TCP/IP and OSI Models

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Aim of the session

Study of OSI and TCP/IP Layers with their comparison.

Instructional Objectives

- Describe the Network Protocol Architecture
- Describe OSI Reference Model and TCP/IP Model

Learning Outcomes

Understand the Network Protocol Architecture.
Describe OSI Reference Model and TCP/IP Model

Network Protocol Architecture

- A **protocol** defines rules related to
  - The structure or format of a message
  - Specifies in which order a message can be transmitted
  - Specifies what actions should be taken after receiving a message

What is the need for protocol architecture?

- Communication requires a very great extent of cooperation between the communicating devices.
- Logics of communication are divided into subtasks and implemented into multiple small modules.
- Modules are arranged in a fashion called layers
- Each layer performs some specific tasks

Single-Layer

Figure: Single-layer protocol

- Maria and Ann are neighbors
- Communication between Maria and Ann takes place in one layer, face to face, in the same language

Three-layer protocol

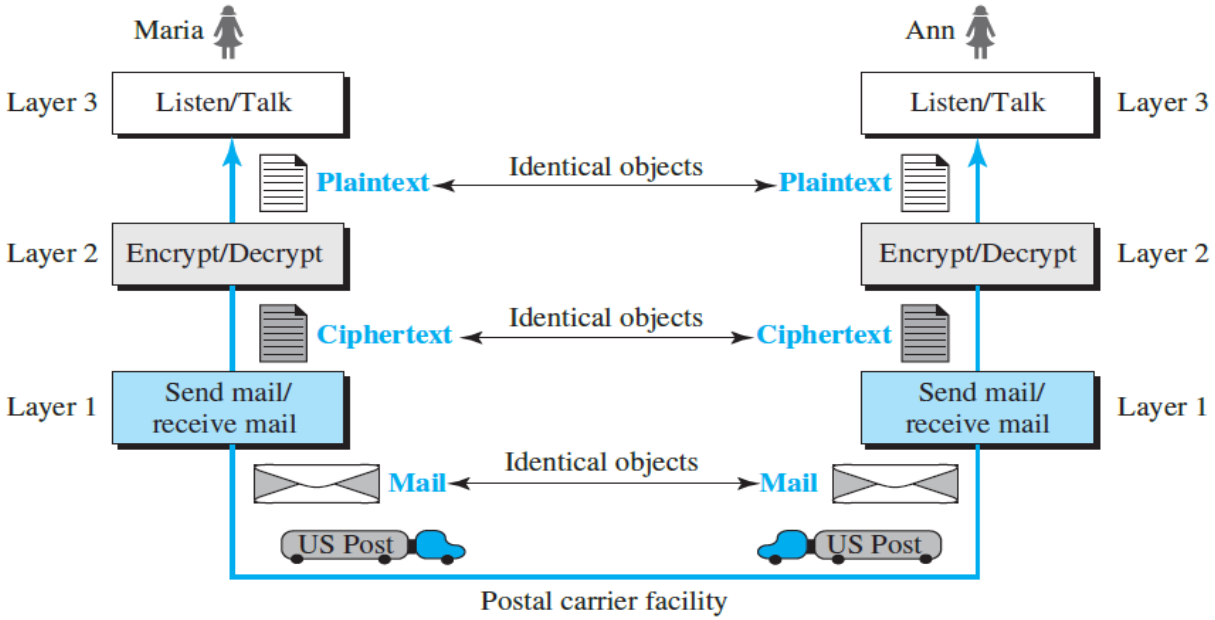


Figure: Three-layer protocol

- Ann is relocated to a city faraway from Maria
- Continue their conversations using regular mail through the post office.
- They do not want their ideas to be revealed to other people. So use encryption/decryption technique

Three-layer protocol

- Communication between Maria and Ann takes place in three layers
- Assume that Ann and Maria each have three machines (or robots) that can perform the task at each layer.
- Maria talks to the machine at the third layer
- The third-layer machine listens to what Maria says and creates the plaintext
- The second-layer machine takes the plaintext, encrypts it, and creates the ciphertext
- The first-layer machine takes the ciphertext, puts it in an envelope, adds the sender and receiver addresses, and mails it.
- Protocol layering enables us to divide a complex task into several smaller and simpler tasks.
- if Maria and Ann decide that the encryption/ decryption done by the machine is not enough they need to change only the second-layer machine; the other two can remain the same

Protocol Layering

- To reduce their design complexity, most networks are organized as a stack of layers
- Purpose of each layer: offer services to the higher layers while shielding those layers from the details of how the offered services are actually implemented
- Each layer is a kind of virtual machine, offering certain services to the layer above it.
- These concepts are similar to information hiding, data encapsulation in CSE
- Fundamental idea : A particular piece of software (or hardware) provides a service to its users but keeps the details of its internal state and algorithms hidden from them.

Protocol Layering

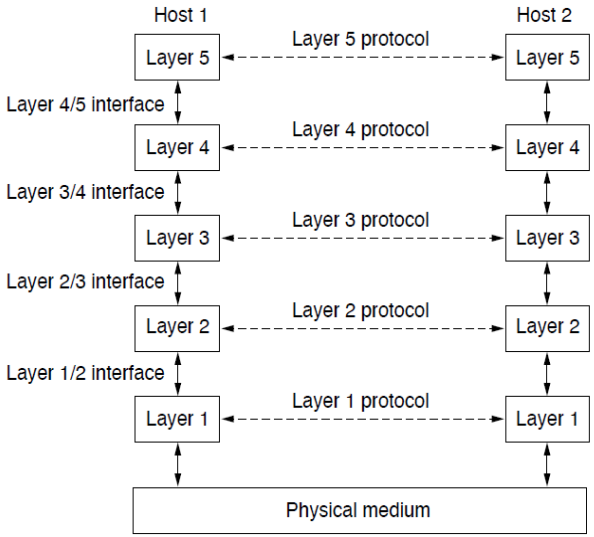


Figure: Layers, protocols, and interfaces

- Corresponding layers on different machines are called **peers**
- Peers communicate by using the protocol to talk to each other.
- Peers have a logical connection
- In reality, each layer passes data and control information to the layer immediately below
- Between each pair of adjacent layers is an **interface**
- A set of layers and protocols is called a **network architecture**

Service and Protocols

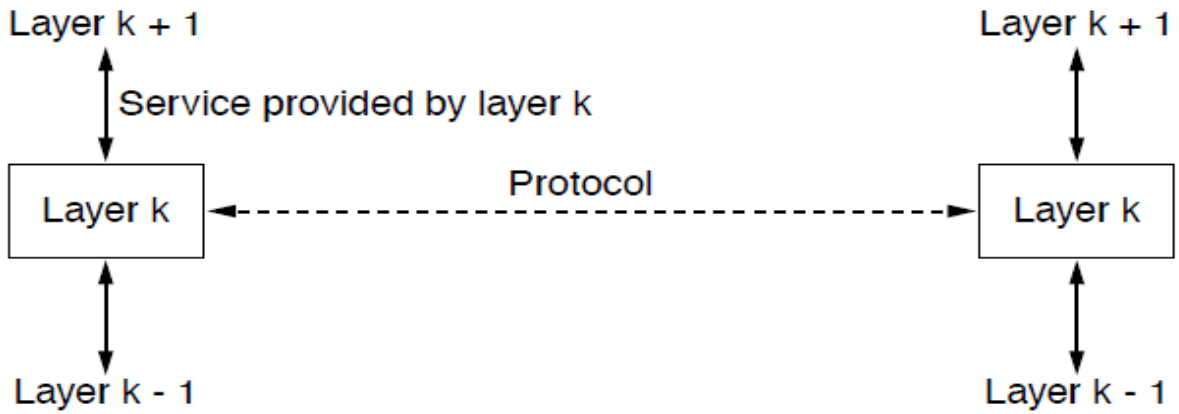


Figure: Relationship between a service and a protocol

- A *service* is a set of primitives (operations) that a layer provides to the layer above it.
- A service relates to an interface between two layers
- A *protocol* is a set of rules governing the format and meaning of the packets/messages that are exchanged by the peer entities
- **Entities use protocols in order to implement their service definitions**

Two Reference Models

- ★ TCP/IP protocol model (Transmission Control Protocol/ Internet Protocol)
- Open System Interconnection (OSI) model

TCP/IP Protocol

- TCP/IP is a protocol suite (a set of protocols organized in different layers)
- It is a hierarchical protocol made up of interactive modules
- *Hierarchical* means that each upper-level protocol is supported by the services provided by one or more lower-level protocols

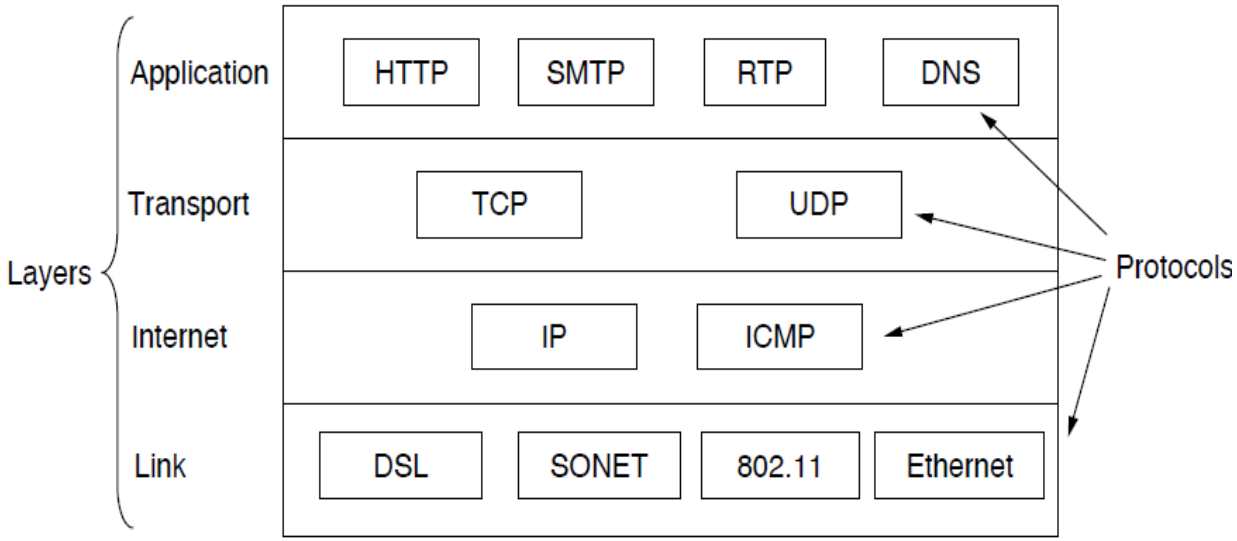


Figure: Layers in the TCP/IP protocol

Application Layer

Application layer protocols define the rules when implementing specific network applications.

- Typical Protocols
  - FTP – File Transfer Protocol, For file transfer
  - SMTP – Simple Mail Transfer Protocol, For mail transfer
  - HTTP – Hypertext Transfer Protocol, For Web browsing
  - DNS- Domain Name System, for mapping host names onto their network addresses
  - RTP- Real Time Transport Protocol, designed to handle real-time traffic (like audio and video)

Transport Layer

It is designed to allow peer entities on the source and destination hosts to carry on a conversation.

- TCP (Transmission Control Protocol)
  - Reliable connection-oriented protocol that allows a byte stream originating on one machine to be delivered without error on any other machine in the internet
  - It segments the incoming byte stream into discrete messages and passes each one on to the internet layer
  - At the destination, the receiving TCP process reassembles the received messages
  - TCP also handles flow control: Fast sender cannot swamp a slow receiver with more messages than it can handle
- UDP (User Datagram Protocol)
  - It is an unreliable, connectionless protocol for applications that do not want TCP's sequencing or flow control and wish to provide their own
  - It is widely used for one-shot, client-server-type request-reply queries
  - In applications where prompt delivery is more important than accurate delivery, such as transmitting speech or video.

Internet/Network Layer

- Network layer is responsible for creating a connection between the source computer and the destination computer
- The internet layer injects packets from the upper layer into the network and lets them travel to their destination host.
- Packets may even arrive in a completely different order than they were sent, in which case it is the job of higher layers to rearrange them
- The Internet Protocol (IP) is used at this layer to provide the routing function across multiple networks
- Internet Control Message Protocol (ICMP) is used for reporting errors and performing network diagnostics

Link Layer

- The lowest layer in the model
- It is a connectionless layer
- Link Layer is an interface between hosts and transmission links
- The link layer describes what must be supported by your physical link to meet the requirement of a connectionless internet layer

Need for Open System Interconnection Model

- The TCP/IP model did not originally clearly distinguish between services, interfaces, and protocols,
- Biggest contribution of the OSI model is that it makes the distinction between these three concepts explicit
- The OSI model is simple and helps you when you're troubleshooting
- When there's a network problem, it helps to partition all that is occurring into the separate layers so you can divide and conquer the issue
- It helps for visualizing **Packet Flow**

OSI Model

- Developed by ISO (International Organisation of Standardization) (1984)
- It is called OSI because it deals with connecting open systems—that is, systems that are open for communication with other systems
- OSI consists of seven layers, and each layer performs a particular network function.
- OSI model divides the whole task into seven smaller and manageable tasks
- The service definition tells what the layer does
- List of protocols in each layer: `https://en.wikipedia.org/wiki/List_of_network_protocols_(OSI_model)`

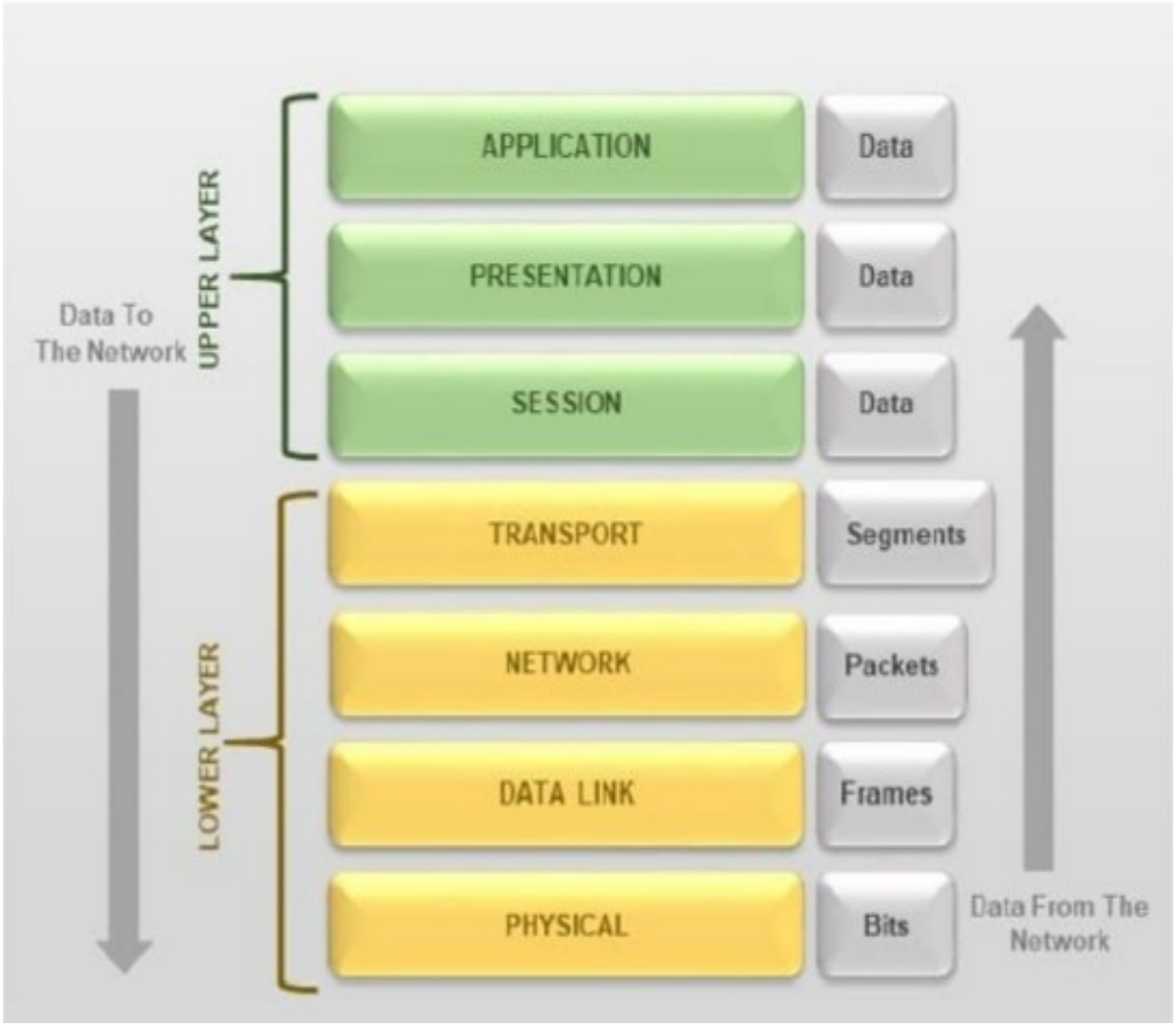


Figure: OSI Model Layers

Application Layer

- This layer provides network services to the end user
- Provide or define protocols that the users need to make a network application
- Protocol at this application layer defines how an application program on the network will request and respond to data communication
- Application layer protocol plays a vital role in network application developments.
- Browsers and eMail -Network applications which use these protocols
- Application layer contains all high level protocols: HTTP, FTP, SMB, TFTP,DNS and SMTP

Application Layer Protocols

Protocols used in Application Layer

- FTP – File Transfer Protocol, For file transfer
- SMTP – Simple Mail Transfer Protocol, For mail transfer
- HTTP – Hypertext Transfer Protocol, For Web browsing
- SMB- Server Message Block Protocol, used for sharing access to files, printers, serial ports and other resources on a network
- TFTP- Trivial File Transfer Protocol is a simple protocol used for transferring files between a client and a server.
- DNS-Domain Name System (DNS), for mapping host names onto their network addresses

Presentation Layer

The presentation layer handles data format conversion, data encryption/decryption, data compression/decompression, incompatibility of data representation between operating systems

- The presentation layer transforms data into the form that the application layer accepts
- Computers/Devices may have a different structure (representation) of data internally, but they communicate on the network with the help of the presentation layer
- It is sometimes called the syntax layer

Session Layer

The session layer creates the setup, controls the connections, and ends the sessions between two or more computers

- Authentication and authorization is performed by this layer
- After the session is established -data is passed to transport layer
- Establishes procedures for checkpointing, suspending, restarting, and terminating a session (in audio and a video stream in a web-conferencing application)
- Commonly implemented explicitly in application environments that use remote procedure calls.

Transport Layer

The transport layer is **responsible for transmission of data across network connections.**

- Responsible for **segmentation, flow control and error control**
- Break long data streams into smaller chunks called **segments**
- Each segement contains sequence number, port number and data
- Network layer imposes a maximum packet size called MTU
- Ethernet has Maximum Transmission Unit (1500)
- Data segment must be small enough to allow for a network-layer header (20 bytes) and a transport-layer header (20 bytes)
- Maximum segment size in Ethernet is 1460 bytes.
- Connection-oriented transport protocols like TCP perform segmentation
- Connectionless transport protocols, such as UDP do not use segmentation

Transport Layer

- Transport Layer ensures the correct order of the packets at the receiving end (error control)
- It takes care of data flow control
- Consider two applications (Browser and WhatsApp) using two ports.
- How computer knows which data bits belong to which application?
- Transport layer identifies the bits using port numbers and IP address
- ♣ Open command prompt and type **netstat -ano -p tcp** to know status of ports on your PC/Laptop
- ♣ Process Identifier (PID) of output can checked in Task Manager to identify the application

Network Layer

The network layer **handles routing of the data**

- Functions: **Logical Addressing, Routing and Path determination**
- The first duty of the network layer is packetizing
- Packet contains segment, sender's and receiver's IP address
- IPv4/IPv6 addressing done in N/W layer is called logical addressing
- Based on IP address and Mask- routing decision are made
- If the packet is fragmented at the source or at routers along the path, the network layer is responsible for waiting until all fragments arrive, reassembling them, and delivering them to the upper-layer protocol.
- To achieve its goals, the network layer must learn about the topology of the network (i.e., the set of all routers and links) and compute appropriate paths through it, even for large networks.
- **Congestion control**: Coordinating traffic flows across multiple networks and managing network utilization.

Data Link Layer

The data link layer is responsible for node-to-node data transfer

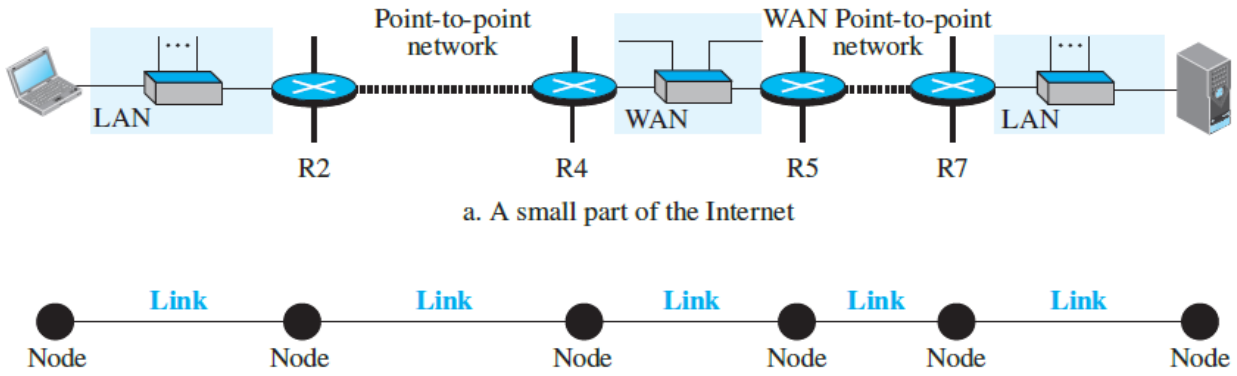


Figure: Nodes and Links

- We refer to any two end hosts and the routers as **nodes**
- Networks in between are referred as **links**
- In a broadcast link data-link layer is divided into two sublayers : data-link control (DLC) and media access control (MAC).
- In a point-to-point link - only data-link control (DLC) is present.

- Logical addressing : Network layer

- Physical addressing : Data Link layer

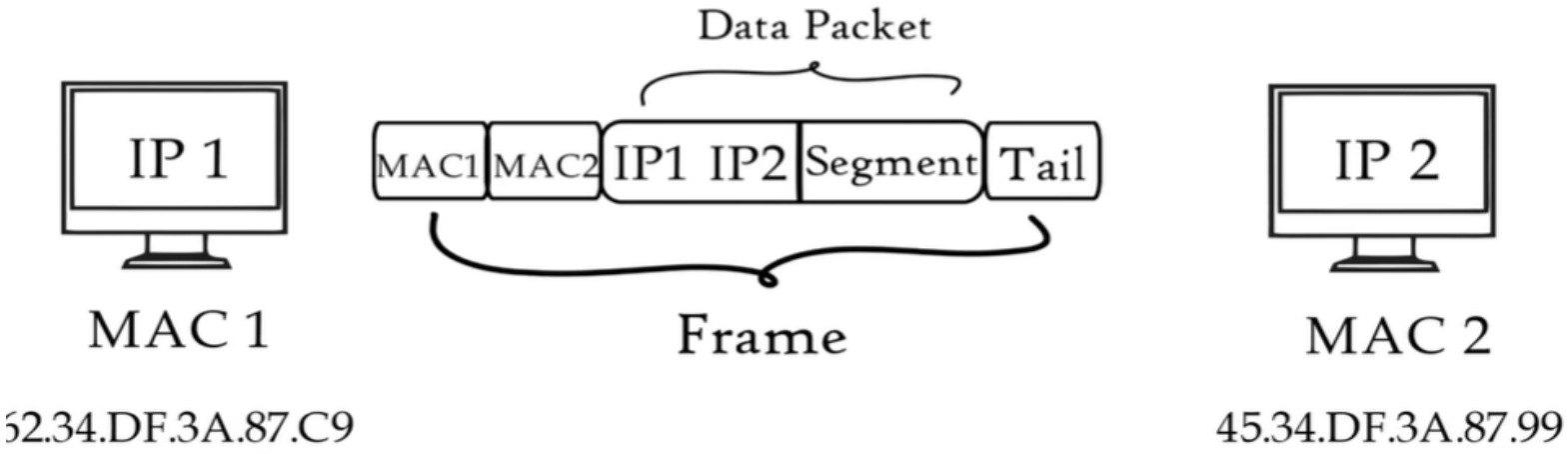


Figure: Logical and Physical Addressing

- MAC address is 12 digit alpha-numeric code embedded in the N/W interface card
- Data link layer is embedded as software on the NIC

Data Link layer

- Data link layer takes the packets it gets from the network layer and encapsulates them into frames for transmission
- Each frame contains a frame header, a payload field for holding the packet, and a frame tail
- Tail of each frame contains bits to detects errors in transmission
- Errors occur due to limitations of Tx media
- DLC functions include *framing* and *error control*
- Data-link control (DLC) deals with the design and procedures for communication between two adjacent nodes
- If the media is shared (wire or air) with other users, we need to have a protocol to first manage the sharing process and then to do the data transfer
- MAC sublayer is responsible for resolving access to the shared media.

Physical Layer

The physical layer is responsible for the transmission and reception of unstructured raw data between a device, such as a network interface controller, Ethernet hub, or network switch, and a physical transmission medium.

- It converts the digital bits into electrical, radio, or optical signals
- **Layer specifications** define characteristics such as voltage levels, the timing of voltage changes, physical data rates, modulation schemes
- Bit rate control is done at the physical layer
- Transmission mode is defined here (simplex, half duplex, and full duplex)
- The physical layer also specifies how encoding occurs over a physical signal (1-5V, 0-0V)

Segment

Data (Hi !)

TRANSPORT LAYER

Packet

Source IP | Destination IP | Segment

NETWORK LAYER

Frame

Source MAC | Destination MAC | Packet | FCS

DATA LINK LAYER

10010111011011001011101101110 11

BITs

SIGNALS

AIR

MEDIA

Physical Layer: Example Specs

Ethernet Physical Layer

- Ethernet family use IEEE 802.3 standard
- Physical media: Twisted pair, optical fiber, coaxial cable
- Maximum distance: 100m (twisted pair), 100km over optical fiber
- Maximum bit rate: 1 Mbit/s to 800 Gbit/s
- Voltage levels: $\pm$ 2.5 V (over twisted pair)

Bluetooth

- Standard: Bluetooth Special Interest Group (SIG)
- Bluetooth operates at frequencies between 2.402 and 2.480 GHz
- Range for Bluetooth 5.0: 40–400 m
- Gaussian frequency shift keying (GFSK) modulation scheme
- Power level: 0.01 and 100 mW
- Speed 2 Mbit/s

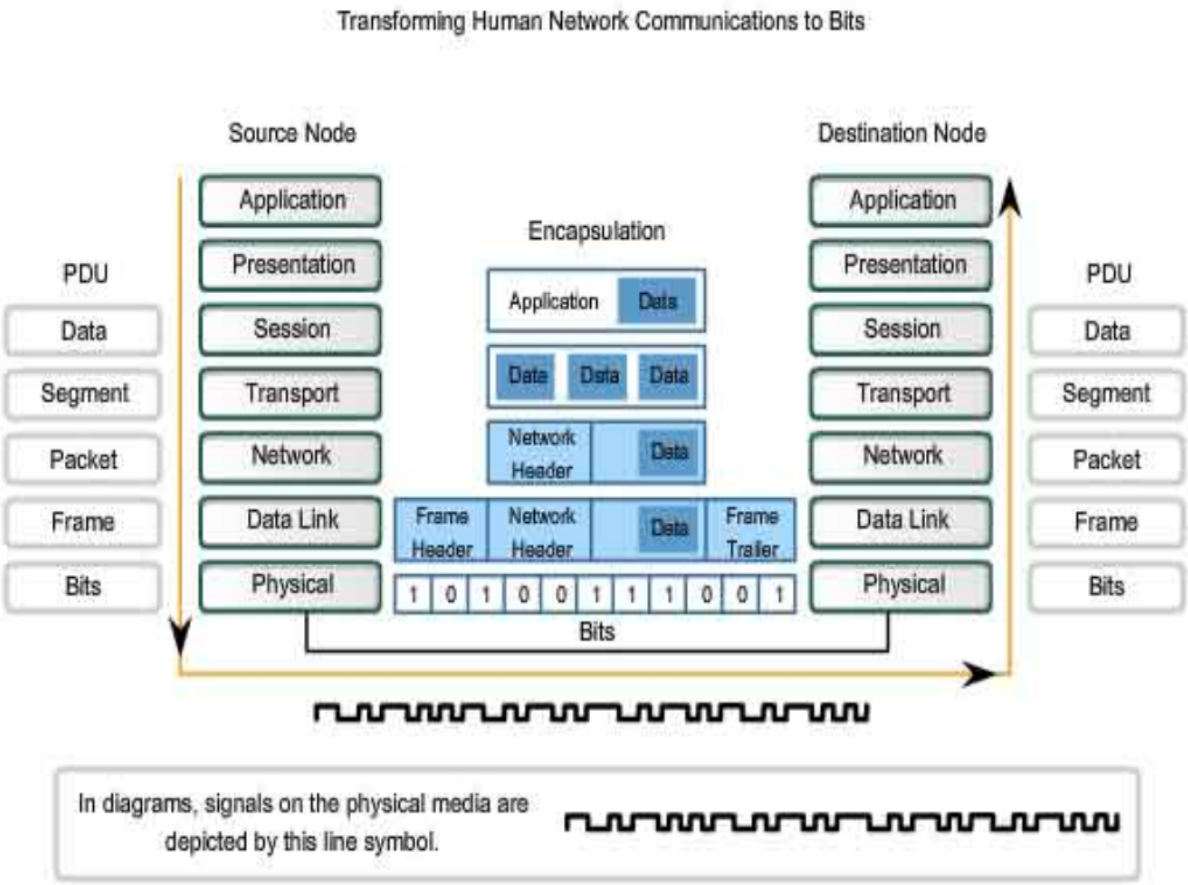
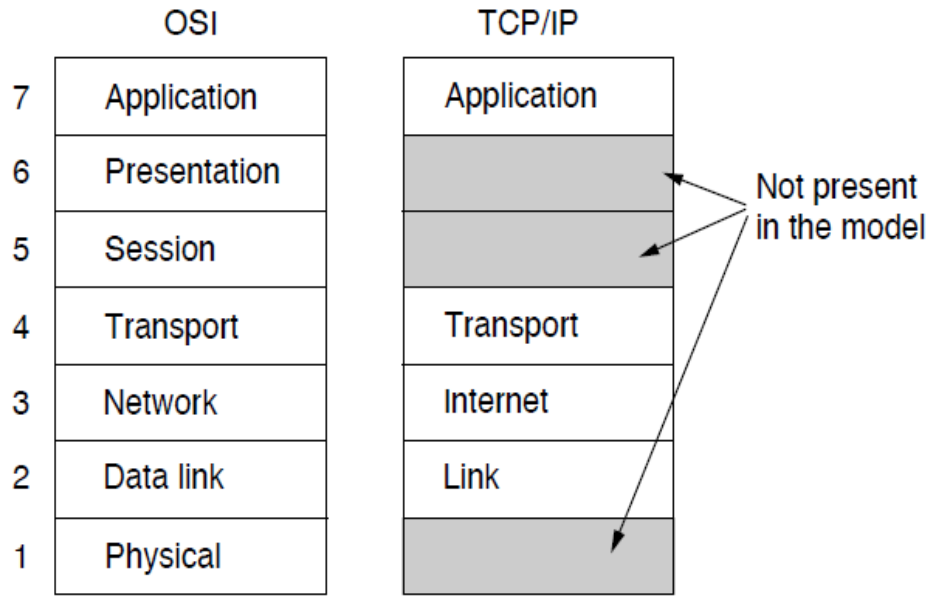


Figure: Data transformation in a Network

Lack of OSI Model's Success

- OSI was completed when TCP/IP was fully in place. Changing it would cost a lot of money
- The choice of seven layers was more political than technical
- Session and presentation- are nearly empty
- when OSI was implemented by an organization in a different application, it did not show a high enough level of performance

TCP/IP Vs OSI Model



TCP/IP Vs OSI Model

OSI Model	TCP/IP Model
It distinguishes between service, interface and protocol in each layer	Does not clearly distinguish between service, interface and protocol
Vertical Approach (OSI): Emphasizes a strict, modular layering system that promotes interoperability and clear separation of functions	Horizontal Approach (TCP/IP): Focuses on practical implementation and the integration of protocols, emphasizing end-to-end communication rather than strict layer separation .
Protocols in the OSI model are hidden and can be easily replaced when the technology changes	The protocol cannot be easily replaced.
OSI model has been developed by ISO	It was developed by ARPANET
Separate session layer and presentation layer	No session and presentation layers Services of presentation layer-Application layer Services of session layer-Transport layer .
In OSI, the model was developed first and then the protocols in each layer were developed.	In TCP/IP, the protocols were developed first and then the model
Contains 7 layers	Contains 4 layers
It is low in usage	It is mostly used

Reading and Writing Assignment

Go through the summary in each chapter

- Application layer: P536 (Forouzan Book)
- Transport layer: P428 (Forouzan Book)
- Network Layer: P494 (Tanenbaum Book)
- Data Link Layer: P261 (Tanenbaum Book)
- Physical Layer: P194 (Tanenbaum Book)

Acknowledge various sources for the images.
Thankyou