Mobile Computing Architecture

UW Bothell, WA

Lecture 2: Networking Basics

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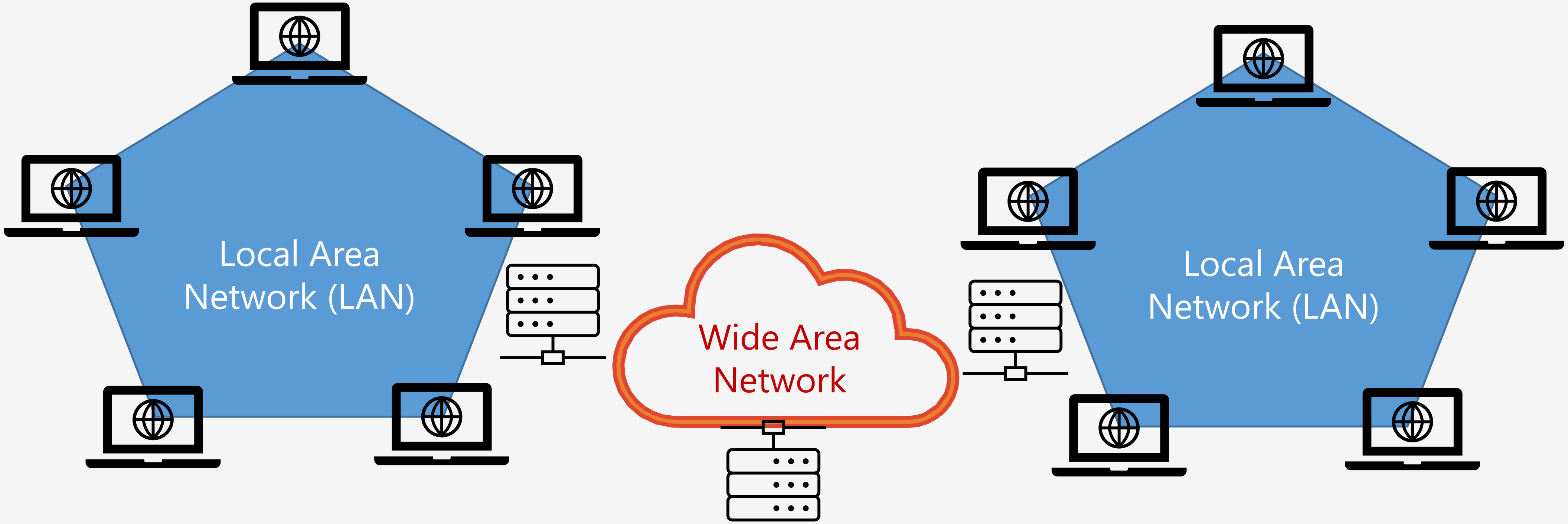
What is a Network?



A network refers to two or more connected computers that can share resources such as data, a printer, an Internet connection, applications, or a combination of these resources.

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Network Protocol

A network protocol is an established set of rules that determine how data is transmitted between different devices in the same network. Essentially, it allows connected devices to communicate with each other, regardless of any differences in their internal processes, structure or design. Network protocols are the reason you can easily communicate with people all over the world, and thus play a critical role in modern digital communications.

Network protocols take large-scale processes and break them down into small, specific tasks or functions.

This occurs at every level of the network, and each function must cooperate at each level to complete the larger task at hand. The term protocol suite refers to a set of smaller network protocols working in conjunction with each other.

Network protocols are typically created according to industry standard by various networking or information technology organizations.

The following groups have defined and published different network protocols:
The Institute of Electrical and Electronics Engineers (IEEE)
The Internet Engineering Task Force (IETF)
The International Organization for Standardization (ISO)
The International Telecommunications Union (ITU)
The World Wide Web Consortium (W3C)

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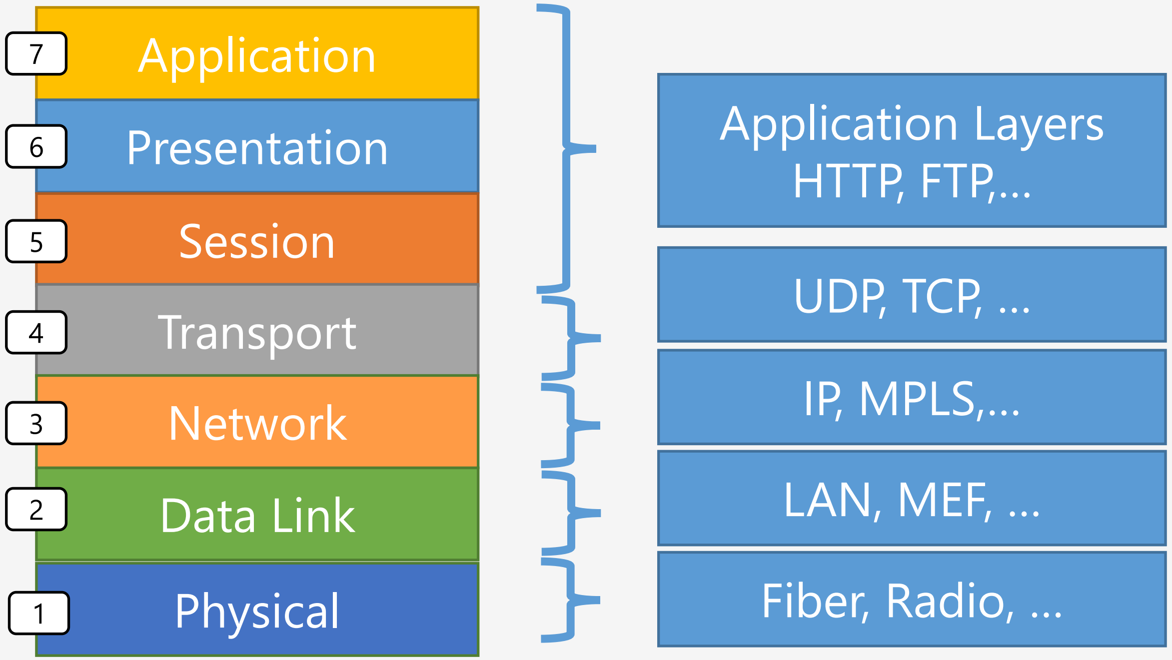
OSI Stack – Layered Network Model

A layer corresponds strongly to the idea of a programming interface, with the understanding that a given layer communicates directly only with the two layers immediately above and below it. The OSI Stack ensures modularity, abstraction, standardized interoperation, innovation, etc.



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OSI Stack – Layered Network Model – Application Layer

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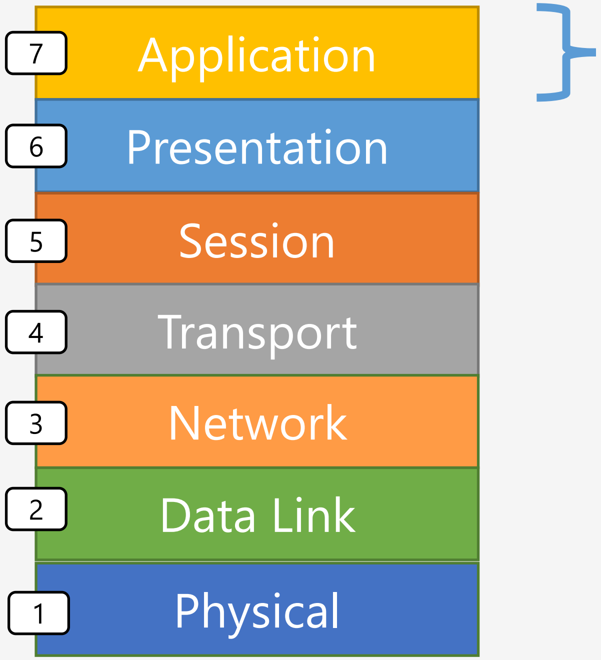

- The application layer is the OSI layer closest to the end user, the user interact directly with the software application
- This layer interacts with software applications that implement a communicating component
- This layer's protocol data unit is often called "Data"

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OSI Stack – Layered Network Model – Application Layer Examples

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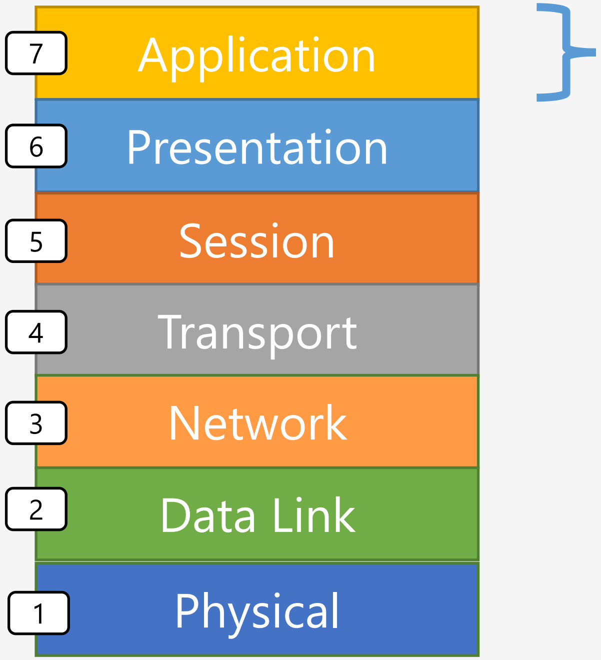

OSI Stack – Layered Network Model – Presentation Layer

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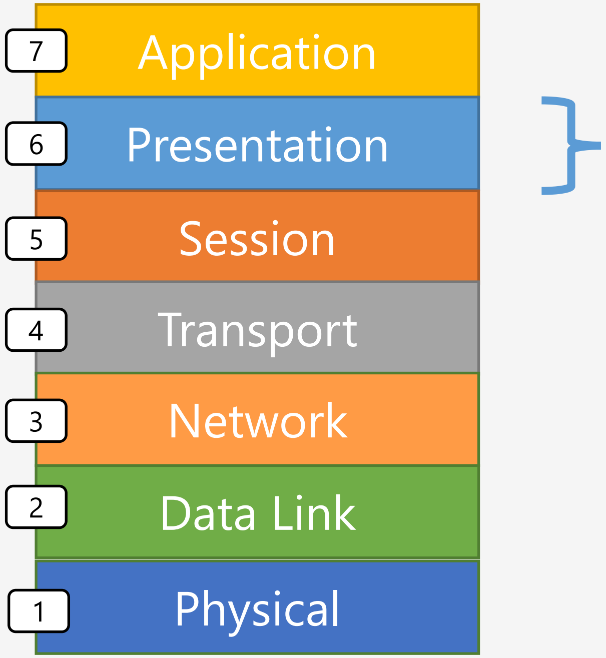

- The presentation layer establishes context between application-layer entities, in which the application-layer entities may use different syntax and semantics if the presentation service provides a mapping between them. If a mapping is available, presentation protocol data units (Data) are encapsulated into session protocol data units and passed down the protocol stack.

- This layer provides independence from data representation by translating between application and network formats. The presentation layer transforms data into the form that the application accepts. This layer formats data to be sent across a network. It is sometimes called the syntax layer. The presentation layer can include compression functions.

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OSI Stack – Layered Network Model – Presentation Layer – Example

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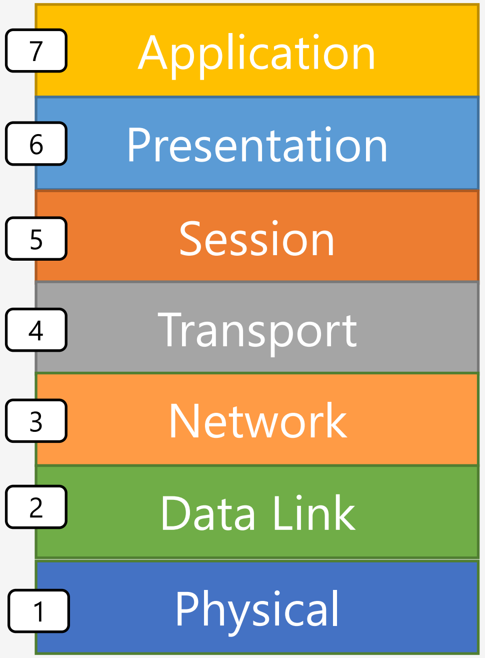

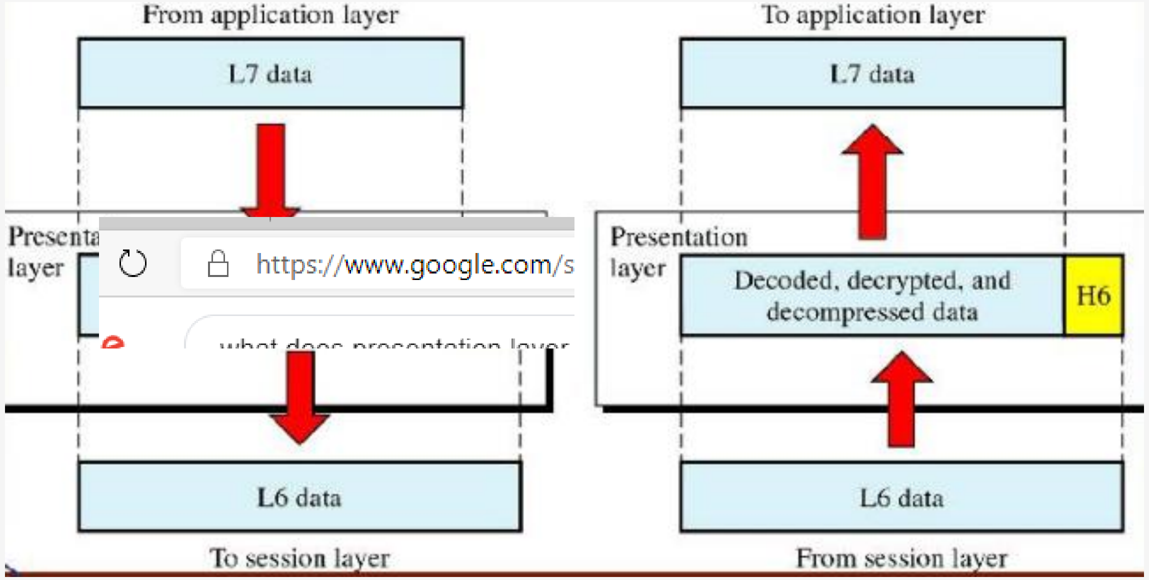

- HTTPS
- SSL

OSI Stack – Layered Network Model – Session Layer

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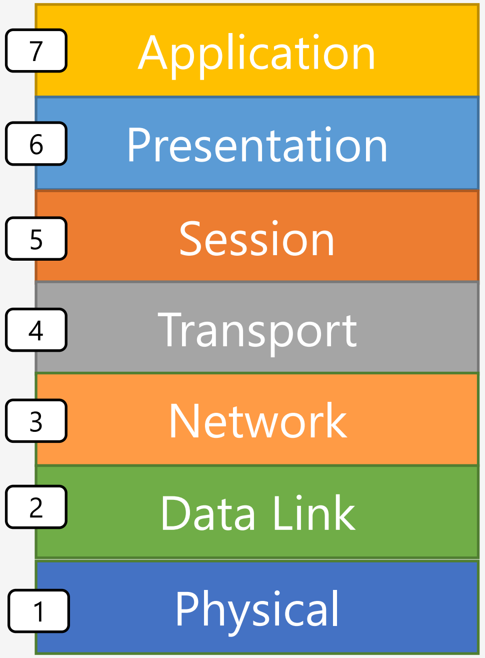

- The session layer controls the dialogues (connections) between computers. It establishes, manages and terminates the connections between the local and remote application.
- It establishes procedures for checkpointing, suspending, restarting, and terminating a session. This layer is also responsible for session checkpointing and recovery. The session layer is commonly implemented explicitly in application environments that use remote procedure calls.

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OSI Stack – Layered Network Model – Session Layer Functions

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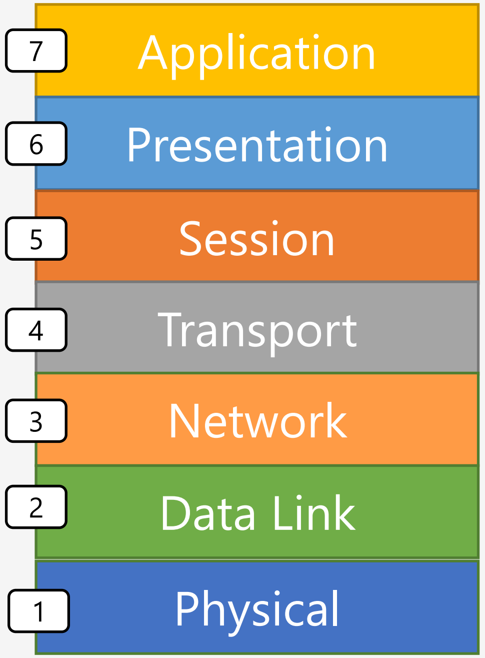
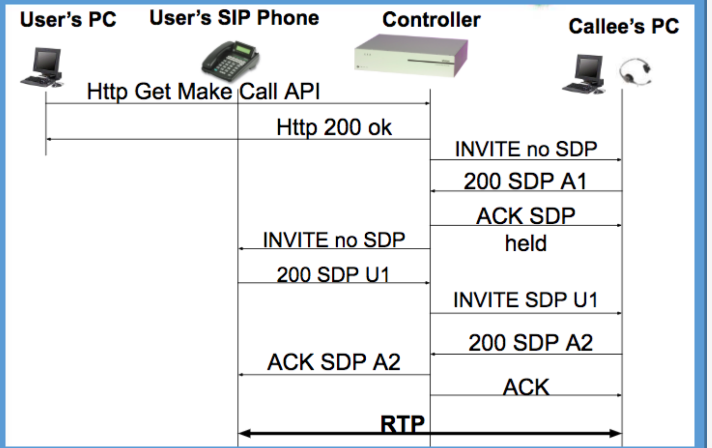


- Session management - the session layer is responsible for managing a session which includes opening, closing and managing a session between end-user application processes. It handles the requests and responses between the two applications.

- Authentication - before establishing a session with some network peer, it is important for one of the computers to know that another peer it is communicating to is a legitimate one. In short terms, you can say that authentication is the process of verifying that "you are who you say you are“

- Authorization: "Are you authorized to do so?“

- Example protocols:
  - Remote procedure call protocol (RPC)
  - Point-to-Point Tunneling Protocol (PPTP)
  - Session Initiation Protocol (SIP)
  - Session Control Protocol (SCP)
  - Session Description Protocol (SDP) etc.



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OSI Stack – Layered Network Model – Session Layer - Example

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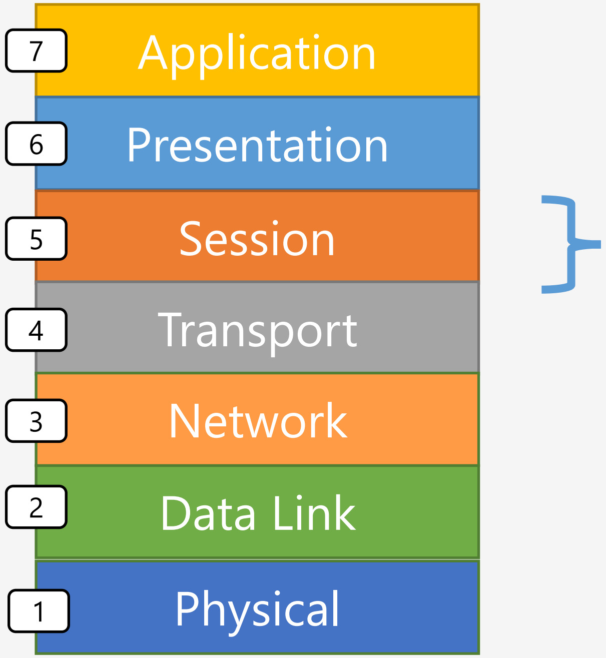

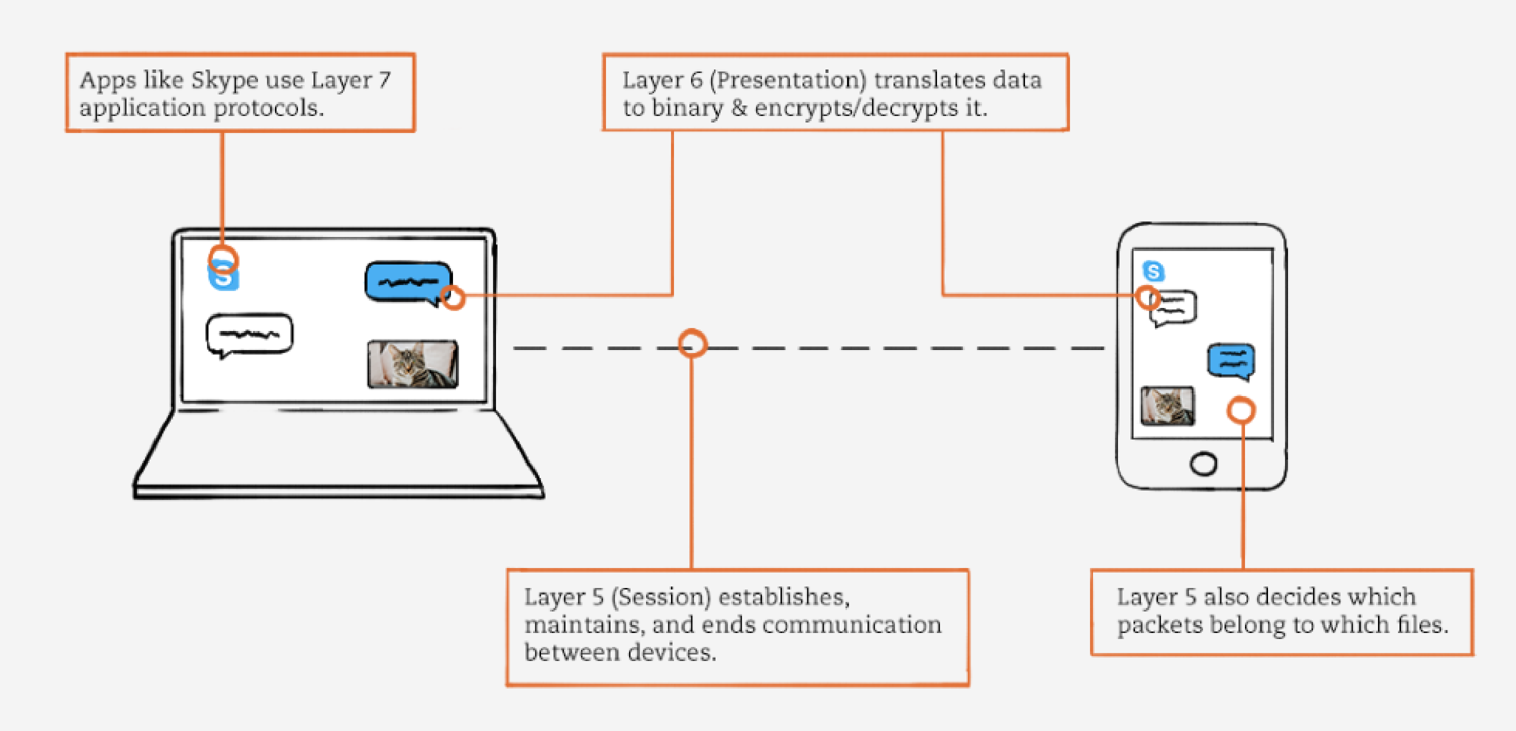

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Group Exercise – 10 minutes

Scenario: A team of engineers is tasked to combine the top three layers (Application, Presentation and Session) into one single layer.

⇒ **What functionality and features this hypothetical layer will have?**

⇒ **Name the hypothetical layer**

⇒ **Be prepared to present under 1 minute the name and the functionality of the features**

Logistics: Breakout room with 3-4 students

OSI Stack – Layered Network Model – Transport Layer

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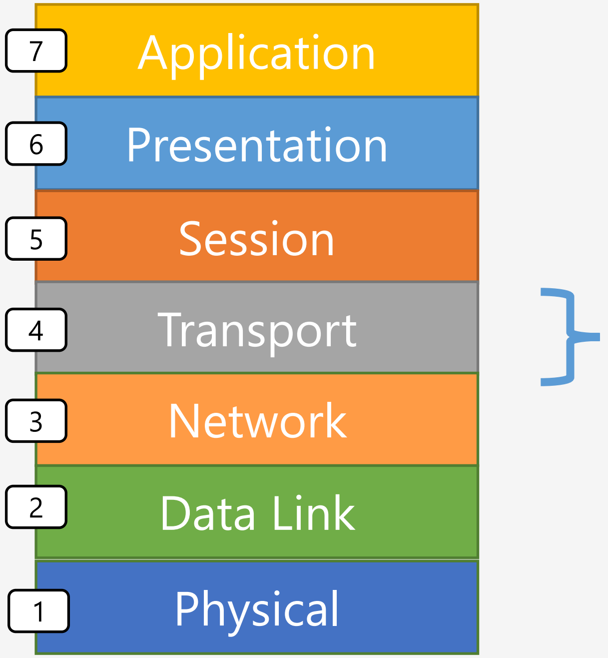

- The transport layer provides the functional and procedural means of transferring variable-length data ***segments*** from a source to a destination host, while maintaining the quality of service functions.
- The transport layer creates ***segments*** out of the message received from the application layer. Segmentation is the process of dividing a long message into smaller messages. The transport layer controls the reliability of a given link through flow control, segmentation/desegmentation, and error control. Some protocols are state- and connection-oriented. This means that the transport layer can keep track of the segments and retransmit those that fail delivery. The transport layer also provides the acknowledgement of the successful data transmission and sends the next data if no errors occurred
- The transport layer is represented by two protocols: **TCP and UDP**

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Transport Layer Protocol: User Datagram Protocol (UDP)

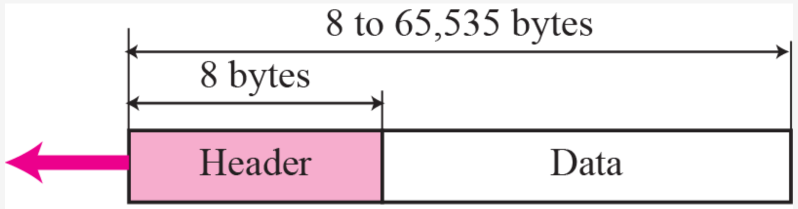
UDP is also popular for **real-time** transport. UDP gives the receiving application the freedom simply to ignore lost packets. This approach is very successful for voice and video, which are **loss-tolerant** in that small losses simply degrade the received signal slightly, but **delay-intolerant** in that packets arriving too late for playback might as well not have arrived at all. Loss tolerance is the reason the **Real-time Transport Protocol**, or RTP. UDP is common for VoIP telephone calls to use RTP and UDP. Used in Mobile Communications in GTP (Control and User planes).

UDP Packet:

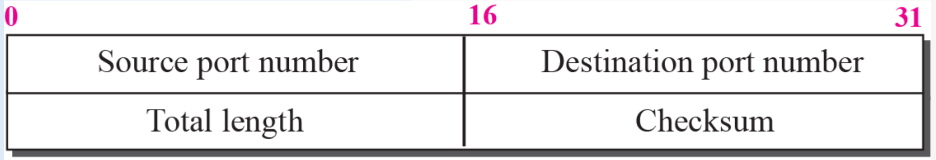
- **Source Port Number**
- **Destination Port Number**
- **Total Length [8 to 65.535 Bytes]**
- **Checksum**
- **Data**

UDP Ports

Port	*Protocol*	*Description*
7	Echo	Echoes a received datagram back to the sender
9	Discard	Discards any datagram that is received
11	Users	Active users
13	Daytime	Returns the date and the time
17	Quote	Returns a quote of the day
19	Chargen	Returns a string of characters
53	Domain	Domain Name Service (DNS)
67	Bootps	Server port to download bootstrap information
68	Bootpc	Client port to download bootstrap information
69	TFTP	Trivial File Transfer Protocol
111	RPC	Remote Procedure Call
123	NTP	Network Time Protocol
161	SNMP	Simple Network Management Protocol
162	SNMP	Simple Network Management Protocol (trap)



a. UDP user datagram



b. Header format

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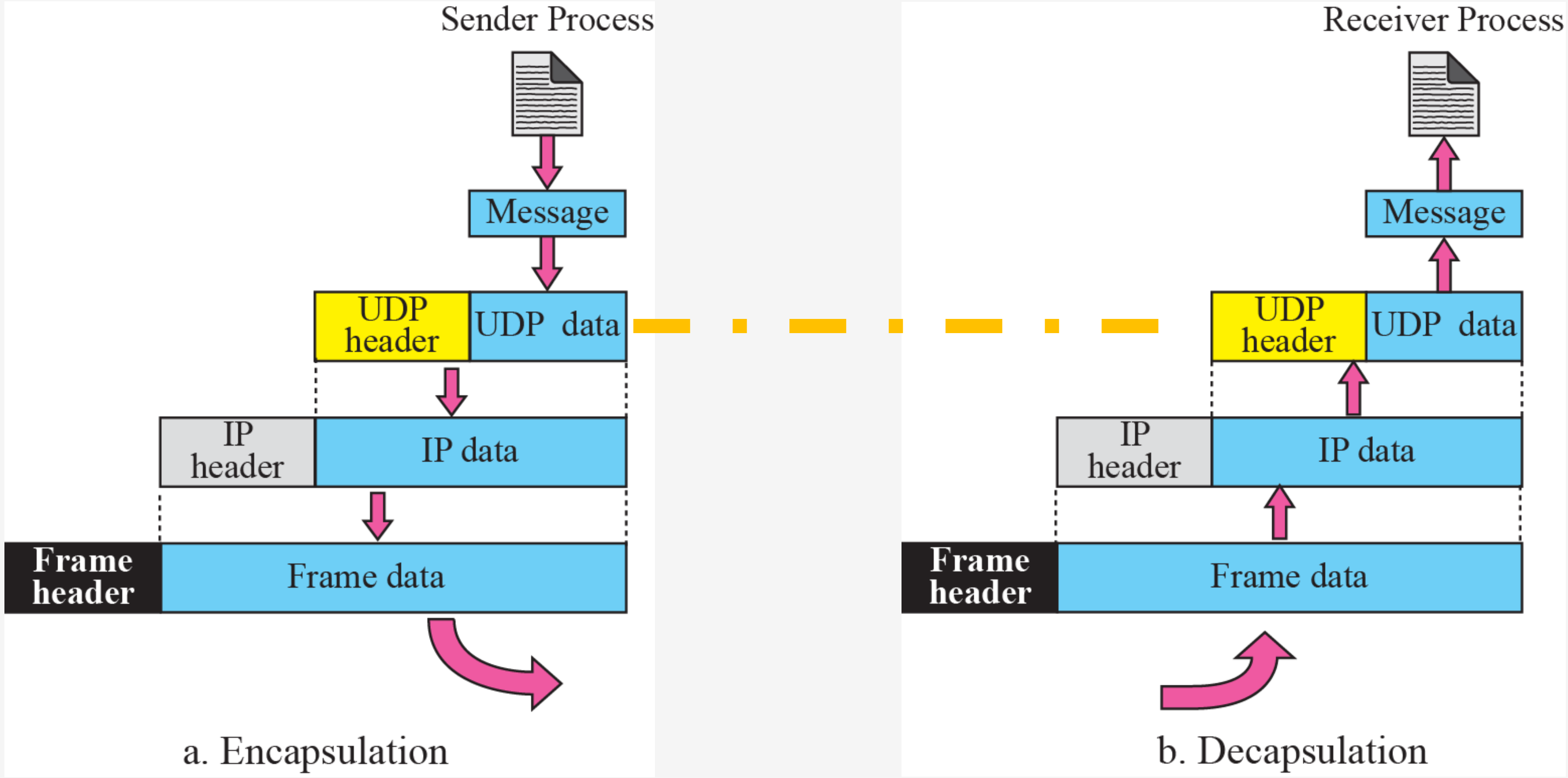
UDP: Client Server Communication

Encapsulation and Decapsulation



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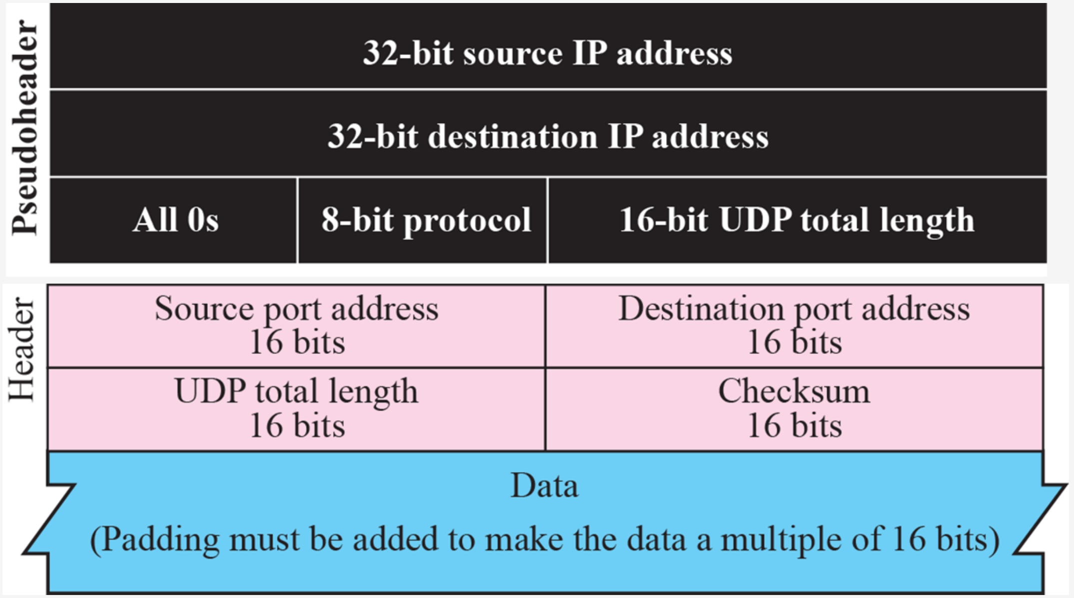
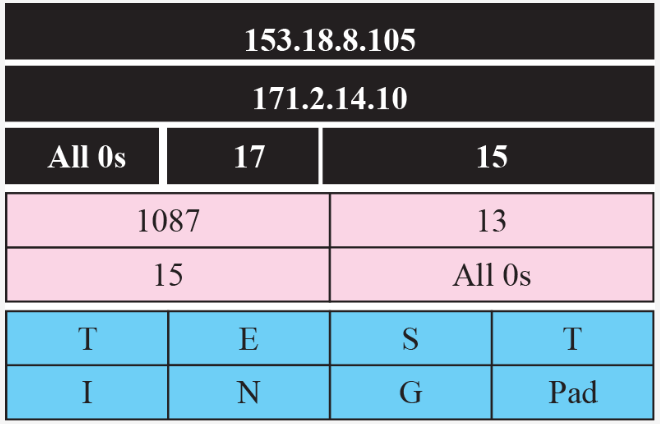
UDP – Checksum
Pseudo header





10011001 00010010	⟶	153.18
00001000 01101001	⟶	8.105
10101011 00000010	⟶	171.2
00001110 00001010	⟶	14.10
00000000 00010001	⟶	0 and 17
00000000 00001111	⟶	15
00000100 00111111	⟶	1087
00000000 00001101	⟶	13
00000000 00001111	⟶	15
00000000 00000000	⟶	0 (checksum)
01010100 01000101	⟶	T and E
01010011 01010100	⟶	S and T
01001001 01001110	⟶	I and N
01000111 00000000	⟶	G and 0 (padding)
10010110 11101011	⟶	Sum
01101001 00010100	⟶	Checksum

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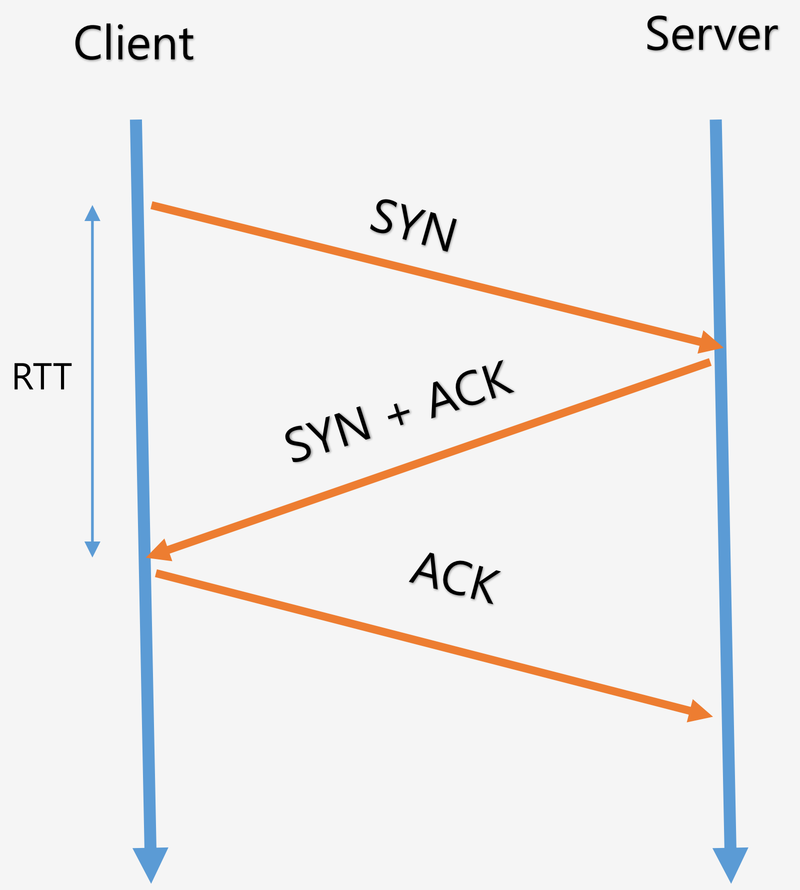
Transport Layer Protocol: Transmission Control Protocol (TCP)

Client initiates the connection and sends the segment with a Sequence number. Server acknowledges it back with its own Sequence number and ACK of client's segment which is one more than client's Sequence number. Client after receiving ACK of its segment sends an acknowledgement of Server's response.

Congestion Control: When large amount of data is fed to system which is not capable of handling it, **congestion** occurs. TCP controls congestion by means of Window mechanism. TCP sets a window size telling the other end how much data segment to send. TCP may use three algorithms for congestion control:

- Slow Start
- Additive increase, Multiplicative Decrease
- Timeout React



RTT = Round Trip Time

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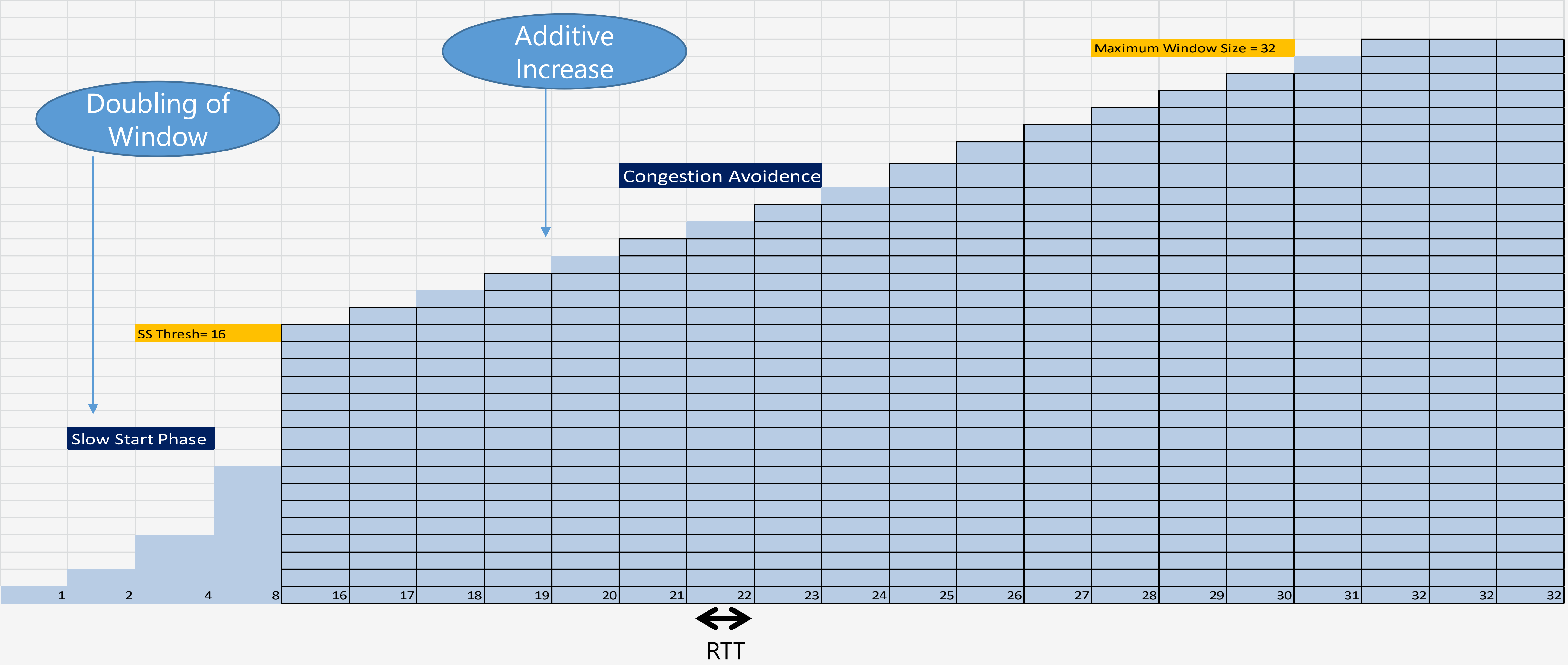
TCP: No Packet Loss behavior



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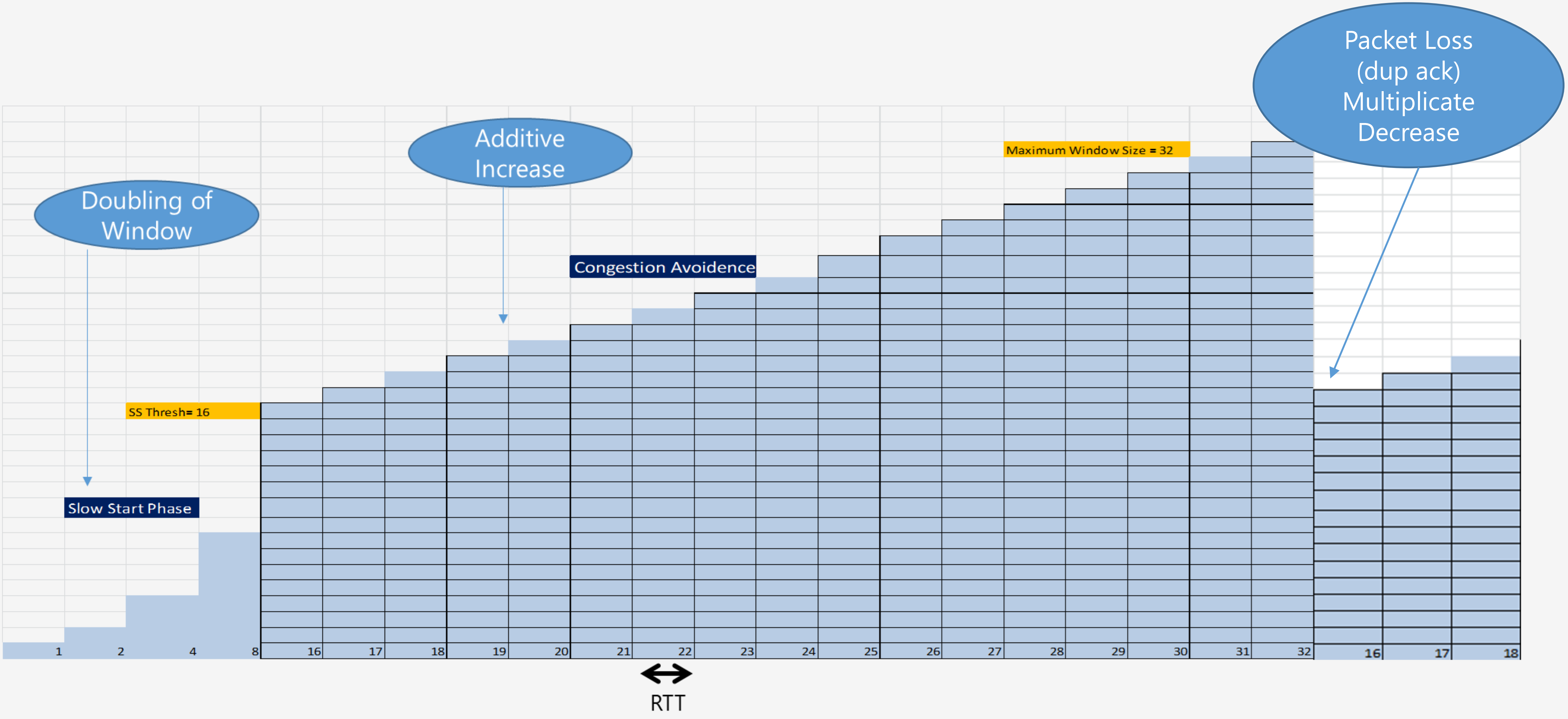
TCP: Packet Loss behavior



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OSI Stack – Layered Network Model – Network Layer (also called Layer 3)

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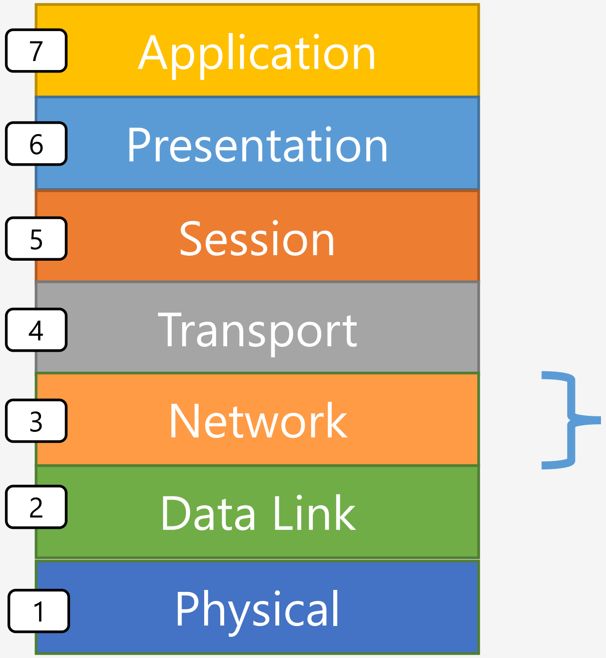

- The network layer provides the functional and procedural means of transferring variable length data sequences (called ***packets***) from one node to another connected in "different networks."
- A network is a medium to which many nodes can be connected, on which every node has an *address*. A network permits nodes connected to it to transfer messages to other nodes connected to it by merely providing the content of a message and the address of the destination node and letting the network find the way to deliver the message to the destination node. This process is called routing and forwarding.
- If the message is too large to be transmitted, the network may implement message delivery by splitting the message into several fragments at one node, sending the fragments independently, and reassembling the fragments at another node. Message delivery at the network layer is not necessarily guaranteed to be reliable.

OSI Stack – Layered Network Model – Network Layer - Example

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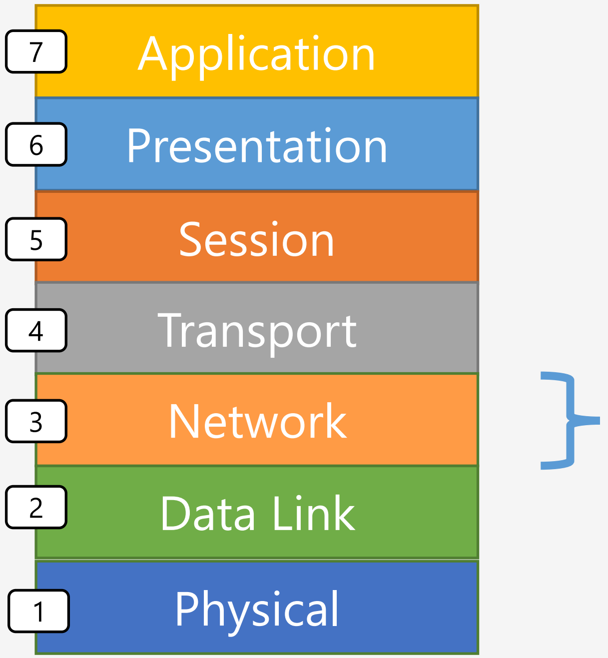

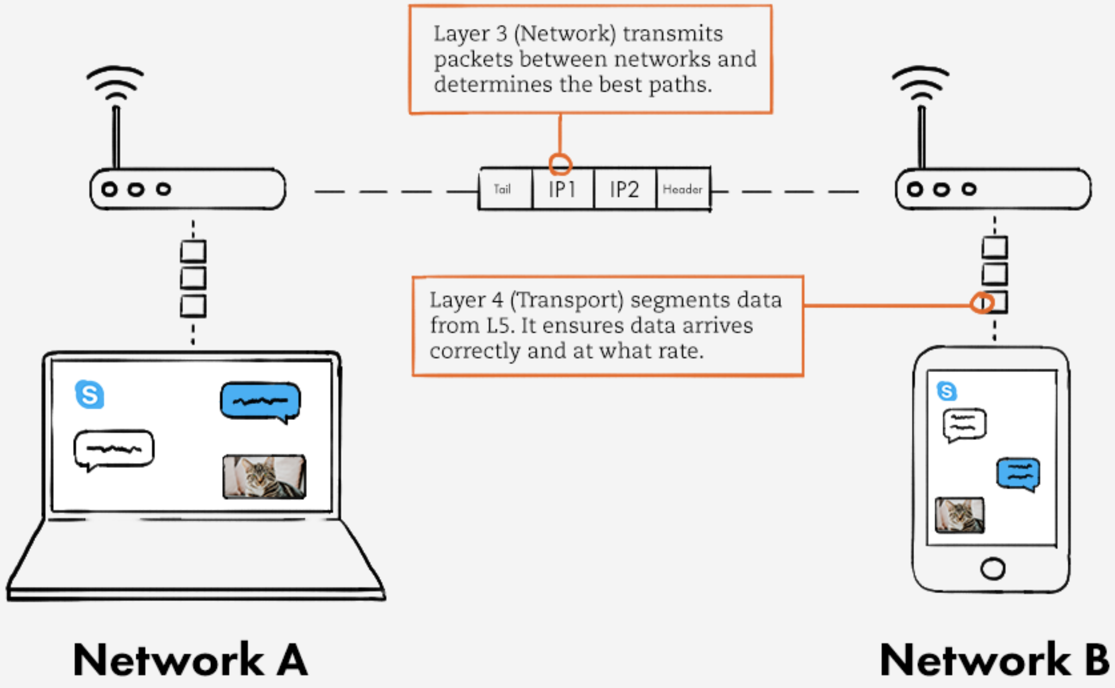

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OSI Stack – Layered Network Model – Network Layer – Example contd

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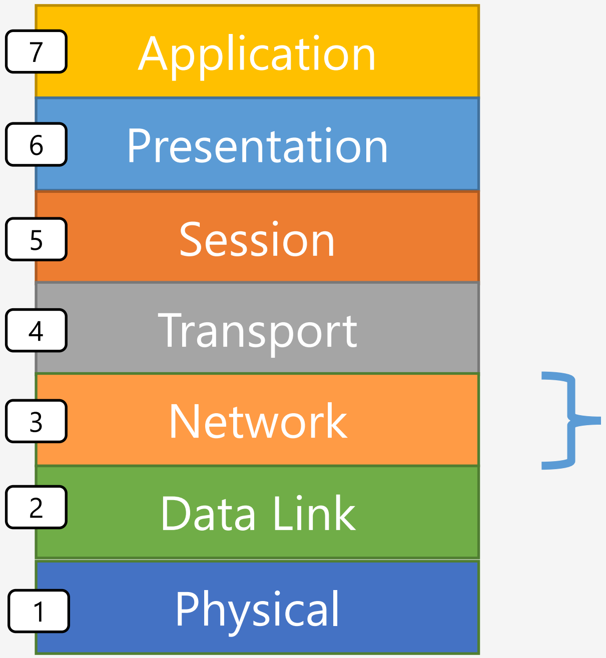

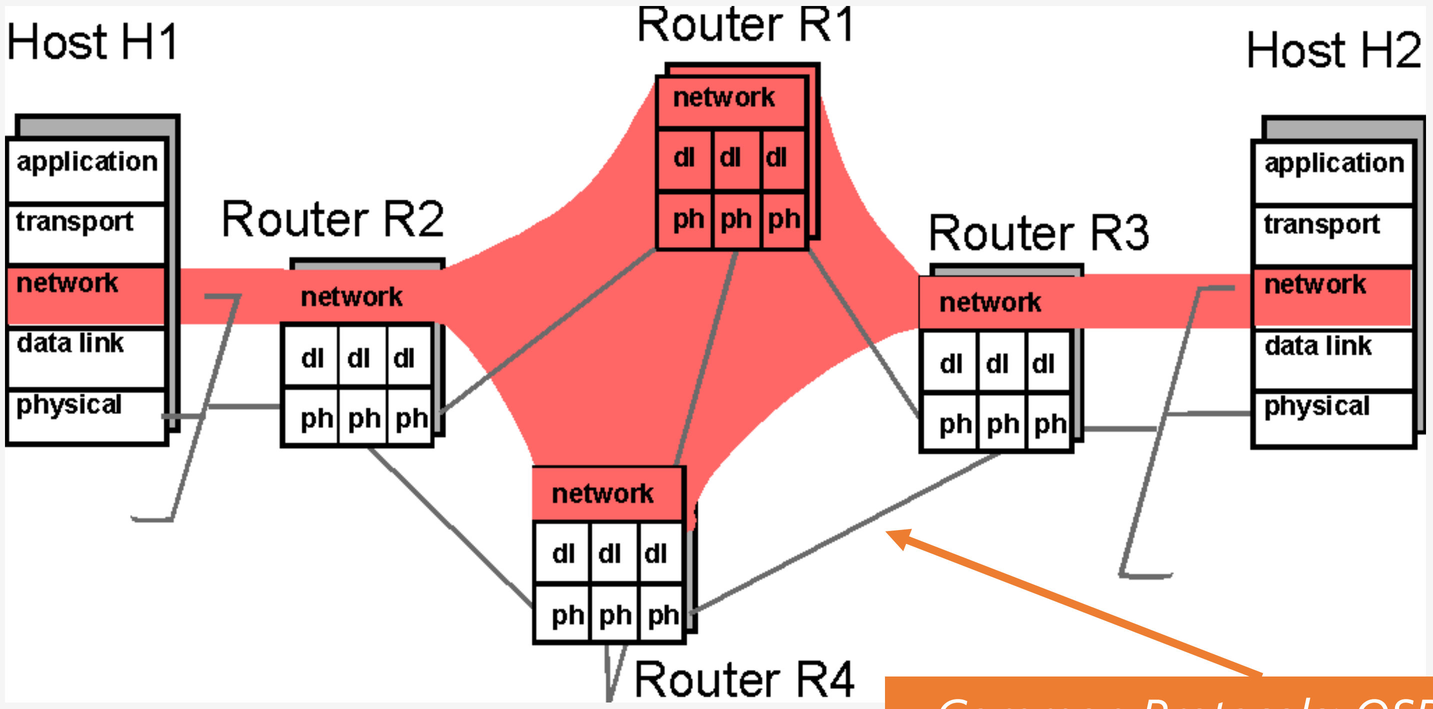

Common Protocols: OSPF, IS-IS, BGP,…

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OSI Stack – Layered Network Model – Data Link Layer

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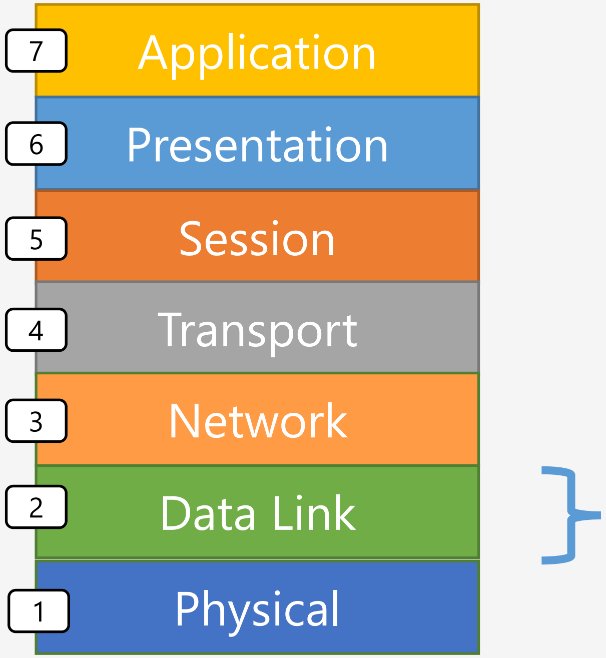
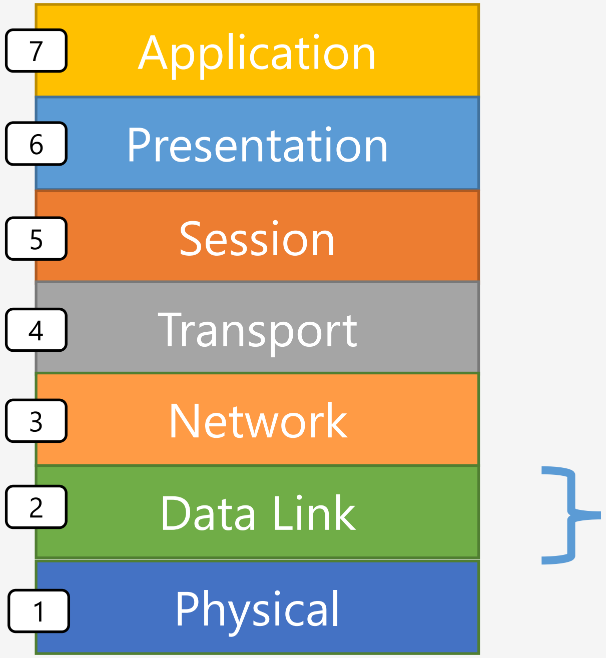


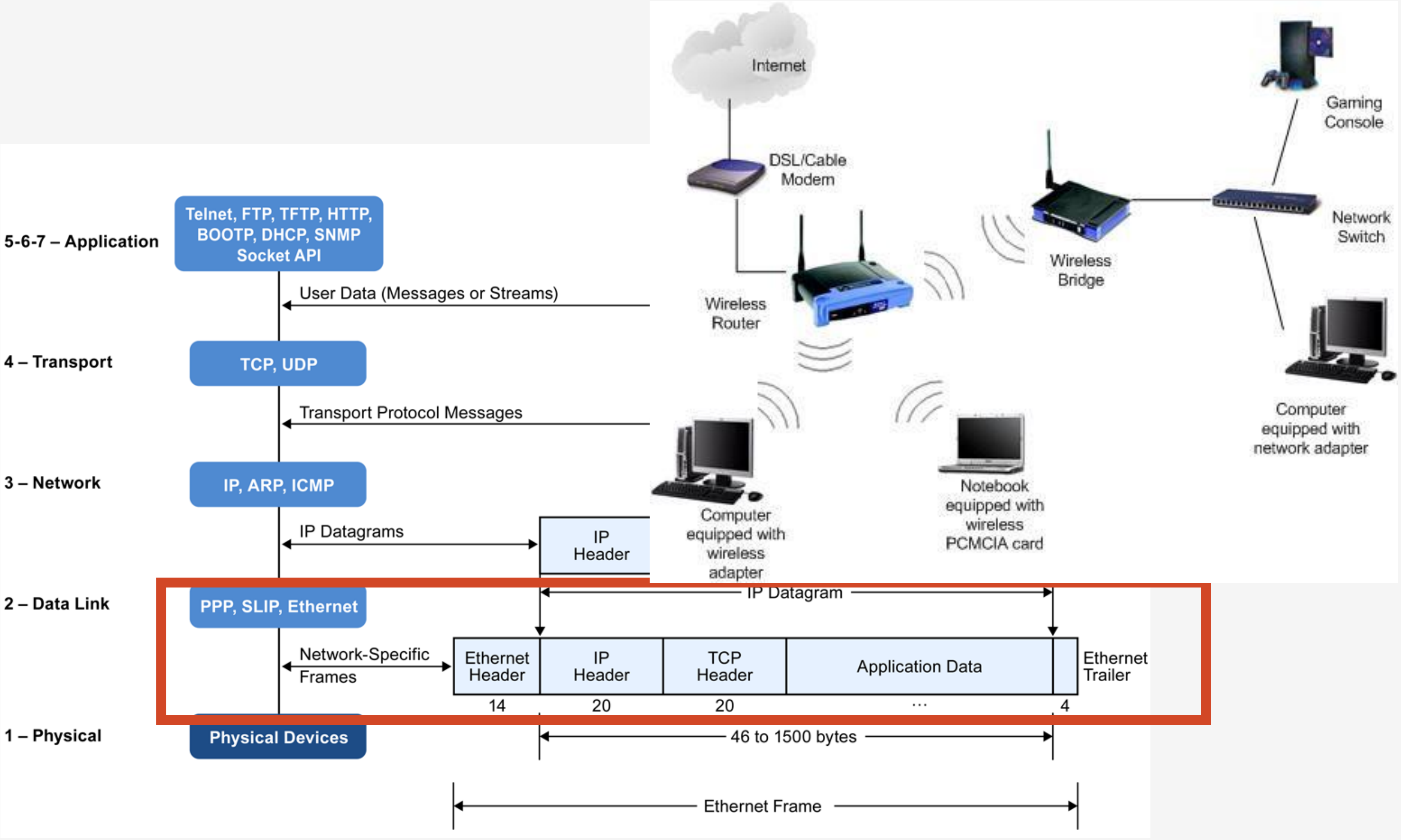
- The data link layer, often called Layer 2, provides node-to-node data transfer of ***frames***—on a link between two directly connected nodes. It detects and possibly corrects errors that may occur in the physical layer. It defines the protocol to establish and terminate a connection between two physically connected devices. It also defines the protocol for flow control between them.

- IEEE 802 divides the data link layer into two sublayers:
  - Medium access control (MAC) layer – responsible for controlling how devices in a network gain access to a medium and permission to transmit data.
  - Logical link control (LLC) layer – responsible for identifying and encapsulating network layer protocols, and controls error checking and frame synchronization.

- The MAC and LLC layers of IEEE 802 networks such as 802.3 Ethernet, 802.11 Wi-Fi, and 802.15.4 ZigBee operate at the data link layer.

OSI Stack – Layered Network Model – Data Link Layer - Example





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OSI Stack – Layered Network Model – Physical Layer

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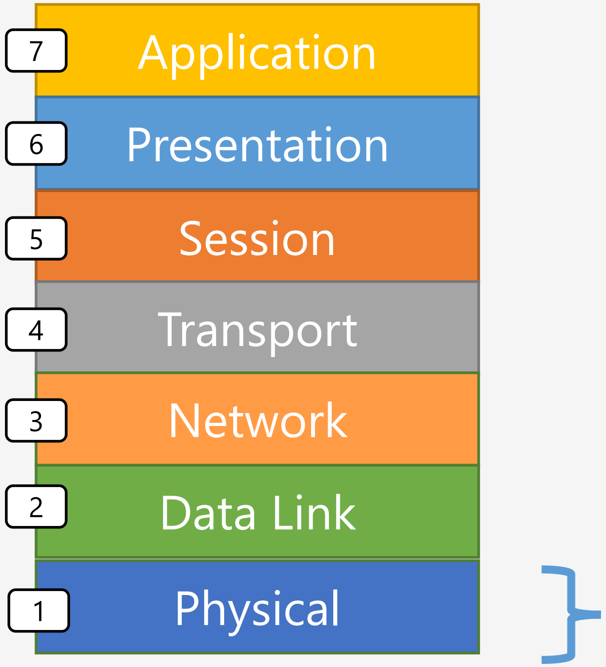

- The physical layer is responsible for the transmission and reception of unstructured raw data between a device and a physical transmission medium.
- It converts the digital bits into electrical, radio, or optical signals.
- Layer specifications define characteristics such as voltage levels, the timing of voltage changes, physical data rates, maximum transmission distances, modulation scheme, channel access method and physical connectors.
- This includes the layout of pins, voltages, line impedance, cable specifications, signal timing and frequency for wireless devices. Bit rate control is done at the physical layer and may define transmission mode as simplex, half duplex, and full duplex. Physical layer specifications are included in the specifications for the ubiquitous Bluetooth, Ethernet, and USB standards.

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OSI Stack – Layered Network Model – Physical Layer - Examples

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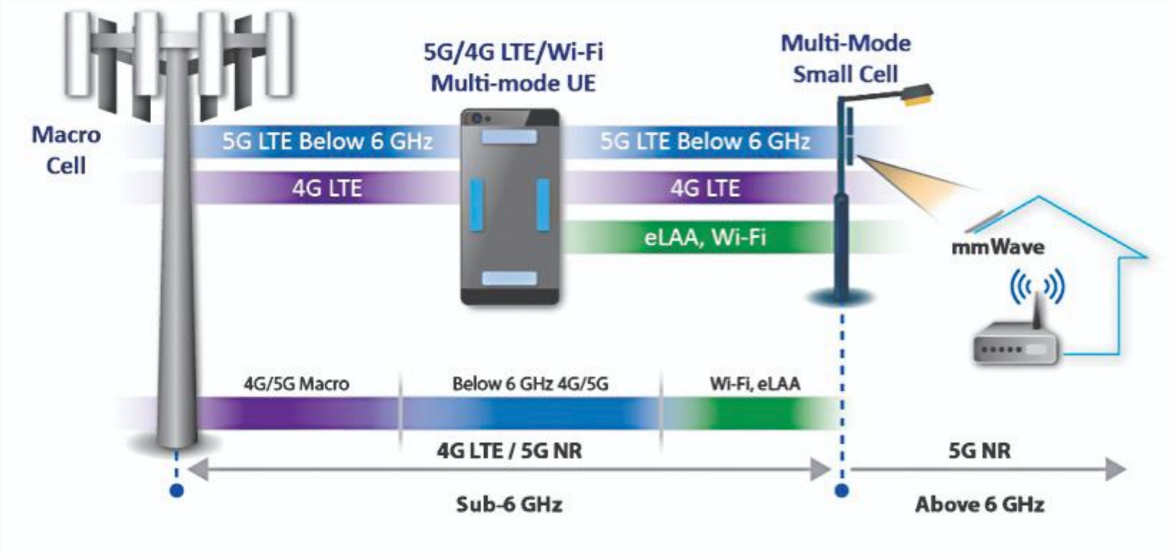
7 Application
6 Presentation
5 Session
4 Transport
3 Network
2 Data Link
1 Physical



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OSI Network Stack - Summary

OSI (Open Source Interconnection) 7 Layer Model

Layer	Application/Example		Central Device/ Protocols			DOD4 Model
Application (7) Serves as the window for users and application processes to access the network services.	**End User layer** Program that opens what was sent or creates what is to be sent Resource sharing • Remote file access • Remote printer access • Directory services • Network management		**User Applications** SMTP		GATEWAY Can be used on all layers	Process
Presentation (6) Formats the data to be presented to the Application layer. It can be viewed as the "Translator" for the network.	**Syntax layer** encrypt & decrypt (if needed) Character code translation • Data conversion • Data compression • Data encryption • **Character Set Translation**		JPEG/ASCII EBDIC/TIFF/GIF PICT			
Session (5) Allows session establishment between processes running on different stations.	**Synch & send to ports** (logical ports) Session establishment, maintenance and termination • Session support - perform security, name recognition, logging, etc.		**Logical Ports** RPC/SQL/NFS NetBIOS names			
Transport (4) Ensures that messages are delivered error-free, in sequence, and with no losses or duplications.	**TCP** Host to Host, Flow Control Message segmentation • Message acknowledgement • Message traffic control • Session multiplexing	PACKET FILTERING	TCP/SPX/UDP			Host to Host
Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	**Packets** ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting		**Routers** IP/IPX/ICMP			Internet
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	**Frames** ("envelopes", contains MAC address) [NIC card — Switch — NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control		**Switch** **Bridge** **WAP** PPP/SLIP	Land Based Layers		Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	**Physical structure** Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts		**Hub**			

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https://www.quora.com/What-devices-are-used-in-each-layer-of-the-OSI-model

OSI Network Stack versus US DoD TCP/IP Stack

OSI Stack

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Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	**Packets** ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting	**Routers** IP/IPX/ICMP		Internet
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	**Frames** ("envelopes", contains MAC address) [NIC card — Switch — NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control	**Switch Bridge WAP** PPP/SLIP Land Based Layers		Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	**Physical structure** Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts	**Hub** Land Based Layers		

US DoD TCP/IP Stack

OSI (Open Source Interconnection) 7 Layer Model

Layer	Application/Example	Central Device/ Protocols		DOD4 Model
Application **(5)** Serves as the window for users and application processes to access the network services.	**End User layer** Program that opens what was sent or creates what is to be sent Resource sharing • Remote file access • Remote printer access • Directory services • Network management	**User Applications** SMTP		
Transport (4) Ensures that messages are delivered error-free, in sequence, and with no losses or duplications.	**TCP** Host to Host, Flow Control Message segmentation • Message acknowledgement • Message traffic control • Session multiplexing PACKET FILTERING	TCP/SPX/UDP	EWAY	Host to Host
Network (3) Controls the operations of the subnet, deciding which physical path the data takes.	**Packets** ("letter", contains IP address) Routing • Subnet traffic control • Frame fragmentation • Logical-physical address mapping • Subnet usage accounting	**Routers** IP/IPX/ICMP	Can be used on all layers	Internet
Data Link (2) Provides error-free transfer of data frames from one node to another over the Physical layer.	**Frames** ("envelopes", contains MAC address) [NIC card — Switch — NIC card] (end to end) Establishes & terminates the logical link between nodes • Frame traffic control • Frame sequencing • Frame acknowledgment • Frame delimiting • Frame error checking • Media access control	**Switch Bridge WAP** PPP/SLIP Land Based Layers		Network
Physical (1) Concerned with the transmission and reception of the unstructured raw bit stream over the physical medium.	**Physical structure** Cables, hubs, etc. Data Encoding • Physical medium attachment • Transmission technique - Baseband or Broadband • Physical medium transmission Bits & Volts	**Hub** Land Based Layers		

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https://www.quora.com/What-devices-are-used-in-each-layer-of-the-OSI-model

Common Network Metrics – Throughput, Data Rate,...

Throughput
Data Rate
Bandwidth

- Any one network connection – eg at the LAN layer – has a data rate: the rate at which bits are transmitted. In some LANs (eg Wi-Fi) the data rate can vary with time.
- Throughput refers to the overall effective transmission rate, taking into account things like transmission overhead, protocol inefficiencies and perhaps even competing traffic. It is generally measured at a higher network layer than the data rate.
- The term bandwidth can be used to refer to either of these, though we here use it mostly as a synonym for data rate. The term comes from radio transmission, where the width of the frequency band available is proportional, all else being equal, to the data rate that can be achieved.
- Data rates are generally measured in kilobits per second (Kbps) or megabits per second (Mbps); the use of the lower-case “b” here denotes bits. The upper-case B denoting bytes often used in MBps etc.

Common Network Metrics – Latency, Loss, Jitter,….

Delay (Latency)
Jitter
Loss

- Delay (Latency) is the time it takes a data packet to travel from point-to-point on the network. Each step the traffic takes through the network will add to its latency. Transmission delay, physical delay, queueing delay, etc. all add to the delay. Latency, for example, higher than 150 milliseconds (ms) will cause unnatural delays in an audio conversation. On a video call, high latency could create a disconnect between the audio and the video. If latency becomes too high, you could experience periods of no audio or video at all.

- Jitter is an inconsistent arrival of packets between two endpoints. Jitter of more than 20 ms will cause delays in packet arrival which, like high latency, will result in delays in your audio or video.

- Packet Loss happens when a packet does not arrive, arrives out of order, or arrives too late. Lost packets are just discarded. Packet loss over a network will cause choppy, poor-quality audio and video.

Sireen Malik. Mobile Computing Architecture, 2020

Example TCP: Throughput (TP)

$$Higher\ TP\colon\ RTT \to 0$$

$$Higher\ Tp\colon Packet\ Loss \to 0$$

$$\mathrm{TP} = \frac{Segment\ Size\ x\ Constant}{RTT * \sqrt{p}}$$

RTT = Round Trip Time
P = packet loss
Maximum Segment Size= typically 1560Bytes

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