

Computer Networks

Unit-1

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Course Objectives

- CO 1: Discuss fundamentals of network concepts and Reference Models
- CO 2: Discuss Communication media and switching techniques
- CO 3: Demonstrate Error control and protocols
- CO 4: Apply Routing algorithms and congestion control algorithms
- CO 5: Discuss Transport layer services and protocols
- CO 6: Describe Application layer protocols

UNIT-1

- What is Computer Network?
- Applications
- Network Hardware
- Network Software
- **The OSI Reference Model**
- **The TCP/IP Reference Model**
- **Examples of Networks (History): Novell Networks, Arpanet, Internet.**
- **Network Topologies: Mesh, Bus, Star, Ring, and Hybrid.**
- **Network Types: WAN, LAN, MAN.**

Day 1(02-07-2020): ILO

- What is Computer Network?
- Applications
- Network Hardware

What is CN?

A **computer network** is a set of **computers** connected together and able to exchange information with one another.



Applications

- **Business Applications**
 - Resource Sharing
 - Emails
 - VPNs
 - E-Commerce
- **Home Applications**
 - TV
 - Smart Homes (IoT)
 - Facebook, Twitter, etc.
- **Mobile Applications**
 - GPS
 - Smart Phones
 - Wearable Devices

Network Hardware

- Participants
 - Connecting Devices
 - Hubs, Switches, Routers, Modems, etc.
 - Communication Medium
 - Wired, Wireless
 - Edge Devices
 - PCs, Laptops, Servers, Sensors, Printers, etc.
- Types of Communication
 - Unicasting or Point to Point
 - Multicasting and Broadcasting

Day 2(03-07-2020): ILO

- Network Software
 - Protocol Hierarchy
 - Design Issues
 - Connection-oriented vs Connection-less
 - Relationship between Services and Protocols

Protocol Hierarchy

- Protocol
 - An agreement between the communicating parties on how communication is to proceed.
- Or
- Set of rules that governs the communication.
- Network Service
 - An application that provides data storage, manipulation, presentation, communication or other capability.
 - Examples: Normal Web Service, Secured Web Service, E-Mail, File server, Remote login, instant messaging, video conferencing, video broadcasting, VoIP Calls, Gaming, IoT,
 - Any service will be provided by clearly following a set of rules i.e. Protocols.

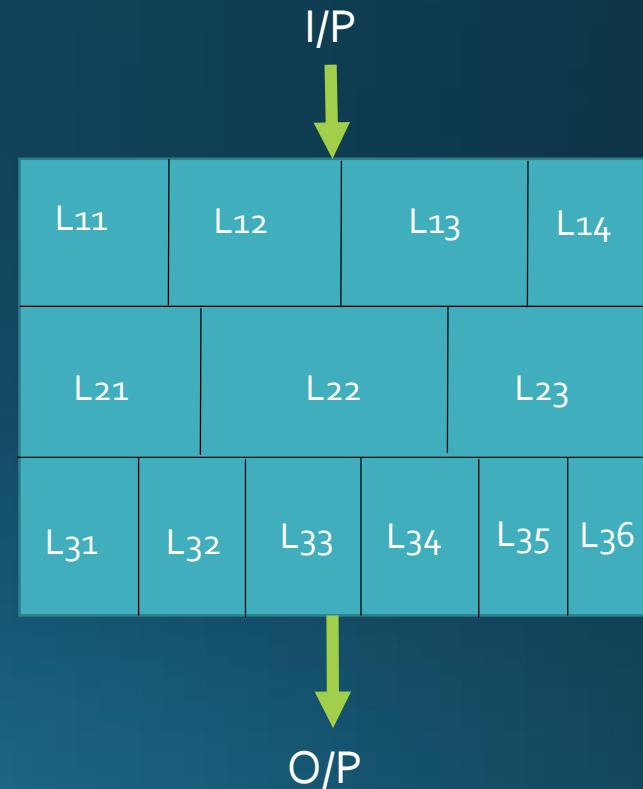
Protocol Hierarchy (Cont..)

- Network software is designed as a stack of layers, where every layer will have a set of protocols that does certain task.
- Imaging a network service as a simple program
 - Takes input from the user
 - Does some magic on it (process)
 - But instead of normal output, the program generates electrical/electro-magnetic/light signal as output.
- So if the program is a continuous program (Single Layer) then we need different programs to provide different services from first to last step.
 - It is like multiple programs created without using Modules/Functions that need to do all the tasks from taking input to generating signals.

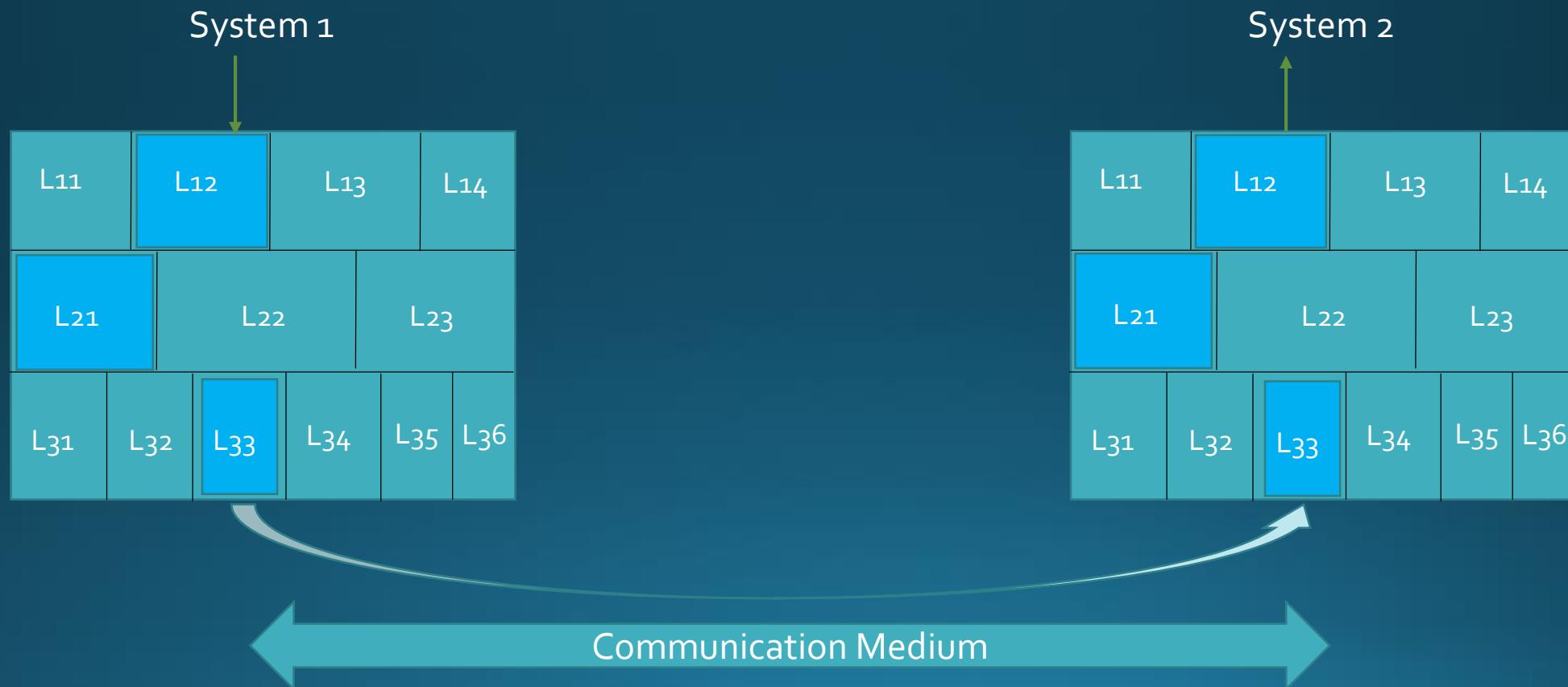


Protocol Hierarchy (Cont..)

- Drawback with single layer is:
 - Design Complexity is Very High
 - Instead, if we combine all the programs into one and divide the program using function/modules to eliminate repeated coding.
- As shown here one such program is capable of providing $4 \times 3 \times 6 = 72$ different types of services.
- Hence, the network software is a layered architecture with multiple protocols in each layer.
- Every layer will provide some service to above layer. (Taking input from above layer, processing it and giving it to bellow layer).

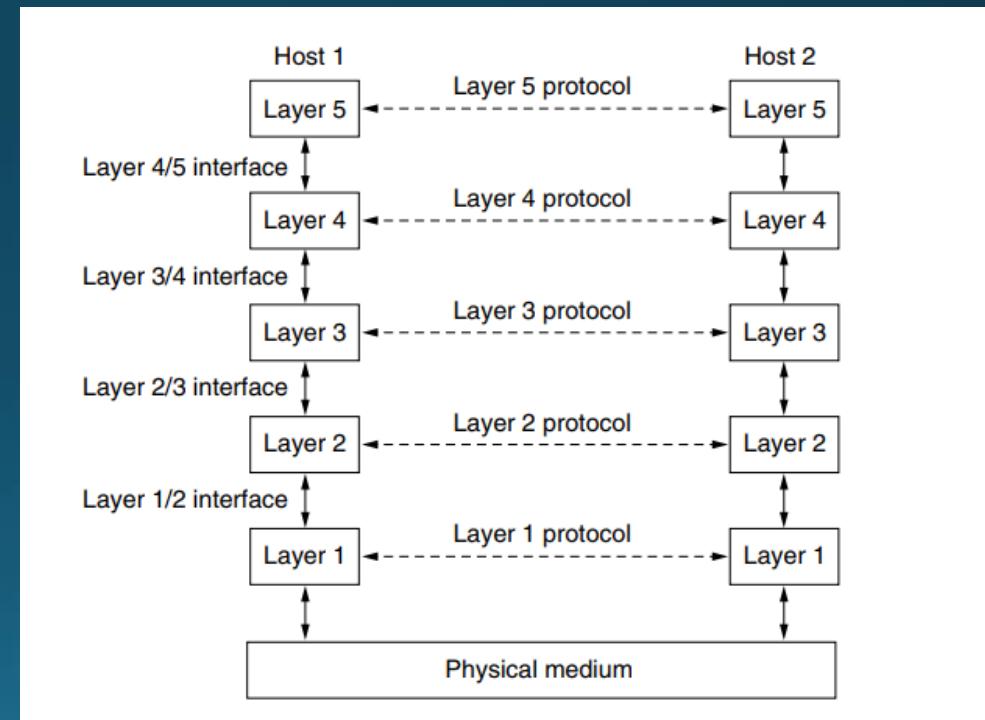


Protocol Hierarchy (Cont..)



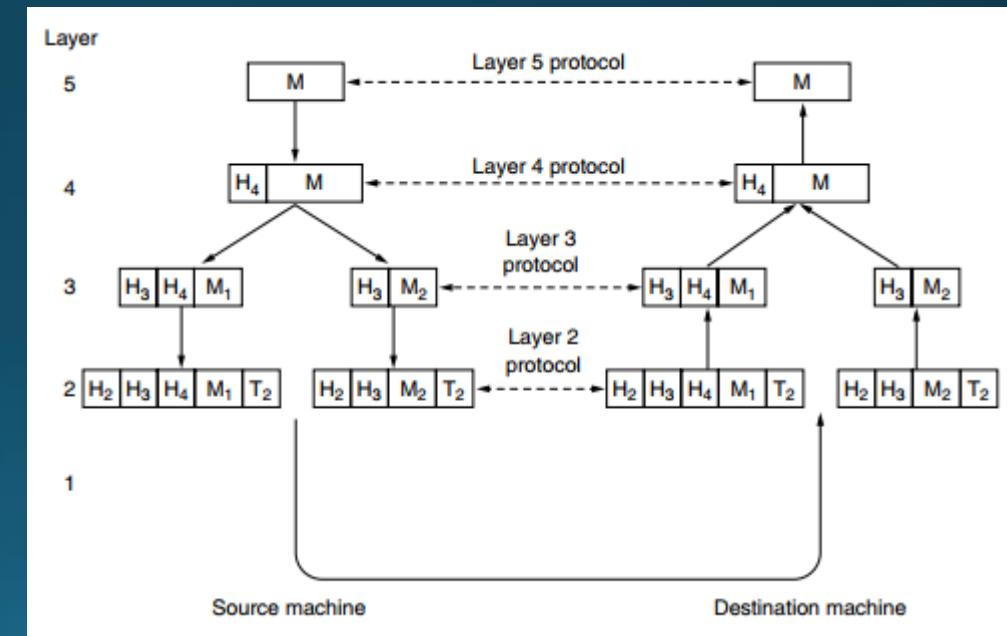
Protocol Hierarchy (Cont..)

- This layered concept provides information hiding, abstract data types, data encapsulation like in OOPs.
- The entities comprising the corresponding layers on different machines are called **peers**.
- A set of layers and protocols is called a **network architecture**.



Protocol Hierarchy (Cont..)

- When data moves from top layer to bottom headers will be added.
- When data moves from bottom layer to top headers will be removed.



Design Issues

- Reliability – Error Control Mechanisms in 2 different layers in two levels.
- Routing – 1 Layer Completely Dedicated
- Addressing and Naming – Diff layers use their diff type of addressing for different levels of communication.
- Scalability
- Flow Control
- Congestion Control
- QoS in Real-time Services

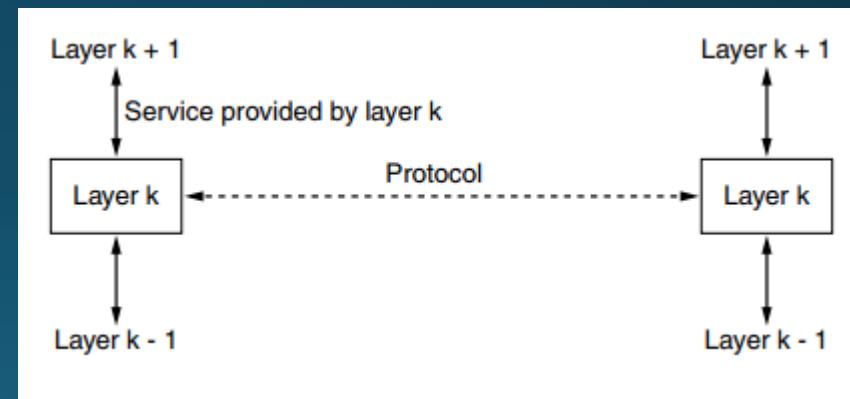
Connection-oriented vs Connection-less

- Layers can offer two different types of service to the layers above them.
- **Connection-oriented** service is modeled after the telephone system.
 - **Negotiation:** Maximum message size, QoS level required, other Issues.
 - Addressing in the begining only.
- **connectionless** service is modeled after the postal system.
 - No need of negotiation.
 - Addressing in every message.
- Reliable (Ack) and Unreliable (No-Ack) Services

	Service	Example
Connection-oriented	Reliable message stream	Sequence of pages
	Reliable byte stream	Movie download
Connection-less	Unreliable connection	Voice over IP
	Unreliable datagram	Electronic junk mail
	Acknowledged datagram	Text messaging
	Request-reply	Database query

Relationship between Services and Protocols

- Service (Layers)
 - A *service* is a set of primitives (operations) that a layer provides to the layer above it.
 - The service defines what operations the layer is prepared to perform on behalf of its users, but it says nothing at all about how these operations are implemented.
 - A service relates to an interface between two layers, with the lower layer being the service provider and the upper layer being the service user.
- Protocol
 - Entities use protocols to implement their service definitions.
 - They are free to change their protocols at will, provided they do not change the service visible to their users.



Day 3(03-07-2020): ILO

- Network Protocol Suite Architectures
 - **OSI Reference Model**
 - TCP/IP Reference Model

Day 4(08-07-2020): ILO

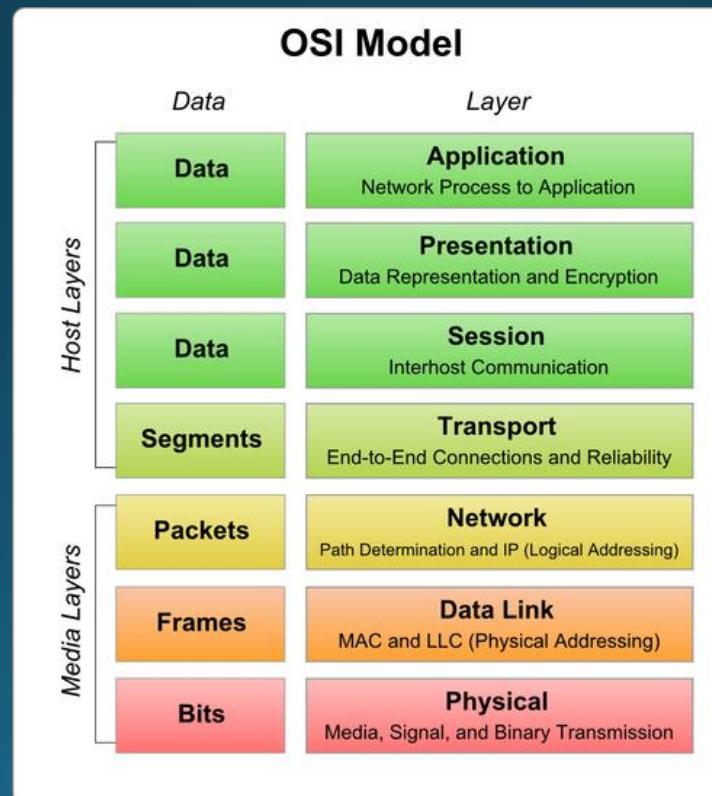
- Able to understand the fundamentals of OSI and TCP/IP Reference models and can differentiate between them.

Reference Models

- **OSI Reference Model**
 - Developed in response of a International Standard Organisation's (ISO) proposal in 1993 & revised in 1995.
 - Not used anymore but layers model is quite general and valid.
- **TCP/IP Reference Model**
 - Designed for ARPANET(Universities and DARPA) for support different types of communications via the network in 1974 & redefined and standardised in 1988
 - Model was not clearly defined but the protocols are widely used.
- The current Internet is successor of ARPANET hence continued using TCP/IP.

OSI Reference Model

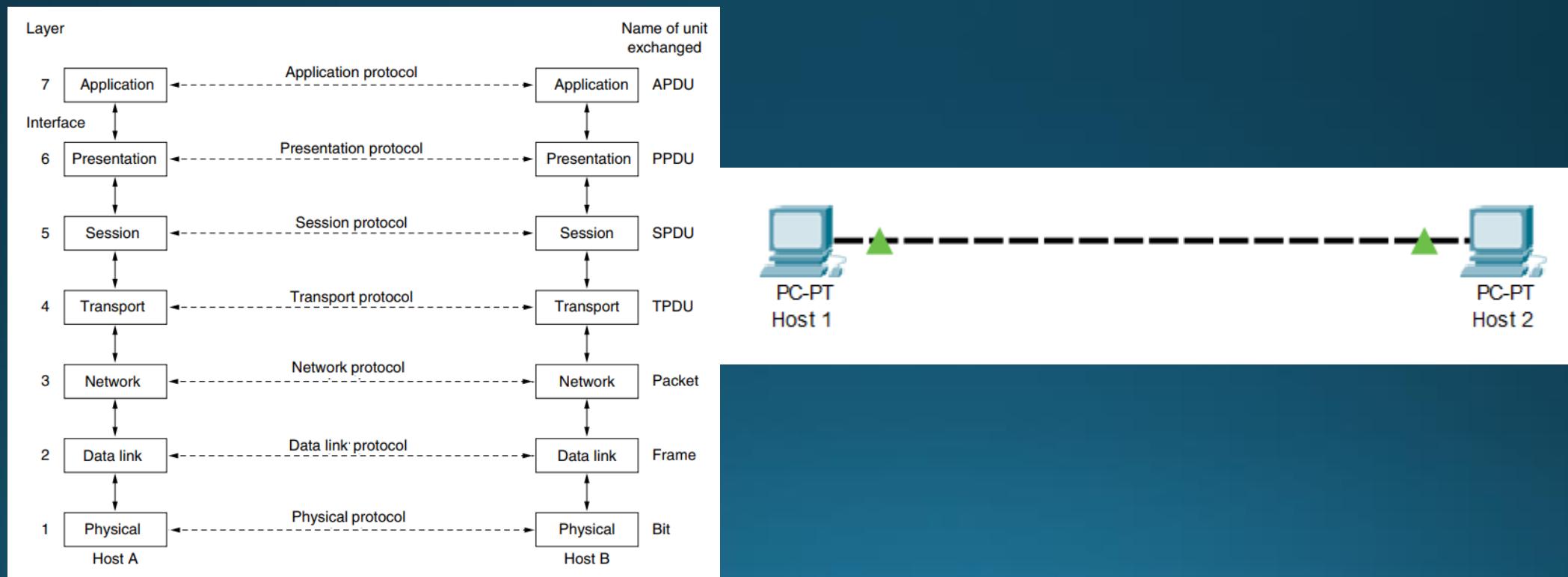
- ISO-OSI: International Standards Organization – Open System Interconnection



OSI Reference Model(Cont.)

- So why 7 layers? The principles behind the coming up with 7 are
 - A layer should be created where a different abstraction is needed
 - Each layer should perform a well-defined function
 - The function of each layer should be chosen with an eye toward defining internationally standardized protocols
 - The layer boundaries should be chosen to minimize the information flow across the interfaces
 - The number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity and small enough that the architecture does not become unwieldy.
- Note that the OSI model itself is not a network architecture because it does not specify the exact services and protocols to be used in each layer. It just tells what each layer should do.

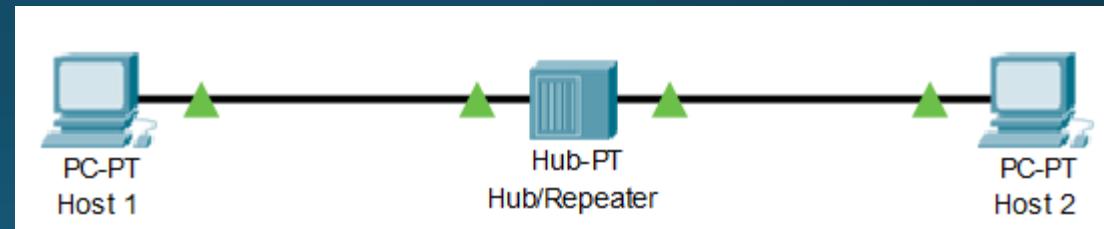
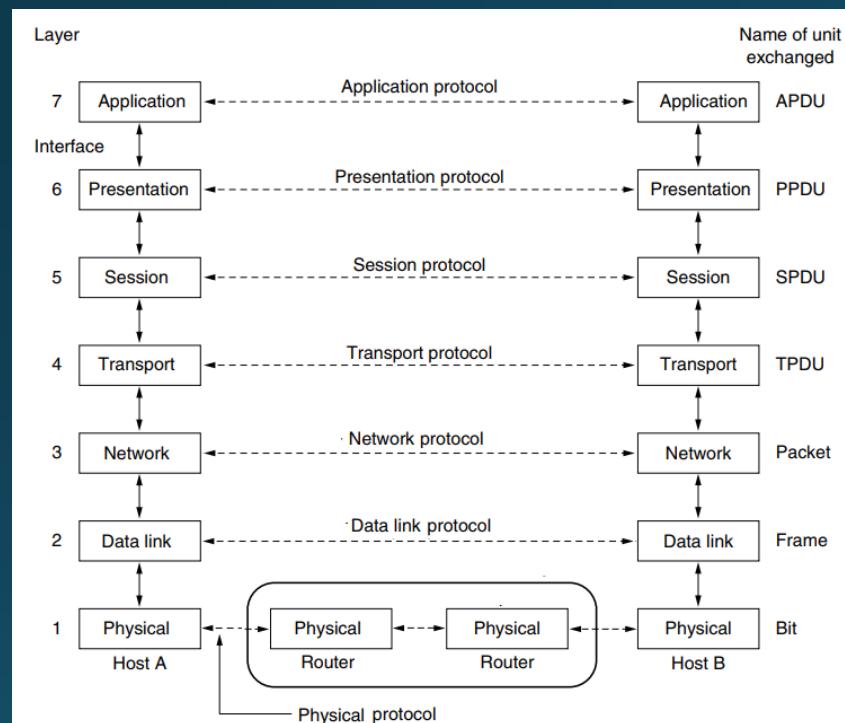
OSI Reference Model(Cont.)



OSI Reference Model(Cont.)

- **Physical Layer:** Concerned with transmitting raw bits over a communication channel.
 - To do so, take cares of
 - What electrical signals should be used to represent a 1 and a 0
 - How many nanoseconds a bit lasts
 - whether transmission may proceed simultaneously in both directions
 - How the initial connection is established
 - How the connection was closed once done
 - How many pins the network connector has? and what is purpose of each pin
 - These design issues largely deal with mechanical, electrical, and timing interfaces, as well as the physical transmission medium, which lies below the physical layer.

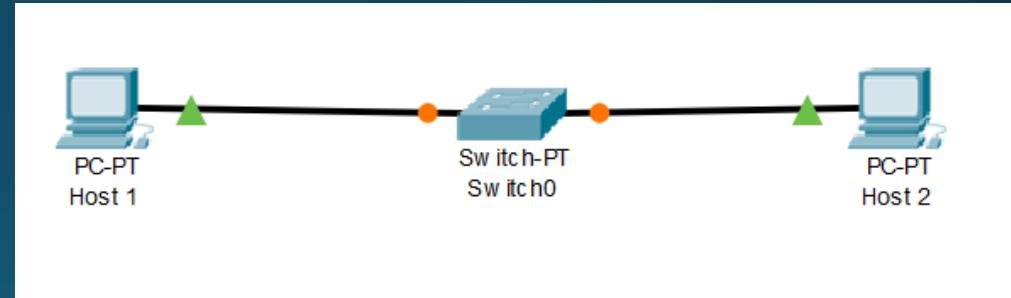
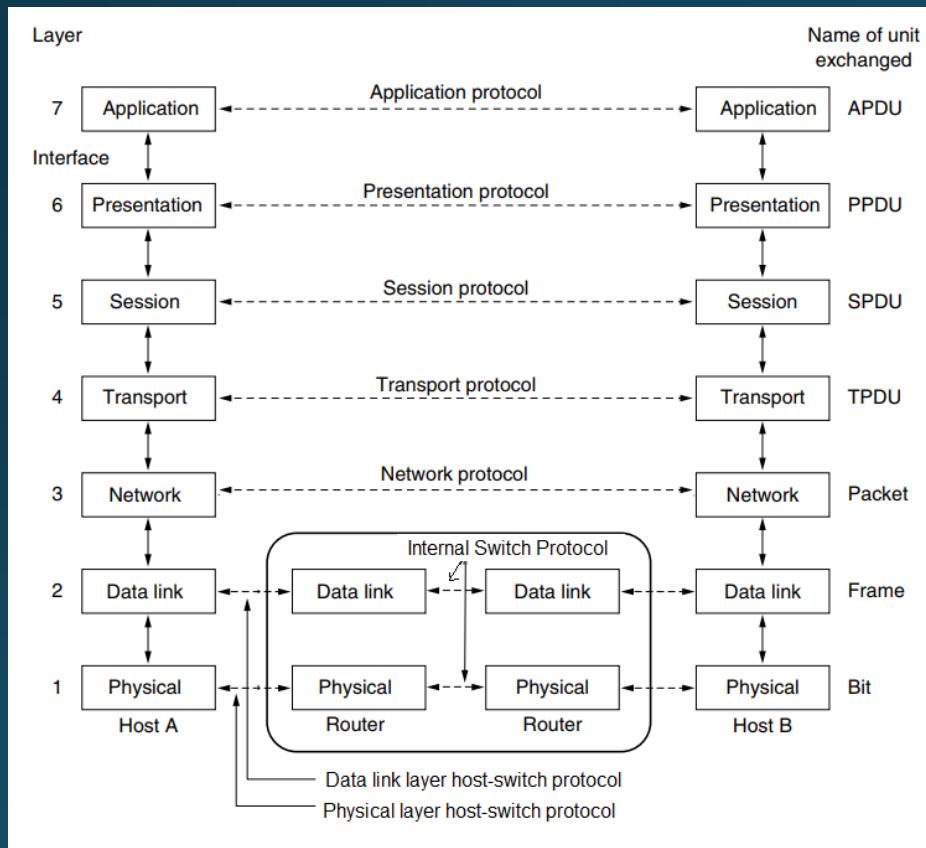
OSI Reference Model(Cont.)



OSI Reference Model(Cont.)

- **Data Link Layer:** Transform a raw transmission facility into a line that appears free of undetected transmission errors.
 - DLL will achieve this by
 - having the sender break up the input data into **data frames** and transmitting them sequentially.
 - Make the receiving device send an acknowledgement in reliable services.
 - Also make sure that a fast receiver will not overrun a slow receiver.
 - In case of broadcasting channels (multi-point), also decides, who can access and transmit (Medium Access Control).
 - Uses physical (MAC) Address for delivery of information to next node (node-to-node delivery).

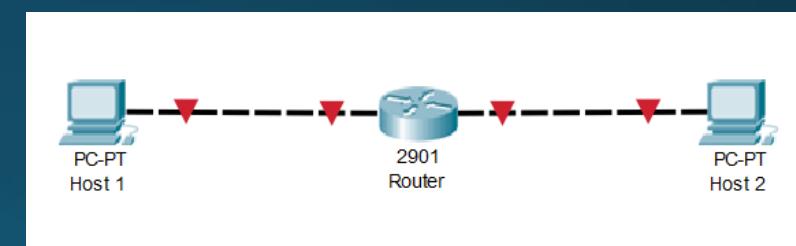
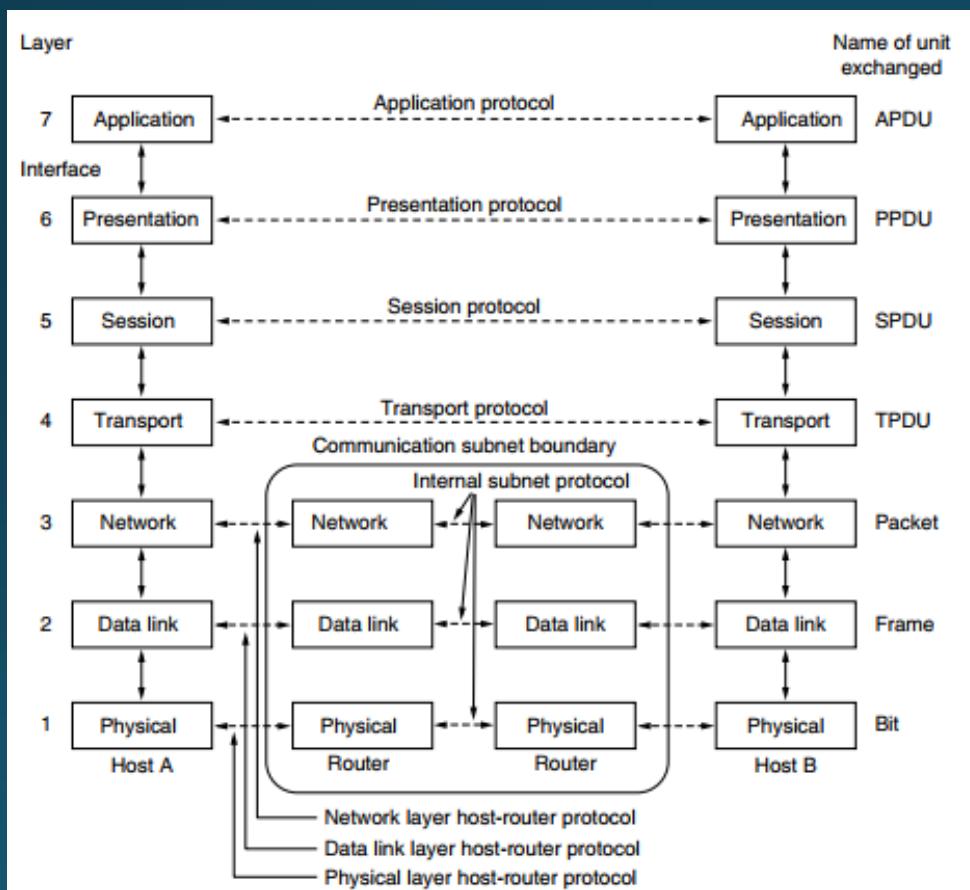
OSI Reference Model(Cont.)



OSI Reference Model(Cont.)

- **Network Layer**
 - Controls the operation of a subnet
 - Takes care of “Routing” from host to host that are in different networks (host-to-host delivery).
 - Uses logical (IP) address for identifying and delivering to a node in the network.

OSI Reference Model(Cont.)

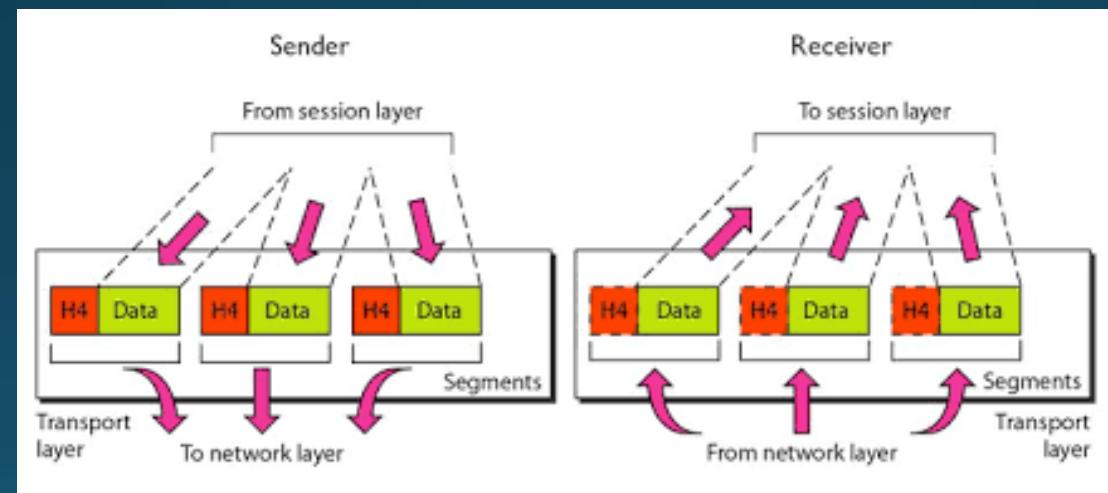


OSI Reference Model(Cont.)

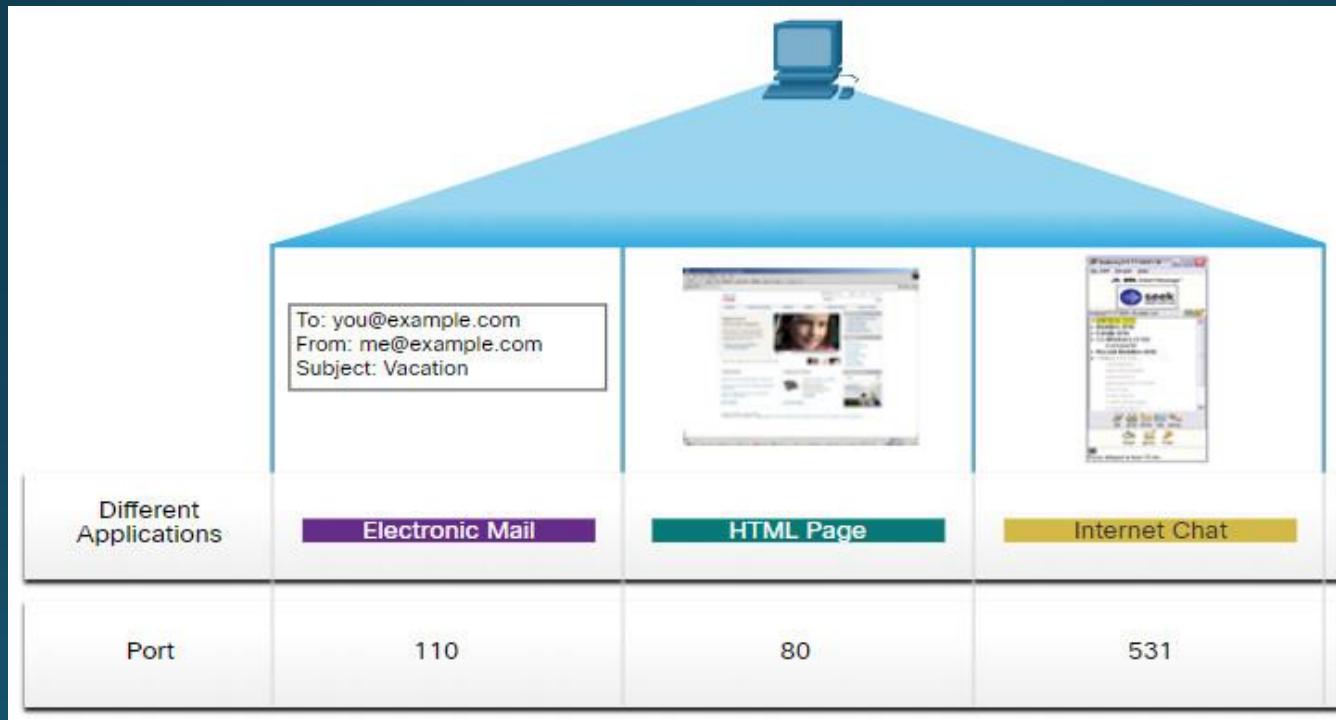
- **Transport Layer**

- Accepts data from above it, split it up into smaller units if need be, pass these to the network layer, and ensure that the pieces all arrive correctly at the other end.
- Provides two types of services, selects which service to provide based on need.
 - Connection-oriented service
 - Connection-less service
- Uses port address to identify communicating processes on both ends (process-to-process delivery)
- A true end-to-end delivery of information.

OSI Reference Model(Cont.)

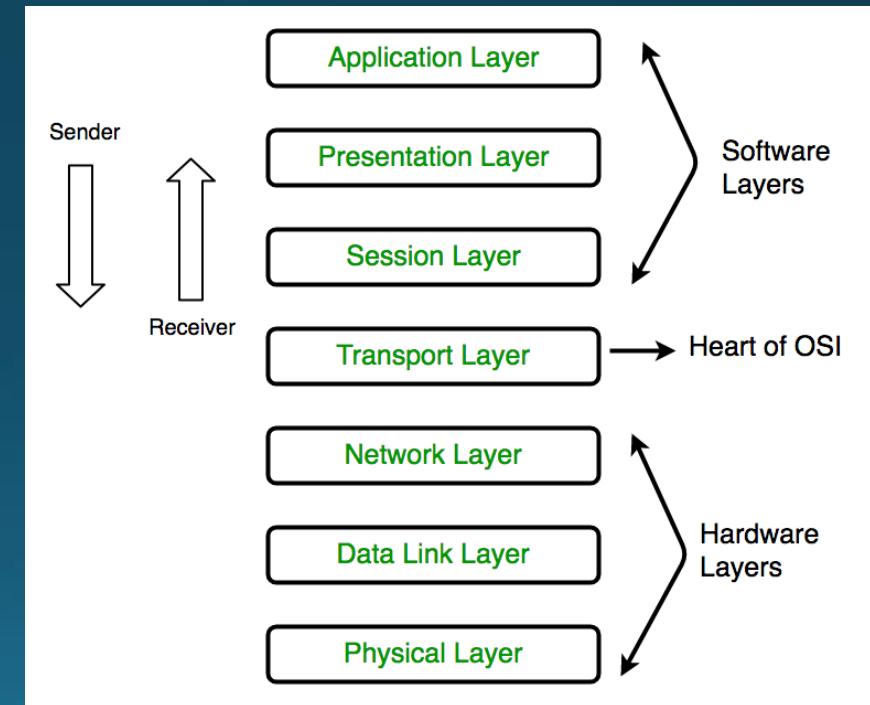


OSI Reference Model(Cont.)



OSI Reference Model(Cont.)

- The physical layer, data link layer, and network layer are N/W dependent layers. They deliver of information from the current device to the next device with the corresponding layer access.
- Whereas the remaining 4 layers will be there in only end devices normally, they will work in the perspective of source to destination(end-to-end).



OSI Reference Model(Cont.)

- **Session Layer**

- Allows users on different machines to establish **sessions** between them
- Sessions offer various services
 - Dialogue Control: Who's turn is it to communicate.
 - Token management: Prevention of simultaneous access of same operation (like deadlocks)
 - Synchronization

OSI Reference Model(Cont.)

- **Presentation Layer**

- Concerned with the syntax and semantics of the information transmitted
- To make it possible for computers with different internal data representations to communicate.
- Defines and uses higher level abstract data structures and encoding mechanisms.

OSI Reference Model(Cont.)

- **Application Layer**

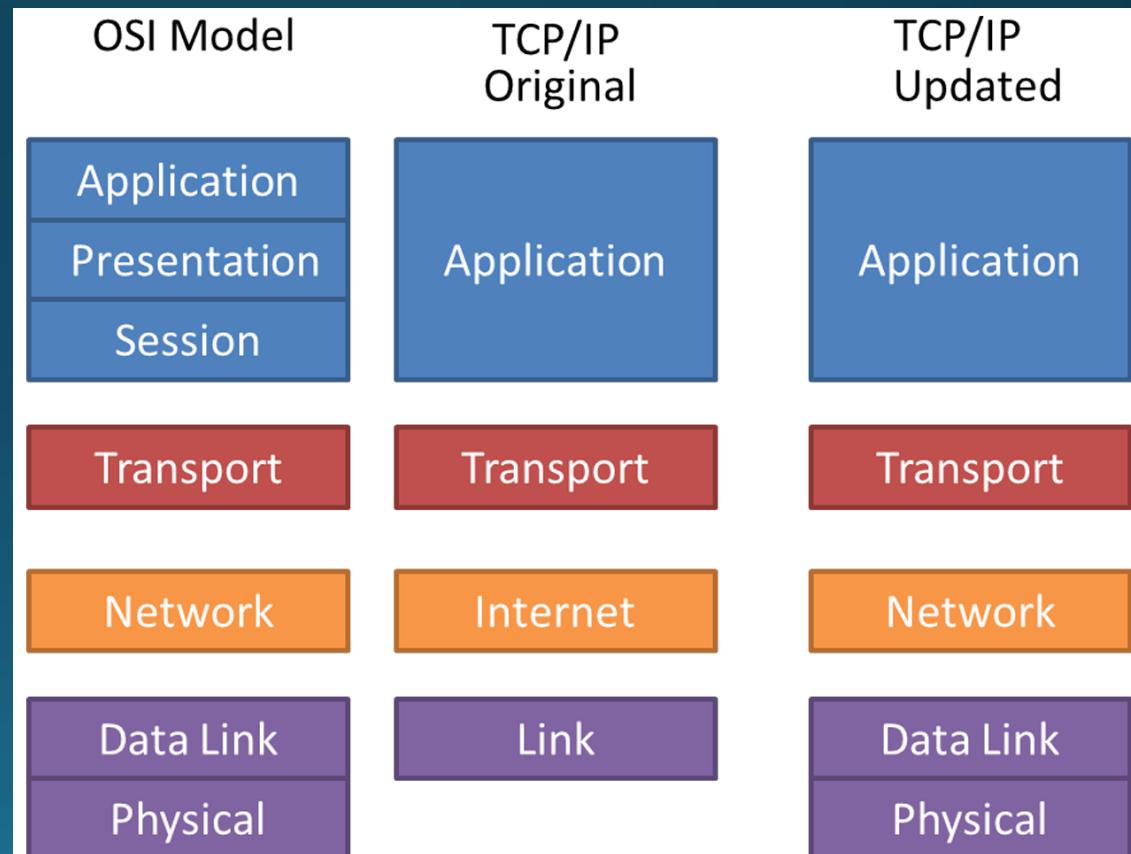
- Contains a variety of protocols that are commonly needed by users.
- Provides a systematic and easy way for users to get a network service.

Day 5(13-07-2020): ILO

- Able to differentiate between TCP/IP and OSI.
- Able to understand the inception of Internet

TCP/IP Reference Model

- ▶ Named after the two major protocols TCP (Transport Layer) and IP (Internet Layer).



TCP/IP Reference Model (Cont.)

- **Link Layer**
 - An interface between hosts and transmission links.
- **Internet Layer**
 - Its job is to permit hosts to inject IP packets into any network and have them travel independently to the destination and delivered (potentially on a different network).
 - The internet layer defines an official packet format and protocol called **IP (Internet Protocol)**, plus a companion protocol called **ICMP (Internet Control Message Protocol)** that helps it function.
 - Routing
 - Uses IP addresses (Logical address) to do host-to-host delivery.

TCP/IP Reference Model (Cont.)

- **Transport Layer**

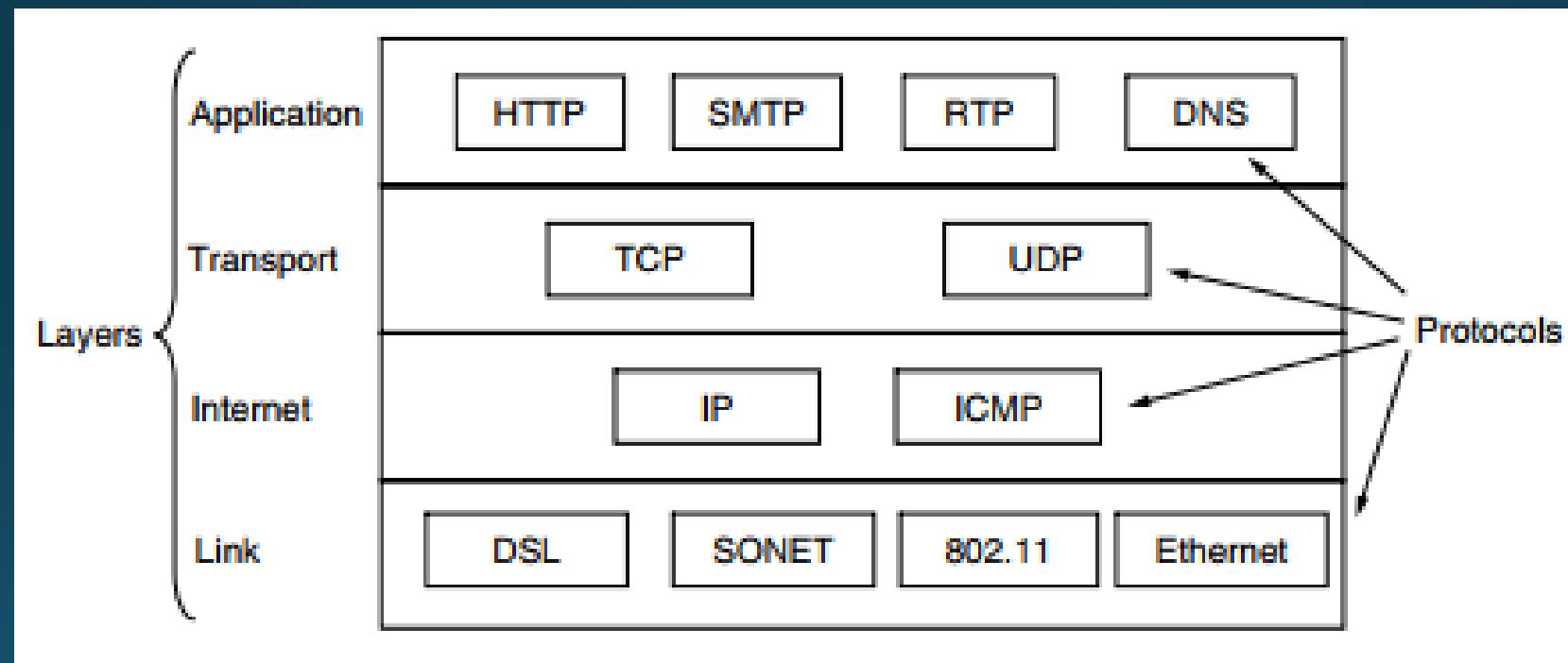
- It is designed to allow peer entities on the source and destination hosts to carry on a conversation, just as in the OSI transport layer.
- Segments data received from above layer and gives them to internet layer.
- Uses two protocols to provide process-to-process communication in two ways
 - TCP
 - Reliable Connection-Oriented Protocol
 - Sends information as stream of bytes.
 - Error Control, Flow Control
 - UDP
 - Unreliable Connectionless Protocol
 - Not provides Error Control, Flow Control.
 - For services that need prompt delivery: Video or Speech Communication

TCP/IP Reference Model (Cont.)

- **Application Layer**

- Applications in TCP/IP simply include any session and presentation functions that they require.
- Contain all the high level protocols like
 - TELNET: Remote Access
 - FTP: File Transferring
 - SMTP: Electronic Mails
 - HTTP: Web Service

TCP/IP Reference Model (Cont.)



OSI vs TCP/IP

- **Similarities**

- Based upon layered architecture.
- The OSI has seven layers while the TCP/IP has four layers.
- In both models, the layers above transport layer are application-oriented users of the transport service.

OSI vs TCP/IP

- **Differences**

- OSI model is a generic model that is based upon functionalities of each layer. TCP/IP model is a protocol-oriented standard.
- OSI model distinguishes the three concepts, namely, services, interfaces, and protocols. TCP/IP does not have a clear distinction between these three.
- OSI model gives guidelines on how communication needs to be done, while TCP/IP define standards on which the Internet was developed. So, TCP/IP is a more practical model.
- In OSI, the model was developed first and then the protocols in each layer were developed. In the TCP/IP suite, the reverse is true.
- The OSI has seven layers while the TCP/IP has four layers.

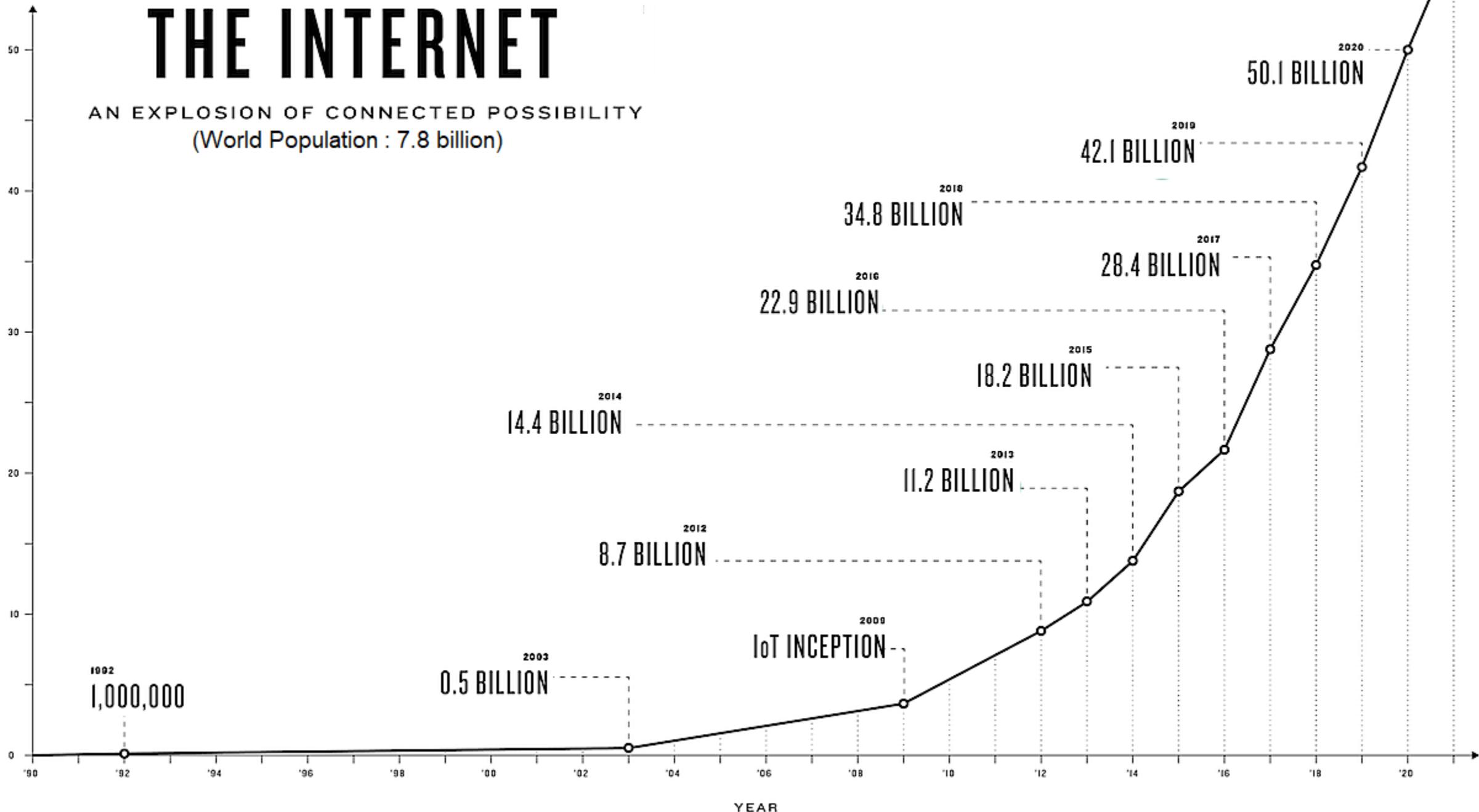
Example Networks

- INTERNET is a collection of vast networks
 - ARPANET
 - NSFNET
 - Other Networks

THE INTERNET

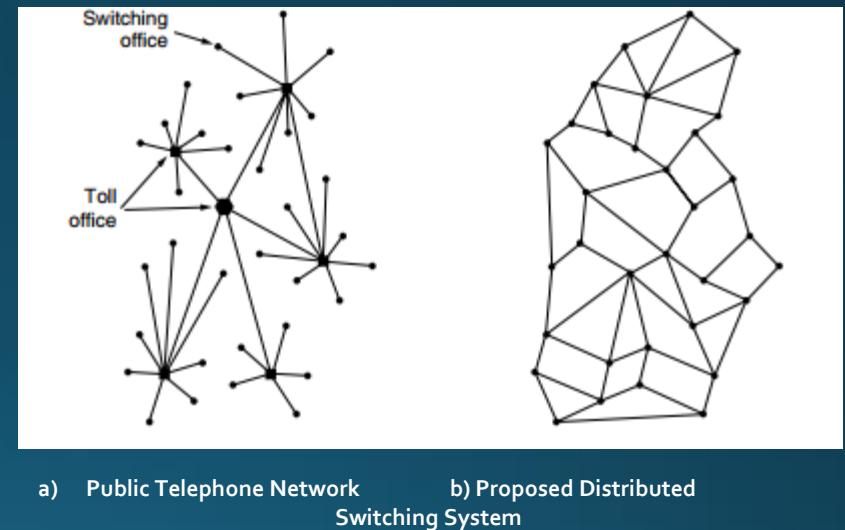
AN EXPLOSION OF CONNECTED POSSIBILITY
(World Population : 7.8 billion)

BILLIONS OF DEVICES



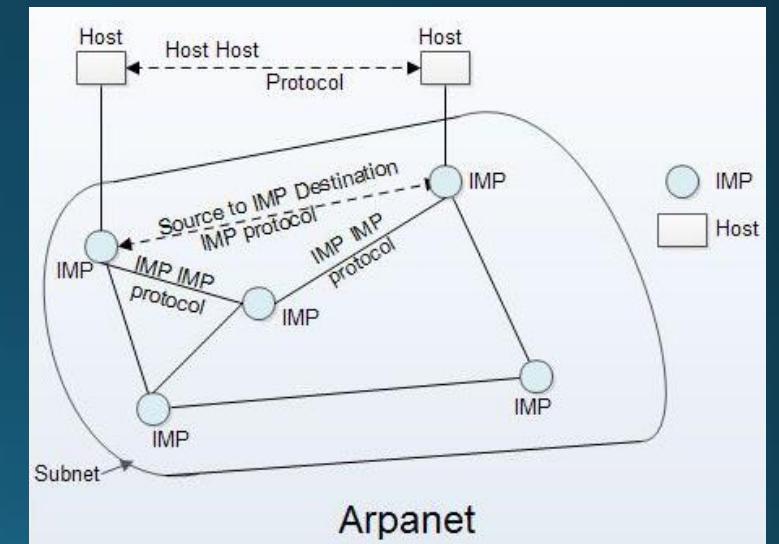
ARPANET

- ▶ Until 1960 US-DoD used public telephone network for military communication.
- ▶ The vulnerability of the system was that the destruction of a few key toll offices will bring down entire communication.
- ▶ Hence in 1960 Baran suggested a distributed switching system that was rejected by AT&T when asked to implement.
- ▶ By the order of director Bob Taylor, to provide remote access to computers an engineer Larry Roberts in Advance Research Projects Agency (ARPA), on suggestion of Wesley Clark, to build a **packet-switched subnet**, and concept of Donald Davies finally it was built on 1969.
- ▶ ARPA later became DARPA where D for Defence.



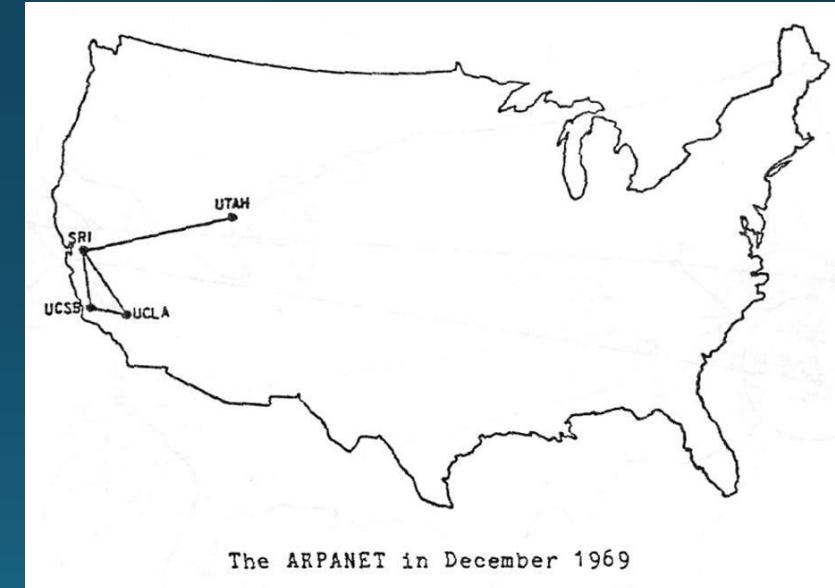
ARPANET (Cont.)

- ▶ The subnet would consist of minicomputers called **IMPs** (**Interface Message Processors**) connected by 56-kbps transmission lines.
- ▶ For high reliability, each IMP would be connected to at least two other IMPs.
- ▶ Each node of the network was to consist of an IMP and a host.
- ▶ A host could send messages of up to 8063 bits to its IMP, which would then break these up into packets of at most 1008 bits and forward them independently toward the destination.

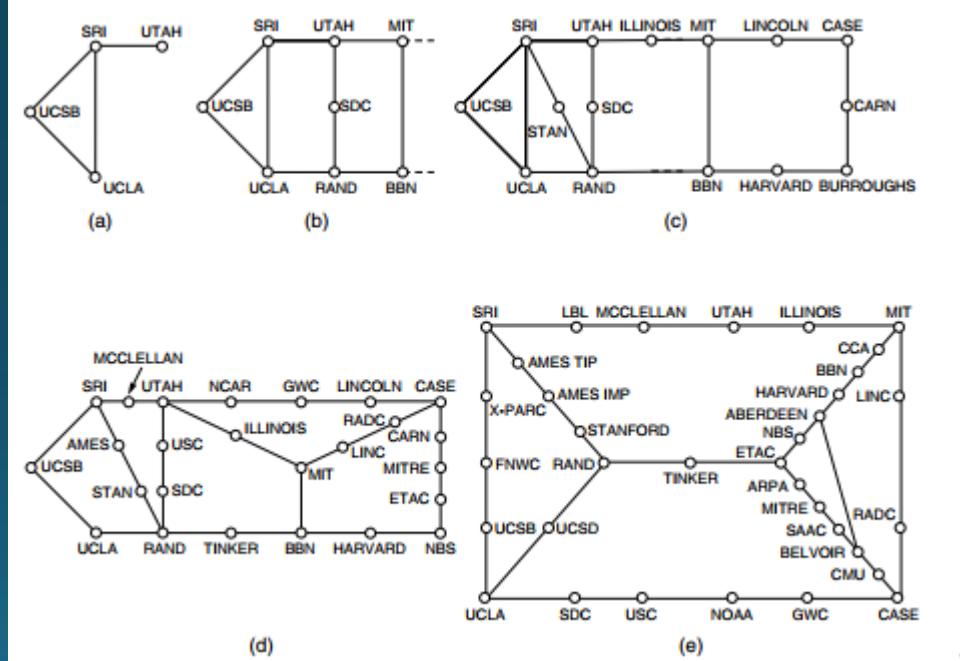
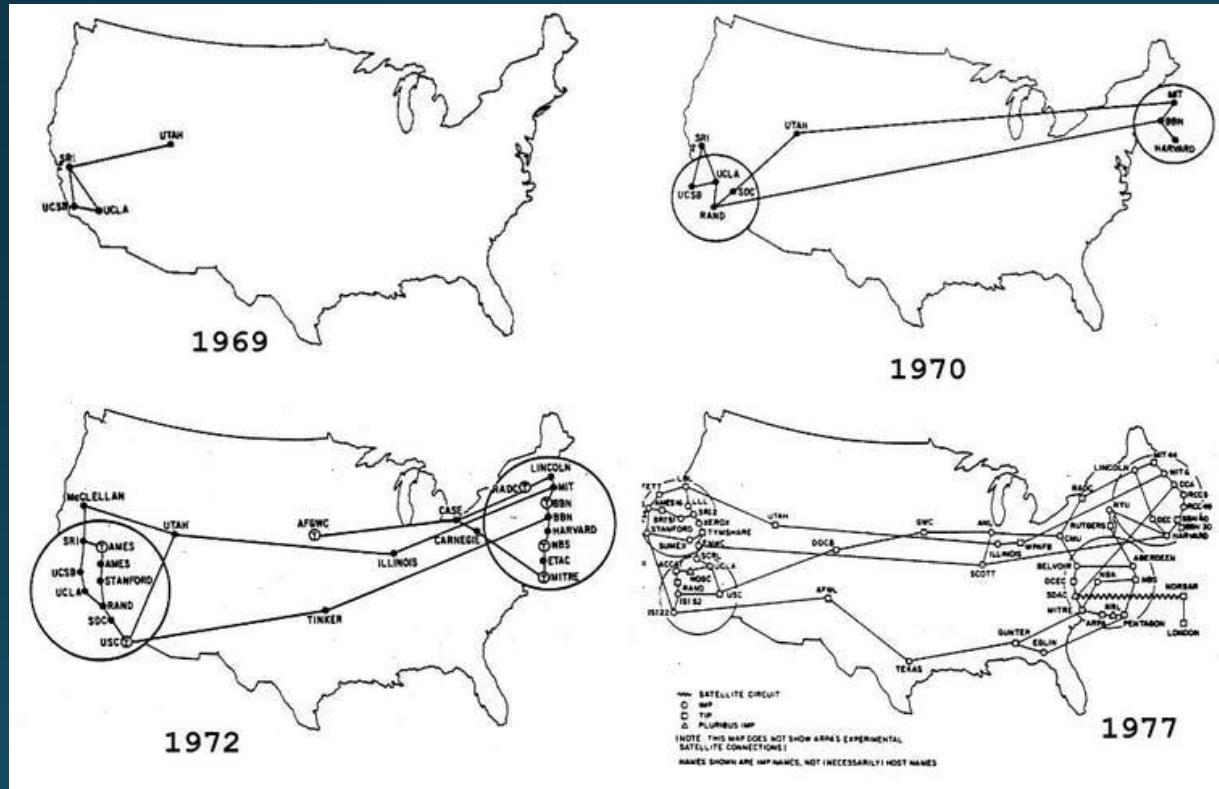


ARPANET (Cont.)

- The first network contains 4 nodes that are incompatible at 4 universities in US:
 - University of California, LA (UCLA)
 - University of California, SB (UCSB)
 - Stanford Research Institute (SRI)
 - University of Utah
- Later it grown exponentially.
- Upon experimented, and realizing that the protocols used in ARPANET were not efficient and not suitable. TCP/IP model came into picture.



ARPANET (Cont.)



NSFNET

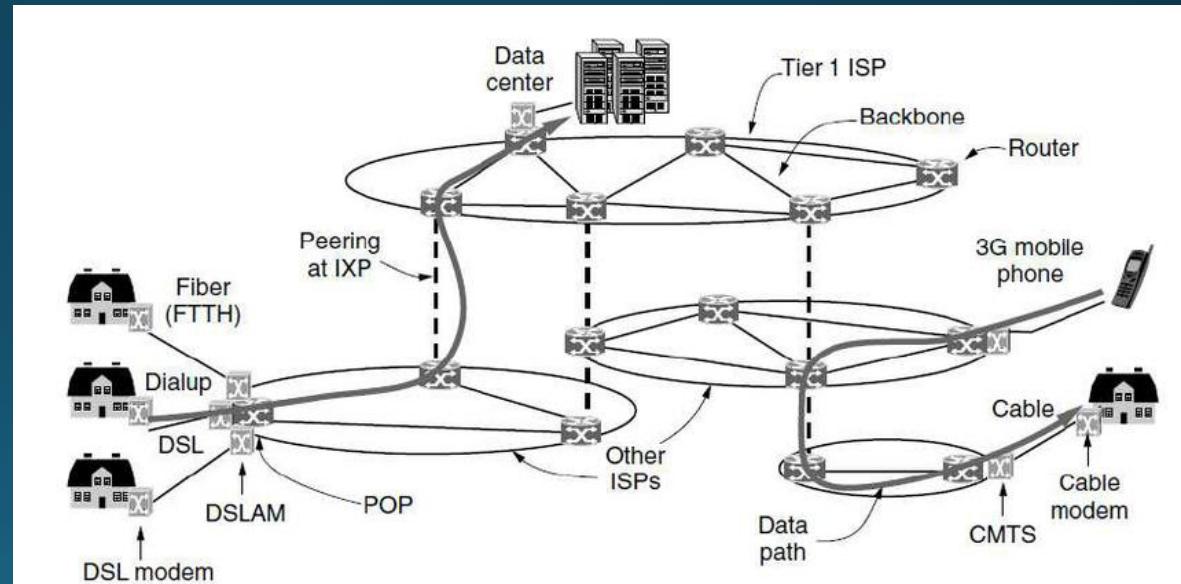
- By U.S. National Science Foundation in 1981 called Computer Science Network (CSNET) to connect different CS departments and industrial research labs to ARPANET via Dial-Up leased line.
- Later in 1986 NSF sponsored NSFNET.
- But due to over growth maintenance, NSF encouraged MERIT, MCI, and IBM to form a non-profit corporation called **ANS (Advanced Networks and Services)**, a first step along the road of commercialization.
- In 1991 ANS took over NSFNET upgraded and formed ANSNET.

Other Networks

- During 1990s many other countries built national research networks
- They include
 - EuropaNET by Delivery of Advanced Network Technology to Europe (DANTE) around 1993.
 - EBONE (European Backbone) went online in 1992 and was deactivated in July 2002.

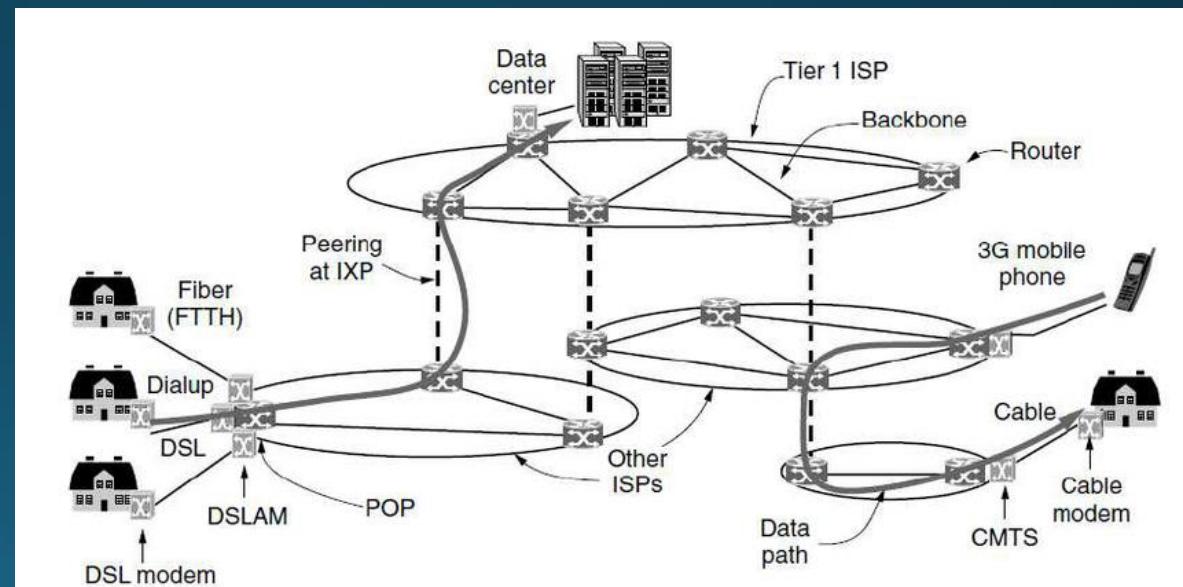
INTERNET

- The linking of commercial networks and enterprises (ARPANET, NSFNET, EuropaNET, EBONE and many more) by the early 1990s marked the beginning of the transition to the **modern Internet**.
- Internet architecture is a multilevel architecture.



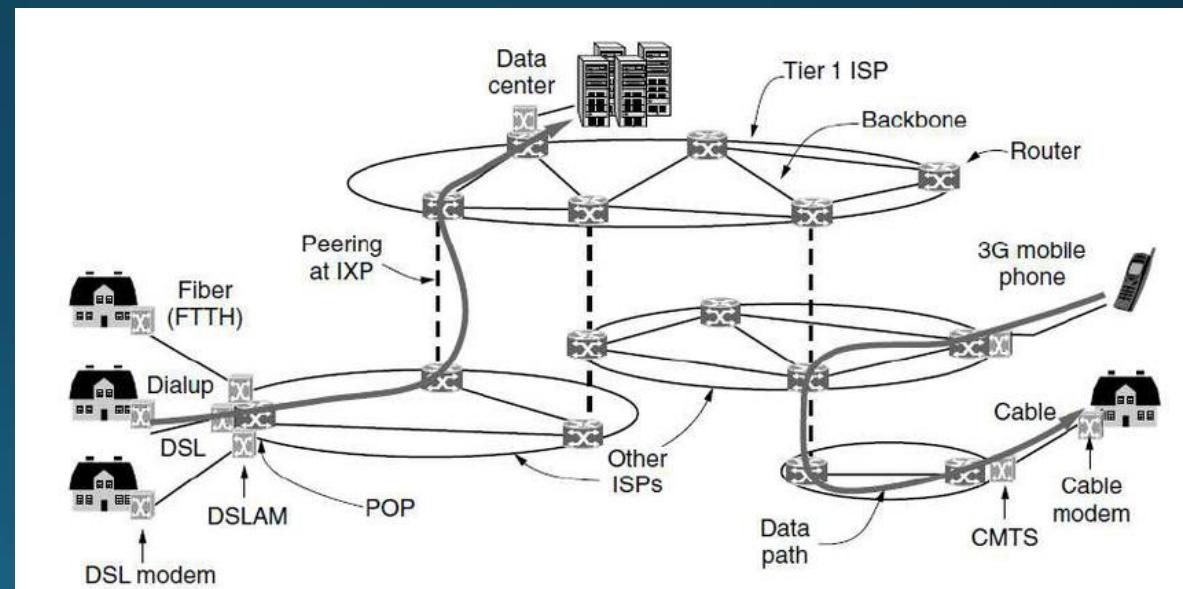
INTERNET (Cont.)

- To access the internet a computer is needed.
- the computer is connected to an **Internet Service Provider**.
- A common way to connect to an ISP is to use the phone line to your house with the help of **DSL (Digital Subscriber Line) modem**.
- DSL is a higher-bandwidth way to use the local telephone line than to send bits over a traditional telephone call instead of a voice conversation (Dial-up).



INTERNET (Cont.)

- Another method is to send signals over the cable TV system.
- But these two are slower, Up to few Mbps.
- Now we are communicating at greater speed like 10 to 100 Mbps because of **FTTH (Fiber to the Home)**.

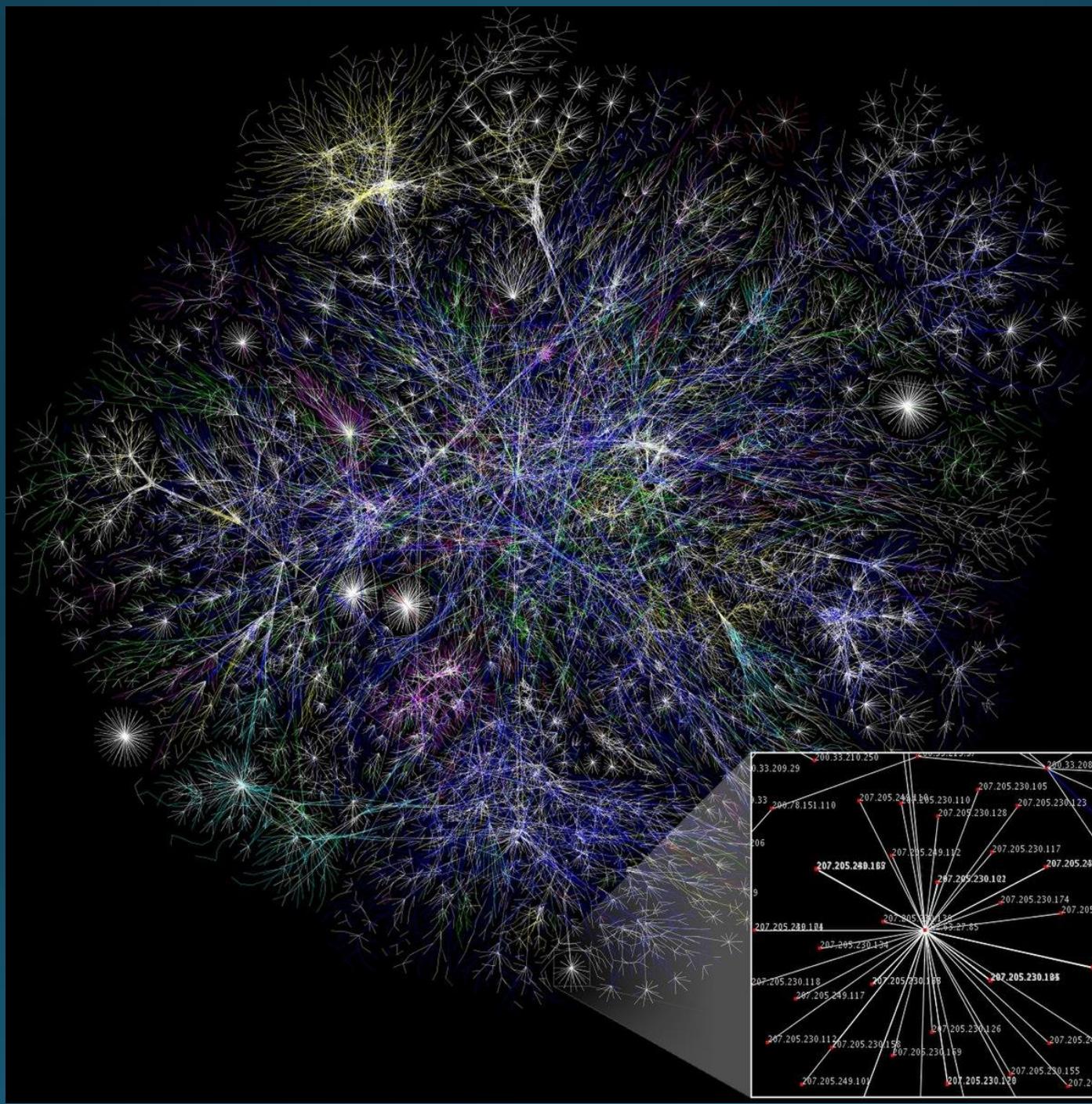


What Happens in an Internet Minute?



And Future Growth is Staggering





Day 6: ILO

- Understanding the different ways of designing networks.
 - Network Topologies
 - Network Types

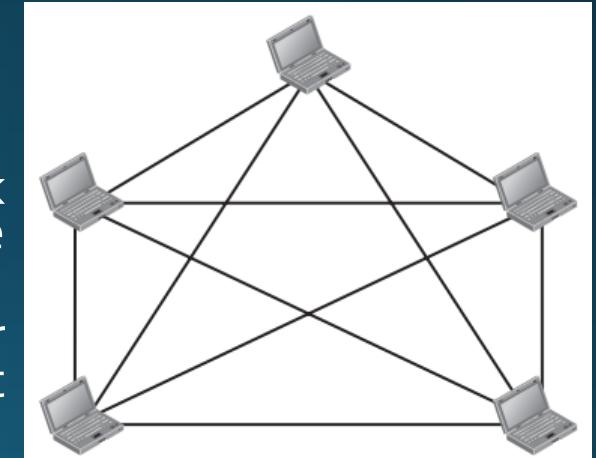
Network Topologies

- ***Network Topology*** refers to the way in which a network is laid out physically.
- Two or more devices connect to a link; two or more links form a topology.
- The topology of a network is the geometric representation of the relationship of all the links and linking devices (usually called ***nodes***) to one another.
- There are four basic topologies possible:
 - Mesh
 - Star
 - Bus
 - ring

Network Topologies (Cont.)

- ***Mesh Topology***

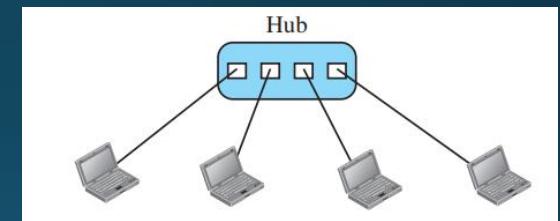
- Every device has a dedicated point-to-point link to every other device.
- To create a fully connected mesh network with n nodes, we need $n(n - 1) / 2$ duplex-mode links.
- To accommodate that many links, every device on the network must have $n - 1$ input/output (I/O) ports to be connected to the other $n - 1$ stations.
- Advantages: No traffic problems, Robust i.e., Failure of one link or node will not effect others, Privacy and Security, & fault identification and isolation is easy.
- Disadvantages: installation and reconnection are difficult, the sheer bulk of the wiring can be greater than the available space, the hardware required to connect each link.



Network Topologies (Cont.)

- *Star Topology*

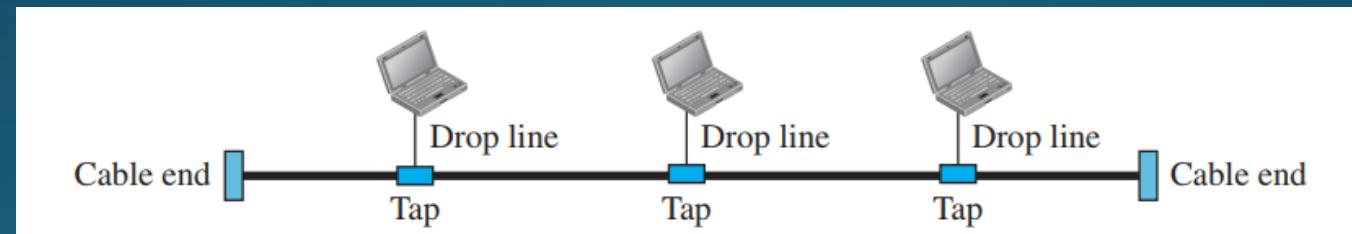
- Each device has a dedicated point-to-point link only to a central controller, usually called a **hub**.
- *Advantages:* Less expensive than a mesh topology, easy to install and reconfigure, robustness in terms of links, and easy fault identification and isolation.
- *Disadvantages:* Dependency of the whole topology on one single point, the hub, more cabling is required in a star than in some other topologies (such as ring or bus).



Network Topologies (Cont.)

- ***Bus Topology***

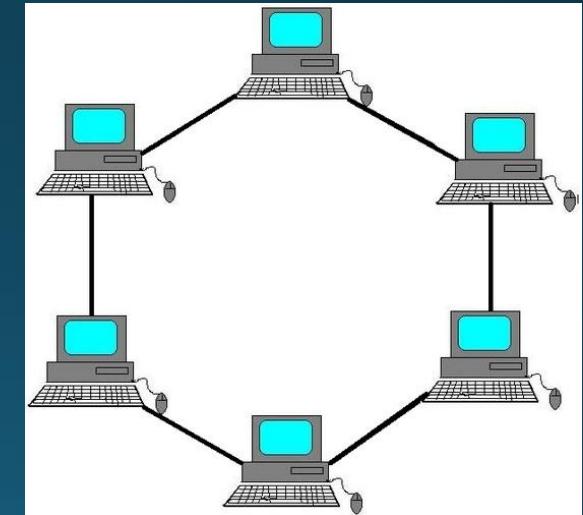
- Unlike the preceding topologies a **bus topology** is multipoint. One long cable acts as a **backbone** to link all the devices in a network. Nodes are connected to the bus cable by drop lines and taps.
- Advantages: Ease of installation, less cabling than mesh or star topologies.
- Disadvantages: difficult reconnection and fault isolation, difficult to add new devices, Signal reflection at the taps can cause degradation in quality, that can be controlled by limiting the number and spacing of devices connected to a given length of cable and a fault or break in the bus cable stops all transmission.



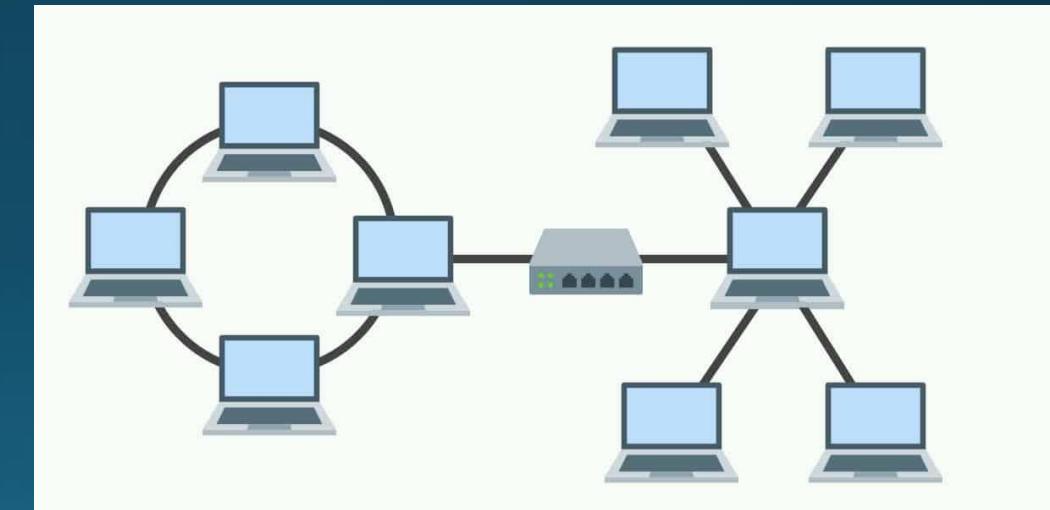
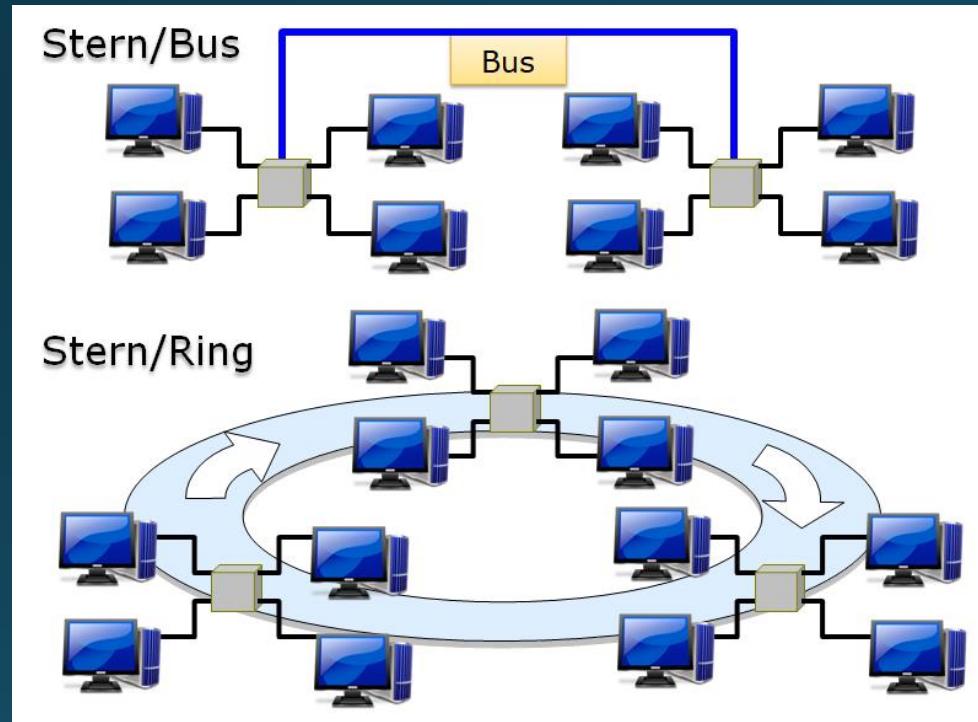
Network Topologies (Cont.)

- *Ring Topology*

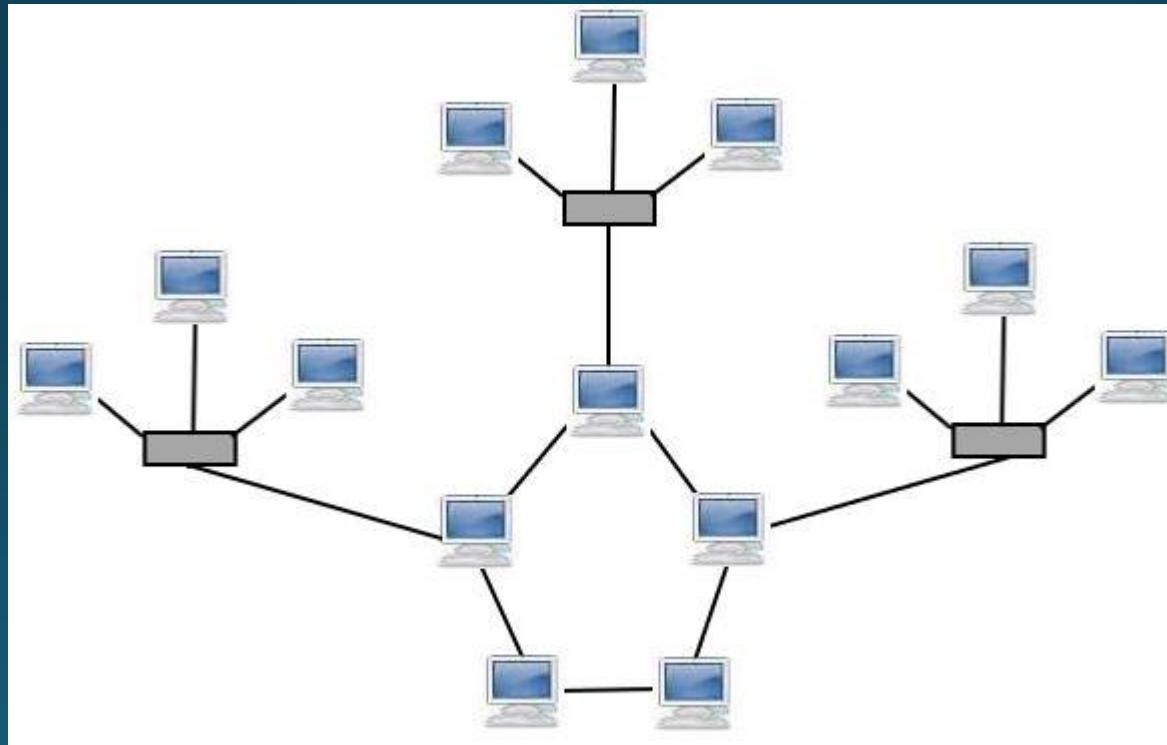
- each device has a dedicated point-to-point connection with only the two devices on either side of it. A signal is passed along the ring in one direction, from device to device, until it reaches its destination. Uses tokens to control the medium access.
- Advantages: Relatively easy to install and reconfigure, Easy fault identification and isolation.
- Disadvantages: Unidirectional traffic, break in a link will bring down the entire network.



Network Topologies (Cont.)

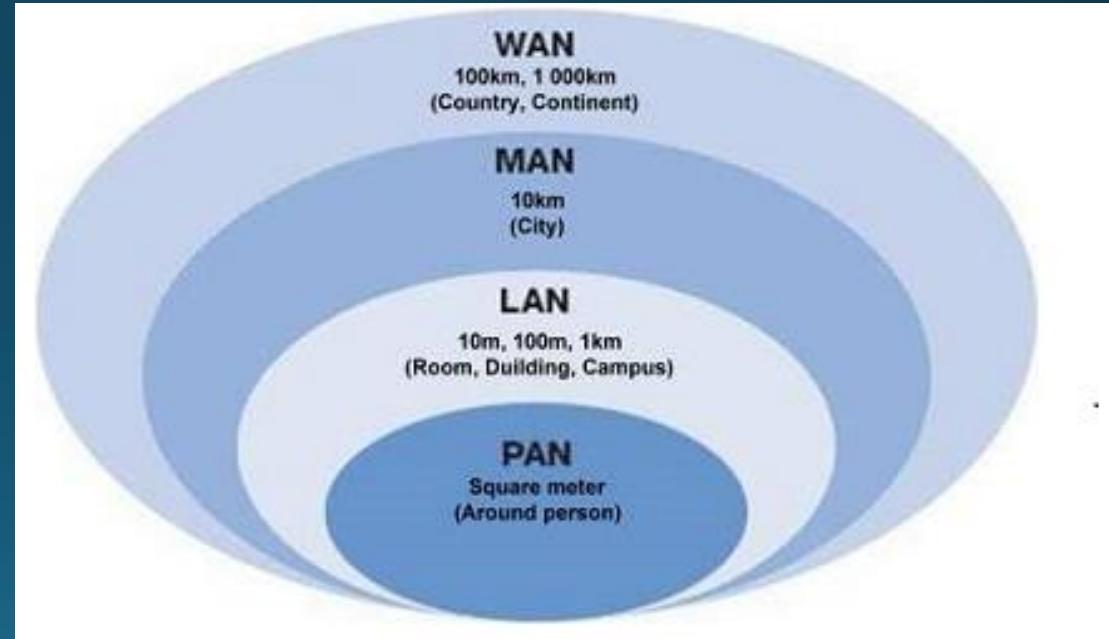


Network Topologies (Cont.)



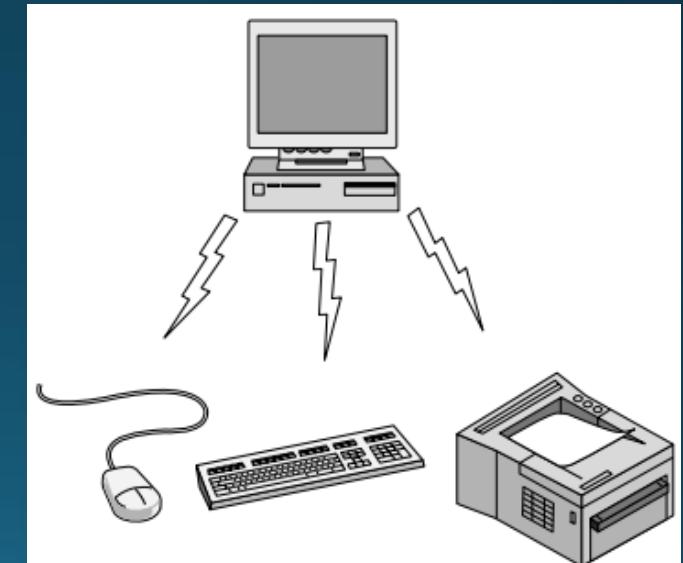
Network Types

- The criteria of distinguishing one type of network from another is difficult and sometimes confusing. We use a few criteria such as size, geographical coverage, and ownership to make this distinction.
- Based on the size/geographical coverage a network will be falling under different categories.



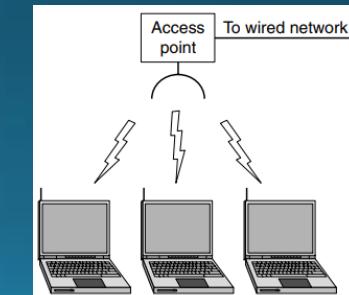
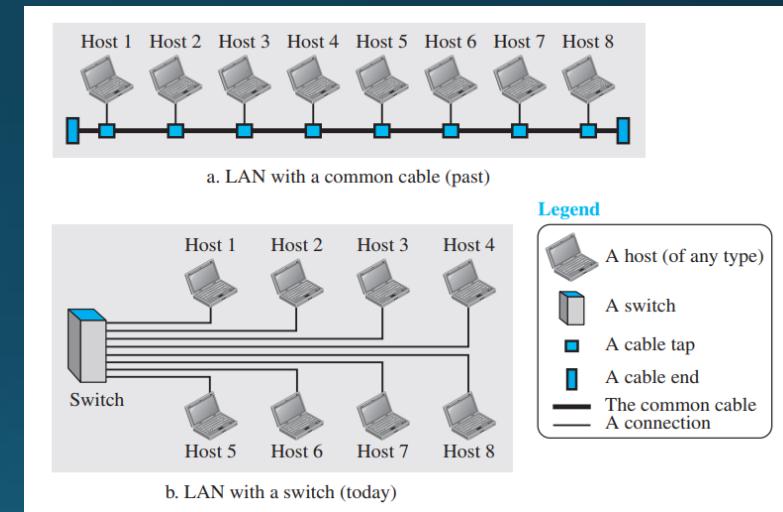
Network Types (PAN)

- **PANs (Personal Area Networks)** let devices communicate over the range of a person.
 - Wired
 - Wireless
 - Bluetooth
 - RFID



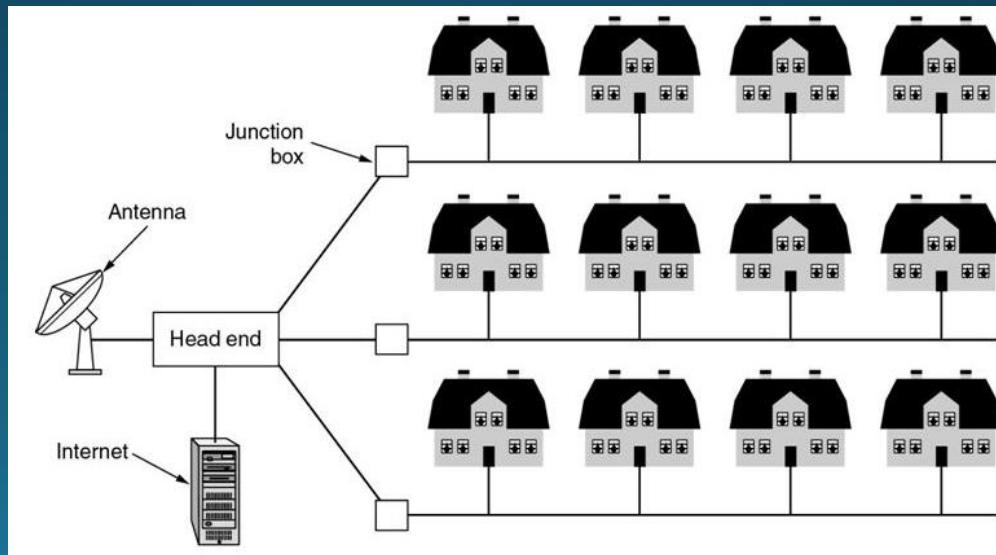
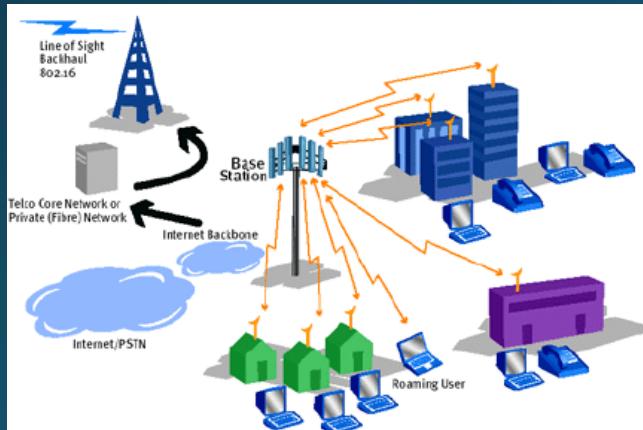
Network Types (LAN)

- A **LAN (Local Area Network)** is a privately owned network that operates within and nearby a single building like a home, office or factory.
- When LANs are used by companies, they are called **enterprise networks**.
- **Wired LANs:** Generally uses copper wires, Older ones operate at 100Mbps to 1Gbps, newer can operate upto 10Gbps.
- **Wireless LANs** are very popular these days that uses: **AP (Access Point), wireless router, or base station**, usually operates at 11 to 100 Mbps.



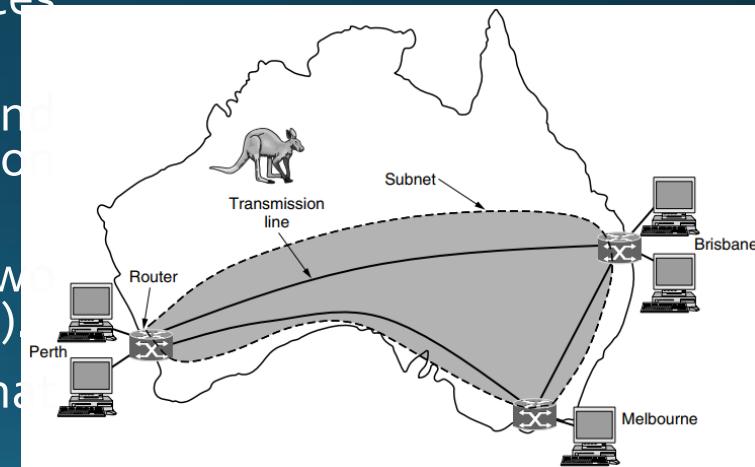
Network Types (MAN)

- A **MAN (Metropolitan Area Network)** covers a city. Ex: Cable Network.
- In this figure we see both television signals and Internet being fed into the centralized **cable headend** for subsequent distribution to people's homes.
- Recent developments in high-speed wireless Internet access have resulted in another MAN, called **WiMAX**.



Network Types (WAN)

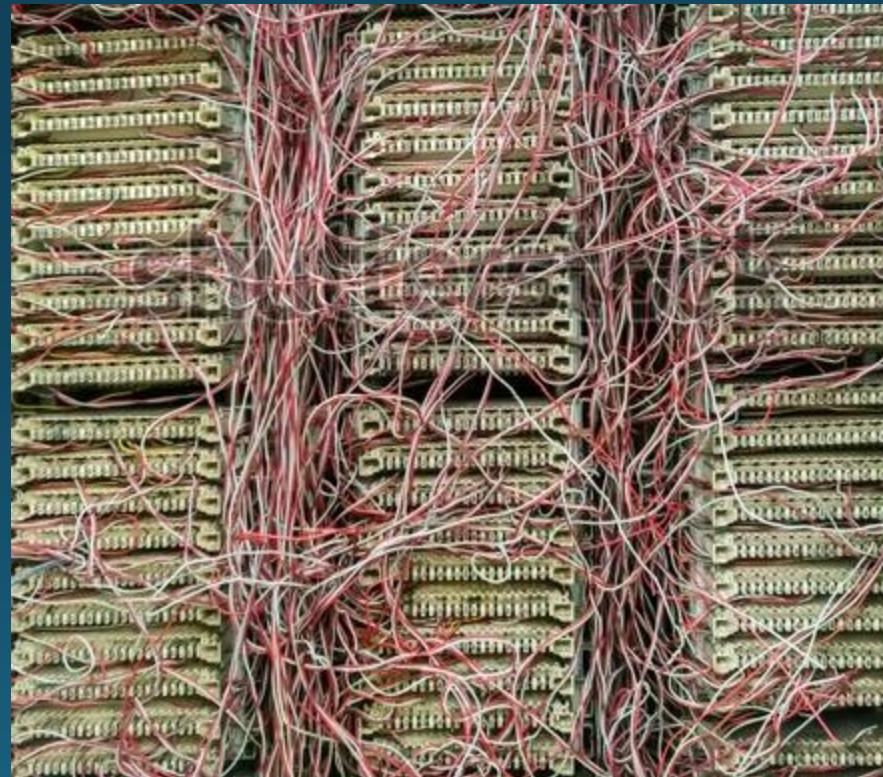
- A **WAN (Wide Area Network)** spans a large geographical area, often a country or continent.
- A LAN interconnects hosts; a WAN interconnects connecting devices such as switches, routers, or modems.
- a WAN is normally created and run by communication companies and leased by an organization that uses it.
- A point-to-point WAN is a network that connects two communicating devices through a transmission media (cable or air).
- Switched WAN is a combination of several point-to-point WANs that are connected by switches.
- **switches**, are specialized computers that connect two or more transmission lines.



Network Types (WAN)



Network Types (WAN)



Network Types (WAN)



Network Types (WAN)



Important Questions

- *Explain the functions of various layers in ISO-OSI reference model.
- *Differentiate OSI reference model with the TCP/IP reference model.
- Explain different Layers and their functionalities in TCP/IP Model.
- What is Internet? Discuss history of Internet and Internet today.
- *Explain the different topologies of the network.
- *Compare the WAN, LAN and MAN topologies
- Define Encapsulation and Peer to Peer communication in the layered architecture.