Lecture 1

Network Models

Learning Objectives

- After this topic, you will be able to:
  - Understand the role of protocols in networking
  - Explain the reason for a layered architecture
  - Describe the OSI model in relation to layers, functions, protocols and devices
  - Identify the five layers of the TCP/IP or internet model

Introduction to Protocols

- A protocol defines the rules that both the sender and receiver and all intermediate devices need to follow to be able to communicate effectively
- It is a logical concept and does not consist of any physical devices
  - Describes how data can be exchanged between computers and other devices of similar architecture
- A protocol suite is combination of protocols that work cooperatively to accomplish network communications

Introduction to Protocols (cont'd)

- Protocols or rules control data communication, which include the following:
  - How the physical network is built
  - How computers connect to the network
  - How the data is formatted for transmission
  - How data is sent
  - How to deal with errors

Introduction to Protocols (cont'd)

- Networks running more than one protocol are called **multiprotocol networks**
- Protocols are created and maintained by organizations and committees such as:
  - Institute of Electrical and Electronic Engineers (IEEE)
  - American National Standards Institute (ANSI)
  - Telecommunications Industry Association (TIA)
  - Electronic Industries Alliance (EIA)
  - International Telecommunications Union (ITU)
  - International Telecommunication Union-Telecommunication Standards Sector (ITU-T)

Elements of Protocols

- The key elements of a protocol are syntax, semantics, and timing.
  - –Syntax
    - Refers to the structure or format of the data, meaning the order in which they are presented.
  - –Semantics
    - Refers to the meaning of each section of bits.
  - –Timing
    - When data should be sent and how fast they can be sent.

Protocol Layering

- Data communication is a complex task
- To reduce complexity, most networks are organized as a stack of layers or levels, each built upon the one below it.
- The purpose of each layer is to offer certain services to the layers above it.
- The number of layers, the name of each layer, the contents of each layer and the function of each layer differ from network to network.
- A set of layers and protocols is called a Network Model or Architecture.

Principles of Protocol Layering

1. If we want bidirectional communication then we need to make each layer able to perform two opposite tasks, one in each direction
2. The two objects under each layer at both sites should be identical
3. Logical connection
    i. We have layer-to-layer communication
    ii. There is a logical connection at each layer through which two end systems can send the object created from that layer

OSI Reference Model

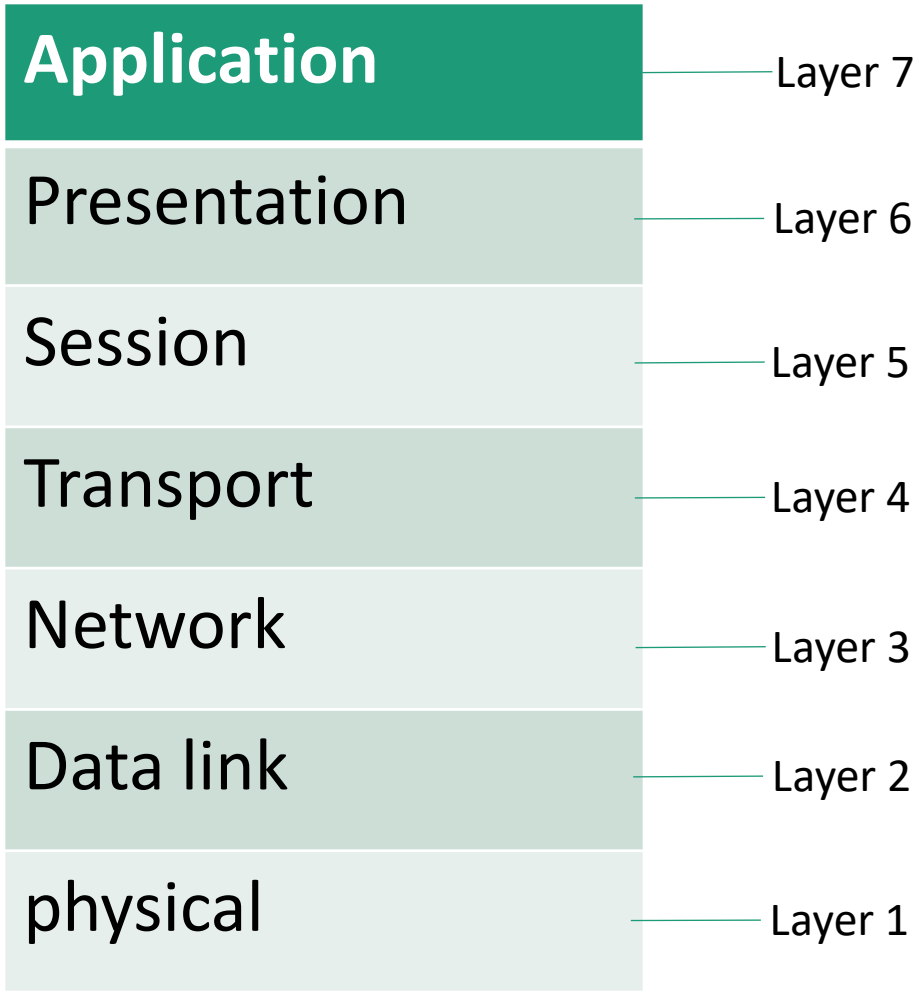
- Introduced in 1978 and revised in 1984 by ISO
- The OSI model is not a protocol but it is a network model that provides designers and users of data communications a logical structure for designing protocols for a variety of network configurations.
- Its purpose is to allow systems with different platforms to communication with each other(Open System).
  - Platform means hardware, software or OS

OSI Reference Model (cont'd)

- OSI consists of seven separate but related layers.
  - Application, presentation, session, transport, network, data link and physical
  - Each layer has specific duties to perform and has to co-operate with the layers above and below it in moving information across a network.
  - This is illustrated in the next slide fig. 7

OSI Reference Model (cont'd)

Fig1: The OSI 7-layered protocol



OSI Reference Model (cont'd)

- For two computers to communicate, the same protocol stacks must be running on each computer
  - Each layer of the protocol stack on one computer communicates with its equivalent (peer) on the other computer
  - This is shown in the next slide, fig. 8

OSI Reference Model (cont'd)

All **P**eople **S**eem **T**o **N**eed **D**ata **P**rocessing

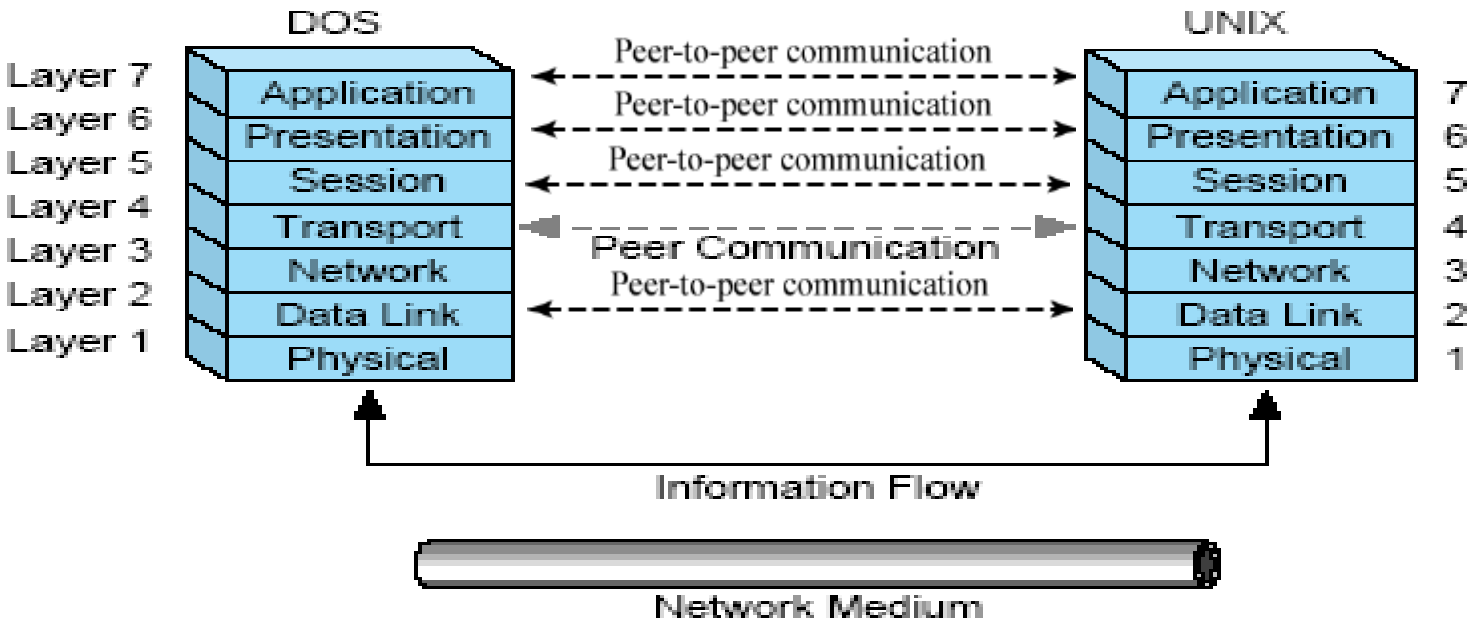


Fig2: The OSI Reference Model

OSI in Action

- A message begins at the top application layer and moves down the OSI layers to the bottom physical layer
- As the message descends, each successive OSI model layer adds a header to it.
- A header is layer-specific information that basically explains what functions the layer carried out.
- Conversely, at the receiving end, headers are striped from the message as it travels up the corresponding layers.

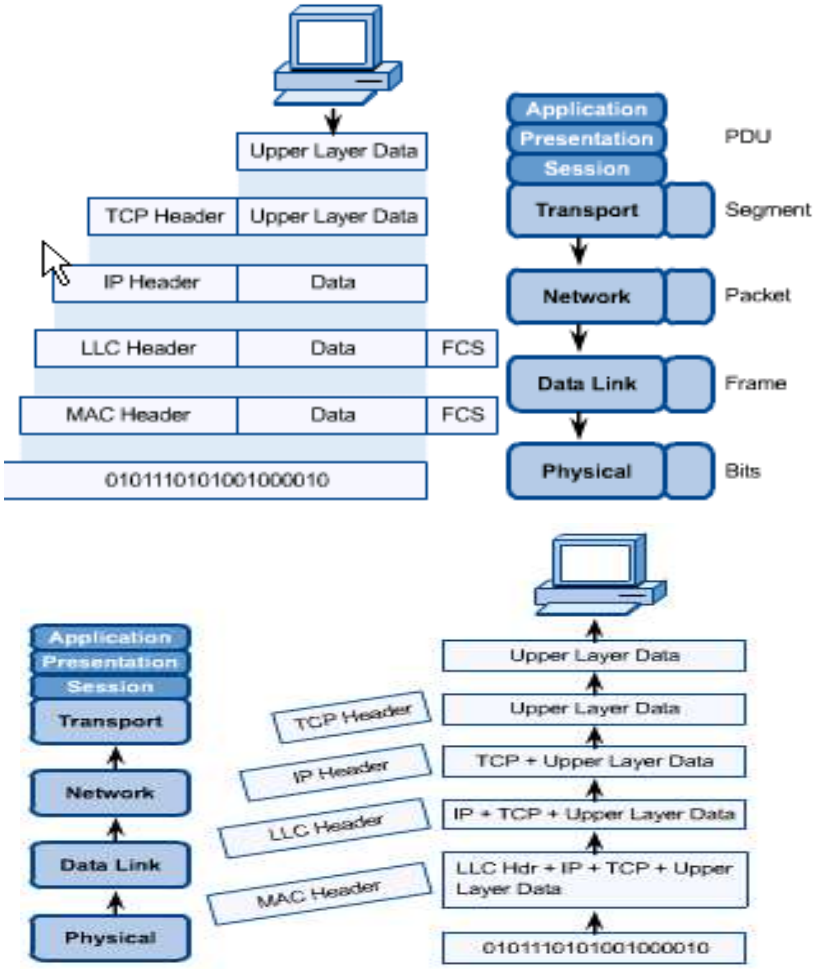


Fig3: OSI in action

Physical Layer

- Protocols at the Physical layer are responsible for sending bits to the transmission media and they define:
  - The structure of a network (its physical topology)
  - The mechanical and electrical specifications of the transmission medium (connections between the cable and NIC)
  - Type of media
  - Bit transmission encoding and synchronization
  - Baseband and broadband transmissions
  - Signal termination

Physical Layer (cont'd)

- **Processes and Methods**
  - Processes are *services* and methods are *protocols*

Table 1: Physical layer processes and methods

OSI Layer	Processes	Methods
Physical	Connection types	Point-to-point Multipoint
	Physical topology	Bus Ring Star Mesh Cellular
	Digital signaling	Current state State transition
	Analog signaling	Current state State transition
	Bit synchronization	Asynchronous Synchronous
	Bandwidth use	Broadband Baseband
	Multiplexing	Frequency-Division (FDM) Time-Division (TDM) Statistical Time-Division (StatTDM)

Physical Layer (cont'd)

- **Hardware Device**
  - Concentrators, hubs, and repeaters, which regenerate electrical signals
  - Transmission media connectors, which provide the mechanical interface to interconnect devices to the transmission media
  - Modems and CODECs, which perform digital and analog conversions

Physical Layer (cont'd)

- **Connection Type**
  - A point-to-point connection: a direct link between two devices (guaranteed bandwidth)
  - A multipoint connection: three or more devices share a single link.
    - Overall bandwidth is divided among every device connected to the media

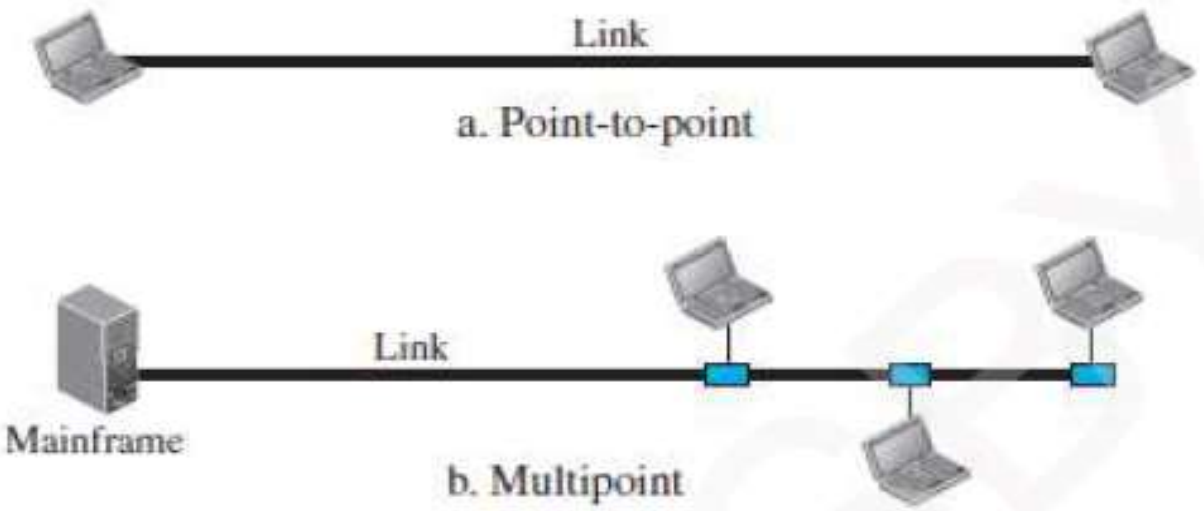


Fig4: Layer 1 connection type

Data Link layer

- Responsible for delivering data from one station to another
  - Framing (header and trailer)
  - Physical addressing (MAC address)
  - Error Control
  - Flow Control
  - Access control

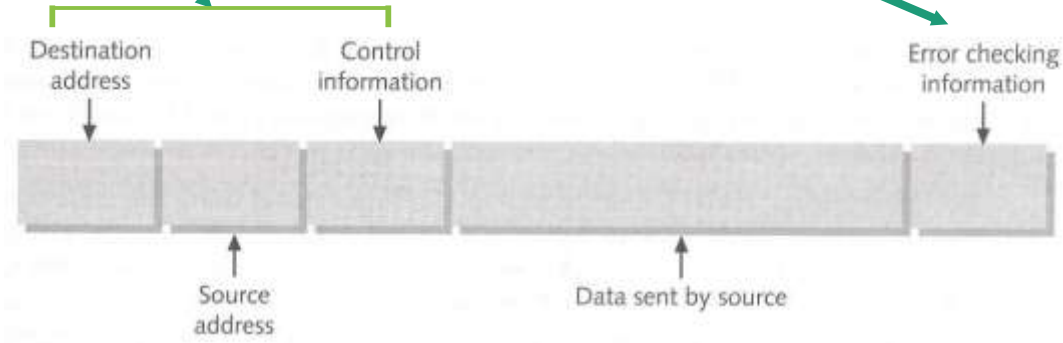


Fig5: frame

Data Link layer (cont'd)

- **Processes and Methods**

OSI Layer	Processes	Methods
Data Link–MAC	Logical topology	Bus Ring
	Media access	Contention Token passing Polling
	Addressing	Physical device
Data Link–LLC	Transmission synchronization	Asynchronous Synchronous Isochronous
	Connection services	LLC-level flow control Error control

Table 2: Layer 2 processes and method

Data Link layer (cont'd)

- **Hardware device**
  - Bridges
  - Switches
  - Network interface cards (NIC)

Data Link layer (cont'd)

- **Sublayers**
  - MAC: the media access control sublayer controls the way transmitters share a single transmission channel
  - LLC: establishes and maintains the link for transmitting data frames from one device to the next
  - The same LLC layer (medium independent) supports various MAC layers (medium dependent)

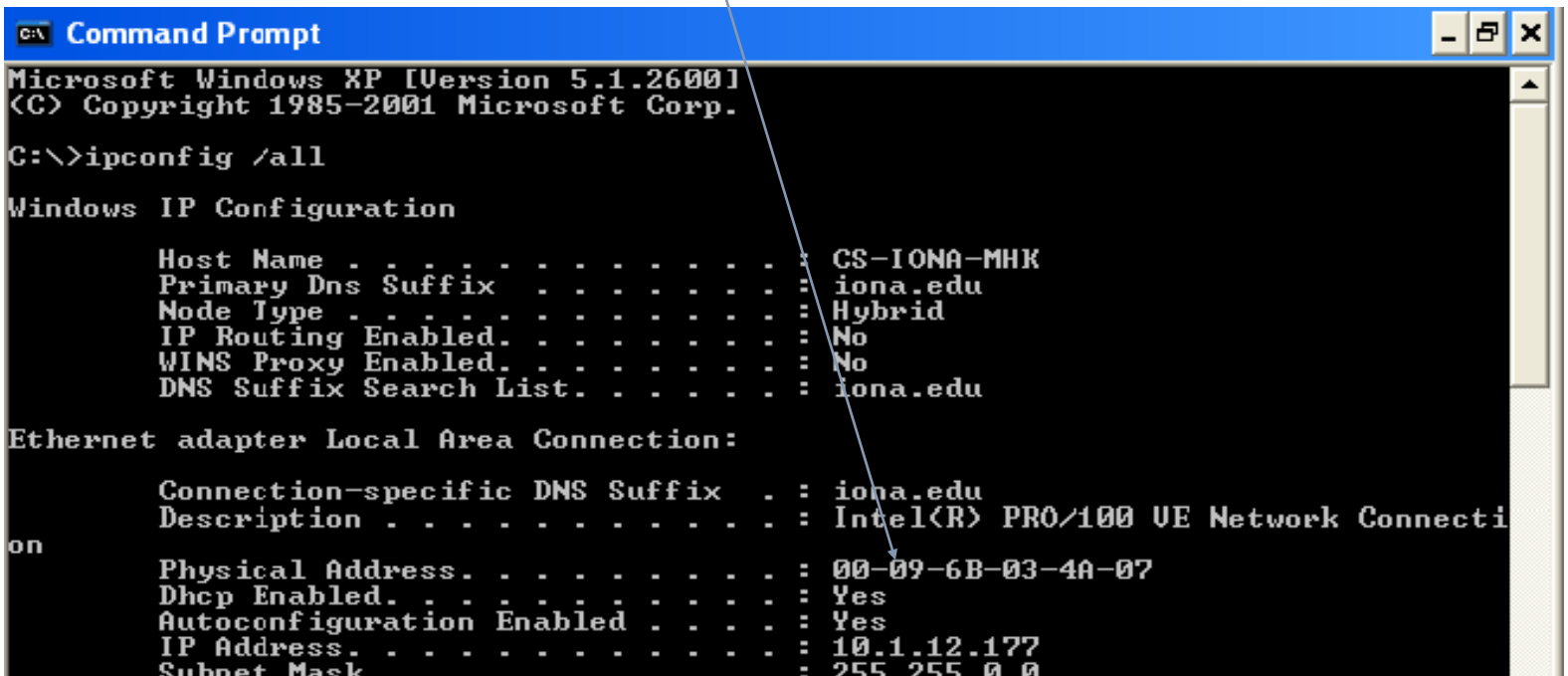
Data Link layer (cont'd)

- **Media Access** - Media access refers to the rules that control which network entities are allowed to transmit
- **Media access methods:**
  - Contention: CSMA/CD
  - Token-passing
  - Polling

Data Link layer (cont'd)

- **Addressing**
  - Data link layer is only concerned with physical device addresses – 48-bit MAC addresses (ipconfig/all)
  - MAC addresses are unique hardware addresses assigned by hardware vendors. Hardware vendors use addresses that are allocated to them by a standards organization (IEEE)

Fig6: MAC Address



Data Link layer (cont'd)

- **Connection Services**
  - Unacknowledged connectionless services
  - Connection-oriented services: provide flow, error, and packet sequence control through acknowledgement
  - Acknowledged connectionless services: use acknowledgement to furnish flow and error control between point-to-point transmissions
  - Users do not choose connection service. The choice is made by the software developers who wrote the user application

Data Link layer (cont'd)

- **Link establishment**

Connection setup handshake

Data exchange

Connection termination

Connectionless

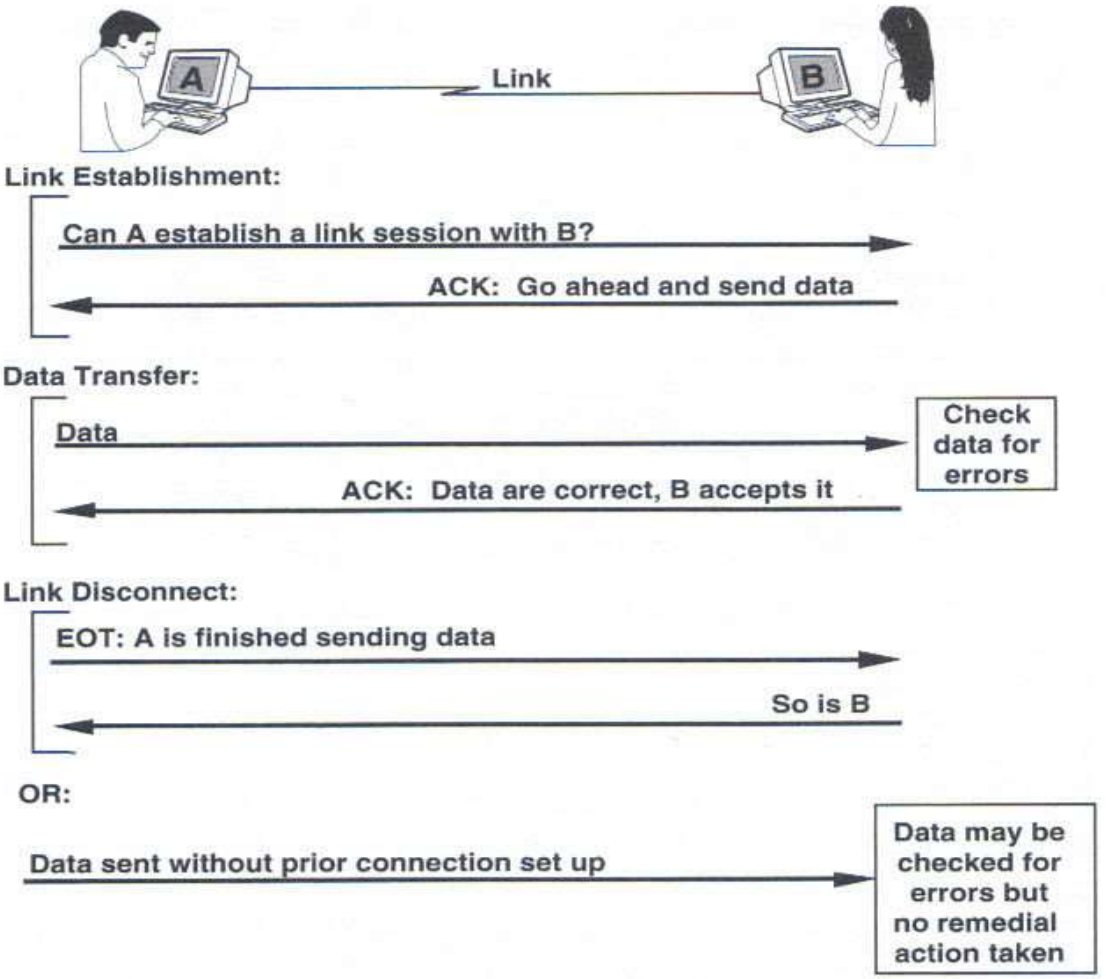


Fig7: Layer 2 connection service

Data Link layer (cont'd)

- **Flow control strategies**
  - Guaranteed rate flow control: set up before data transmissions where sending and receiving applications agree on an acceptable transmission rate for the entire conversation
  - Windows flow control
    - Static: fixed window size
    - Dynamic: the number of allowed outstanding frames changes according to the current status of the receiver (choke packet)

Network Layer

- Responsible for the source-to-destination delivering of packets
- The source-to-destination delivering of packets is achieved through logical addressing and routing
- Routing techniques are link-state and distance vector
  - With distance vector, routers periodically send a routing updates to all neighbors by broadcasting their entire routing table (RIP)
  - With link-state, each router originates information about itself and its directly connected links and their states and pass that information from router to router (OSPF)

Network Layer (cont'd)

Processes and Methods

OSI Layer	Processes	Methods
Network	Addressing	Logical network Service
	Switching	Packet Message Circuit
	Route discovery	Distance vector Link-state
	Route selection	Static Dynamic
	Connection services	Network-layer flow control Error control Packet sequence control
	Gateway services	Network layer translation

Table 3: Layer 3 processes and method

Network Layer (cont'd)

- **Layer 3 or Network Layer Hardware Device**
  - Routers
  - Brouters: work as a bridge and as a router.
  - Layer-3 switches

Network Layer (cont'd)

- **Addressing**
  - The OSI network layer uses the following addressing:
    - Physical address: device MAC address
    - Logical network address: IP address, used to logically distinguish two different networks in an internetwork
    - Service address: a port or a socket, identifies a specific upper layer software process or protocol

Network Layer (cont'd)

- **Route Discovery**
  - To identify routes and maintain routing tables
  - Routing tables are lists that indicate the next route packets should take to reach the destination and they include network addresses, next hop address, and the cost to reach the destination network
  - The cost is calculated using routing algorithm based on hop count, line speed, delay, and relative expense
  - Route discovery uses the following method:
    - Distance vector: ex. RIP
    - Link state: ex. OSPF

Network Layer (cont'd)

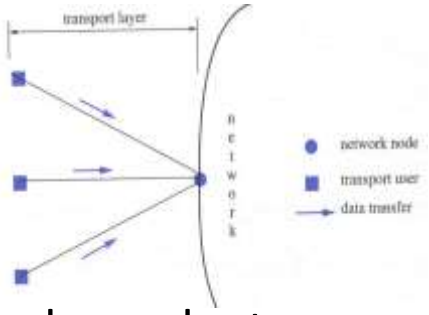
- **Route Selection**
  - Cost information from routing tables is used to select the best path through an internetwork
  - Dynamic route selection: flexible and can recover from failed or overworked routers, require little management, but more complex and expensive
  - Static route selection:
    - path selected by network administrator (manually created routing table) or source-route (routing info on the header) where intermediary routers are not allowed to make route selection decisions

Network Layer (cont'd)

- **Connection service**
  - Unacknowledged connectionless services
  - Connection-oriented services: provide flow, error, and packet sequence control through acknowledgement
  - Acknowledged connectionless services: use acknowledgement to furnish flow and error control between point-to-point transmissions
  - Network connection services use the same acknowledgment provided in the LLC sublayer to provide network flow control, error control, and packet sequence control

Transport Layer

- Responsible for the process-to-process delivery of the entire message. It defines:
  - End-to-end flow control/error control
  - Service-point addressing: use port address for specific process on one computer
  - Segmentation and reassembly of data
  - Multiplexing
  - Connection management
    - connectionless protocol: treats each segment as independent packet, ex. UDP
    - connection oriented protocol: virtual circuit, ex. TCP



Transport layer

Processes and Methods

OSI Layer	Processes	Methods
Transport	Address/name resolution	Service requester-initiated Service provider-initiated
	Addressing	Connection identifier Transaction identifier
	Segment development	Division and combination
	Connection services	Segment sequencing Error control End-to-end flow control

Table 4: Layer 4 processes and method

Session Layer

- **Function**
  - Sessions are controlled by mechanisms that establish, synchronize, and manage dialogue between devices.
  - It performs the functions that enable two applications to communicate across the network, performing security, name recognition, logging, administration, etc.
  - Session layer processes help the upper-layer processes identify and connect to available services
  - Session layer implementations negotiate and establish session parameters used by the lower-layers

Session Layer (cont'd)

- **Processes and Methods**

OSI Layer	Processes	Methods
Session	Dialog control	Simplex Full-duplex Half-duplex
	Session administration	Connection establishment Data transfer Connection release

Table 5: Layer 5 processes and method

Session Layer (cont'd)

- Dialog control modes define the direction of data flow

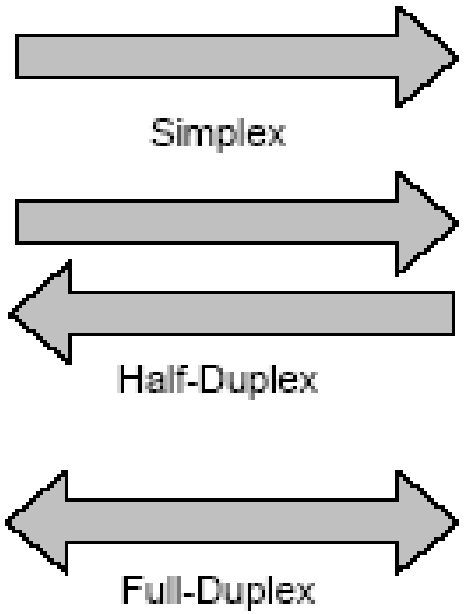


Fig 8: Dialog control modes

Session Layer (cont'd)

- Connection establishment
  - Verifying user login names and passwords
  - Establishing connection identification numbers
  - Agreeing on which services are required and for what duration
  - Determining which entity begins the conversation
  - Coordinating acknowledgment numbering and retransmission procedures
- Data transfer
  - Transfer of data
  - Acknowledgment of data receipt (including negative acknowledgment when data is not received)
  - Resumption of interrupted communications
- Connection release

Presentation Layer

- **Function**
  - The presentation layer transforms the data into a mutually agreed-upon format that can be understood by each network application and the computers they run on
  - Translation
    - Bit order (lsb first? msb first?)
    - Byte order (little endian vs big endian method)
    - Character code (ASCII, EBCDIC, Unicode)
    - File syntax
  - Compression/decompression
  - Encryption/decryption

Presentation Layer (cont'd)

- **Processes and Methods**

OSI Layer	Processes	Methods
Presentation	Translation	Bit order Byte order Character code File syntax
	Encryption	Public keys Private key

Table 6: Layer 6 processes and method

Application Layer

- **Functions**
  - Application layer provides the protocols necessary to perform the network services:
    - File Transfer Protocol (FTP)
    - Mail Server (SMTP)
    - Domain Name Server (DNS)
    - Remote Login (Telnet)
    - Transaction Server
    - Network Management (SNMP)
    - WWW Server
    - Browser (HTTP)
    - Internet Telephony (VoIP)
    - IPTV (VoD)

Application Layer (cont'd)

- **Processes and Methods**

OSI Layer	Processes	Methods
Application	Network services	(See Section 2)
	Service advertisement	Active Passive
	Service use	OS call interception Remote operation Collaborative

Table 7: Layer 7 processes and method

Summary of OSI Functions

- Application: initiates or accepts a request to transfer data
- Presentation: adds formatting, display, and encryption information
- Session: adds communication session control information, synchronize users
- Transport: adds flow-control, sequencing, and reliability information
- Network: adds addressing information
- Data link: adds error-checking, physical addressing, and formats data for physical transmission
- Physical: sends data as bit stream

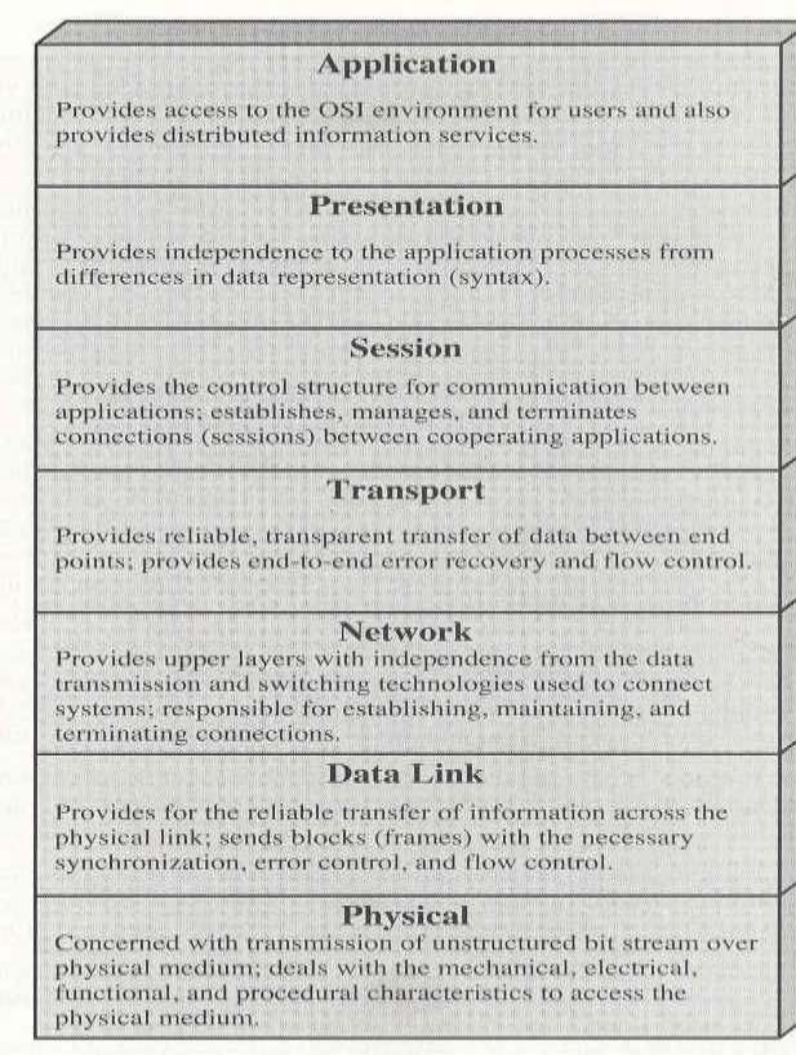


Fig9: The OSI functions Summ ary

Organization of the Layers

- Layers 1, 2, and 3 are the network support layers they deal with the physical aspects of moving data from one device to another (implemented by hardware and software)
- Layers 5, 6, and 7 are the user support layers; they allow interoperability among unrelated software systems (implemented by software)
- Layer 4 ensures end-to-end reliable data transmission

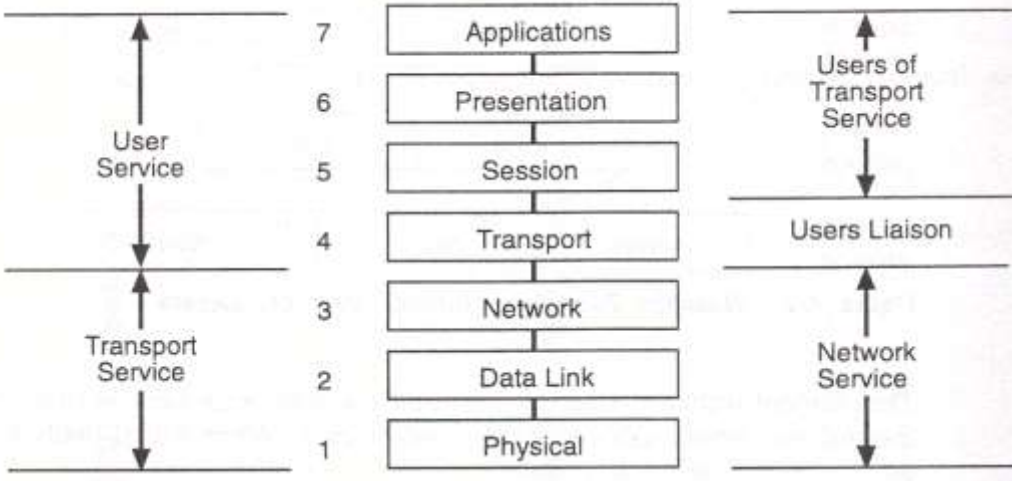


Fig 10: organization of the layers

TCP/IP or Internet Model

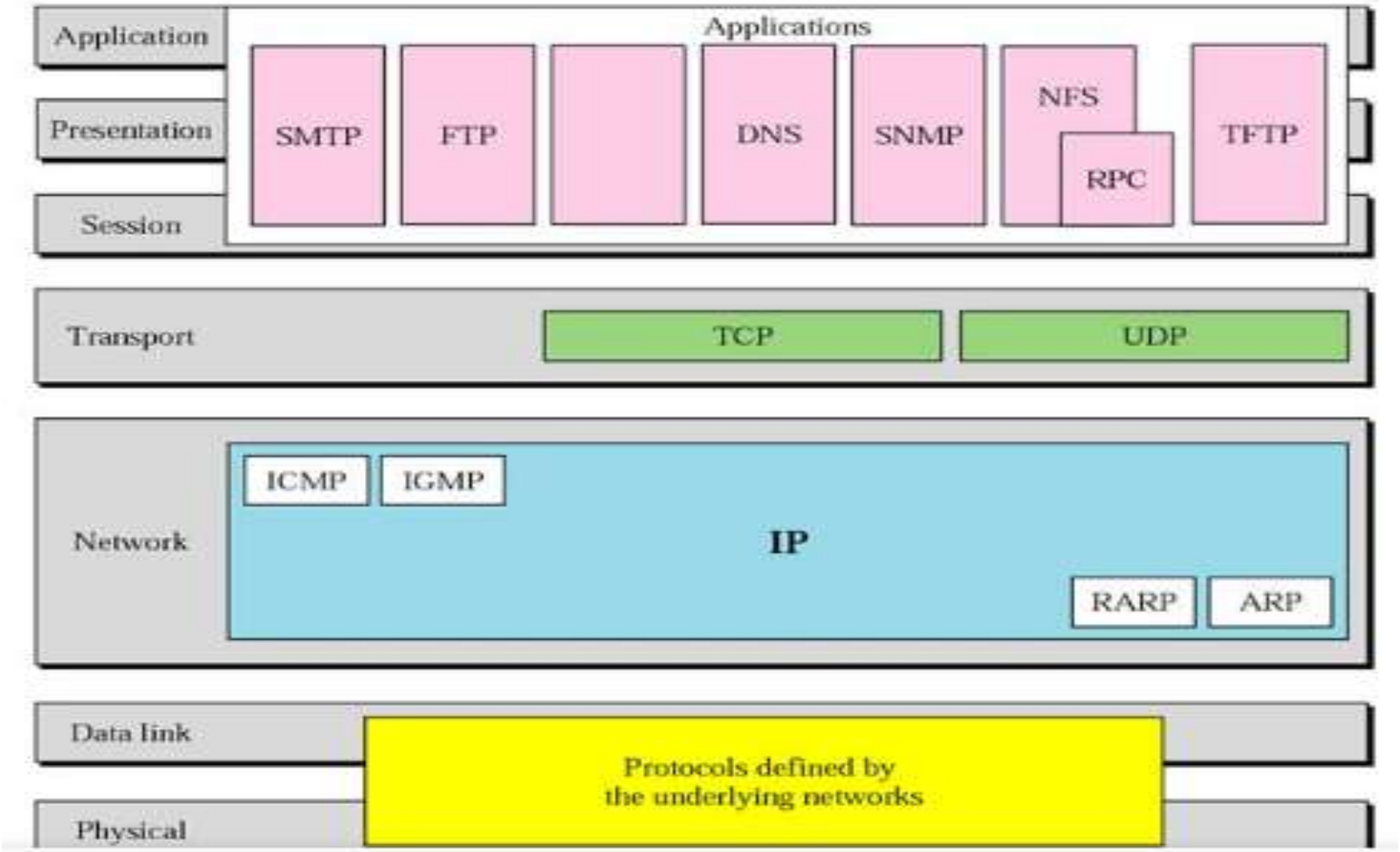


Fig11: TCP/IP or Internet Model

End, thank you.