecture:*
  - *uses multiple public cloud services*
  - *include greater flexibility to choose and deploy the cloud services that are most likely to satisfy varying organizational requirements*
  - *reduced reliance on any single cloud services vendor for greater cost savings and a lower likelihood of vendor lock-in*
  - *required to support microservices-based containerized applications, where services exist on multiple clouds.*

Cloud Computing – Components

- *Virtualization:*
  - *Clouds are built upon virtualization of servers, storage, and networks. Virtualized resources are a software-based, or virtual, representation of a physical resource such as servers or storage*
- *Infrastructure:*
  - *real servers.*
  - *includes all the components of traditional data centers including servers, persistent storage and networking gear including routers and switches.*
- *Middleware:*
  - *traditional data centers*
  - *software components such as databases and communications applications enable networked computers, applications and software to communicate with each other.*

Cloud Computing – Components

- *Management:*
  - *These tools enable continuous monitoring of a cloud environment's performance and capacity.*
  - *IT teams can track usage, deploy new apps, integrate data and ensure disaster recovery, all from a single console.*
- *Automation software:*
  - *The delivery of critical IT services through automation and pre-defined policies can significantly ease IT workloads, streamline application delivery, and reduce costs.*
  - *automation is used to easily scale up system resources to accommodate a spike in demand for compute power, deploy applications to meet fluctuating market demands, or ensure governance across a cloud environment.*

Cloud Computing –IDaaS

- *Okta*
  - *Identity as a Service, or IDaaS is cloud-based authentication built and operated by a third-party provider. IDaaS companies supply cloud-based authentication or identity management to enterprises who subscribe.*
- *OAuth*
  - *Every organization that uses a login box must have some form of identity and access management (IAM) system to keep track of users and control access to data and services.*
  - *When an organization creates or updates an application, they have to choose which functionalities to write themselves and which to entrust to a third party.*
  - *IDaaS providers offer cloud-based solutions for IAM functions.*

Cloud Computing –IDaaS (3 Classes of Users)

- Customer identity and access management (CIAM)
  - applies to end-users.
- Workforce IAM
  - manages your staff and their access to internal applications.
- B2B IAM
  - lets businesses integrate identity with their business partners and enterprise customers.

Cloud Computing –IDaaS (Core Festures)

- Single factor authentication: user id & password
- Two factor authentication: user id, password, token number
- Multi-factor authentication (MFA)
  - requires users to log in with more than one piece of identifying information
    - Knowledge: Something the user knows (such as a password)
    - Possession: Something the user has (such as a cell phone)
    - Inheritance: Something the user is (such as a fingerprint or retina scan)

Cloud Computing –IDaaS (Core Festures)

- Biometrics
  - Biometrics means the use of an "inheritance" criteria — something the user is as a means of verification
- Single Sign-On (SSO)
  - allows users to log in to one application and then automatically be logged in to other designated applications.
- User management and access control
  - ability to control who is permitted to access data by provisioning users with different roles. IDaaS systems simplify this process by centralizing identity and putting these controls into a single location like a user dashboard.

Cloud Computing –Map Reduce

- feasible approach handling large-scale data processing
  - divide and conquer
- solutions based on a parallel model
  - the parallel database, which is based on the shared-nothing distributed architectures
- MapReduce is
  - a new parallel programming model
  - parallel data flow system that works through data partitioning across machines, each machine independently running the single-node logic
  - handle large datasets with the guarantee of scalability, load balancing, and fault tolerance, and MapReduce is applicable to a wide range of problems
  - a data-driven parallel computing model proposed by Google
  - Runs over Hadoop File System (HDFS)

Cloud Computing –Map Reduce

- Data Flow Model
  - distributed computation on large datasets by using a large number of computers with scalability and fault tolerance guarantees.
  - the map phase
    - the master node takes the input, and divides it into sub-problems, then distributes them to the worker nodes.
    - Each worker node solves a sub-problem and sends the intermediate results ready to be processed by reducer
  - the reduce phase
    - intermediate results are processed by reduce function on different worker nodes, and the final results are generated.
  - A *map* function processes a fragment of a key-value pairs list to generate a list of intermediate key-value pairs. A *reduce* function merges all intermediate values associated with a same key, and produces a list of key-value pairs as output.
    - map(key1,value1) → list(key2,value2)
    - reduce(key2,list(value2) → list(key2,value3)