Data Communication & Network

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Switches (Multiport Bridges)

- **Switches operate at the Data Link layer (layer 2) of the OSI model**
- A switch is a device that is used to segment networks into sub networks called subnets. (Used to build LAN)
- **Can interpret address information**
- Uses Addressing Scheme knows as MAC Addressing.
- Switches are capable of inspecting data packets as they are received, determining the source and destination device of that packet, and forwarding it appropriately
- Switch conserves network bandwidth and offers generally better performance than a hub.
- **Switch may Broadcase , unicast or Multicast .**

Learning the MAC Addresses and forwarding to the respective machine is switching.

- Switches have
  - ASIC (Application Specific IC)
  - OS is hardcoded in microprocessor
  - So switches are hardware based.
  - Ports are unlimited

- Bridges have
  - OS is separated
  - So bridges are not used
  - Bridges are software based.
  - Limited Ports (16)

Routers

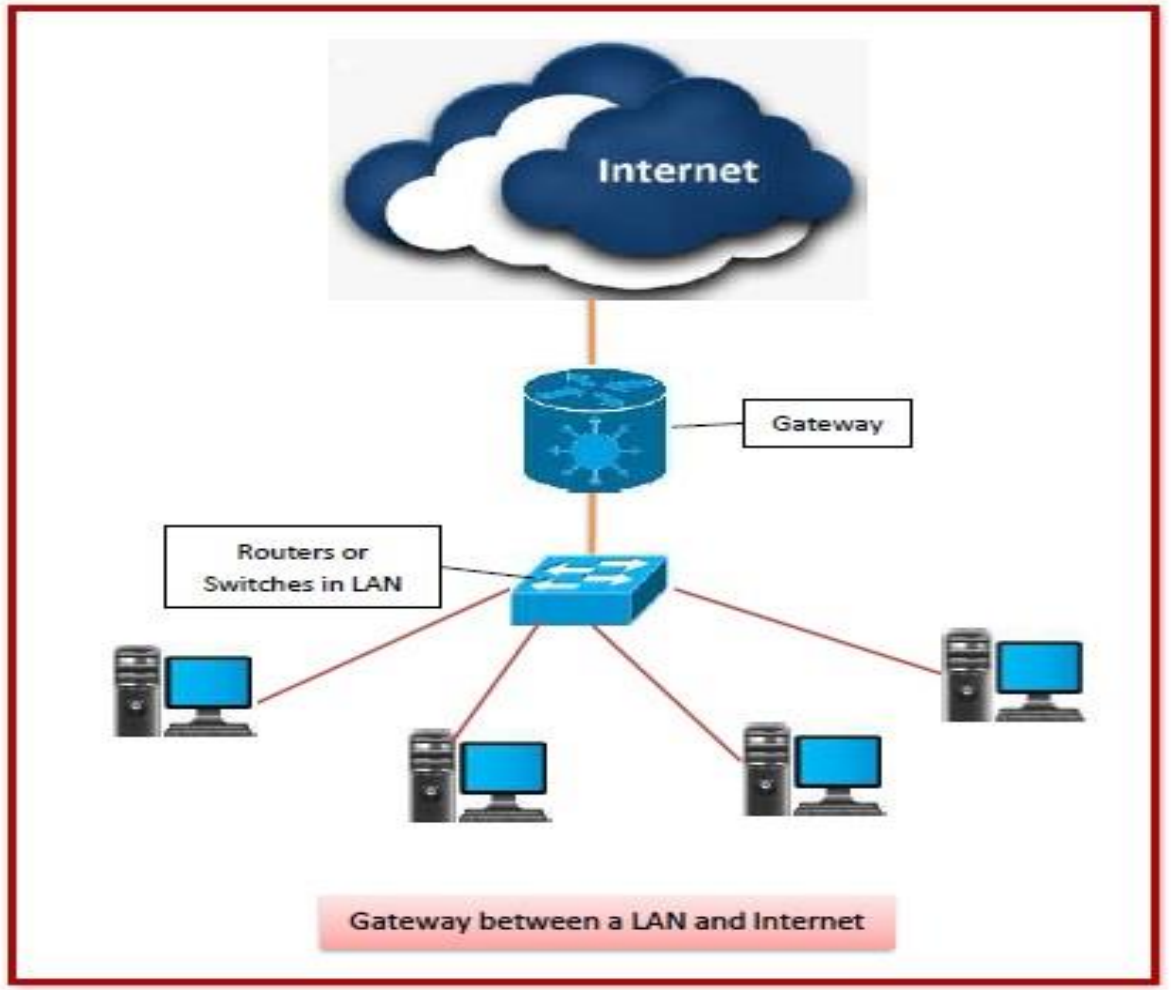
- Used to build WAN
- Router connect multiple networks and route the packets.
- Uses IP Address to identify every machine uniquely.
- Routers are used to connect two or more networks. For routing to be successful, each network must have a unique network number
- Routers have the ability to make intelligent decisions as to the best path for delivery of data on the network.
- **They use the "logical address" of packets and routing tables to determine the best path for data delivery.**
- To determine the **best path**, routers communicate with each other through **routing protocols**
- The four most common routing protocols:
  - RIP (Routing Information Protocol) for IP
  - OSPF (Open Shortest Path First) for IP
  - EIGRP (Enhanced Interior Gateway Routing Protocol) for IP, IPX, and AppleTalk
  - BGP (Border Gateway Protocol) for IP

Gateways

- Device that connects dissimilar networks.
- Operates at the highest level of abstraction.
- Expands the functionality of routers by performing data translation and protocol conversion.
- Establishes an intelligent connection between a local network and external networks with completely different structures.
- Gateways serve as an entry and exit point for a network as all data must pass through or communicate with the gateway prior to being routed.
- If a network wants to communicate with devices, nodes or networks outside of that boundary, they require the functionality of a gateway.
- A gateway is often characterized as being the combination of a router and a modem.

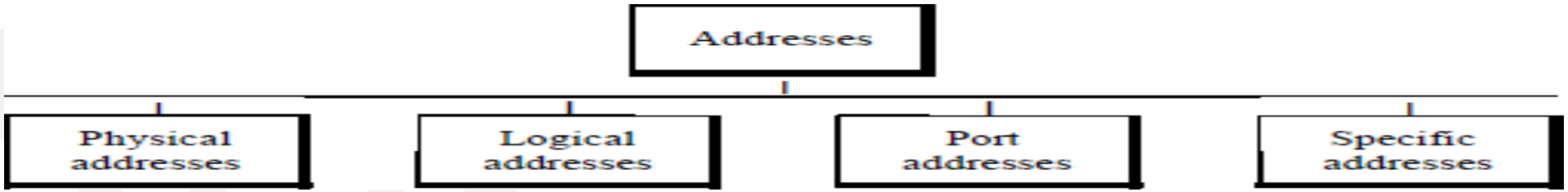
Gateways

- A gateway is a network node that forms a passage between two networks operating with different transmission protocols.
- The most common type of gateways, the network gateway operates at layer 3, i.e. network layer of the OSI (open systems interconnection) model.
- However, depending upon the functionality, a gateway can operate at any of the seven layers of OSI model.
- It acts as the entry – exit point for a network since all traffic that flows across the networks should pass through the gateway..



Addressing

Addressing



Physical Address/ Link Address

- For example, Ethernet uses a 6-byte (48-bit) physical address that is imprinted on the network interface card (NIC).

Logical Address

- logical address in the Internet is currently a **32-bit address** that can uniquely define a host connected to the Internet. IP address

Port Address

- computer A can communicate with computer C by using TELNET(login into a remote computer). At the same time, computer A communicates with computer B by using the File Transfer Protocol (FTP).

Specific Addresses

- Examples include the e-mail address and any Uniform Resource Locator (URL)

TELNET

- **A network protocol that allows a user on one computer to log into another computer that is part of the same network**.
- A program that establishes a connection from one computer to another by means of telnet.
- A link established using a telnet program.
- Login into a remote computer using a telnet program.

- **File transfer protocol (FTP)** is an Internet tool provided by TCP/IP.
- It helps to transfer files from one computer to another by providing access to directories or folders on remote computers and allows software, data, text file to be transferred between different kinds of computers.

- **A Uniform Resource Locator (URL),** is a web address. It is a reference to a web resource that specifies its location on a computer network and a mechanism for retrieving it.

MAC Address / Physical Address/ Ethernet Address

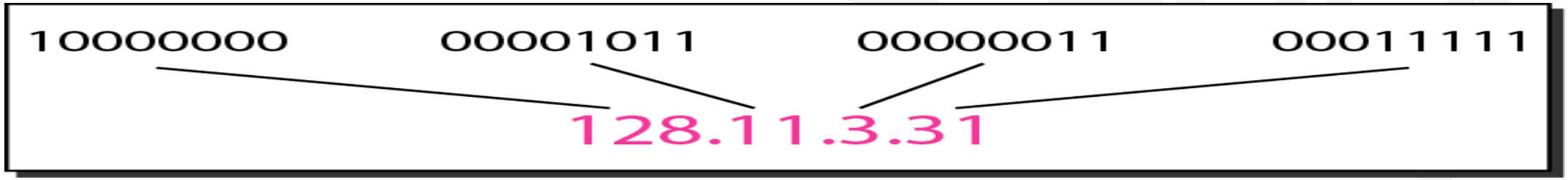
- used on data link layer
- used to identify every NIC uniquely
- is burnt into the ROM part of NIC once written the MAC address can not be changed
- also known as read only address
- to find the MAC address of NIC
  - windows: ipconfig /all
  - linux/macOS: ifconfig
- e.g. 78 : 4f : 43 : 90 : 13 : d0
- size: 6 bytes = 8 x 6 = 48 bits
- Group of first three bytes(78 : 4f : 43) represent's manufacturer ID and last 3 bytes (90 : 13 : d0) represents NIC's unique address.
- to find the manufacturer, please visit https://hwaddress.com/

IP Address / Logical Address

- IP address to mean a logical address in the network layer of the TCP/IP protocol suite.
- Identify a machine / device uniquely.
- Size = 4 bytes = 32 bits
- to find the IP address of Machine
  - windows: ipconfig
  - linux/macOS: ifconfig
- IP Versions:
  - IPV4 (32 bits address length)
  - IPV6 (128 bits address length)
- IP addresses are made up of four sets of numbers called **"Octets".**
- Types
  - Private : used to identify a machine on the LAN and can not be used to connect to internet
  - Public : used to connect to the internet
- e.g.
  - decimal: 192.168.1.6
  - binary : 11000000.10101000.00000001.00000110

IP Addressing Types

- Classful : IP Address is split into 5 classes
- Classless
  - IPv4 uses 32-bit addresses, which means that the address space is 2^{32} or4,294,967,296 (more than 4 billion)
  - **There are two prevalent notations to show an IPv4 address:**
    - binary notation
    - dotted decimal notation



Example

- *Find the error, if any, in the following IPv4 addresses.*

a. 111.56.045.78
b. 221.34.7.8.20
c. 75.45.301.14
d. 11100010.23.14.67

Example

- *Find the error, if any, in the following IPv4 addresses.*

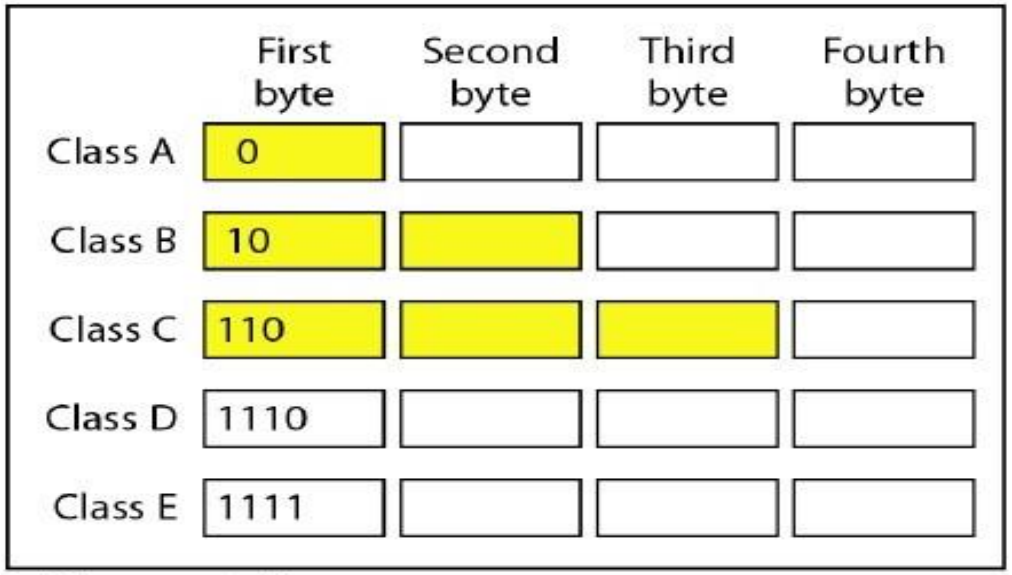
a. 111.56.045.78
b. 221.34.7.8.20
c. 75.45.301.14
d. 11100010.23.14.67

Solution

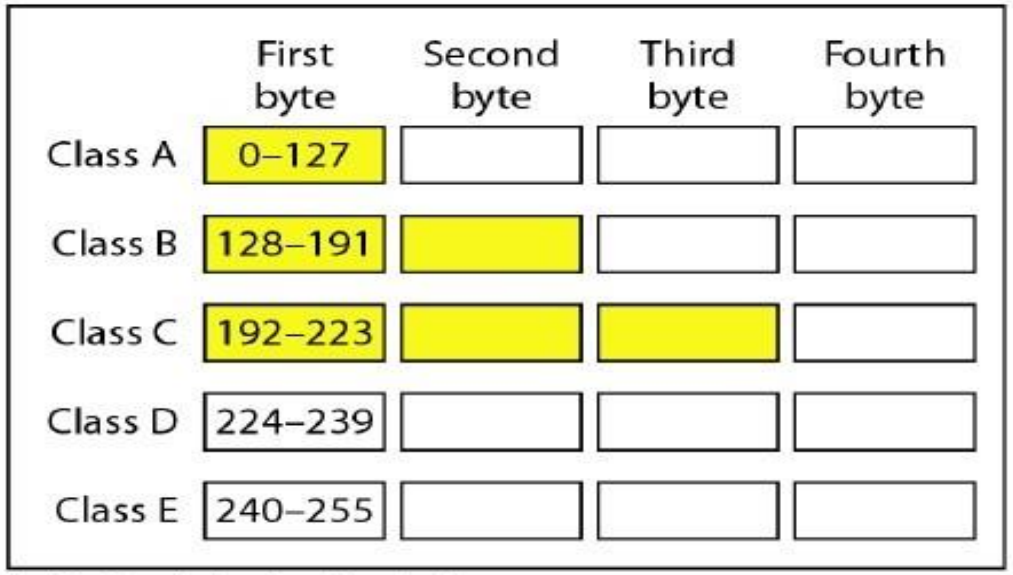
a. There must be no leading zero (045).
b. There can be no more than four numbers.
c. Each number needs to be less than or equal to 255.
d. A mixture of binary notation and dotted-decimal notation is not allowed.

Classful Addressing

- IP is 32 bit means 2^{32} IP Addresses. (more than 4 billion , so many IP Addresses)
- We need to distribute those that's why we have classes.
- In classful addressing, the address space is divided into five classes: A, B, C, D, and E.



a. Binary notation

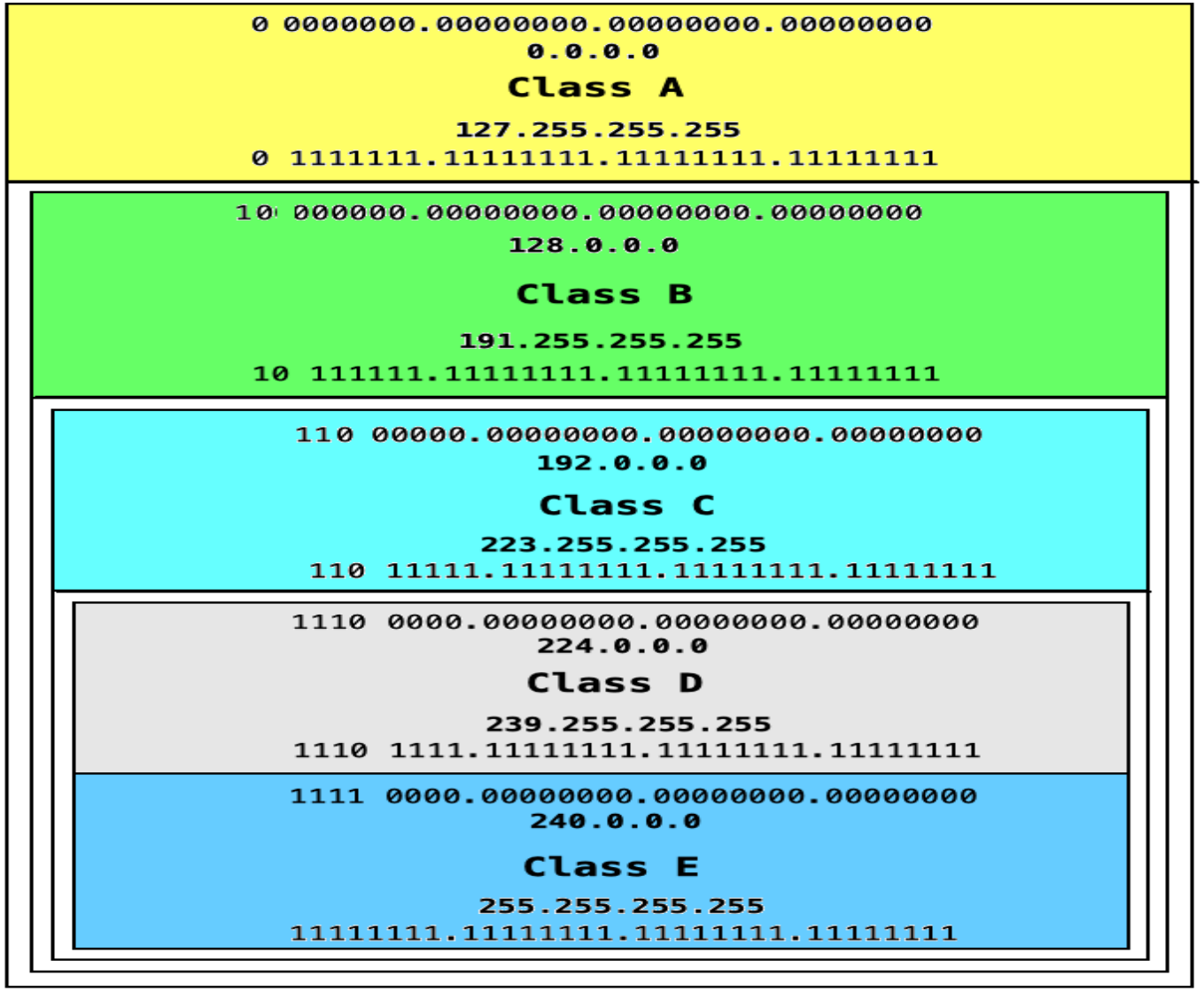


b. Dotted-decimal notation

How range of IP Address is defined

2^7	2^6	2^5	2^4	2^3	2^2	2^1	2^0		
128	64	32	16	8	4	2	1		Range
0	x	x	x	x	x	x	x	Class A	0-127
1	0	x	x	x	x	x	x	Class B	128-191
1	1	0	x	x	x	x	x	Class C	192-223
1	1	1	0	x	x	x	x	Class D	224-239
1	1	1	1	x	x	x	x	Class E	240-255

IP Classful Addressing



- IP addresses starting with 0
- 0.0.0.0 – 127.255.255.255

- IP addresses starting with 10
- 128.0.0.0 – 191.255.255.255

- IP addresses starting with 110
- 192.0.0.0 – 223.255.255.255

- IP addresses starting with 1110
- 224.0.0.0 – 239.255.255.255

- IP addresses starting with 1111
- 240.0.0.0 – 255.255.255.255

Example

- Find the class of each address.

1. 00000001 00001011 00001011 11101111
2. 11000001 10000011 00011011 11111111
3. 14.23.120.8
4. 252.5.15.111

Solution-

1. The first bit is 0. This is a class A address.
2. The first 2 bits are 1; the third bit is 0. This is a class C address.
3. The first byte is 14 (between 0 and 127); the class is A.
4. The first byte is 252 (between 240 and 255); the class is E.

Points to be noted

- Any IP Address start with 127, That is : 127.x.x.x means its **a loop back series** that is used for **self testing**.
- E.g. Ping 127.0.0.1 (ping to yourself)
- That is 127.0.0.1 is **Universal IP** ,
- We can not configure **universal IP**. Its by default configured.
- PING (Packet Internet Groper) is a tool used to troubleshoot networking issues .

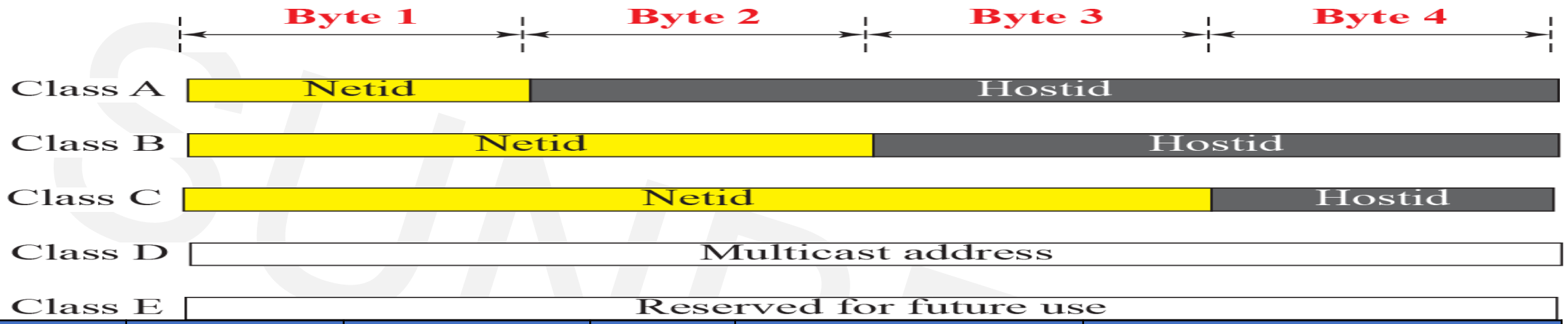
IANA(Inter Associated Number Association) manages private IP's.

Regular Private IP Addresses

Address Class	Reserved Private IP Addresses
Class A	10.0.0.0 - 10.255.255.255
Class B	172.16.0.0 - 172.31.255.255
Class C	192.168.0.0 - 192.168.255.255

Private network will have private IP's means devices that we connect to our router will get private IP addresses provided by IANA.

Netid and hostid of A, B, and C Classes



Class	Network bits	Networks	Host bits	Hosts Per Network	Suitable for
Class A	8	2^8=256	24	2^{24} - 2* =16,777,214 maximum hosts	For large organizations like Apple/Google/MS/Amazon
Class B	16	2^{16}=65536	16	2^{16} - 2* = 65,534 maximum hosts	for medium scaled organizations like Sunbeam
Class C	24	2^{24}=16million	8	2^8 - 2* = 254 maximum hosts	for small organizations/home network

**** Subtracting the network and broadcast address***

Example: What is the type of the given IP address

1. 11.34.56.66
2. 10.46.34.67
3. 156.46.36.46
4. 172.20.34.56
5. 172.45.66.77
6. 192.168.2.5
7. 192.169.34.6

1. 11.34.56.66 : public
2. 10.46.34.67 : private
3. 156.46.36.46 : public
4. 172.20.34.56 : private
5. 172.45.66.77 : public
6. 192.168.2.5 : private
7. 192.169.34.6 : public

Example (Solution): What is the type of the given IP address

1. 11.34.56.66 : public
2. 10.46.34.67 : private
3. 156.46.36.46 : public
4. 172.20.34.56 : private
5. 172.45.66.77 : public
6. 192.168.2.5 : private
7. 192.169.34.6 : public

Example : which class needs to be used for following number of Devices?

1. 200 devices
2. 3000 devices
3. 50000 devices
4. 200000 devices

1. 200 devices : class C
2. 3000 devices : class B
3. 50000 devices : class B
4. 200000 devices : class A

Example (Solution) : which class needs to be used for following number of Devices?

1. 200 devices : class C
2. 3000 devices : class B
3. 50000 devices : class B
4. 200000 devices : class A

Protocol

Protocol and Standards

- ***Protocols define the format and order of messages sent and received among network entities, and actions taken on message transmission and receipt.***
- A protocol defines what, how, when it communicated.
- **The key elements of a protocol :**
  - **syntax :** structure and format of the information data(what can be communicated)
  - **Semantics:** meaning of each section of bits. an route identify the route to be taken or the final destination of the message(how it can be communicated)
  - **Timing(synchronization):** when data should be sent and how fast it should be sent(when and at what speed it can be communicated)

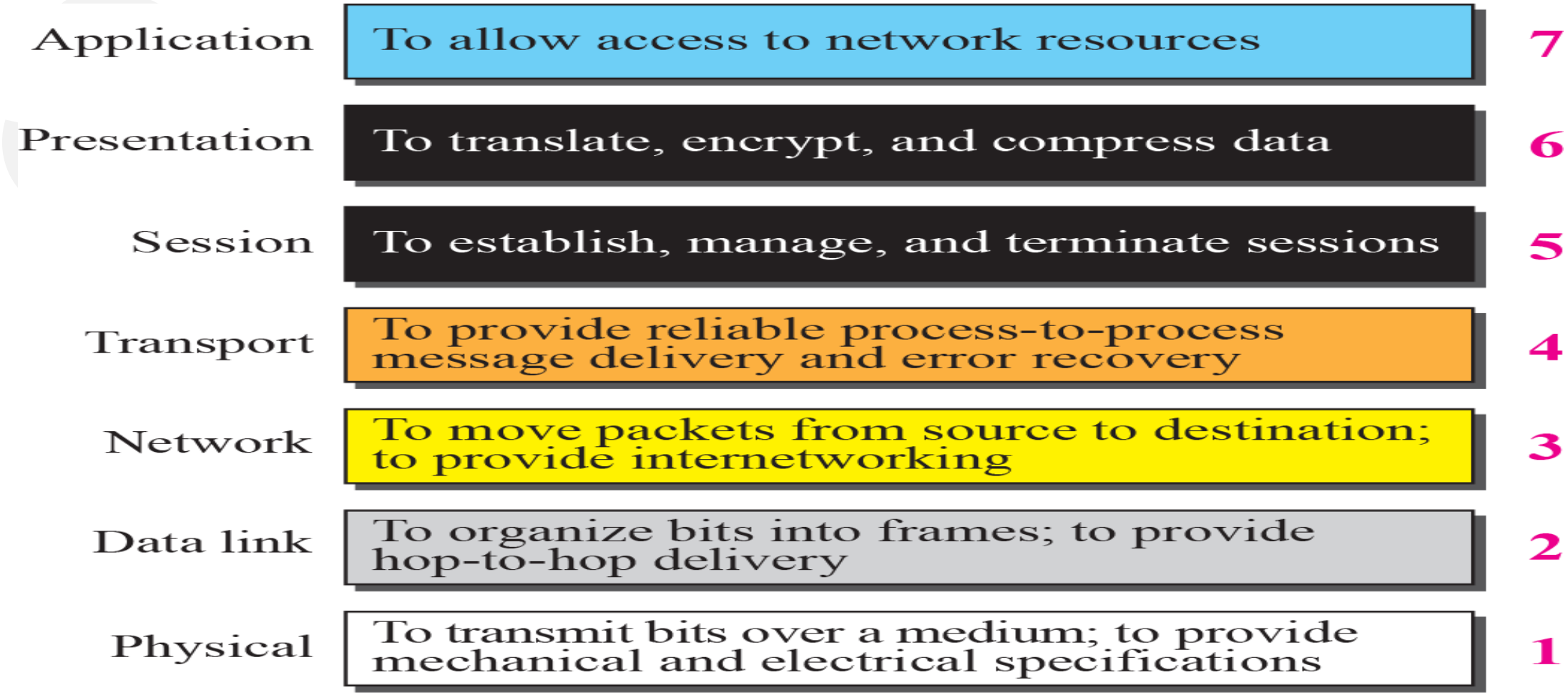
Standards

- Standards are developed by cooperation among standards creation committees, forums, and government regulatory agencies.
- Standards Creation Committees
  1. International Standards Organization (ISO)
  2. International Telecommunications Union (ITU)
  3. American National Standards Institute (ANSI)
  4. Institute of Electrical and Electronics Engineers (IEEE)

OSI Model & Layers

- Established in 1947, **the International Standards Organization (ISO)** is a multinational body dedicated to worldwide agreement on international standards.
- We can not see standard but we can represent them.
- An ISO standard that covers all aspects of network communications is the **Open Systems Interconnection (OSI)** model.
- OSI model is now considered the primary Architectural model for inter-computer communications.
- **Term "open" denotes the ability to connect any two systems which conform to the reference model and associated standards.**

OSI Layers


Application
To allow access to network resources
7
Presentation
To translate, encrypt, and compress data
6
Session
To establish, manage, and terminate sessions
5
Transport
To provide reliable process-to-process message delivery and error recovery
4
Network
To move packets from source to destination; to provide internetworking
3
Data link
To organize bits into frames; to provide hop-to-hop delivery
2
Physical
To transmit bits over a medium; to provide mechanical and electrical specifications
1

Application Layer

- Interacts with application programs and is the highest level of OSI model.
- contains management functions to support distributed applications.
- enables the user, whether human or software, to access the network
- Examples : browser , applications such as file transfer, electronic mail, remote login etc.
- Protocols
  - http [80]: hyper text transfer protocol
  - https [443]: secure hyper text transfer protocol
  - ftp [20/21]: file transfer protocol
  - Smtp (25) : simple mail transfer protocol
  - Pop3 (110) : post office protocol
  - telnet(23) : used to connect to the remote machine
  - ssh [22]: secure shell
  - dns (53) : domain name service (used to get the IP address from the domain name)

Presentation Layer

Translation

- **On sender side : translates from ASCII to EBDIC (Extended Binary Coded Decimal Interchange Code)**
- **On receiver side: translates from EBDIC to ASCII**

Encryption/Decryption

- **Plain Text to Cipher Text**
- **Algorithms : RSA, SHA**

Compression / Decompression

- **Sender Side : Compression**
- **Receiver Side : Decompression**

Data Representation [Content-type] (Used to Decide Common File Formats)

- For text (plain: text/plain , html: text/html , json: application/json , xml: text/xml)
- For image (bmp: image/bmp , png: image/png, jpg: image/jpg , jpeg: image/jpeg)
- For audio & Video (wave: audio/wav, mp3: audio/mp3, mp4: video/mp4, fllv: video/flv

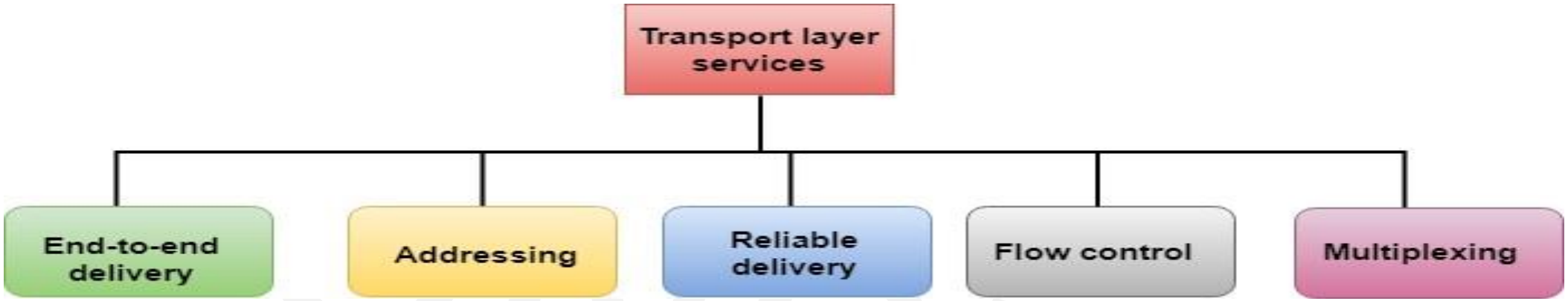
Session Layer

- **To start/manage/terminate the session.**
  - how to start, control and end conversations (called sessions) between applications.
  - log-on or password validation is also handled by this layer.
- **The session layer is the network *dialog controller.***
  - mechanism for controlling the dialogue between the two end systems and synchronization.
  - Allows the communication between two processes to take place in either half duplex (one way at a time) or full-duplex (two ways at a time) mode.
- **Synchronization**
  - Session layer can also provide check-pointing mechanism such that if a failure of some sort occurs between checkpoints, all data can be retransmitted from the last checkpoint.
  - It establishes, maintains, and synchronizes the interaction among communicating systems.
- **Protocols**
  - SIP: session initiation protocol
  - NetBIOS : Network Basic Input Output Service
  - RPC: Remote Procedure Call

Transport Layer

- Most Important Layer of OSI
- Responsible **for process-to-process/ End to End delivery** of the entire message.
- Provide a reliable mechanism for the **exchange of data between two processes** in different computers.
- Segment
  - smaller part of session PDU
  - every segment contains sequence number
  - every segment contains checksum for error checking
  - Segment contains:
    - **data** (from the session layer PDU)
    - **sequence number** : used for re-assembling the segments on the receiver machine
    - **checksum :** used to check if the data is not damaged

Responsibilities of Transport Layer



End –to-End delivery

- The transport layer transmits the entire message to the destination

Addressing

- The transport layer provides the user address which is specified as a station or port.

Reliable delivery

- provides reliability services by retransmitting the lost and damaged packets
- Error control, sequence control, loss control, duplicate control.

Error Control

- performs the checking for the errors end-to-end to ensure that the packet has arrived correctly.

Flow Control

- Flow control is used to prevent the sender from overwhelming the receiver.
- If the receiver is overloaded with too much data, then the receiver discards the packets & ask for retransmission of packets.

Multiplexing

- uses the multiplexing to improve transmission efficiency.

Transport Layer Protocol

TCP

- Transmission Control Protocol (Reliable)
- connection oriented protocol
  - connection will be kept alive till the data transfer in progress
- flow control, error checking and sequencing
- slower than UDP
- E.g. Email (no data loss)

UDP

- User Datagram Protocol (Unreliable)
- Connection Less Protocol
- does not provide error checking/ flow control
- Faster than TCP because no ACK only sending of data packets
- E.g: Online Games, Streaming

Network Layer

- The network layer is responsible for the source-to-destination delivery of a packet, possibly across multiple networks (links).
- It determines the route from the source to the destination and also manages the traffic problems such as switching, routing and controls the congestion of data packets.
  - Segment Contains :
    - data
    - source IP address
    - destination IP address
  - **Network Layer Responsibilities:**
    - Logical Addressing : The network layer translates the logical addresses into physical addresses
    - Routing : sending the data across the network
    - Internetworking : provides the logical connection between different types of networks
    - Fragmentation : breaking the packets into the smallest individual data units that travel through different networks.
  - **Protocols :**
    - IP : internet protocol
    - IPx : internetwork packet exchange
    - ICMP : Internet Control Messaging Protocol
    - NAT : Network Address Translation
    - ARP : Address Resolution Protocol
    - PPP: Point to Point Protocol
  - **Device** : Router

Data Link Layer

- Data link layer attempts to provide reliable communication over the physical layer interface.
- **DATA LINK Layer Responsibilities :**
  - **Framing:**
    - Breaks the outgoing data into frames and reassemble the received frames.
    - every frame contains (Source MAC address and Destination MAC address)
  - **Physical Addressing:**
    - uses MAC address to identify every NIC uniquely
  - **Flow Control:**
    - A flow control mechanism to avoid a fast transmitter from running a slow receiver by buffering the extra bit is provided by flow control. This prevents traffic jam at the receiver side.
  - **Error Control:**
    - Error control is achieved by adding a trailer at the end of the frame. Duplication of frames are also prevented by using this mechanism. Data Link Layers adds mechanism to prevent duplication of frames.
  - **Access Control:**
    - Protocols of this layer determine which of the devices has control over the link at any given time, when two or more devices are connected to the same link.
- **Protocols**
  - ARP(Address Resolution Protocol) : getting physical address from logical address
  - RARP: Reverse Address Resolution Protocol
- **Device :** Switch

Physical Layer

- Provides physical interface for transmission of information.
- Covers all - mechanical, electrical, functional and procedural - aspects for physical communication. Characteristics like voltage levels, timing of voltage changes, physical data rates, etc.
- send data in the form of 1's and 0's.
- senders and receivers clock must be synchronized.
- **Transmission mode:**
  - Defines direction of transmission simplex, half duplex and full duplex
- **Devices:**
  - NIC , Cables , hubs , repeaters , connectors

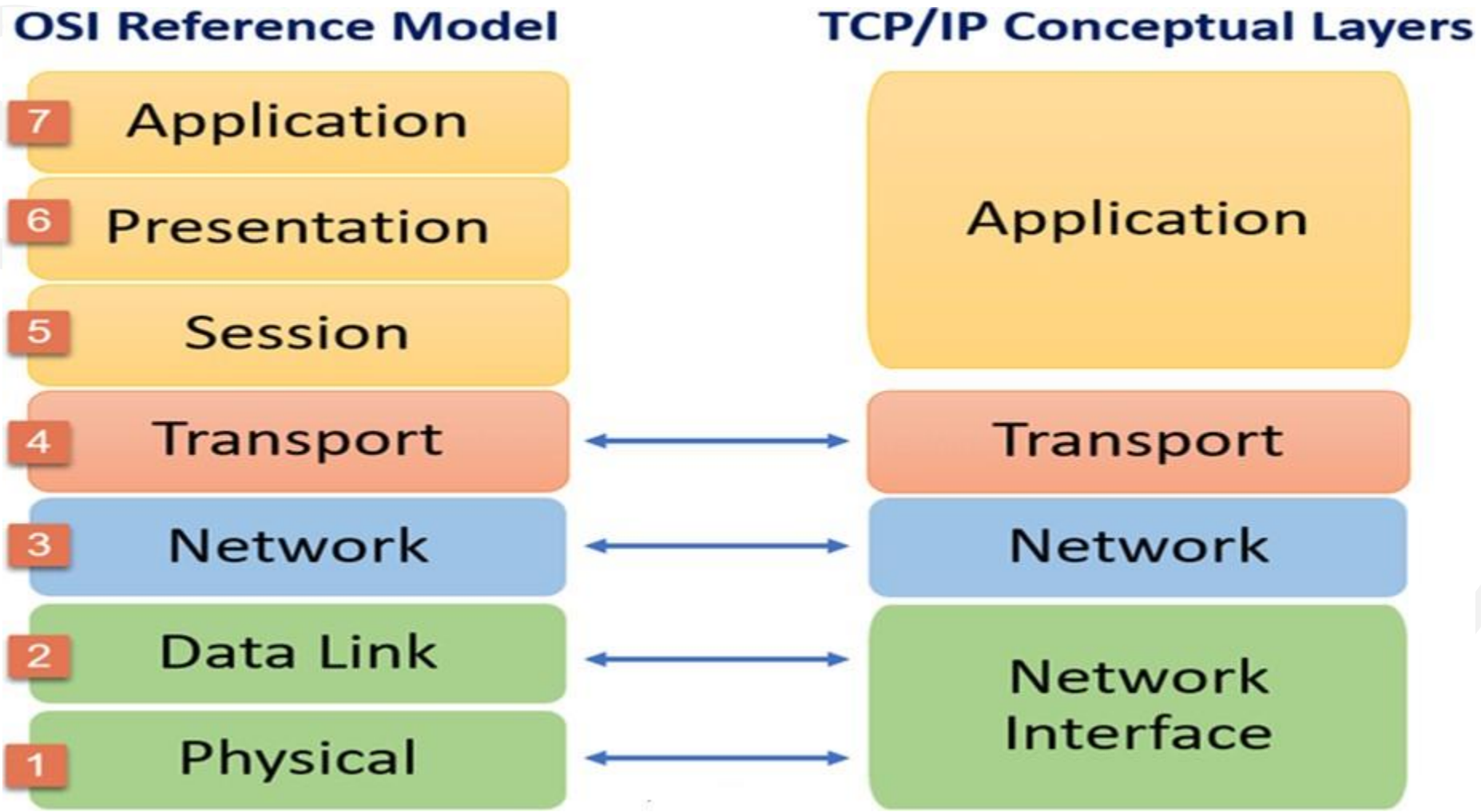
7 Layers of OSI Model

Application (PDU : Data)	• End user Layer • HTTP, FTP, IRC, SSH, DNS
Presentation (PDU : Data)	• Syntax Layer • SSL, SSH, IMAP, FTP, MPEG, JPEG
Session (PDU : Data)	• Synch and Send to port • API's, Sockets
Transport (PDU : Segment)	• End to end Connections • TCP , UDP
Network (PDU : Packet)	• Packets • IP, ICMP, IPSec, IGMP
Data Link (PDU : Frame)	• Frames • Ethernet, PPP. Switch, Bridge
Physical (PDU : Bits)	• Physical Structure • Coax, Fiber, Wireless, Hubs, Repeaters

OSI and TCP/IP Model

- 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 protocols layout 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 protocols were developed first and then the model was developed.
- The OSI has seven layers while the TCP/IP has four layers.

OSI and TCP/IP Model



Thank You!!