

INTRODUCTION TO COURSE

Module No – 001

- ~~• This course is designed to cover different dimensions of Cloud Computing.~~
- ~~• The course aims at providing good knowledge regarding the Cloud Computing.~~
- ~~• The course begins with the background knowledge.~~
- ~~• Cloud Computing has overlapping features with various other forms of computing.~~
- Basically **it** is the provision of computing (over **virtualized resources**) as a (**charged for**) service over the **Internet**.
- ~~• It is important to build some conceptual foundations.~~
- **Cloud computing** has somehow evolved from the fields of **Cluster Computing and Grid Computing**.
- ~~• The course begins with the overview of these field.~~
- Since the **Cloud Computing aims at providing computations over Internet**, ~~this course builds and revises~~ the basic and advanced networking concepts such as:
 - Network structures, designs, protocols etc.
 - Switching, routing and network virtualization.
 - Data center networking
- **Cloud Computing** depends upon a technology called **Virtualization** technology for **dynamic creation** and **provisioning of computing resources**.
- ~~• Up to date knowledge of virtualization is discussed before proceeding.~~
- ~~• Different features of Cloud Computing with reference to course books and **National Institute of Standards and Technology (NIST) USA** will be introduced/explained as and when an enough background knowledge is gained.~~
- ~~• The course continues with the coverage of Cloud architecture, services, examples and issues related to security and privacy etc. for Cloud Computing.~~
- ~~• Later on, the in depth coverage of Cloud mechanisms are covered.~~
- ~~• The delivery models of Cloud Computing and Cloud Services are periodically discussed with increasing complexity.~~
- The **consumers** of **Cloud Computing** are under a **legal cover** of **Service Level Agreement (SLA)**.
- ~~• The rights and liabilities of Cloud consumers and Cloud providers are also covered.~~
- ~~• A significant volume of the course covers the security issues related to computers and Cloud computing.~~
- ~~• We shall also discuss the disaster recovery and decision making for Cloud computing.~~
- **Cloud Computing setup and hosting is a complex task.**
- ~~• Cloud management and Cloud hosting data center architectures are also covered.~~
- **Cloud Computing** is also provisioned through **mobile phones**.
- ~~• As special contribution:~~
 - ~~○ The course covers the Mobile Cloud Computing field.~~
 - ~~○ The emerging field of **Software Defined Networking (SDN)** is introduced.~~
- **Recommended books and publications:**

- ~~○ “Cloud Computing: Concepts, Technology & Architecture” Book by Ricardo Puttini, Thomas Erl, and Zaigham Mahmood; Prentice Hall/Pearson PTR~~
- ~~○ “Cloud Computing” Book by Kris Jamsa; Jones & Bartlett Publishers~~
- ~~○ Liu, Fang, et al. "NIST cloud computing reference architecture." NIST special publication 500.2011 (2011): 292.~~
- ~~● Please follow these important points:~~
 - ~~○ Cover the course according to modules.~~
 - ~~○ If a key term is confusing to you, use the recommended course book/s and/or Google.~~
 - ~~○ Usually, the detail of the key term is covered in the same module or coming modules, so be patient.~~
 - ~~○ Background knowledge is provided to refresh the previous knowledge only. Not for knowledge building.~~
 - ~~○ Students are encouraged to study/consult the books related to Networks and Computer Architecture, Computer Security, Network Security etc. as well.~~
- ~~● Instructor’s email: mtayyabeh@yahoo.com~~

Lesson No. 02

INTRODUCTION TO CLOUD COMPUTING

Module No – 002:

“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.”

National Institute of Science and Technology (NIST) USA

- Essential Characteristics according to NIST definition:
 - *On-demand self-service*
 - *Broad network access*
 - *Resource pooling*
 - *Rapid elasticity*
 - *Measured service*
- **On-demand self-service:** A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service provider.
- **Broad network access:** Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous client devices (e.g., mobile phones, tablets, laptops, and workstations).

- **Resource pooling:** The provider's computing resources are pooled to serve multiple consumers according to consumer demand. The customer generally has no control or knowledge over the exact location of the provided resources (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, and network bandwidth.
- **Rapid elasticity:** Capabilities can be elastically provisioned and released with demand. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be appropriated in any quantity at any time.
- **Measured service:** Cloud systems automatically control and optimize resource use by leveraging a metering capability. Typically this is done on a pay-per-use or charge-per-use basis.

Module No – 007:

- Cloud Service Models according to NIST definition:
 - *Software as a Service (SaaS)*
 - *Platform as a Service (PaaS)*
 - *Infrastructure as a Service (IaaS)*
- Software as a Service (SaaS):
 - The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure. A cloud infrastructure is the collection of hardware and software that enables the five essential characteristics of cloud computing.
 - The applications are accessible from various client devices a web browser (e.g., web-based email), or a program interface.
 - The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, except for limited user specific application configuration settings.
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- Platform as a Service (PaaS):
 - The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, and tools supported by the provider.
- Infrastructure as a Service (IaaS):
 - 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, and deployed applications; and possibly limited control of selected networking components (e.g., host firewalls).
- Cloud Deployment Models according to NIST definition:
 - *Private cloud*
 - *Community cloud*
 - *Public cloud*
 - *Hybrid cloud*
- **Private cloud:** The cloud infrastructure is provisioned for exclusive use by a single organization comprising multiple consumers (e.g., business units). It may be owned,

managed, and operated by the organization, a third party, or some combination of them, and it may exist on or off premises.

- **Community cloud:** The cloud infrastructure is provisioned for exclusive use by a specific community of consumers from organizations that have shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be owned, managed, and operated by one or more of the organizations in the community, a third party, or some combination of them, and it may exist on or off premises.
- **Public cloud:** The cloud infrastructure is provisioned for open use by the general public. It may be owned, managed, and operated by a business, academic, or government organization, or some combination of them. It exists on the premises of the cloud provider.
- **Hybrid cloud:** The cloud infrastructure is a composition of two or more distinct cloud infrastructures (private, community, or public).

Lesson No. 03

HISTORY AND BACKGROUND OF CLOUD COMPUTING

Module No – 003:

- **Computer Scientist John McCarthy** is attributed with delivering the idea that computations will be provisioned as **utilities in future**. This idea was presented in **1961**.
- In 1960s and 1970s, the **mainframes (giant powerful computers)** were **leased** out by the **manufacturers**.
- The idea of **grid computing** emerged in **1990s** to use the **processing power of networked PCs** for **scientific calculations** during **idle** times.
- In **1990s**, **Salesforce.com** started bringing remotely provisioned software services to the enterprises. **Amazon Web Services (AWS)** were launched in **2002**.
- In **2006**, the term “**cloud computing**” emerged that enabled organizations to “**lease**” the **computing capacity and processing power** from **cloud providers**.

Module No – 004: Overview of Cluster Computing:

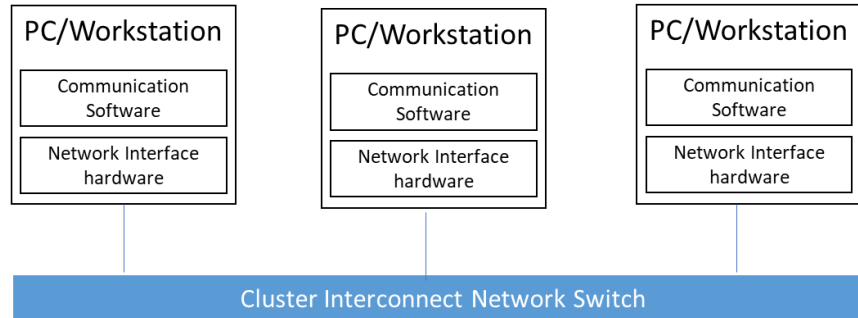
- A **computer cluster** is a collection of **interconnected stand-alone** computers which cooperate to work as a **single resource pool** of **computing resources**.
- **Clusters** became popular in **1990s** when **mainframes** and traditional **supercomputers** were becoming less **cost-effective** for **high performance computing (HPC)**.
- In **2010**, out of top **500** supercomputers. **85%** were **computer clusters** built with **homogeneous nodes**.
- **Cluster computing** has laid the foundation of modern day **super computers, computational grids and cloud computing**.
- Important Benefits of Cluster Computing:
 - **Scalability**
 - **High availability and fault tolerance**
 - **Use of commodity computers**

- Cluster Architecture (basic):

Sequential and Parallel Applications

Parallel Programming Environment

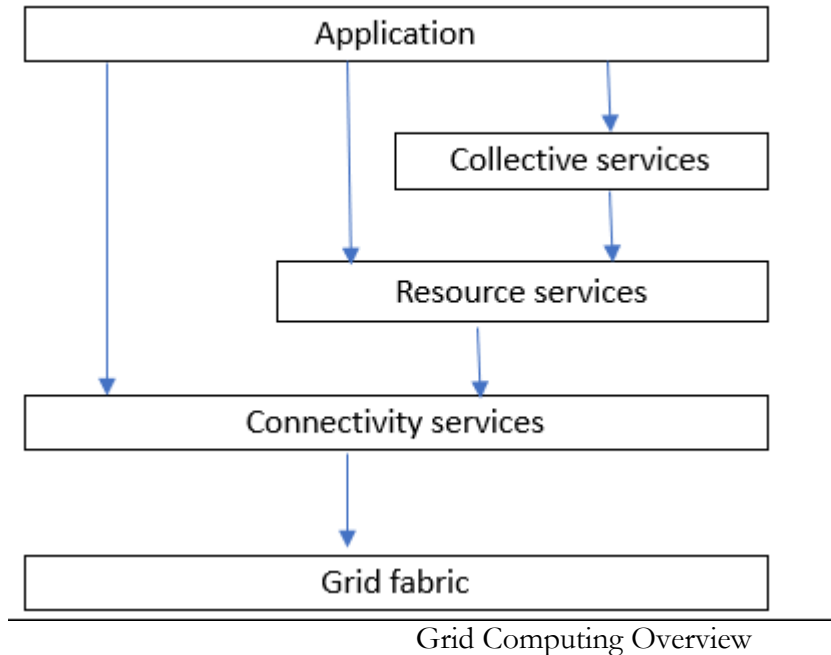
Cluster Middleware Ensuring High Availability and Single System Image



Cluster Architecture

Module No – 005: Overview of Grid Computing:

- The **grid** is an **integrated computing** infrastructure for bringing together **computers** to create a large collection of **compute, storage, and network resources**.
- Grid** is used to solve **large-scale computation** problems or to enable **fast information retrieval** by registered **users or user groups**.
- Computers** include PCs, workstations, server clusters, supercomputers, laptops, notebooks, mobile computers, PDAs, etc.
- Building **virtual grid** through **CPU scavenging**: Creating a grid by using unutilized CPU cycles in a network of computers at night or periods of inactivity.
 - This is done on **voluntary** basis. The grid hosts donate some **RAM, disk space and network bandwidth** as well.
 - The most famous example is the **SETI@Home** which applied over **3 million** computers to achieve **23.37 TFlops** as of **Sept. 2001**.
- Grid Middle ware Layered Architecture (deployed on participant computers):**



- **Application:** The top layer consisting of user applications to be run on grid.
- **Collective Services:** Focus on interaction among the resources. implements functions such as resource discovery, scheduling, brokering etc.
- **Resource service:** Deals with the aggregated computing resources (software and hardware) available for user applications in collective operations.
- **Connectivity Layer:** Provides the core networking among the computational resources of fabric layer through physical or virtual networking.
- **Grid fabric:** Consists of all the computational resources such as storage systems, catalogs, network resources, servers and their network connections.

Module No – 006: Difference between Cluster, Grid and Cloud Computing:

- The purpose of *Grid Computing* is to solve large scale computational problems.
- Just like *Clusters*, except that
 - The **Grids** make use of **computational resources** are spread across the nation or the globe.
 - These computational resources are owned by **different organizations** and are shared (as **grid resources**) by **multiple users**.
 - **Grids** heavily depend upon **WAN/LAN** resources.
 - **Virtual Supercomputer** term is derived from **Grid Computing** whereby multiple computers collaborate over network to create an illusion of a **single big computer**.
- As compared to cloud:
 - The resources do not join or leave the grid dynamically.
 - Majority of the resources are not provisioned from data centers.

- Several organizations may unite to form a grid in the shape of a virtual organization (VO). For example multiple hospitals and research centers may collaborate in a VO to find a cure for cancer.

Module No – 042: Business Drivers for Cloud Computing:

- Various business drivers lure the organizations to start using **Cloud**.
- These include (but not limited to):
 - **IT Capacity Planning**
 - **Cost Reduction**
 - **Organizational Agility**
 - IT Capacity Planning:
 - It is the estimation and fulfillment of future IT requirements of an organization.
 - The over provisioning of IT happens when acquired equipment is more than the estimated requirements. Resulting in over expenditure.
 - The under provisioning occurs when the equipment turns out to be inadequate to fulfill the IT requirements of the future.
 - IT Capacity planning is a difficult job as it should cover the fluctuating load.
 - Usually the companies adopt any of the following strategies:
 - **Lead Strategy:** Adding new IT capacity in anticipation of future needs.
 - **Lag Strategy:** Adding new IT capacity when the IT resources reach the full utilization
 - **Match Strategy:** Adding IT capacity in small increments.
 - The **capacity planning** may lead to adopting the option of **Cloud Computing** and then planning for future needs of **Cloud resources rental** instead of **purchasing the IT equipment**.
 - Cost Reduction: The costs include
 - Cost of acquiring the IT infrastructure
 - Operational overheads such as technical personnel salaries, upgrades, utility bills, security, accounts and administrative staff salaries
 - Why not choose the Cloud instead ?
 - **Organizational Agility:** It is the responsiveness to the change. We consider the *change* in IT for this topic.
- A possible shift, **upgrade or acquiring** a new **software** may require to upgrade the **hardware**.
 - The routine procedures and the business may come **to halt** or the competitors may out run if the organization fails to invest in IT just because of lack of **affordability**.
- **The Cloud on the other hand, just charges for the usage of IT resources, no need to invest in infrastructure.**

BASICS OF COMPUTERS**Module No – 008:**

- **Mainframe:**
 - A **mainframe** is a large, expensive, powerful server that can handle hundreds or thousands of connected **users/servers** **simultaneously**. For example a single mainframe server of **IBM's Z series** can provide the equivalent computing throughput of at least **500 servers**.
 - In **1960s and 1970s**, the **mainframes** were **leased** out by the **manufacturers** rather than sold because of **enormous cost of ownership**.
- **Mainframe leasing model:**
 - The customers were charged on **monthly basis** for the **use of hardware** such as **CPU, memory and peripheral devices**.
 - The **software (compilers, editors etc.)** usage was charged for the **time of usage**.
 - The **mainframe leasers** used to develop **customized software** exclusively for a **client organization** and **charged** for it.
 - The **client** was also **charged** for the **maintenance** of those **customized software**.
 - This model still exists in the form of **cloud computing**.
- **Server:**
 - A **server** is a **computer** which provides **services** to other **computers** and/or **devices** connected to it. Services provided by a **server** include the **controlled access to hardware and software resources and storage**.
 - A **server** can support hundreds and thousands of **simultaneous users**.
 - Servers are available in a variety of sizes and types.
 - **Web server:** **stores websites and web apps and provides them on your desktops and mobiles through web browsers.**
 - **Domain Name Server (DNS):** **Stores domain names and the corresponding IP addresses.**
 - **Database server:** **Hosts database and provides access to data and provides data manipulation functionality.**
- **Desktop:**
 - A **desktop** is a **computer** which is designed to remain in a **stationary** position. It is used as a **personal** computer.
 - Intended to be used by **one person at a time**.
 - Performs the activities such as
 - **Input**
 - **Processing**
 - **Output**
 - **Storage**

BASICS OF DATA COMMUNICATIONS

Module No – 009:

- **Data Communication:** Exchange of data over some transmission medium between two devices.
- The following factors are essential for data communication:
 - Data must be delivered to correct destination.
 - There must be timely delivery of the data.
 - There must not be uneven delay among the packet arrival time during audio or video transmission.
- Components:
 - **Message:** The data to be sent. Can be text, numbers, pictures, audio and video.
 - **Sender**
 - **Receiver**
 - **Transmission medium:** The physical path through which a message travels from sender to receiver.
 - **Protocol:** The set of agreed-upon communication-rules between sender and receiver devices. Two devices can be connected but not communicating without a protocol.
- Data Representation:
 - **Text:** Represented by bit pattern called code e.g.; Unicode and American Standard Code for Information Interchange (ASCII).
 - **Numbers:** Directly converted binary of the number. ASCII is not used to represent numbers.
 - **Images:** Sent as binary patterns. Image is represented by a matrix of pixels. *Pixel* is a small dot. Each pixel is assigned a bit pattern on the basis of color.
 - **Audio:** A continuous stream of data. Different from text, numbers and images.
 - **Video:** Can be a continuous stream or a sequence of image combinations.

Module No – 010: Data Flow:

- Data Flow:
 - **Simplex:** Unidirectional communication in which either one of the sender or receiver device can transmit. For example: key board, monitor etc.
 - **Half Duplex:** Both devices can communicate but one at a time. The entire capacity of the transmission medium is available to the transmitting device. For example: walkie-talkies.
 - **Full Duplex:** Both devices can send and receive at the same time. The transmission medium should provide separate paths (channels) for the transmission of each device. For example telephone conversation is full duplex.

BASICS OF COMPUTER NETWORKING

Module No – 011:

- **Computer networking** was conceived in **1960s** soon after the invention of **computers**.
- A **network** is a collection of **computers and devices** connected together through **transmission media**.
- Devices:
 - **Hosts:** Large computers, desktops, laptops, cellular phone or security system.
 - Connecting devices:
 - **Router:** A device which connects the network with other networks.
 - **Switch:** A device which connects devices within the network.
 - **Modem:** A device which changes the form of data (modulates-demodulates).
 -
- Network Criteria:
 - ~~Performance: It is often evaluated by two metrics:~~
 - **Throughput** (bulk of data transmitted in unit of time) and delay.
 - **Performance:** It is often evaluated by **two** metrics:
 - Increasing the **throughput** may increase the **congestion** and hence increase the **network delay**.
 - The **transit time** (message travel time) and **response time** (time between inquiry and response) indicate the **network performance** also.
 - **Reliability:** It is measured in terms of **frequency of network failure**, time to recover from a **failure** and **robustness from disasters**.
 - **Security:** Protecting data from unauthorized access and damage, and implementation of security policies and procedures for recovery from breaches and data losses.
- Physical Structures:
 - **Network Connections:** Communication can only take place if the devices are **simultaneously connected to the same communication-path or link or connection**.
 - **Link:** A link can be dedicated link (Point to Point) or shared among devices (multipoint).

Module No – 012: Network Topologies:

- **Mesh:** Every device has a dedicated point to point link to every other device.
 - Advantage: **Robustness of network from failure of any link**.
 - Disadvantage: **The bulk of cabling involved**.
- **Star:** All devices are connected to a central device. Unlike mesh, there is no direct traffic between any two devices but through the central device such as **hub**.

- Advantage: Requires only one I/O port in each device as compared to mesh.
- Disadvantage: If the central device fails, the whole network fails.
-
- **Bus:** A multipoint topology in which one long cable is used as a network backbone.
 - Advantage: Ease of installation. Requires less cabling than mesh and star.
 - Disadvantage: Difficult to extend, signal drops along the length of cable results in limited number of connections, breaking of backbone cable isolates the network segments and introduces noise.
- **Ring:** The devices are connected in the form of ring. Each device acts as repeater.
 - Advantages: Easy to expand and alter the network.
 - Disadvantage: Failure of a single device can disable the entire network, transmitting device needs to retain the token signal to perform transmission which slows down the data rate.

Module No – 013: Network Types:

- **Local Area Network (LAN):** It is a privately owned network and has a scope of an office, building or a campus. A LAN can even extend throughout a company.
 - Each host in a LAN has a unique identifier or address.
 - The communication packets between any two hosts in a LAN contain the source and destination hosts' addresses.
 - Key features:
 - Media type: wired/wireless, twisted pair/cable/fiber, radio, infrared
 - Topologies: Bus, Star, Mesh, Ring, Tree
 - Bit rate: from 1Mbps to 1Gbps
 - Unicast, Broadcast, Multicast
 - Typical LANs:
 - **Ethernet (CSMA/CD):** Carrier Sense with Multiple Access with Collision Detection (retransmission after collision detection)
 - **Local Talk (CSMA/CA):** CSMA with Collision Avoidance (reserve the media before transmission)
 - **Wireless LAN:** IEEE 802.11, Range: < 100 m, Speed: 2Mbps
 - **Token Ring:** A token travels around the ring, it must be retained by the sender computer to send a single packet, 4,6 or 100 Mbps
 - **FDDI:** Token ring with fiber optic cable, 100 Mbps
 - **ATM:** Star based, uses switch, multiple devices can communicate simultaneously, 25, 45, 155, 600+ Mbps
- **Wide Area Network (WAN):** A network that spans large geographical area such as town, cities, states or even countries. Usually interconnects multiple LANs.
 - Unlike LAN which is owned by the user organization, a WAN is normally created and run by communication companies. It is leased to the user organizations.
 - Types: Point to Point (P2P), Switched

- **P2P WAN:** Connecting two devices through wired or wireless media eg; connecting two LANs to form a private internet or internetwork of a company.
- **Switched WAN:** A network with more than two ends. It is a combination of several P2P WANs connected by switches.
- **Metropolitan Area Network (MAN):** It is a computer network covering a large geographical area bigger than LAN and smaller than WAN.
 - Diameter: 5 to 50 km, several buildings or a whole city
 - MAN is not owned by a single organization generally just like WAN. The MAN equipment are usually owned by a **service provider**.
 - MAN usually provides high speed connectivity to allow sharing regional resources.

Module No – 014: Switching:

- A WAN is a switched network in which a switch connects two links together to forward data from one network to the other.
- **Two** common types of switched networks are:
 - **Circuit-Switched Network:** A dedicated physical connection (circuit) is established, maintained and terminated through a carrier network for each communication session.
 - Used extensively by telephone companies. Only useful when all the circuits are being utilized simultaneously; otherwise the network is being underutilized.
 - **Packet-Switched Network:** It is a WAN switching method in which a single link is shared among multiple network devices.
 - Statistical multiplexing is used to enable devices to share the packet-switching circuits.

Module No – 015: The Internet History and Accessing the Internet:

- **Internet:** It is a network of interconnected networks which include:
 - **Backbones:** Large networks owned by communication companies such as PTCL, AT&T etc.
 - **Provider Networks:** Use the service of backbone for a fee. Connected to backbone through *peering points*. Sometimes connected to other provider networks as well.
 - **Customer Networks:** Use the services such as internet connectivity provided by provider networks and pay a fee to provider for that.
 - The **Backbones** and **provider networks** are also called **Internet Service Providers (ISPs)**.
 - Accessing the Internet:
 - **Telephone Networks:** Dial-up service, DSL Service
 - **Cable Networks**
 - **Wireless Networks**
 - Internet today: **World Wide Web, Multimedia, Peer-to-Peer Applications**

Module No – 016: TCP/IP Suite:

- **TCP/IP Protocol Stack:** Transmission Control Protocol (TCP) was proposed in 1973 to ensure a reliable, end-to-end and error free transmission control.
 - It was later split into TCP and Internet Protocol (IP) layers with IP handling the message routing and TCP performing the error control.
 - Since 1981, TCP/IP is included in the operating systems.
 - Consists of layers of protocols which paved the way for creating today's internet. These layers help in dividing a complex task into several smaller and simpler tasks:
 - **Physical Layer:** Deals with transmission of bits into signals and transmission of signals over the link.
 - **Data-link Layer:** Creates the frames of data. Each frame contains the data and is addressed with the MAC address of the receiving device and also contains the MAC address of sending device.
 - **Network Layer:** Is responsible for host to host communication through their IP addresses and related protocols. No control for error and congestion is performed. Packets are called datagrams.
 - **Transport Layer:** Responsible for transporting a message from application program running over source host to corresponding application program on destination host. Works on port numbers on corresponding hosts. Main protocols are:
 - **Transmission Control Protocol (TCP):** Provides flow control, congestion control and error control as it is a connection oriented protocol.
 - **User Datagram Protocol (UDP):** Is light weight and is not connection oriented.
 - **TCP Message = segment**
 - **UDP Message = datagram**
 - **Application Layer:** Consist of programs running on two hosts and exchanging messages. Applications use these protocols for communication:
 - **HTTP**
 - **FTP**
 - **SMTP**

Module No – 017: IP Addressing:

- The identifier used in Network layer of TCP/IP suit is the address of the internet connection of receiver and sender devices.
- **IPv4** is a 32 bit universally unique address while **IPv6** is the 128 bit universally unique address.
 - Total IPv4 addresses = 2^{32}
 - Total IPv6 addresses = 2^{128}
- The address is in fact of the connection and may change when the device is moved to another network.

- A device can have **two IP addresses** if it has **two connections with the internet**.
- **IP address** is usually represented by **dotted decimal numbers**. For example: **IP v4** address: **193.63.82.10**
- The **IP addresses** are allocated by the **Internet Corporation for Assigned Names and Numbers (ICANN)** to **ISPs** and **large** organizations.
- **Smaller** organizations can get **IP addresses** from **ISPs**.
- The IP address consists of a **prefix part (the Network ID)** and **postfix part (the Host ID or the Subnet)**.
- Classification of IPv4 addresses:
 - **Class A: 8 bits** for Network ID
 - Total networks **2^7**
 - Network id starts with **'0'** binary
 - First byte: **0 to 127**
 - **Class B: 16 bits** for Network ID
 - Total networks **2^{14}**
 - Network id starts with **'10'** binary
 - First byte: **128 to 191**
 - **Class C: 24 bits** for Network ID
 - Total networks **2^{21}**
 - Network id starts with **'110'** binary
 - First byte: **192 to 223**
 - **Class D: Used for multicasting**
 - **No prefix or Network ID**
 - First byte: **224 to 239**
 - **Class E: Reserved for future use**
 - First byte: **240 to 255**
- Address Masking:
 - **Classful addressing lead to depletion of IP addresses and/or unused addresses.**
 - Solution:
 - **Classless addresses with variable sized prefix according to the needs of organizations**
 - **A notation representing the length of prefix is added at the end of a classless address with a slash '/' to indicate the addresses in a classless address block.**

Module No – 018: IP Addressing:

- **Dynamic Host Configuration Protocol (DHCP)** is used to **automatically assign IP addresses** from an acquired block of **IP addresses**.
- Organizations use **private IP addressing** for the **LAN** devices and can use **Network Address Translation (NAT)** mechanism for having a single or a few registered global IP address/es for internet communication.
- **NAT enabled router** replaces the local address of sending device with the registered global IP address before sending the packets on internet.

- The mapping of incoming internet packets is done through **NAT table** which contains the source device **local address port number** of the program along with corresponding **IP address** of internet device.
- The **internal network** is supposed to initiate the internet communication in **NAT** mechanism for **mapping** to take place.
- Anytime a **host or a router** needs to find the **link-layer address** of another host or router in its network, it broadcasts an **Address Resolution Protocol (ARP)** request packet with the **destination IP address and its own IP and link level address**.
- The destination device replies to the sender device with its **link level address**.
- As compared to IPv4, the next generation IP protocol is **IPv6**. Some important changes are:
 - **No more NAT (Network Address Translation)**
 - **No more private address collisions**
- ~~• As compared to IPv4, the next generation IP protocol is IPv6. Some important changes are:~~
 - **Built-in authentication and privacy support**
 - **Easier administration (no more DHCP required)**
 - **Simplified routing**
- There are **three** categories of **IPv6** addresses:
 - **Unicast address: For a single connection**
 - **Multicast address: For a set of interfaces, one message transmitted to all.**
 - **Anycast address: For a group of interfaces, one message transmitted to a single interface**

Module No – 019: Ethernet:

- **It** is a popular **LAN** technology for **data-link and physical layers**.
- **Institute for Electrical and Electronic Engineers (IEEE)** developed an **Ethernet** standard known as **IEEE Standard 802.3**
- **TCP/IP** does not specify any **protocols** for **data-link and physical layers**. It **accepts all** the protocols working at these layers.
- Ethernet was developed in **1970s** and since then it has gone through **four** generations. ~~This evolution is in fact the reason of vast implementation of Ethernet in the world.~~
- Data rate **10 Mbps**
- **Connectionless**
- **No flow control**
- **No error control**
- **No retransmission and acknowledgement**
- **Hence unreliable like IP and UDP**
- **Uses link-layer addresses (the 48 bit MAC address)**
- **CRC** is present but corrupted frames are simply **discarded** by **receiver**
- Each frame is of **64-1518** bytes of length including **46-1500** bytes of data
- **CSMA/CD** is used
- **Unicast address:** Significant bit of **first** byte is **0**
- **Multicast address:** Significant bit of **first** byte is **1**

- **Broadcast address: All 48 bits are 1s.**
- Note: All devices on Ethernet receive all the messages but keep only those that are addressed according to above.
- Standard Ethernet types:
 - Bridged
 - Switched
 - Full duplex switches
- **Fast Ethernet:**
 - Next generation of standard Ethernet
 - Raised speed to 100 Mbps
 - Downward compatible with standard Ethernet (speed is reduced for compatibility)
 - Same 48 bit addressing
 - Frame format is same as of standard Ethernet
 - Uses star topology for connecting three or more devices using switch or hub
- **Gigabit Ethernet:**
 - 1Gbps speed
 - Compatible with standard and fast Ethernet
 - Star topology using hub or switch
 - Up to 5 kilometers range
- 10 Gigabit Ethernet:
 - 10 Gbps speed
 - Compatible with standard and fast Ethernet
 - Increases the range to tens of kilometers
 - Possibility to interconnect LANs

Module No – 020: Wired LAN vs. Wireless LAN:

- **Wired LAN:**
 - Medium: Wires
 - Broadcasting and multicasting possible when required
 - Physical connection to network
 - Hosts are connected through link layer switch
 - Connection to other networks through router
- **Wireless LAN**
 - Medium: Air
 - All devices are broadcasting
 - No physical connection to network
 - No link layer switch exists
 - Connected to other networks through access point (a device that connects a wireless and wired network)
- **IEEE 802.11**
 - It is a wireless LAN standard by IEEE that covers physical and data-link layers
 - Synonyms: WiFi, Wireless LAN
 - Basic architecture consists of an access point (AP) and capable devices connected to Access Point (AP)
 - In the absence of AP, the wireless devices connect to form adhoc network

- Multiple overlapping APs are used to cover a larger area
- A device is connected to **only one** of the nearest APs
- **CSMA/CA** is used. The sender sends a **Request To Send (RTS)** packet, the receiver sends **Clear To Send (CTS)** packet, the sender sends data after receiving **CTS**, the receiver sends **acknowledgement**, the other senders can send now.
- If no CTS is received, the sender marks it as a **collision**
- **802.11 a, b, g, n**
- 802.11a: **50 feet, 22 Mbps**
- 802.11b: **100 feet, 11 Mbps**
- 802.11g: **100 feet, 54 Mbps**
- 802.11n: **50 feet, 700 Mbps (to be implemented)**

Module No – 021: Bluetooth:

- It is a **wireless LAN** technology that provides **short distance connectivity** to devices which have different functionalities for example, **mobile phones, headsets, notebooks, desktops, computer peripheral devices, cameras and even the home appliances.**
- Multiple devices can be connected through **Bluetooth** to form a **piconet**
- Bluetooth supports:
 - **Voice and data transmission**
 - **Adhoc networking** for up to **10 meters**
- ~~● Multiple devices can be connected through Bluetooth to form a piconet~~
- **IEEE standard 802.15** covers the **Personal Area Network (PAN)** using **Bluetooth** for an area covering a **room**
- Versions:
 - **1.x:** up to **1Mbps**, **obsolete**
 - **2.x:** up to **3 Mbps**, improved pairing capability between devices from different manufacturers
 - **3.x:** up to **24 Mbps using WiFi 802.11**
 - **4.x:** Up to **24 Mbps**, works seamlessly with **4G**, works with data collection from sensors an **internet of things (IoT)**

Module No – 022: WiMAX:

- **WiMax** stands for **Worldwide Interoperability for Microwave Access**
- Provides **wireless** access to **Internet** for: **Homes and offices** when the wired access is either not available or is expensive (**fixed WiMAX**)
- Mobile phones (**mobile WiMAX**)
- **Fixed WiMAX** requires the installation of **antennas** at the premises of the subscriber to receive and send the data from the base station of **Internet provider.**
- **Mobile WiMAX** users move from one place to another while connected to the base station of **Internet provider** .

- WiMAX is the result of IEEE 802.16 project. It is a standard for wireless WAN (or MAN). The subscriber station may be tens of kilometers away from the base station of the provider.
- Remember that 802.11 is the standard for wireless LAN.
- Uses 48-bit MAC address of subscriber station and base station at Data-link layer
- Connection oriented protocol. Each connection has a unique id and hence there is no address field in the frame of WiMAX
- Full duplex communication

Module No – 023: Evolution of Cellular Networks:

- Cellular network or telephony is a radio-based technology
- Radio waves are electromagnetic waves propagated by antennas
- Note: Antenna is a transducer device which converts the altering current into radio waves and vice versa
- 7 billion mobile connections
- 25 billion interconnected devices count predicted in 2020
- Over 100 billion downloads completed in 2013, 270 billion expected in 2017
- The base stations receive from and transmit to cellular phones.
- Cellular Networks have evolved from first generation (1G) to fifth generation (5G). Let us briefly look at these generations:
 - 1G
 - Invented around 1980.
 - First implementation in Tokyo (Japan)
 - Based upon analog technology
 - Expanded to cover all the population of Japan in few years
 - Not secure
 - Anyone with an all-band radio can listen to calls and get the phone number of the subscriber
 - Analog mobiles were larger in size and heavy in weight
 - 2G
 - Invented in 1991, implemented first time in Finland
 - Technologies: Global System for Mobile (GSM) Communication, General Packet Radio Service (GPRS), Code Division Multiple Access (CDMA) [digital signal] and Enhanced Data Rates for GSM Evolution (EDGE)
 - Short Messaging Service (SMS), Multi-Media Messaging Service (MMS)
 - Typical data rate: 100 Kbps
 - Email, Web browsing, Camera phones
 - Signal strength decay problem, performance degrades with the rise in number of users in a cell (area maintained by a base station)
 - 3G
 - From 2000 to 2010
 - Technologies: CDMA, WLAN, Bluetooth, Universal Mobile telecommunication Systems (UMTS), High Speed Downlink Packet Access (HSDPA)

- Features: Global Roaming Clarity in voice calls, Fast Communication, Internet, Mobile T.V, Video Conferencing, Video Calls, Multi Media Messaging Service (MMS), 3D gaming and Multiplayer-Gaming, smart phones
- Typical data rate: Up to a few Mbps
- Expensive mobile phones, battery life issue
- 4G
 - Since 2010
 - Technologies: Long Term Evolution (LTE) Standard based on the GSM/EDGE and UMTS/HSPA, Multiple In Multiple Output (MIMO) smart antenna technology, Orthogonal Frequency Digital Multiplexing (OFDM), WiMAX
 - Typical data rate: Up to a few tens of Mbps
 - MAGIC: Mobile multimedia–Anytime anywhere–Global mobile support–Integrated wireless solutions–Customized personal service
 - Maintaining data rate is an issue, not fully implemented in all the world, battery consumption is a bigger problem than 3G
- 5G
 - To be implemented
 - Technologies: New releases of LTE
 - Faster data rate than 4G (> 1Gbps), higher data rate at cell edges
 - Research is still in progress

Module No – 024: Connecting Devices:

- These are the devices used to connect:
 - Hosts to form LANs
 - LANSs to implements WANs and Internet
- The class of each device depends upon the layer/s on which it operates. That is:
 - Hub: Physical layer
 - Link-layer Switch: Physical layer, Data-link layer
 - Router: Network layer, Data-link layer, Physical layer
- **Hub**
 - It is a multipoint repeater device used in star topology.
 - A repeater device regenerates the signal before it become too weak or corrupted.
 - The hub repeats the signal received from any port 'A' to all the other ports except the port 'A' (broadcasting)
 - This is because the hub is a physical layer device. It does not has its own MAC address and can not access the data-link layer address (MAC address) of the data frames.
- **Switch**
 - It is a multipoint bridge device.
 - A bridge joins two logical segments of the same network and intelligently forwards the packets from one segment to other on the basis of destination MAC address and forwarding table.

- It is a **two** layer device. It performs functionality on **data-link layer** as well as it **regenerates the signals** it receives.
- A **data-link layer switch** works by maintaining a **switching table** and forwarding the packets received from a port 'A' only to the destination port 'B'.
- **Switching** table consists of **MAC address** of the hosts arranged according to the **port numbers** to which they are attached. It is consulted before **forwarding a packet**.
- Switches perform learning to fill the **switching table** by reading the **MAC address** of sending device for each port.
- **Broadcast packets are forwarded to all ports**
- **In a situation when two LANs are connected through more than one switch then the looping problem can arise.**
- **Looping**
 - **The frame/s sent by one host 'X' in LAN1 to a host 'Y' in LAN2 will go through multiple switches and get duplicated when reaching the destination host.**
 - Reason: **The switches generically forward the frame received for an unregistered MAC to all the ports (except the sender's port).**
- Advantages of Switch
 - **Collision elimination**
 - **Connecting heterogeneous devices (in terms of data rate capacity)**
- **Router**
 - It is a **three** layer device:
 - **Physical** (regenerating the signals)
 - **Data-link layer**(checking the **MAC addresses** of **source and destination**)
 - ~~It is a three layer device:~~
 - **Network layer** (checks the **IP addresses** of **source and destination**, connects multiple networks to form bigger networks)
 - Has multiple interfaces. Each interface has a **MAC address** and **IP address**.
 - A router:
 - **Only processes those packets which are addressed to the interface at which they arrive.**
 - Has multiple interfaces. Each interface has a **MAC address** and **IP address**.
 - A **router** changes the source and destination MAC address when it forwards the packets.
- **Virtual LAN (VLAN):**
 - A **logical (not physical)** segment of a **physical LAN**.
 - **VLANs** are defined by **software**. Each **VLAN** is a work group in an organization, has a **VLAN ID** and receives the broadcast messages addressed to its own **ID**.
 - A **VLAN** may span over multiple **switches** in a **LAN**.
 - No need to update the **physical topology** to relocate a person from one VLAN to other, just the **software configuration** is to be updated.

Module No – 025: Routing:

- In a **physical** network, multiple LANs and WANs are joined together by the **routers**.
- Hence there can be more than one route between two hosts.

- **Routing** is a service of **Network** layer to find the best route.
- **Routing** is performed by applying **routing protocols** and using the **decision tables** called **routing tables** in each router.
- **Forwarding** is the action performed by a **router** on the basis of **routing protocol and routing table** according to the destination address of each packet received at any interface.
- At network layer, each message from higher layer is broken down into **packets**.
- A router performs **packet switching**.
- Types of routing:
 - **Unicast routing**: A router forwards the packet to only one of the attached networks.
 - **Multicast routing**: A packet is forwarded to multiple attached networks.
- Routing a packet from a source host to destination host can also be defined as routing a packet from a source router (the default router of the source host) to a destination router (the router connected to the destination network) through the intermediate routers using routing algorithms.
- Types of routing:
 - **Connectionless routing**: All packets of the same message are treated independently and may or may not follow the same route.
 - **Connection oriented routing**: All the packets of same message are labeled and routed through a *virtual circuit* or a fixed route.
- An **internet** can be considered as a **graph** with each **network** as an **edge** and each router as a **node**.
- In a weighted graph, each edge has a weight or cost.
- Least cost routing can be performed. Example algorithms: Distance-Vector routing, Link-State routing

Lesson No. 07

~~ADVANCED TOPICS OF COMPUTER NETWORKS~~

Module No – 026: Broadband Networks & Internet:

- ~~All clouds are inherently dependent upon internetworking or Internet for ubiquitously remote provisioning of IT resources.~~
- ~~The cloud providers and consumers connect to Internet through ISPs.~~
- ~~The largest backbone networks of the Internet are strategically interconnected by core routers.~~
- ~~The core routers connect the international networks.~~
- ~~The Internet has become a dynamic and complex aggregate of ISPs.~~
- ~~There is a hierarchical topology for worldwide interconnectivity composed of tiers.~~
- ~~There are three tiers of worldwide connectivity:~~
 - ~~Tier 1 consists of large scale international connectivity providers.~~
 - ~~Tier 2 consists of large regional ISPs connected to tier 1.~~
 - ~~Tier 3 consists of local ISP providers connected to tier 2.~~
- ~~The cloud providers and users connect directly to tier 3 providers.~~