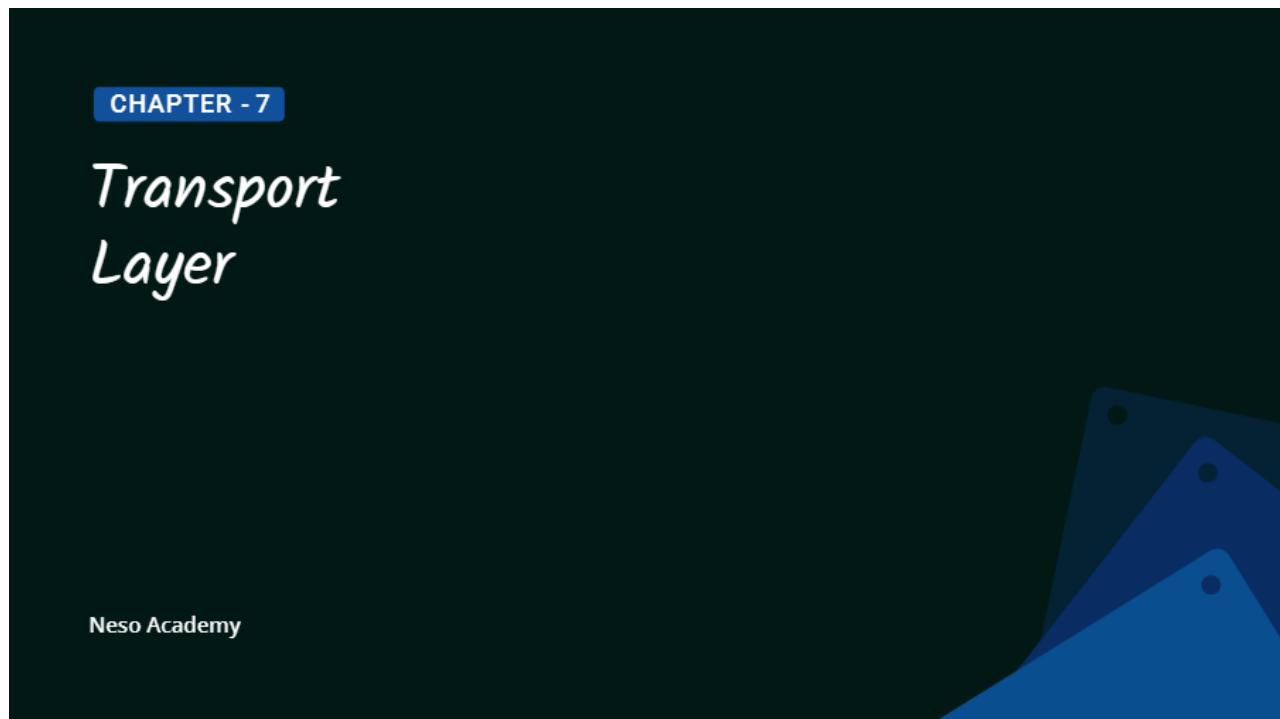
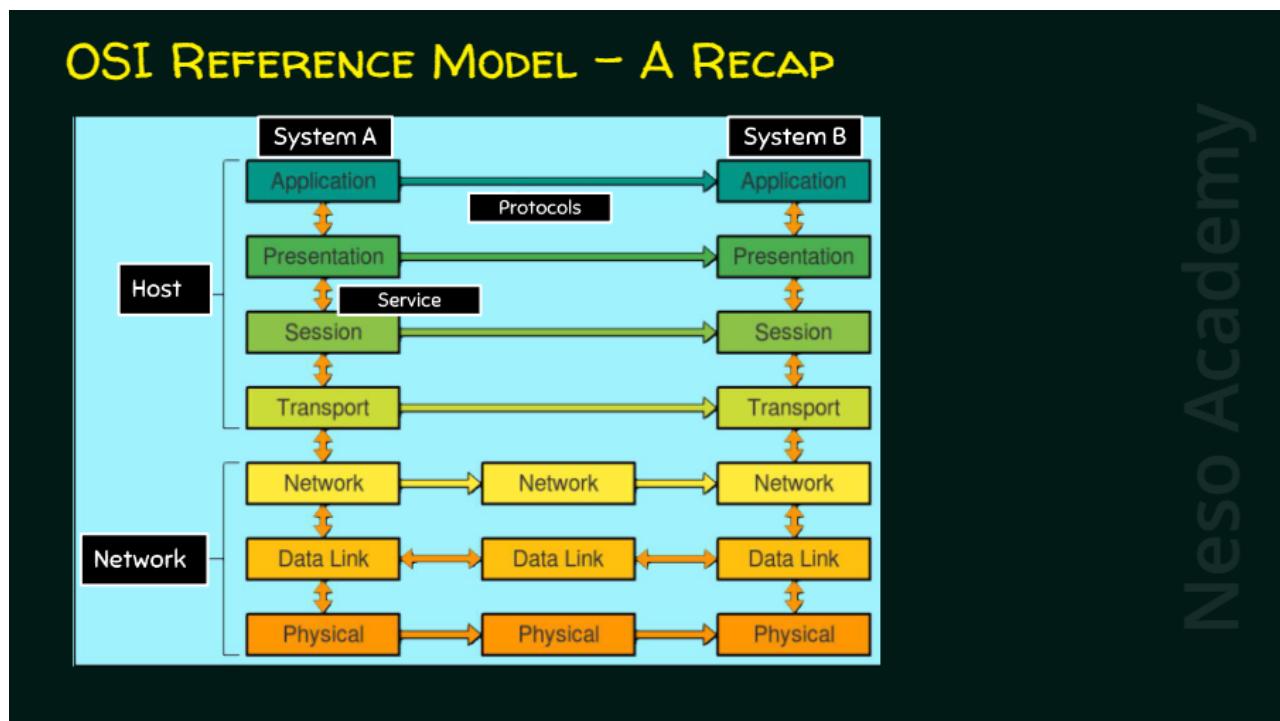


Transport Layer | Neso Academy

 nesoacademy.org/cs/06-computer-networks/ppts/07-transportlayer

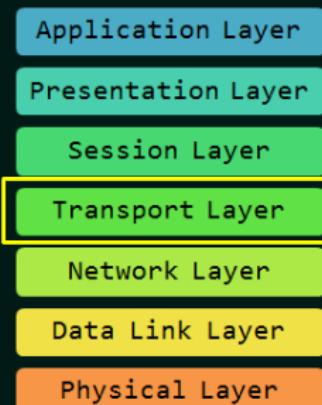


TransportLayerNeso AcademyCHAPTER - 7



OSI Reference Model -A RecapNeso Academy

OSI REFERENCE MODEL



It is responsible for process to process delivery of the entire message.

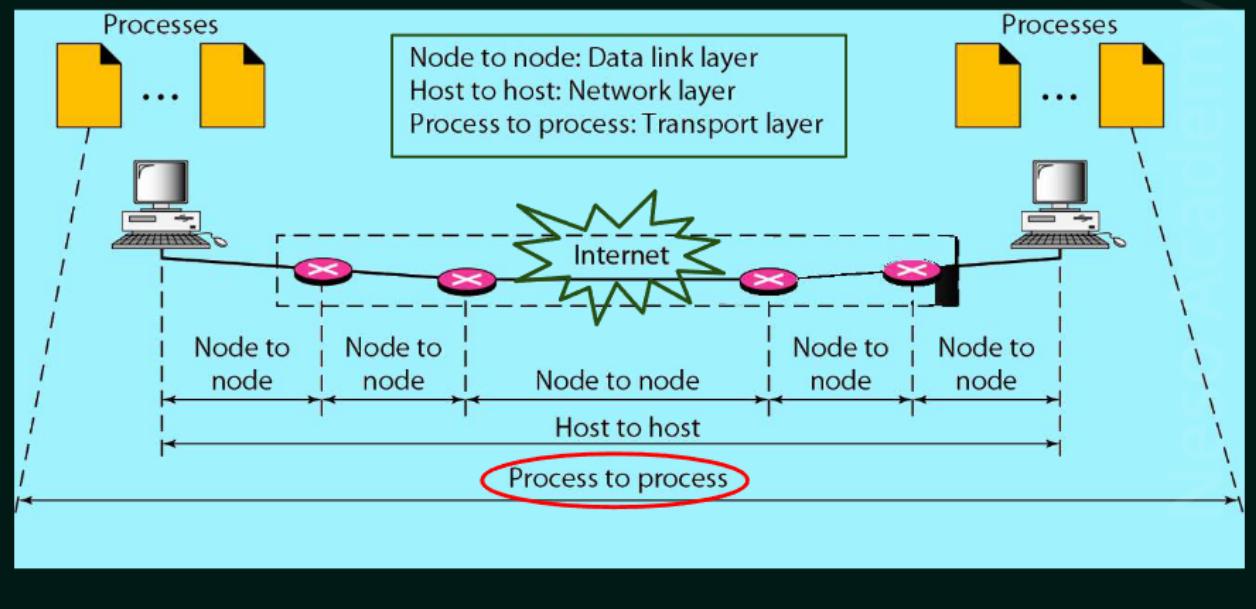
SERVICES PROVIDED BY TRANSPORT LAYER

- ★ Port addressing.
- ★ Segmentation and Reassembly.
- ★ Connection control.
- ★ Flow Control.
- ★ Error Control



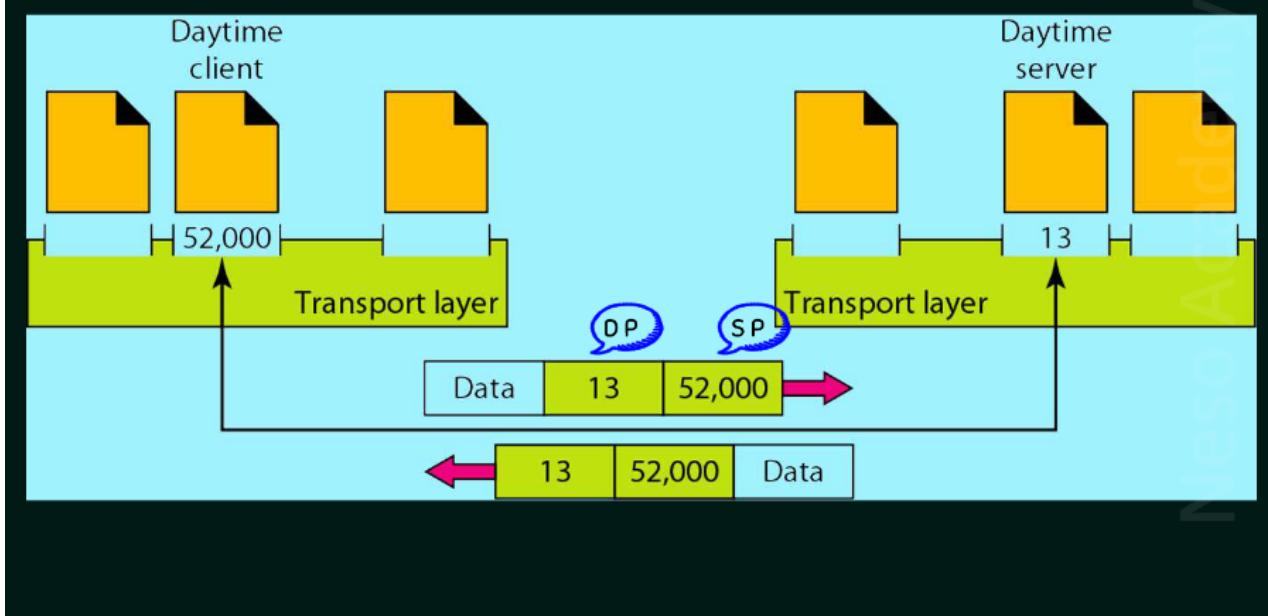
★★★★★ OSI Reference Model Neso Academy

TRANSPORT LAYER



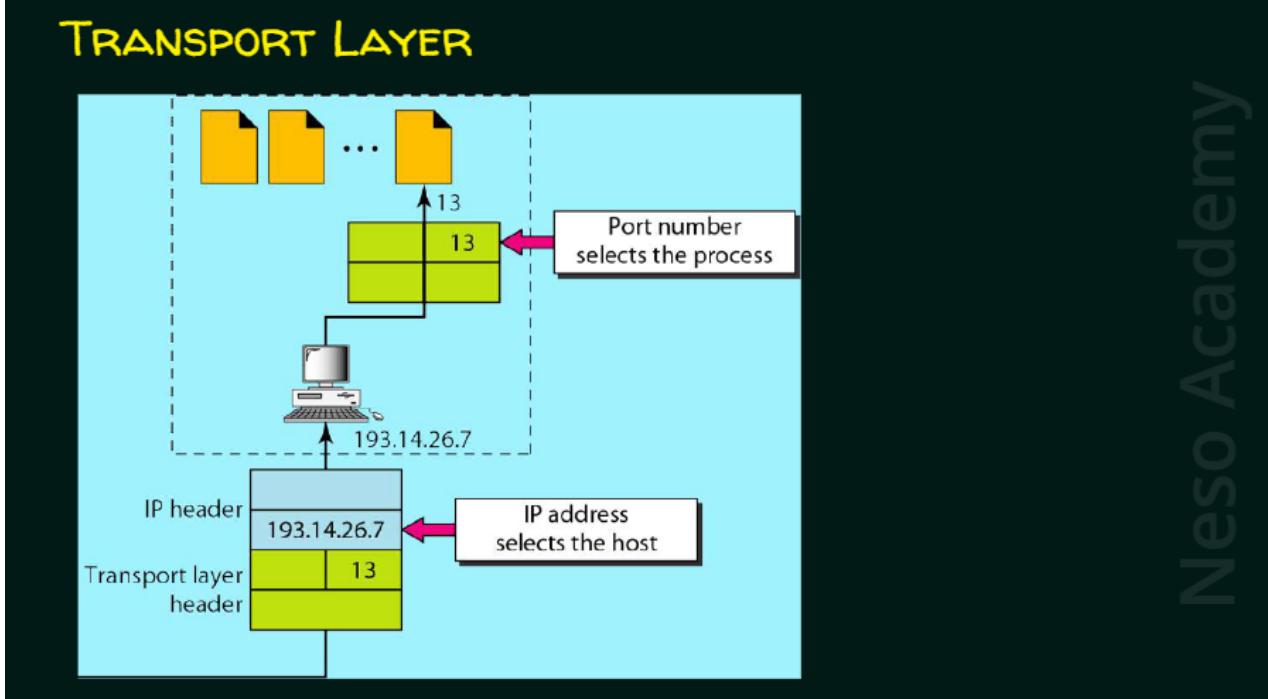
Transport Layer Neso Academy

TRANSPORT LAYER



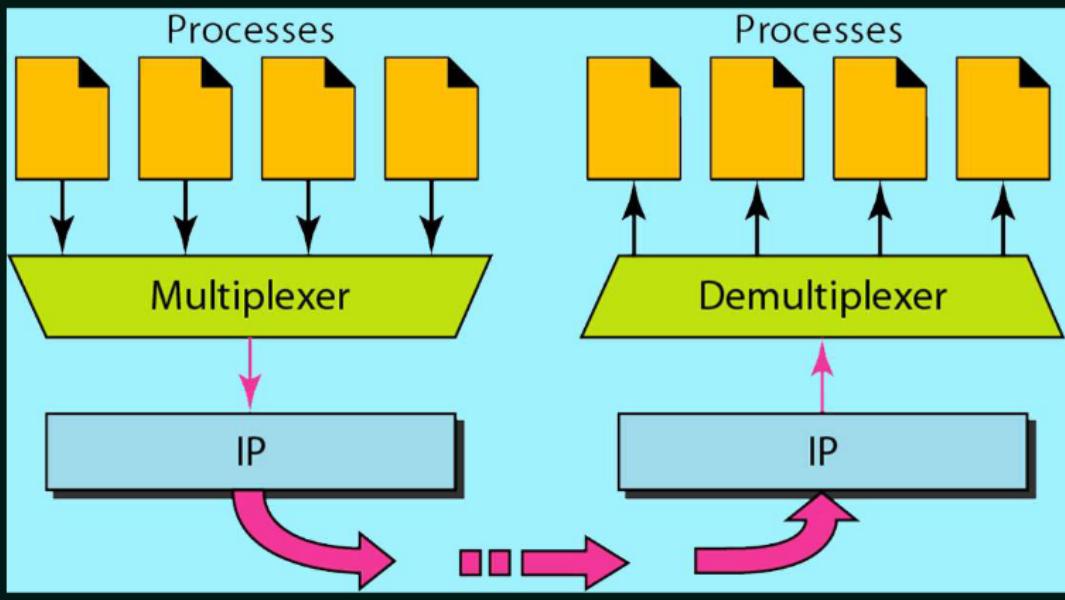
Transport LayerNeso Academy

TRANSPORT LAYER



Transport LayerNeso Academy

TRANSPORT LAYER



Neso Academy

Transport LayerNeso Academy



COMPUTER NETWORKS

A Bottom up approach



Neso Academy

Port Numbers

Computer NetworksA Bottom up approachPort NumbersNeso Academy

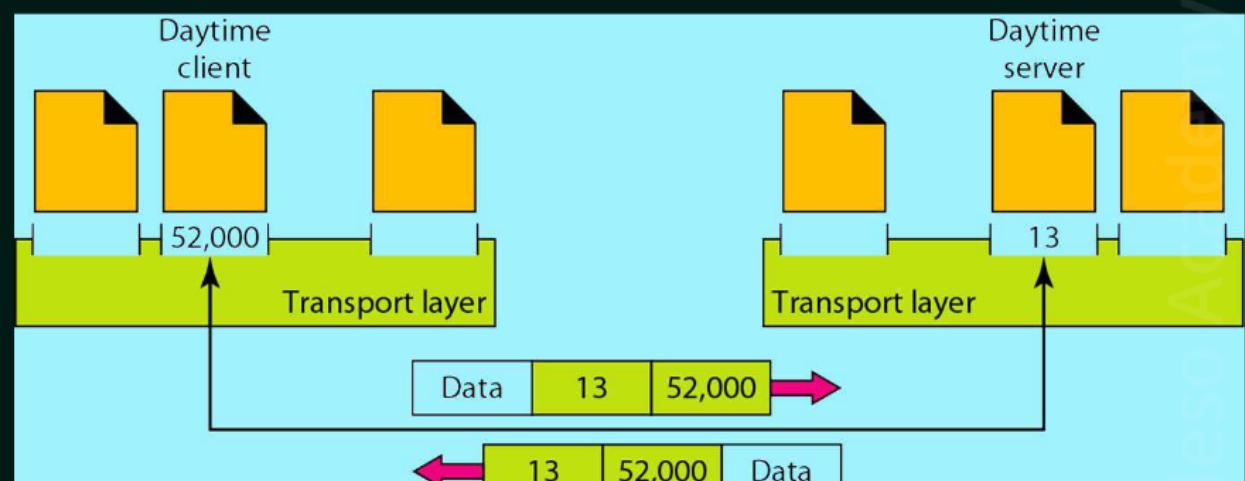
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the role of port numbers.
- ★ Know the various ranges of port numbers.
- ★ Understand well-known, registered and dynamic port numbers.
- ★ Know how port number is used in URLs.

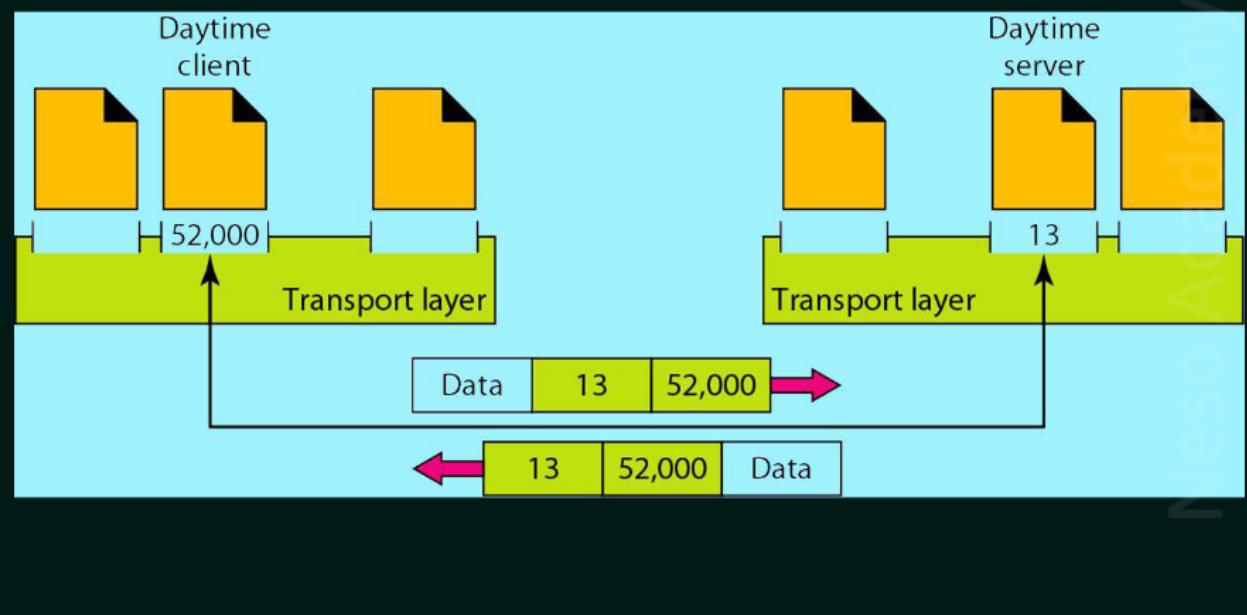
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Neso Academy

TRANSPORT LAYER



Transport Layer Neso Academy

TRANSPORT LAYER



Transport LayerNeso Academy

PORT NUMBERS

- ★ In computer networking, a port is a communication endpoint.
- ★ At the software level, within an operating system, a port is a logical construct that identifies a specific process or a type of network service.
- ★ A port is identified for each transport protocol and address combination by a 16-bit unsigned number, known as the port number.
- ★ The most common transport protocols that use port numbers are the Transmission Control Protocol (TCP) and the User Datagram Protocol (UDP).

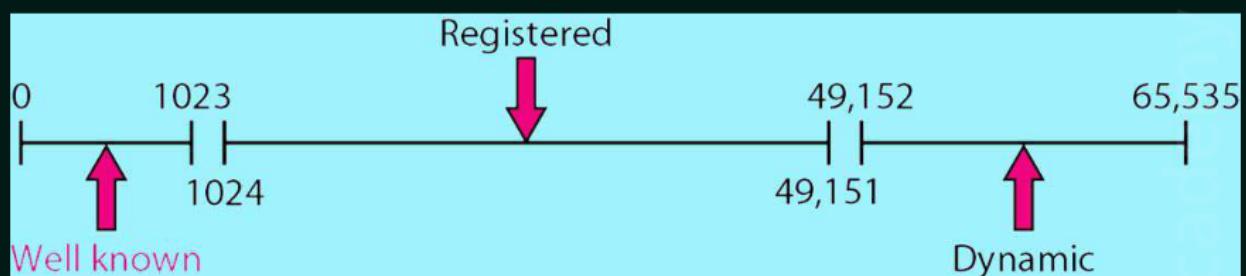
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PORT NUMBERS



- ★ This includes the registration of commonly used port numbers for well-known Internet services.
- ★ The port numbers are divided into three ranges:
 - Well-known ports,
 - Registered ports, and
 - Dynamic or private ports.

Port Numbers★This includes the registration of commonly used port numbers for well-known Internet services.★The port numbers are divided into three ranges:

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Neso Academy

2. REGISTERED PORTS

- ★ The registered ports are those from 1024 through 49151.
- ★ IANA maintains the official list of well-known and registered ranges.
- ★ IANA is responsible for the global coordination of the DNS Root, IP addressing, and other Internet protocol resources.
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2. Registered Ports★The registered ports are those from 1024 through 49151. ★IANA maintains the official list of well-known and registered ranges.★IANA is responsible for the global coordination of the DNS Root, IP addressing, and other Internet protocol resources. ★This includes the registration of commonly used port numbers for well-known Internet services.Neso Academy

3. DYNAMIC PORTS

- ★ The dynamic or private ports are those from 49152 through 65535.
- ★ Assigned by the Operating System dynamically.

3. Dynamic Ports★The dynamic or private ports are those from 49152 through 65535.★Assigned by the Operating System dynamically.Neso Academy

PORT NUMBER IN URLs

- ★ Port numbers are sometimes seen in web or other uniform resource locators (URLs).
- ★ By default, HTTP uses port 80 and HTTPS uses port 443.
- ★ URL - <http://www.example.com:8080/path/> specifies the web browser to connect to port 8080 of the HTTP server.

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HOMEWORK

The port number of Simple Mail Transfer Protocol (SMTP) is _____

- A) 45
- B) 65
- C) 25
- D) 35

HomeworkThe port number of Simple Mail Transfer Protocol (SMTP) is _____.A) 45B)
65C) 25D) 35Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the role of port numbers.
- ★ Know the various ranges of port numbers.
- ★ Understand well-known, registered and dynamic port numbers,
- ★ Know how port number is used in URLs.

OutcomesUpon the completion of this session, the learner will be able to★Understand the role of port numbers.★Know the various ranges of port numbers.★Understand well-known, registered and dynamic port numbers,★Know how port number is used in URLs.Neso Academy

THANK YOU!

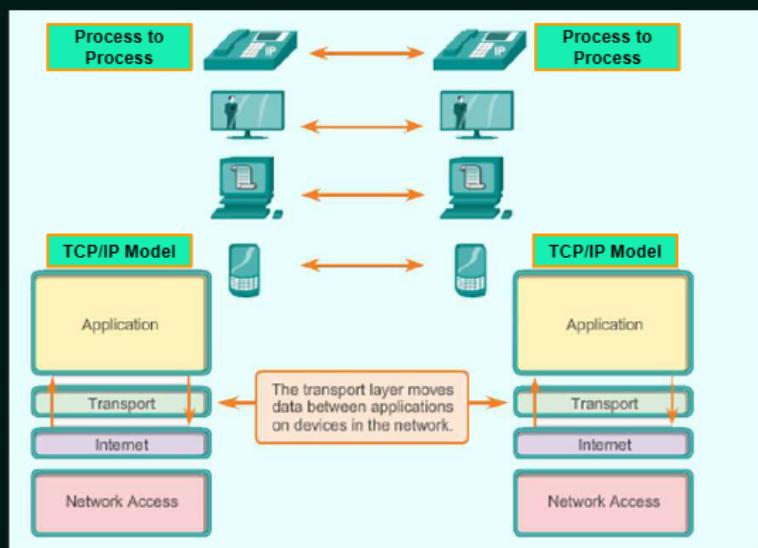
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand about Reliability-Delay tradeoff.
- ★ Understand the need for TCP and UDP.
- ★ Know the applications that use TCP/UDP.

Outcomes ★★★ Neso Academy

TRANSPORT LAYER PROTOCOLS



Transport Layer Protocols TCP/IP Model TCP/IP Model Process to Process Process to Process Neso Academy

TRANSPORT LAYER PROTOCOLS – TCP AND UDP

SCENARIO 1



SCENARIO 2



Transport Layer Protocols -TCP and UDP Neso Academy

APPLICATIONS THAT USE TCP

- ★ HTTP
- ★ FTP
- ★ SMTP
- ★ Telnet

Applications that use TCP ★★★ Neso Academy

APPLICATIONS THAT USE UDP

- ★ DHCP
- ★ DNS
- ★ SNMP
- ★ TFTP
- ★ VoIP
- ★ IPTV

Applications that use UDP ★★★★★ Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the basics of UDP.
- ★ Know various uses of UDP.

Outcomes ★★ Neso Academy

UDP

- ★ UDP = User Datagram Protocol.
- ★ Simple protocol that provides the basic transport layer function.
- ★ Used by applications that can tolerate small loss of data.
- ★ Used by applications that cannot tolerate delay.
- ★ Used by:
 - Domain Name System (DNS)
 - Simple Network Management Protocol (SNMP)
 - Dynamic Host Configuration Protocol (DHCP)
 - Trivial File Transfer Protocol (TFTP)
 - IP telephony or VoIP
 - Online games

UDP★★★★★○○○○○ Neso Academy

UDP

- ★ Connectionless and unreliable.
- ★ Prior communications are not required in order to set up communication channels or data paths.
- ★ UDP-based server applications are assigned well-known or registered port numbers.
- ★ UDP client process randomly selects port number from range of dynamic port numbers as the source port.
- ★ UDP is suitable for purposes where error checking and correction are either not necessary or are performed in the application; UDP avoids the overhead of such processing in the protocol stack.
- ★ No Error control.

UDP★★★★★ Neso Academy

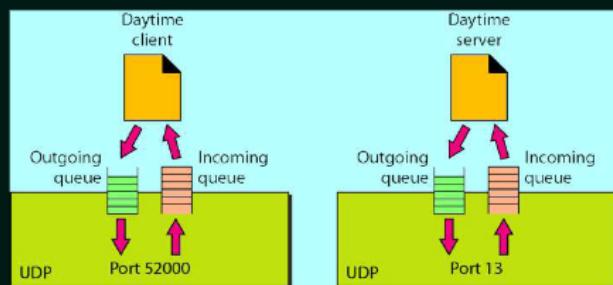
UDP

- ★ Time-sensitive applications often use UDP because dropping packets is preferable to waiting for packets delayed due to retransmission, which may not be an option in a real-time system.
- ★ No Flow Control.
- ★ Encapsulation and Decapsulation.
- ★ Queuing.

UDP★★★★Neso Academy

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- ★ No Flow Control.
- ★ Encapsulation and Decapsulation.
- ★ Queuing.



UDP★★★★Neso Academy

USE OF UDP

- ★ It is transaction-oriented, suitable for simple request-response protocols such as the DNS or the NTP.
- ★ It provides datagrams, suitable for modeling other protocols such as IP tunneling or remote procedure call and the Network File System.
- ★ It is simple, suitable for bootstrapping or other purposes without a full protocol stack, such as the DHCP and TFTP.
- ★ It is stateless, suitable for very large numbers of clients, such as in streaming media applications such as IPTV.

Use of UDP★★★★Neso Academy

USE OF UDP

- ★ The lack of retransmission delays makes it suitable for real-time applications such as VoIP, online games, and many real-time streaming applications.
- ★ UDP is a suitable transport protocol for multicasting. Multicasting capability is embedded in the UDP software but not in the TCP software.
- ★ UDP is used for some route updating protocols such as Routing Information Protocol.

Use of UDP★★★★Neso Academy

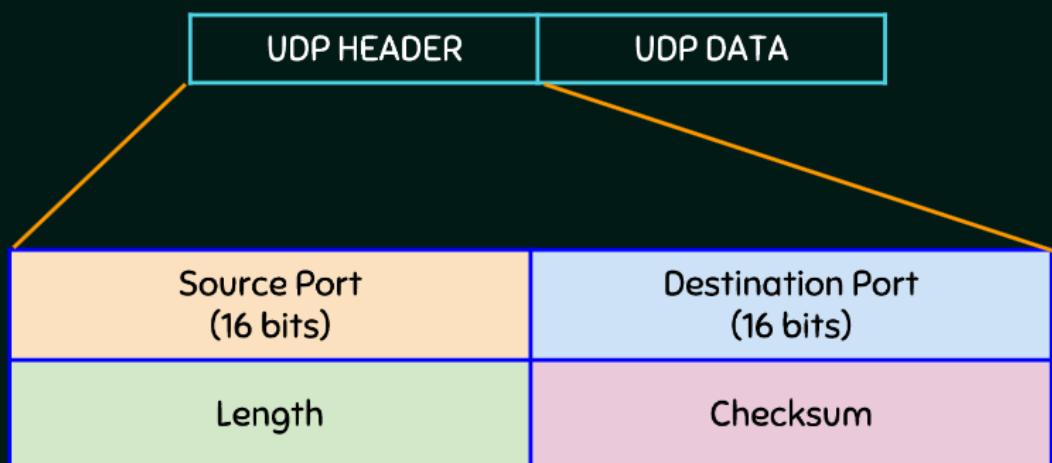
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the UDP header format.
- ★ Understand various fields in UDP header.

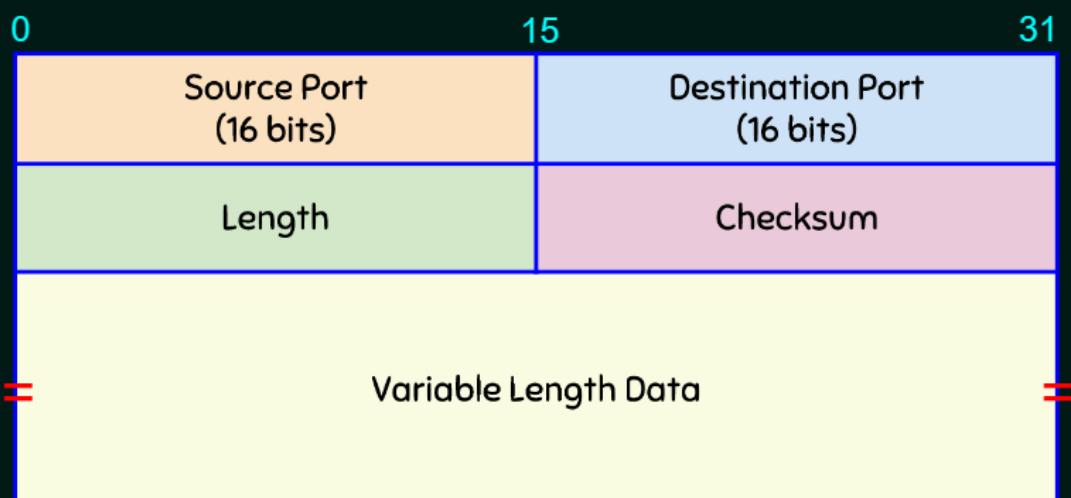
Outcomes ★ Neso Academy

UDP HEADER FORMAT



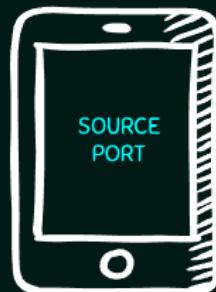
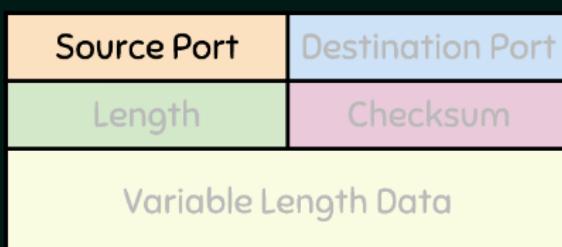
UDP Header Format Neso Academy

UDP HEADER FORMAT



UDP Header Format 01531 == Neso Academy

UDP HEADER FORMAT



- ★ This is the port number used by the process running on the source host.
- ★ It is 16 bits long, which means that the port number can range from 0 to 65,535.
- ★ If the source host is the client (a client sending a request), the port number, in most cases, is an ephemeral port number requested by the process and chosen by the UDP software running on the source host.
- ★ If the source host is the server (a server sending a response), the port number, in most cases, is a well-known port number.

UDP Header Format ★★★★ Neso Academy

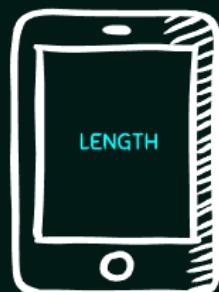
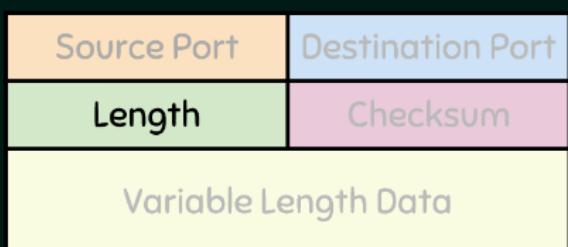
UDP HEADER FORMAT



- ★ This is the port number used by the process running on the destination host.
- ★ It is also 16 bits long. If the destination host is the server (a client sending a request), the port number, in most cases, is a well-known port number.
- ★ If the destination host is the client (a server sending a response), the port number, in most cases, is an ephemeral port number.
- ★ In this case, the server copies the ephemeral port number it has received in the request packet.

UDP Header Format★★★Neso Academy

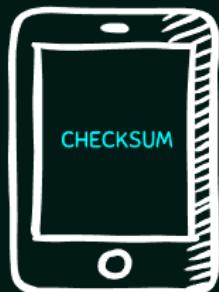
UDP HEADER FORMAT



- ★ This is a 16-bit field that defines the total length of the user datagram, header plus data. The 16 bits can define a total length of 0 to 65,535 bytes.
- ★ However, the total length needs to be much less because a UDP user datagram is stored in an IP datagram with a total length of 65,535 bytes.
- ★ $\text{UDP length} = \text{IP length} - \text{IP header's length}$

UDP Header Format★★★Neso Academy

UDP HEADER FORMAT



- ★ This field is used to detect errors over the entire user datagram (header plus data).

UDP Header Format★Neso Academy

QUESTION

The following is a dump of a UDP header in hexadecimal format.

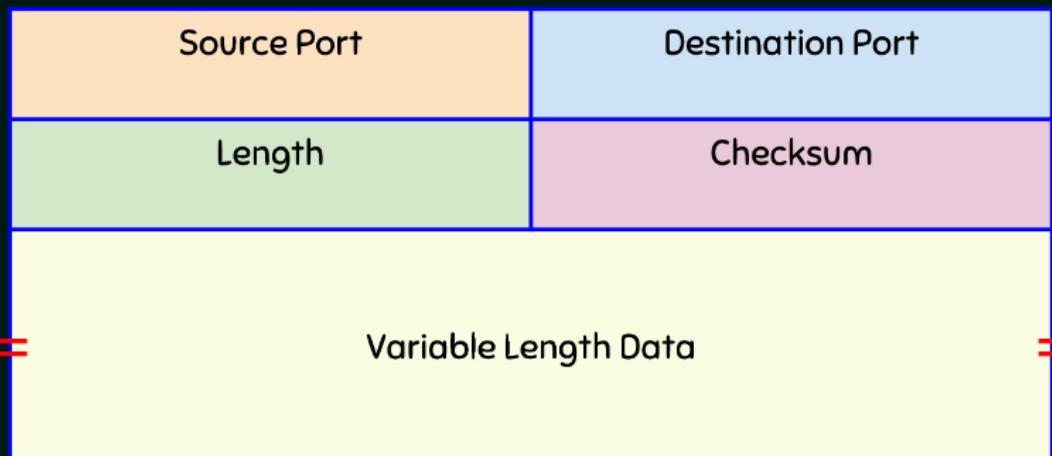
0632000D001CE217

- What is the source port number?
- What is the destination port number?
- What is the total length of the user datagram?
- What is the length of the data?
- Is the packet directed from a client to a server or vice versa?
- What is the client process?

QuestionNeso Academy

UDP HEADER FORMAT

0632000D001CE217

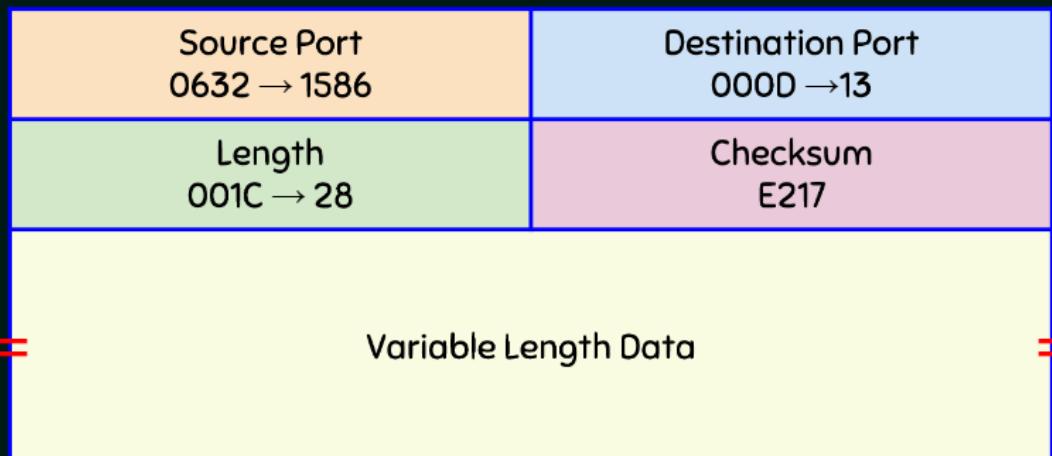


Neso Academy

UDP Header Format==Neso Academy

UDP HEADER FORMAT

0632 000D 001C E217



Neso Academy

UDP Header Format→→→==Neso Academy

UDP HEADER FORMAT

0632 000D 001C E217

Source Port 0632 → 1586	Destination Port 000D → 13
Length 001C → 28	Checksum E217

UDP Header Format→→→Neso Academy

ANSWER

Source Port 0632 → 1586	Destination Port 000D → 13
Length 001C → 28	Checksum E217

- What is the source port number? Answer: 1586
- What is the destination port number? Answer: 13
- What is the total length of the user datagram? Answer: 28 bytes
- What is the length of the data? Answer: $28 - 8 = 20$ bytes
- Is the packet directed from a client to a server or vice versa? Answer: C→S
- What is the client process? Answer: Daytime

Answer→→→Neso Academy

QUESTION 1

The transport layer protocols used for real time multimedia, file transfer, DNS and email, respectively are:

[GATE CS 2013]

- (A) TCP, UDP, UDP and TCP
- (B) UDP, TCP, TCP and UDP
- (C) UDP, TCP, UDP and TCP ✓
- (D) TCP, UDP, TCP and UDP

Question 1✓Neso Academy

QUESTION 2

Which of the following is NOT true about User Datagram Protocol in transport layer?

- (A) Works well in unidirectional communication, suitable for broadcast information.
- (B) It does three way handshake before sending datagrams. ✓
- (C) It provides datagrams, suitable for modeling other protocols such as in IP tunneling or Remote Procedure Call and the Network File System.
- (D) The lack of retransmission delays makes it suitable for real-time applications.

Question 2✓Neso Academy

QUESTION 3

Which one of the following uses UDP as the transport protocol?

[GATE CS 2007]

- (A) HTTP
- (B) Telnet
- (C) DNS ✓
- (D) SMTP

Question 3✓Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the need for pseudo-header in UDP.
- ★ Understand how checksum is calculated in UDP.

Outcomes★★Neso Academy

PSEUDO-HEADER IN UDP

- ★ The UDP checksum calculation is different from the one for IP and ICMP.
- ★ In UDP, the checksum includes three sections:
 - A Pseudo-Header,
 - The UDP header, and
 - The data (coming from the application layer).
- ★ The Pseudo-Header is the part of the header of the IP packet in which the user datagram is to be encapsulated with some fields filled with Os.

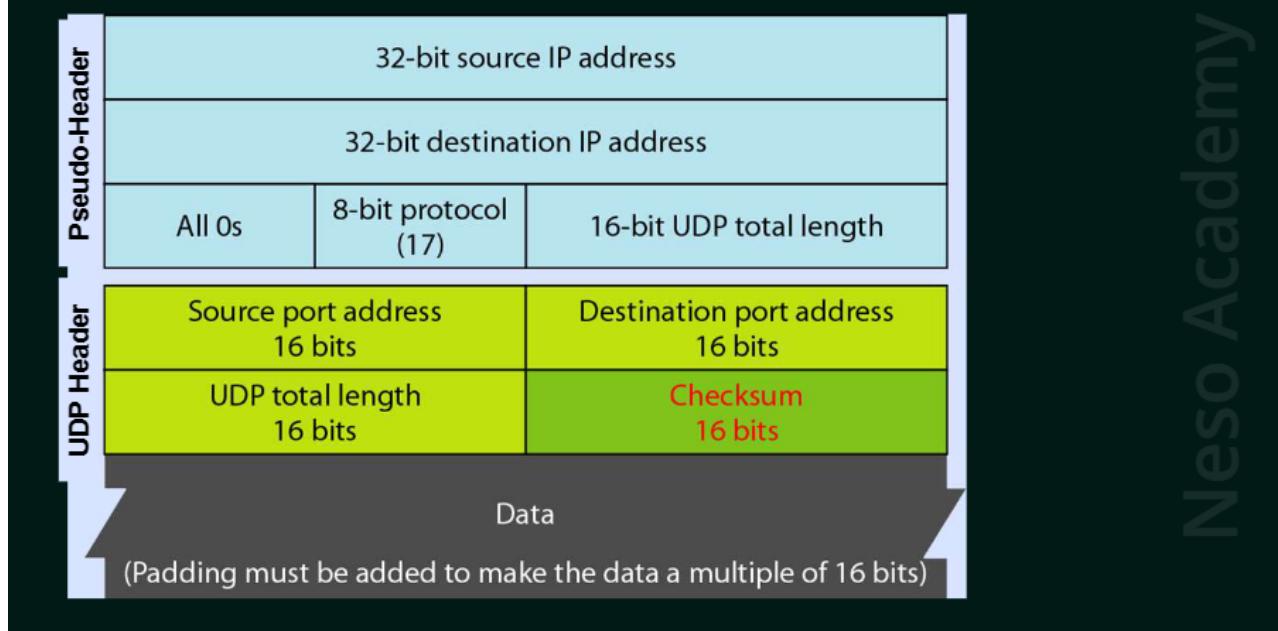
★★■■■★Pseudo-header in UDPNeso Academy

PSEUDO-HEADER IN UDP

- ★ If the checksum does not include the pseudo-header, a user datagram may arrive at destination without errors.
- ★ However, if the IP header is corrupted, it may be delivered to the wrong destination.
- ★ The protocol field is added to ensure that the packet belongs to UDP, and not to other transport-layer protocols.
- ★ The value of the protocol field for UDP is 17.
- ★ If this value is changed during transmission, the checksum calculation at the receiver will detect it and UDP drops the packet.
- ★ Thus, the packet is not delivered to the wrong protocol.

★★★★★Pseudo-header in UDPNeso Academy

PSEUDO-HEADER IN UDP



Pseudo-header in UDPUDP HeaderPseudo-HeaderNeso Academy

EXAMPLE

153.18.8.105			10011001 00010010 → 153.18	
171.2.14.10			00001000 01101001 → 8.105	
All Os	17	15	10101011 00000010 → 171.2	
1087			00001110 00001010 → 14.10	
15			00000000 00010001 → 0 and 17	
All Os			00000000 00001111 → 15	
1087			00000100 00111111 → 1087	
13			00000000 00001101 → 13	
15			00000000 00001111 → 15	
All Os			00000000 00000000 → 0 (checksum)	
T	E	S	T	01010100 01000101 → T and E
I	N	G	All Os	01010011 01010100 → S and T
All Os			01001001 01001110 → I and N	
All Os			01000111 00000000 → G and 0 (padding)	
			10010110 11101011 → Sum	
			01101001 → Checksum	
			00010100	

Example01101001 00010100Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the basics of TCP.
- ★ Understand the features of TCP.

Outcomes ★★ Neso Academy

TCP

- ★ TCP = Transmission Control Protocol.
- ★ Widely used transport layer protocol.
- ★ It creates a virtual connection between two TCPs to send data.
- ★ In addition, TCP uses flow and error control mechanisms at the transport level.
- ★ Used by applications that can tolerate delay but cannot tolerate loss.
- ★ Used by:
 - World Wide Web
 - HTTP
 - FTP
 - Telnet
 - SMTP

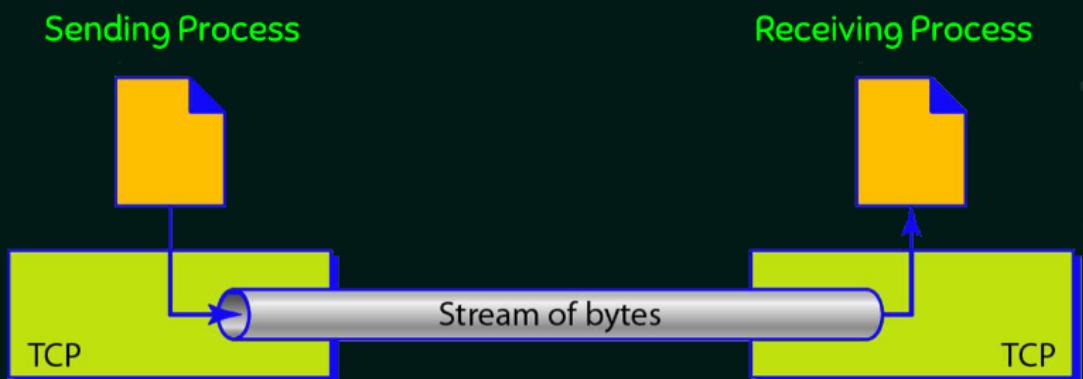
TCP ★★★★★ ooooo Neso Academy

FEATURES OF TCP

- ★ Connection oriented
- ★ Reliable delivery
- ★ Acknowledgment Oriented
- ★ Retransmission
- ★ Flow Control
- ★ Error Control
- ★ Congestion Control
- ★ Segmentation and Reassembly
- ★ Full Duplex Support

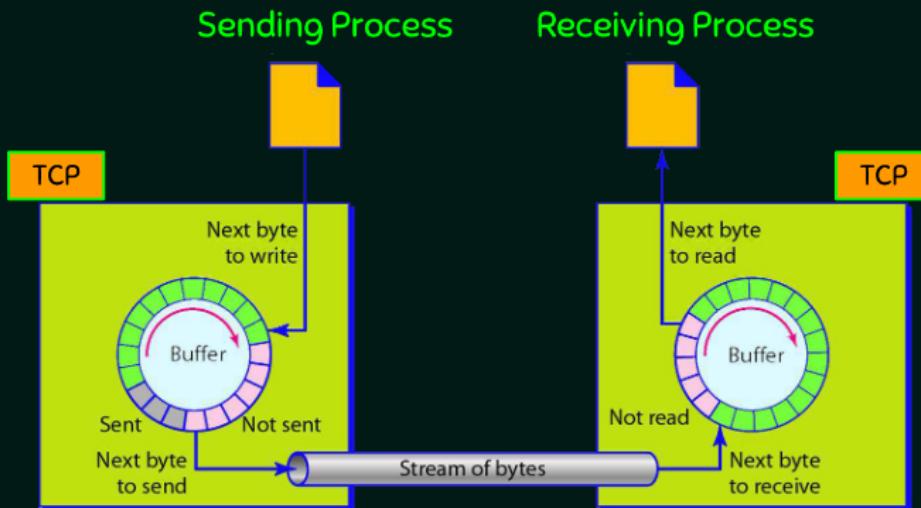
Features of TCP ★★★★★★★ Neso Academy

TCP STREAM DELIVERY



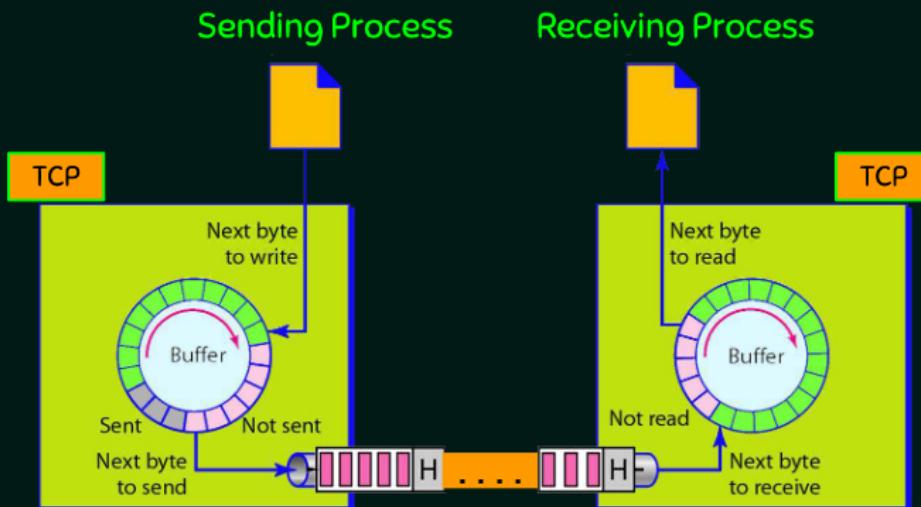
TCP Stream Delivery Neso Academy

TCP SENDING AND RECEIVING BUFFERS



TCP Sending and Receiving Buffers Neso Academy

TCP SEGMENTS



TCP Segments . . . Neso Academy

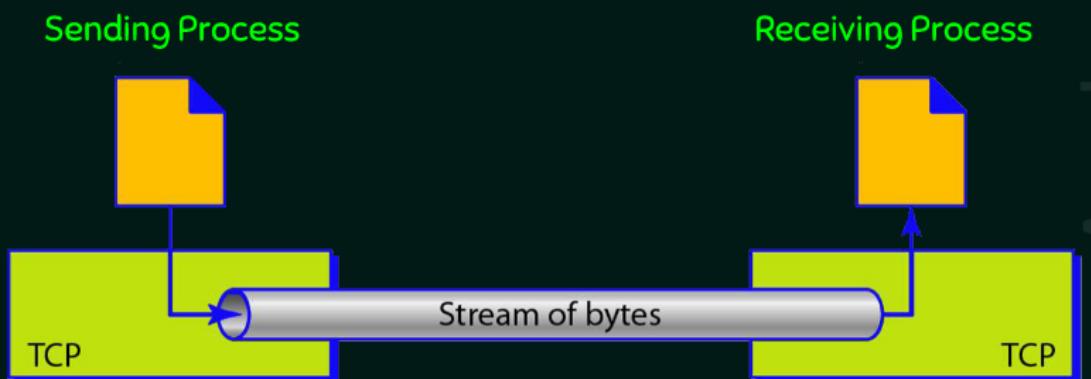
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the basics of TCP.
- ★ Understand TCP stream delivery.
- ★ Know various buffer involved in TCP.
- ★ Know about TCP segments.

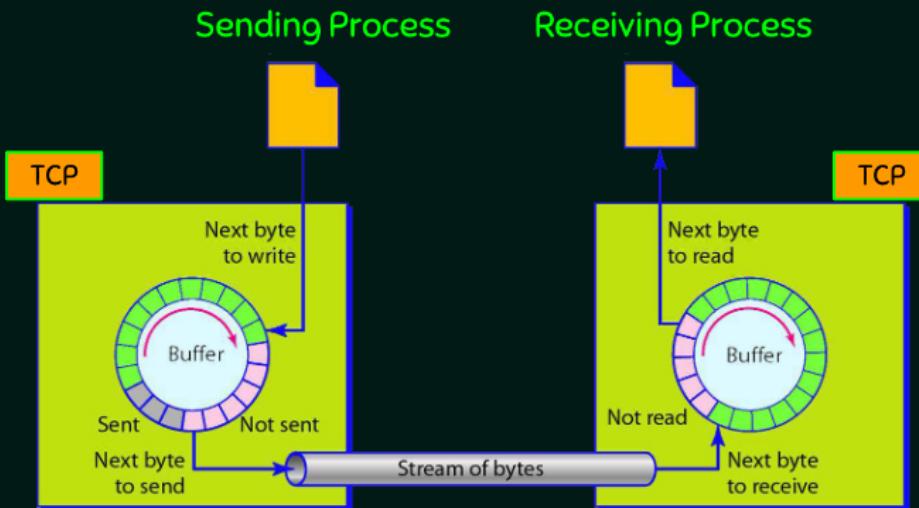
Outcomes ★★★ Neso Academy

TCP STREAM DELIVERY



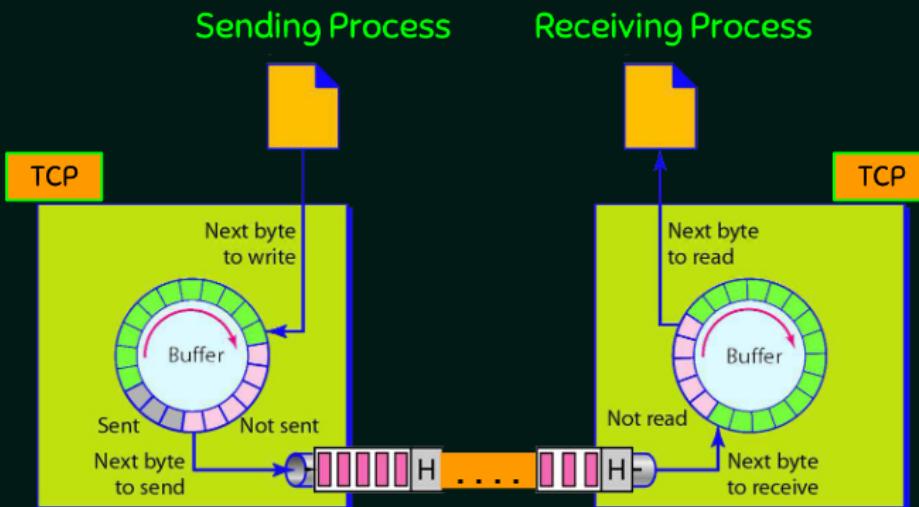
TCP Stream Delivery Neso Academy

TCP SENDING AND RECEIVING BUFFERS



TCP Sending and Receiving Buffers Neso Academy

TCP SEGMENTS



TCP Segments . . . Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the TCP header format.
- ★ Know various fields in TCP header and its function.

Outcomes ★ Neso Academy

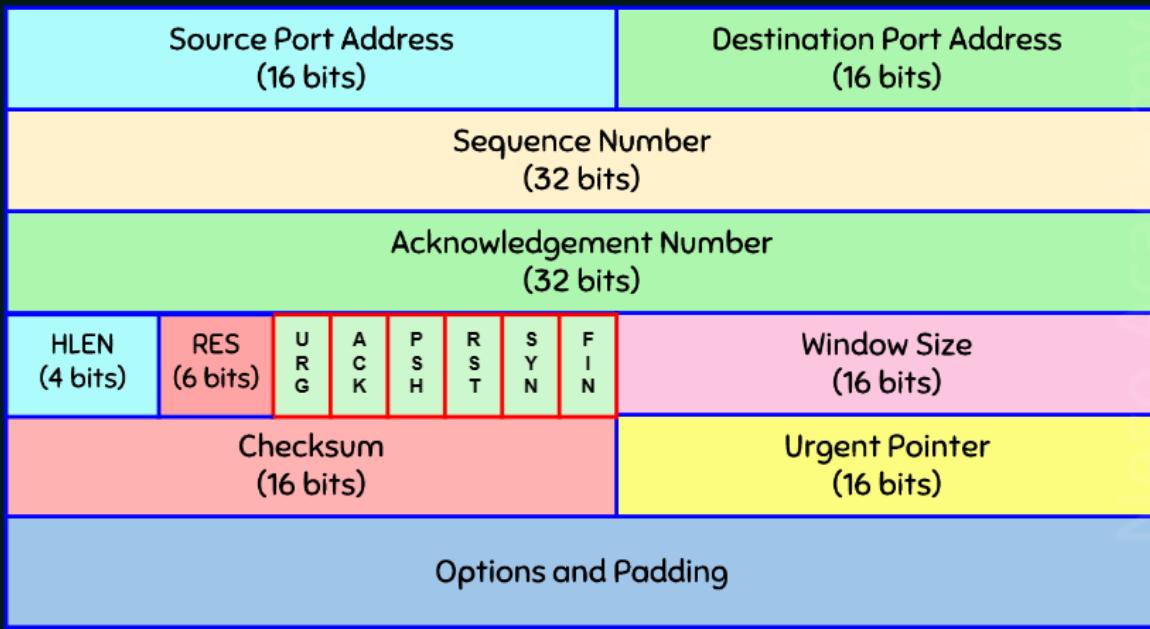
PROTOCOL DATA UNIT (PDU)

Protocol Data Units (PDUs) are named according to the protocols of the TCP/IP suite: data, segment, packet, frame, and bits.

Application Layer - Data
Transport Layer - Segment
Network Layer - Packet
Data Link Layer - Frame
Physical Layer- Bits

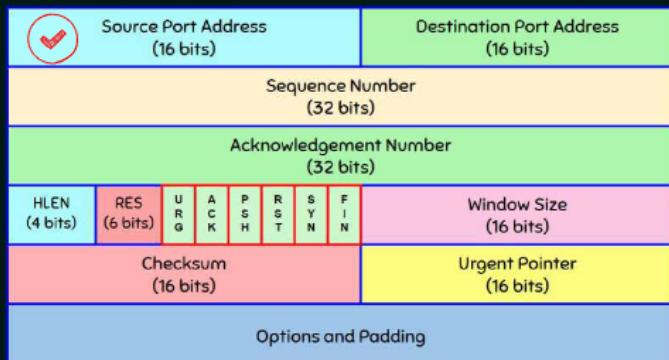
Protocol Data Unit (PDU) Neso Academy

TCP HEADER FORMAT



TCP Header Format URG ACK PSH RST SYN FIN Neso Academy

TCP HEADER FORMAT



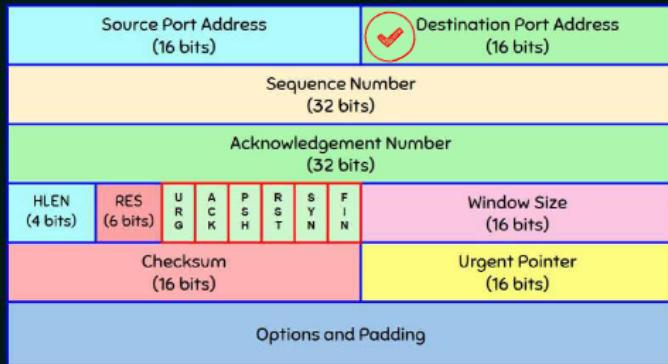
This is a 16-bit field.

Source Port Address:

- ★ It defines the port number of the application program in the host that is sending the segment.
- ★ This serves the same purpose as the source port address in the UDP header.

TCP Header Format ★★ Neso Academy

TCP HEADER FORMAT



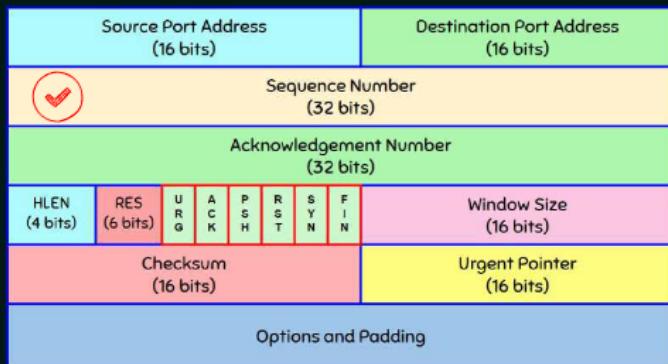
This is a 16-bit field.

Destination Port Address:

- ★ It defines the port number of the application program in the host that is receiving the segment.
- ★ This serves the same purpose as the destination port address in the UDP header.

TCP Header Format ★★ Neso Academy

TCP HEADER FORMAT



This is a 32-bit field that defines the number assigned to the first byte of data contained in this segment.

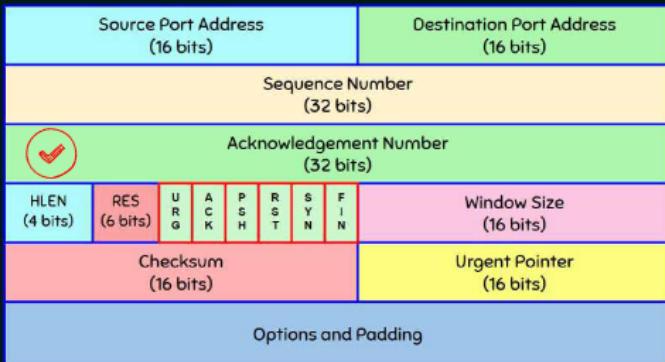
Sequence Number:

Has a dual role:

- ★ If the SYN flag is set to 1, then this is the initial sequence number. The sequence number of the actual first data byte and the acknowledged number in the corresponding ACK are then this sequence number plus 1.
- ★ If the SYN flag is 0, then this is the accumulated sequence number of the first data byte of this segment for the current session.

TCP Header Format ★★ Neso Academy

TCP HEADER FORMAT



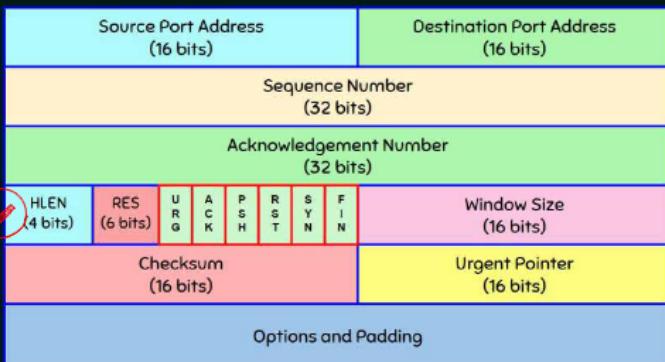
This is a 32-bit field.

Acknowledgement Number:

- ★ It defines the byte number that the receiver of the segment is expecting to receive from the other party.
- ★ If the receiver of the segment has successfully received byte number x from the other party, it defines $x + 1$ as the acknowledgment number. Acknowledgment and data can be piggybacked together.

TCP Header Format ★★ Neso Academy

TCP HEADER FORMAT



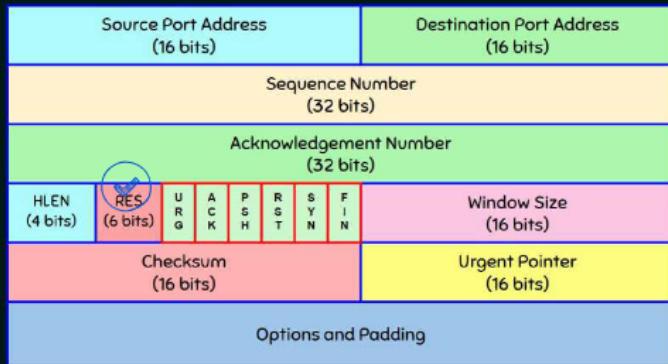
This is a 4-bit field.

Header Length:

- ★ It indicates the number of 4-byte words in the TCP header.
- ★ The length of the header can be between 20 and 60 bytes.
- ★ Therefore, the value of this field can be between 5 ($5 \times 4 = 20$) and 15 ($15 \times 4 = 60$)

TCP Header Format ★★ Neso Academy

TCP HEADER FORMAT



This is a 6-bit field.

Reserved:

- ★ This is a 6-bit field reserved for future use.
- ★ This field is set to 0.

TCP Header Format ★★ Neso Academy

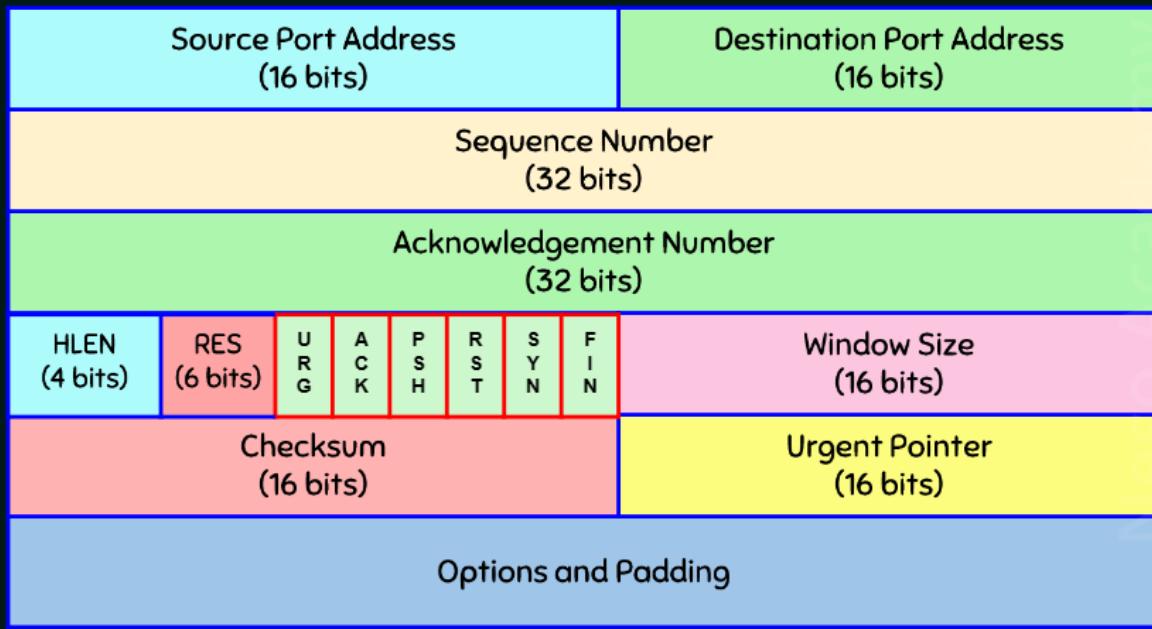
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the TCP header format.
- ★ Know various fields in TCP header and its function.

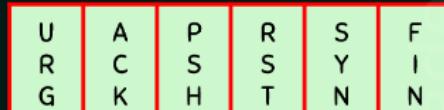
Outcomes ★★ Neso Academy

TCP HEADER FORMAT



TCP Header Format URGACKPSHRSTSYNFINNeso Academy

TCP HEADER FORMAT

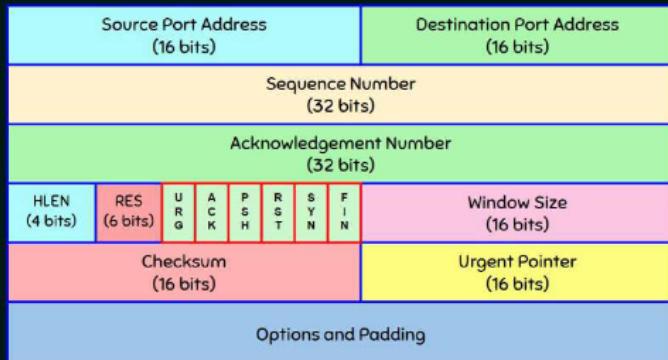


Flag:

- ★ This field defines 6 different control bits or flags.
- ★ One or more of these bits can be set at a time.

TCP Header Format ★★ Neso Academy

TCP HEADER FORMAT

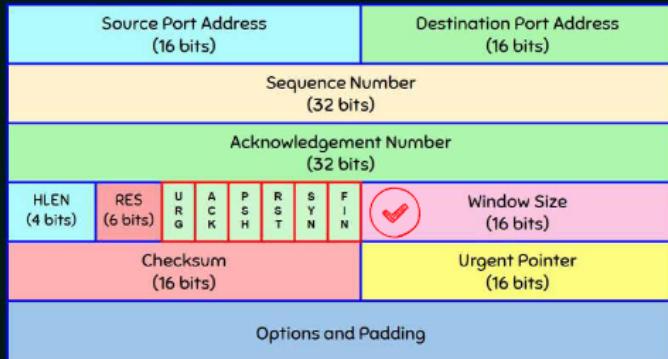


U	A	P	R	S	F
R	C	S	S	Y	I
G	K	H	T	N	N

- ★ **URG (1 bit):** Indicates that the Urgent pointer field is significant.
- ★ **ACK (1 bit):** Indicates that the Acknowledgment field is significant.
- ★ **PSH (1 bit):** Push function. Asks to push the buffered data to the receiving application.
- ★ **RST (1 bit):** Reset the connection.
- ★ **SYN (1 bit):** Synchronize sequence numbers.
- ★ **FIN (1 bit):** Last packet from sender.

TCP Header Format★★★★★Neso Academy

TCP HEADER FORMAT



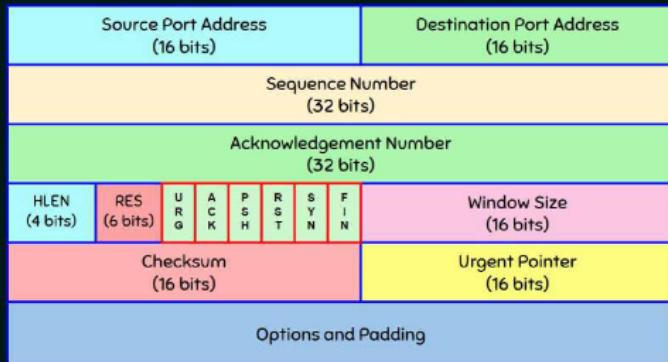
This is a 16-bit field.

Window size:

- ★ This field defines the size of the window, in bytes, that the other party must maintain.
- ★ Note that the length of this field is 16 bits, which means that the maximum size of the window is 65,535 bytes.
- ★ This value is normally referred to as the receiving window (rwnd) and is determined by the receiver.
- ★ The sender must obey the dictation of the receiver in this case.

TCP Header Format★★★★★Neso Academy

TCP HEADER FORMAT



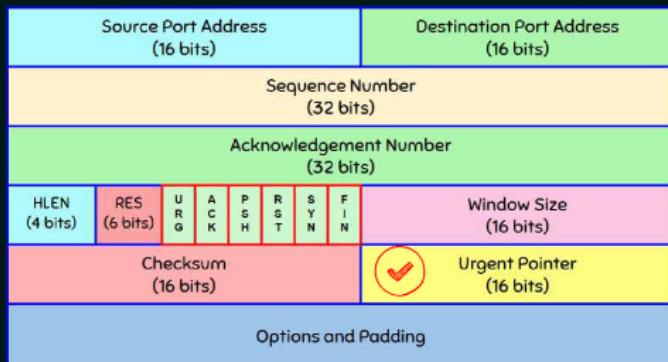
This is a 16-bit field.

Checksum:

- ★ The calculation of the checksum for TCP follows the same procedure as the one described for UDP.
- ★ However, the inclusion of the checksum in the UDP datagram is optional, whereas the inclusion of the checksum for TCP is mandatory.
- ★ The same pseudo-header, serving the same purpose, is added to the segment. For the TCP pseudo-header, the value for the protocol field is 6.

TCP Header Format★★★Neso Academy

TCP HEADER FORMAT



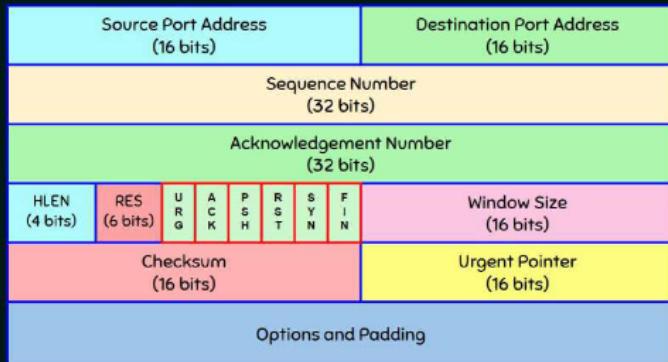
This is a 16-bit field.

Urgent Pointer:

- ★ This 16-bit field, which is valid only if the urgent flag is set, is used when the segment contains urgent data.
- ★ It defines the number that must be added to the sequence number to obtain the number of the last urgent byte in the data section of the segment.

TCP Header Format★★Neso Academy

TCP HEADER FORMAT



This field can be up to a maximum of 40 bytes.

Options:

- ★ There can be up to 40 bytes of optional information in the TCP header.
- ★ The length of this field is determined by the data offset field. Options have up to three fields: Option-Kind (1 byte), Option-Length (1 byte), Option-Data (variable).

Padding

- ★ The padding is composed of zeros. The TCP header padding is used to ensure that the TCP header ends, and data begins, on a 32-bit boundary.

TCP Header Format ★★★ Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the TCP connection with the help of an analogy.
- ★ Know the three phases of TCP connection.

Outcomes ★★★ Neso Academy

TCP CONNECTION

- ★ Connection-oriented.
- ★ Virtual path.
- ★ Acknowledgment process.
- ★ Retransmission of lost or damaged frames.
- ★ TCP connection – Virtual not Physical.
- ★ IP – Connectionless.
- ★ Full-duplex mode.
- ★ Approval from other party.

TCP Connection★★★★★★Neso Academy

ANALOGY



AnalogyNeso Academy

THREE PHASES OF TCP CONNECTION

1. Connection Establishment
2. Data Transfer
3. Connection Termination

Three phases of TCP connection Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Recall the three phases of TCP connection.
- ★ Understand the connection establishment process in TCP.

Outcomes ★★ Neso Academy

THREE PHASES OF TCP CONNECTION

1. Connection Establishment

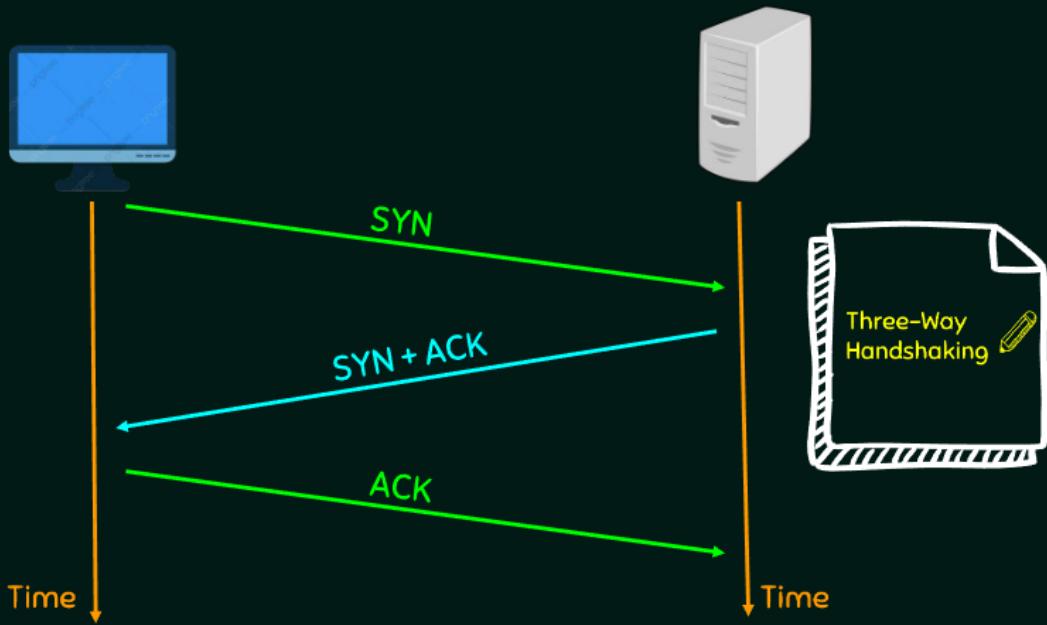
2. Data Transfer

3. Connection Termination

Neso Academy

Three phases of TCP connection Neso Academy

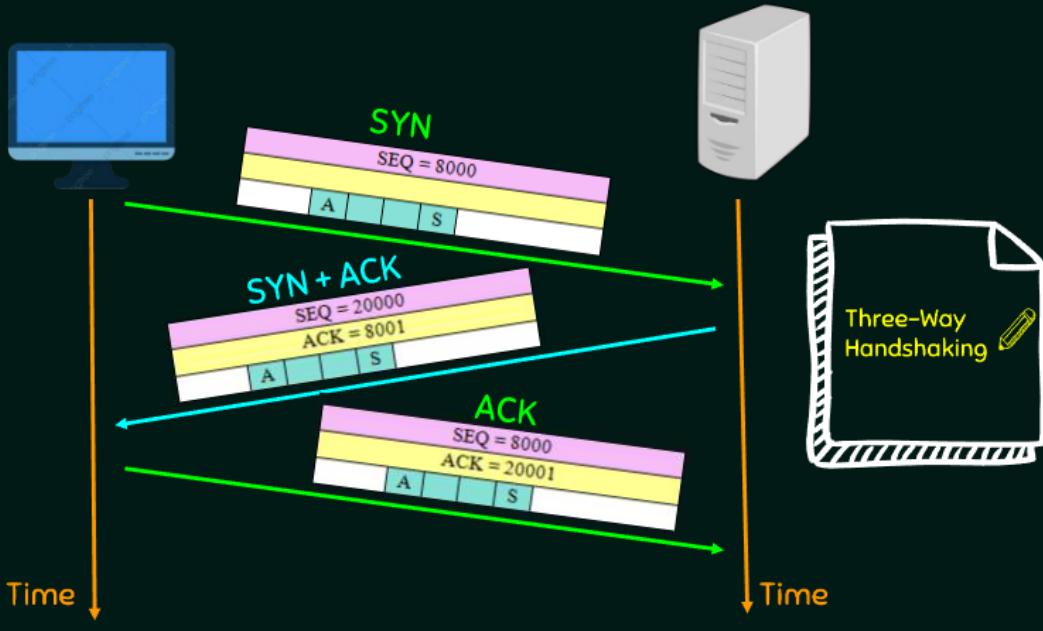
TCP CONNECTION ESTABLISHMENT



Neso Academy

TCP Connection Establishment Neso Academy

TCP CONNECTION ESTABLISHMENT



TCP Connection Establishment Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the data transfer phase in TCP.
- ★ Know about Piggybacking.
- ★ Understand the significance of PSH and URG flag in TCP header.

Outcomes ★★★ Neso Academy

THREE PHASES OF TCP TRANSMISSION

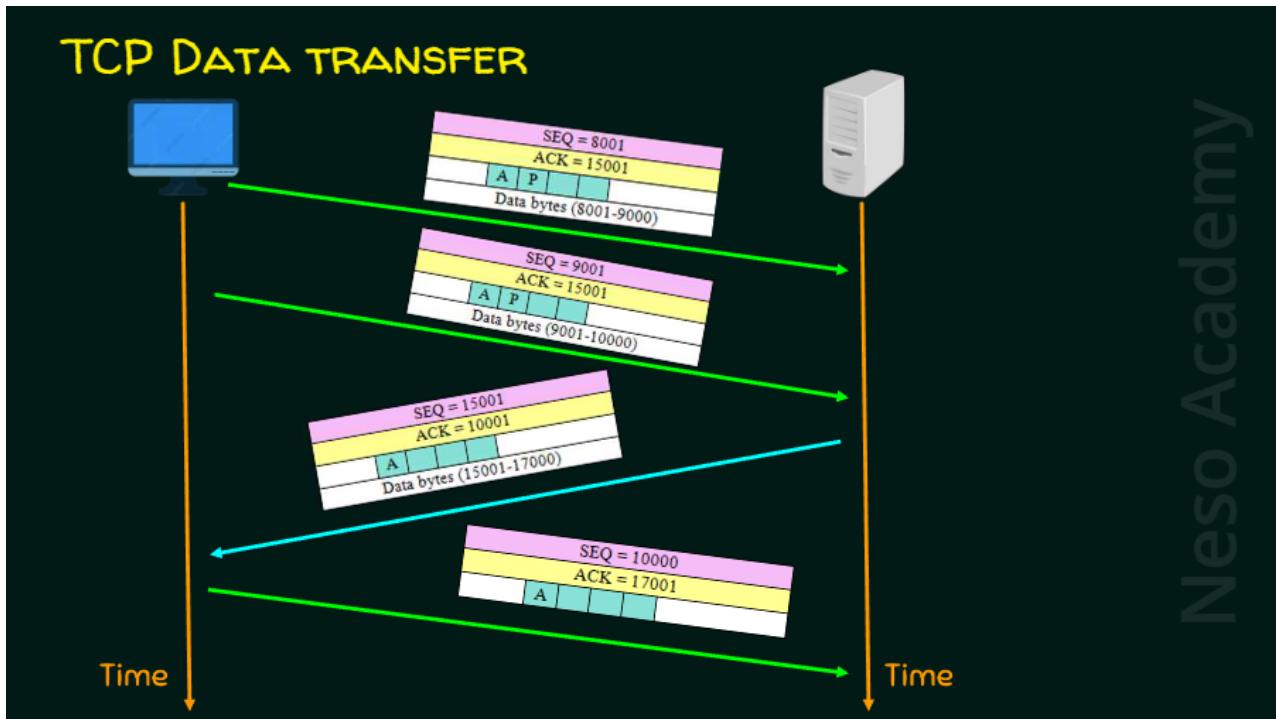
1. Connection Establishment
2. Data Transfer
3. Connection Termination

Three phases of TCP transmission Neso Academy

TCP DATA TRANSFER

- ★ Bidirectional data transfer.
- ★ Piggybacking.
- ★ The acknowledgement is piggybacked with data.
- ★ Push and Urg Flags.

TCP Data transfer ★★★★ Neso Academy



TCP Data transfer Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the TCP connection termination process.
- ★ Know three-way handshaking and four-way handshaking with half-close option.

Outcomes ★★ Neso Academy

THREE PHASES OF TCP TRANSMISSION

1. Connection Establishment
2. Data Transfer
3. Connection Termination



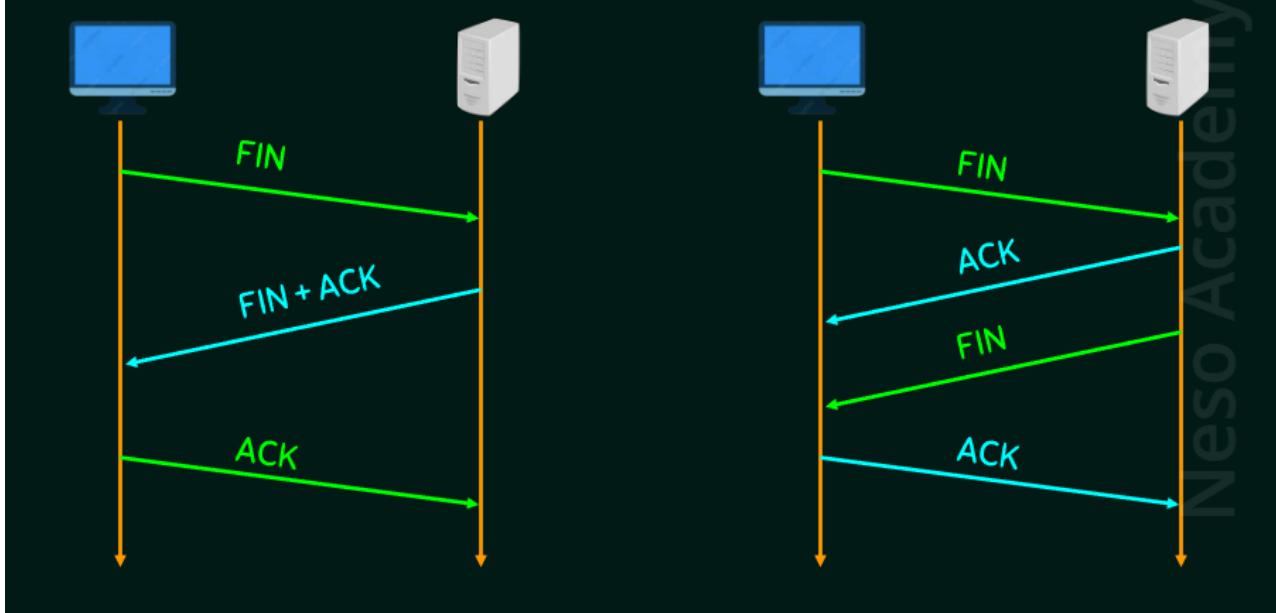
Three phases of TCP transmission Neso Academy

TCP CONNECTION TERMINATION

- ★ Usually initiated by the client.
- ★ Two options for connection termination
 - Three-way handshaking.
 - Four-way handshaking with a half-close option.

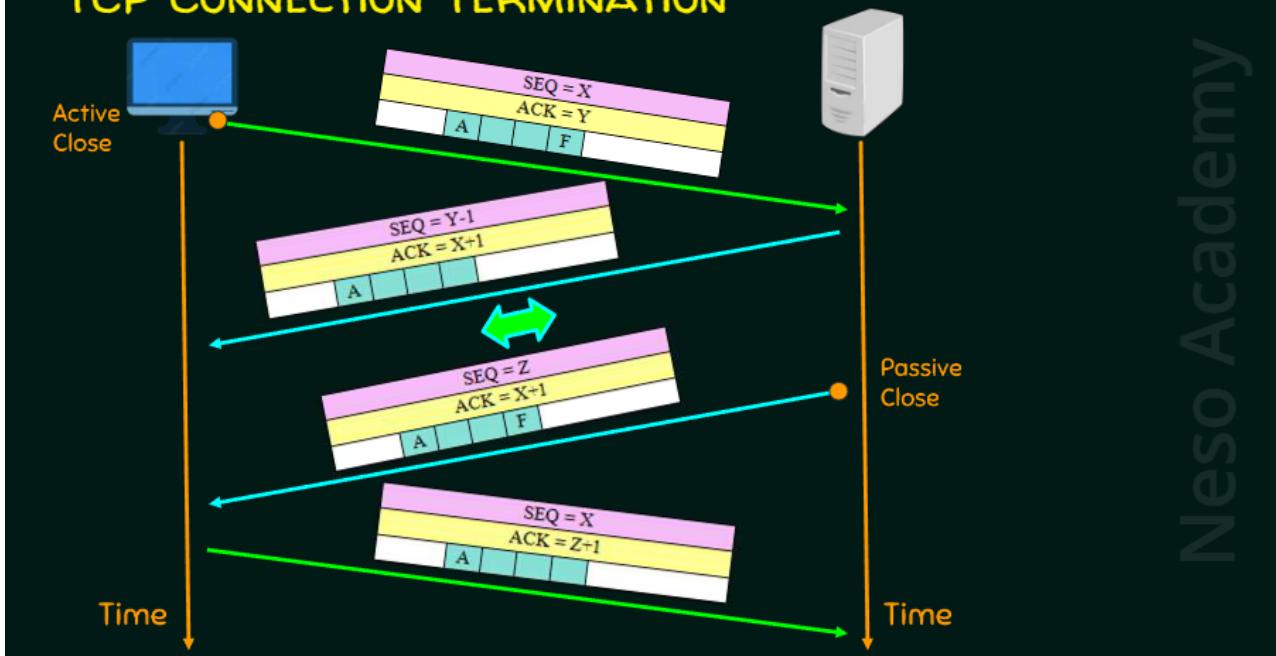
TCP Connection Termination ★★○○ Neso Academy

TCP CONNECTION TERMINATION



TCP Connection TerminationNeso Academy

TCP CONNECTION TERMINATION



TCP Connection TerminationNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand the TCP flow control process.
- ★ Know how the window size is set.

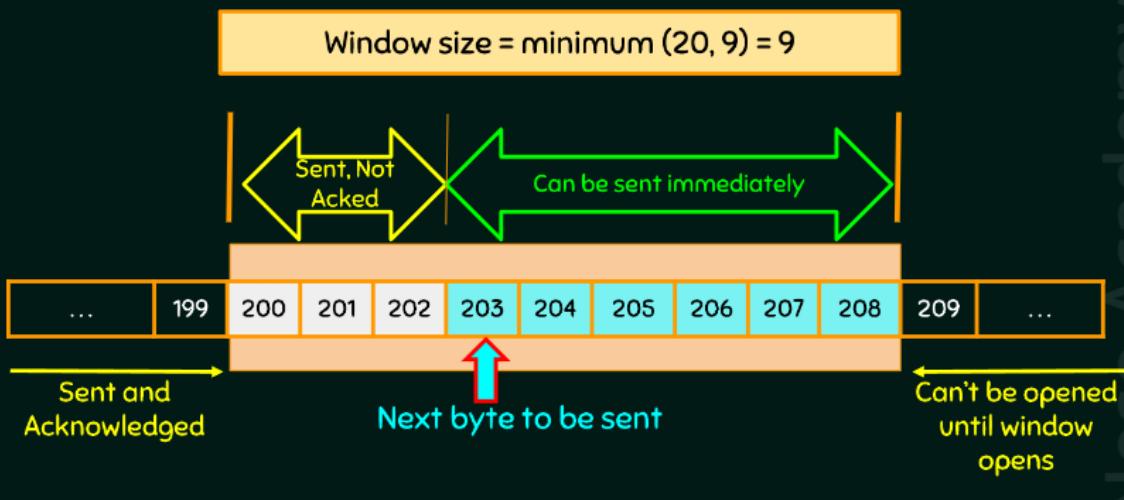
Outcomes ★★ Neso Academy

FLOW CONTROL

- ★ TCP uses a sliding window to handle flow control.
- ★ Between Go-Back-N and Selective Repeat.
- ★ Does not use NAK.
- ★ The receiver holds out-of-order segments.
- ★ TCP Sliding window is byte-oriented.
- ★ TCP's sliding window is of variable size.
- ★ Imaginary Window.

Flow Control ★★★★★ Neso Academy

TCP SLIDING WINDOW



TCP Sliding Window Neso Academy

POINTS TO PONDER

- ★ Window size = $\min(rwnd, cwnd)$
- ★ The source does not have to send a full window's worth of data.
- ★ The window can be opened or closed by the receiver, but should not be shrunk.
- ★ The destination can send an ACK at any time.
- ★ The sender can send 1-byte segment even after the window is shut down in the receiver side.

Points to Ponder ★★★★★ Neso Academy

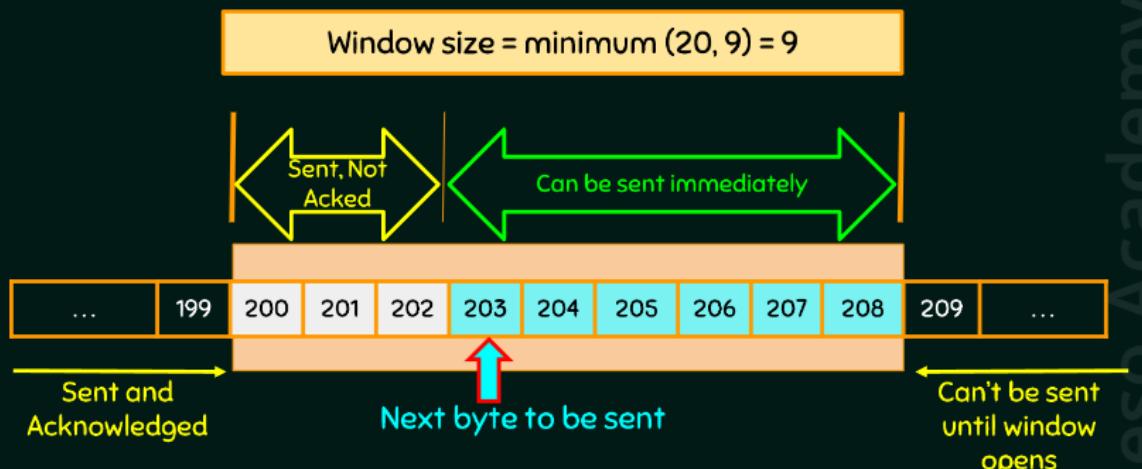
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know how the window size is set.
- ★ Know few points to ponder about TCP sliding window.

Outcomes ★★ Neso Academy

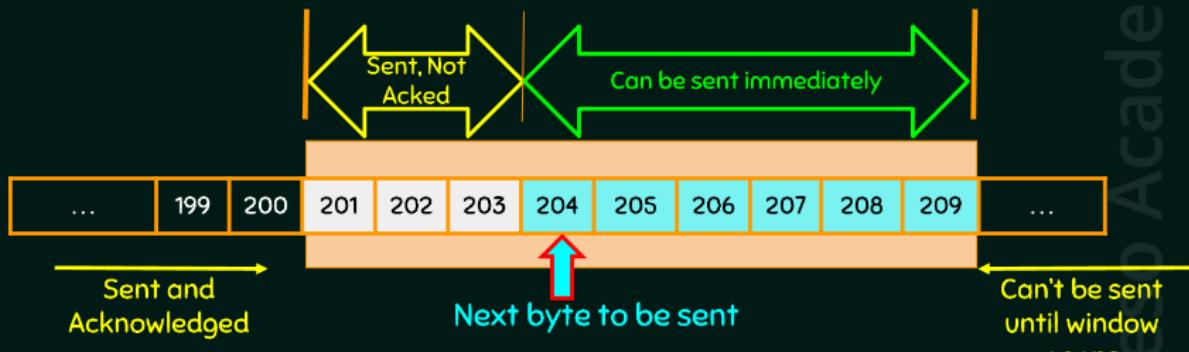
TCP SLIDING WINDOW



TCP Sliding Window Neso Academy

TCP SLIDING WINDOW

Window size = minimum (20, 9) = 9



TCP Sliding Window Neso Academy

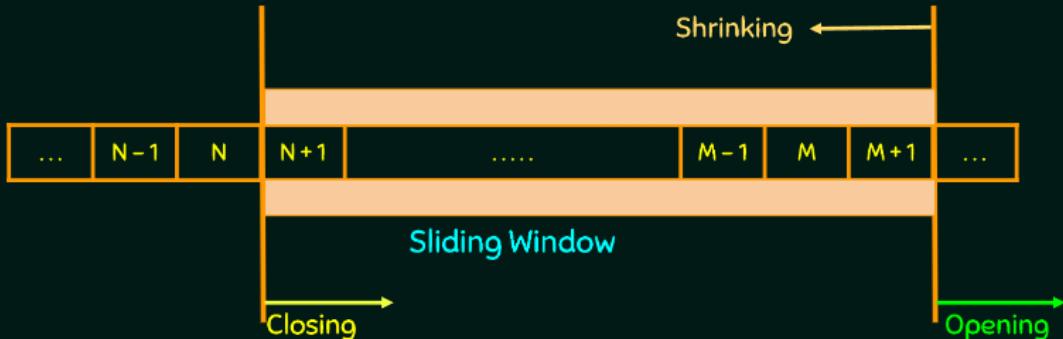
POINTS TO PONDER

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Points to Ponder ★★★★★ Neso Academy

TCP SLIDING WINDOW

Window size = minimum (rwnd, cwnd)



TCP Sliding WindowNeso Academy

QUESTION

Suppose two hosts use a TCP connection to transfer a large file. Which of the following statements is/are FALSE with respect to the TCP connection?

- I. If the sequence number of a segment is m , then the sequence number of the subsequent segment is always $m + 1$.
- II. If the estimated round trip time at any given point of time is ' t ' sec, the value of the retransmission timeout is always set to greater than or equal to ' t ' sec.
- III. The size of the advertised window never changes during the course of the TCP connection.
- IV. The number of unacknowledged bytes at the sender is always less than or equal to the advertised window.

[GATE CS 2015]

- a) III Only
- b) I and III Only
- c) I and IV Only
- d) II and IV Only

QuestionNeso Academy

QUESTION 2

What is the value of the receiver window (rwnd) for host A if the receiver host B, has a buffer size of 5000 bytes and 1000 bytes of received and unprocessed data?

SOLUTION:

$$\text{rwnd} = 5000 - 1000$$

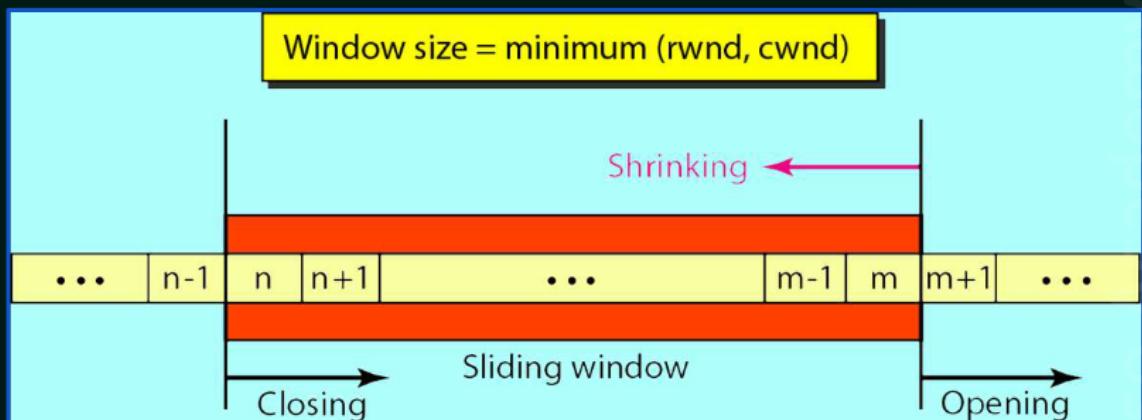
$$\text{rwnd} = 4000$$

Host B can receive only 4000 bytes of data before overflowing its buffer.

Host B advertises this value 4000 in its next segment to Host A.

Question 2Neso Academy

TCP SLIDING WINDOW



TCP Sliding WindowNeso Academy

POINTS TO PONDER

- ★ Window size = minimum(rwnd,cwnd)
- ★ The source does not have to send a full window's worth of data.
- ★ The window can be opened or closed by the receiver, but should not be shrunk.
- ★ The destination can send an ACK at any time.
- ★ The sender can send 1-byte segment even after the window is shut down in the receiver side.

Points to Ponder★★★★★Neso Academy

QUESTION 1

The TCP sliding window

- A) can be used to control the flow of information. ✓
- B) always occurs when the field value is 0.
- C) always occurs when the field value is 1.
- D) occurs horizontally.

[ISRO CS 2008]

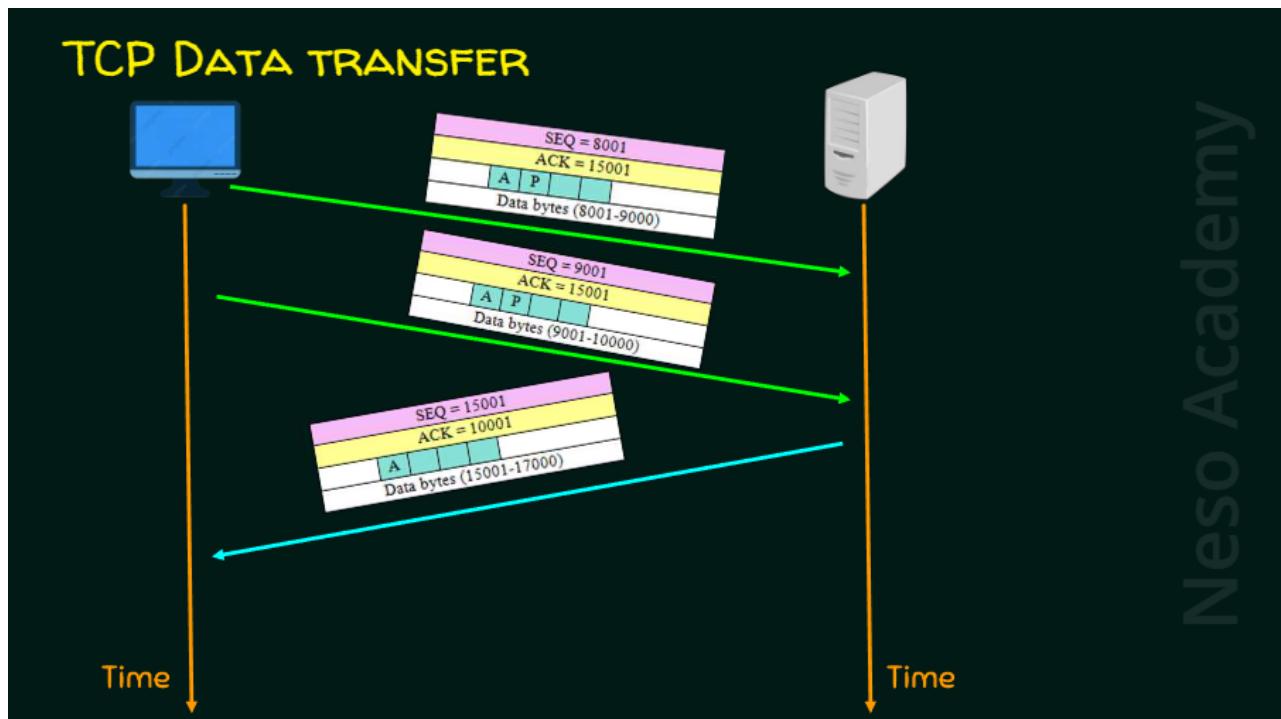
Question 1✓Neso Academy

QUESTION 2

Suppose a TCP connection is transferring a file of 1000 bytes. The first byte is numbered 10001. What is the sequence number of the segment if all data is sent in only one segment?

- a) 10000
- b) 10001
- c) 12001
- d) 11001

Question 2Neso Academy



TCP Data transferNeso Academy

QUESTION 2

Suppose a TCP connection is transferring a file of 1000 bytes. The first byte is numbered 10001. What is the sequence number of the segment if all data is sent in only one segment?

- a) 10000
- b) 10001 ✓
- c) 12001
- d) 11001

Question 2✓Neso Academy

QUESTION 3

What is the size of the window for host A if the value of rwnd is 3000 bytes and the value of cwnd is 3500 bytes?

SOLUTION:

Window size = minimum (rwnd,cwnd)

Window size = minimum (3000,3500)

Window size = 3000

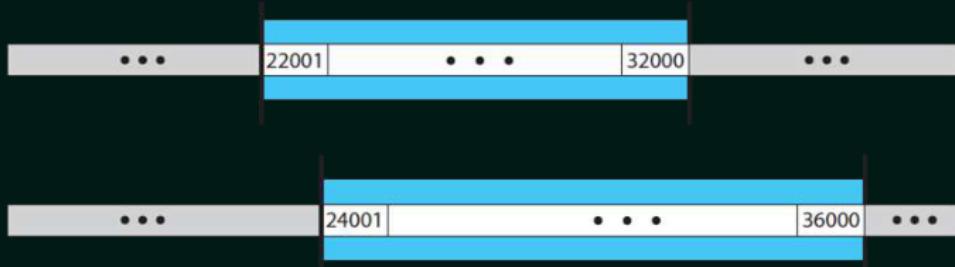
Window size = 3000 bytes

Question 3Neso Academy

QUESTION 4

A TCP connection is using a window size of 10,000 bytes, and the previous acknowledgment number was 22,001. It receives a segment with acknowledgment number 24,001 and window size advertisement of 12,000. Draw a diagram to show the situation of the window before and after.

SOLUTION:

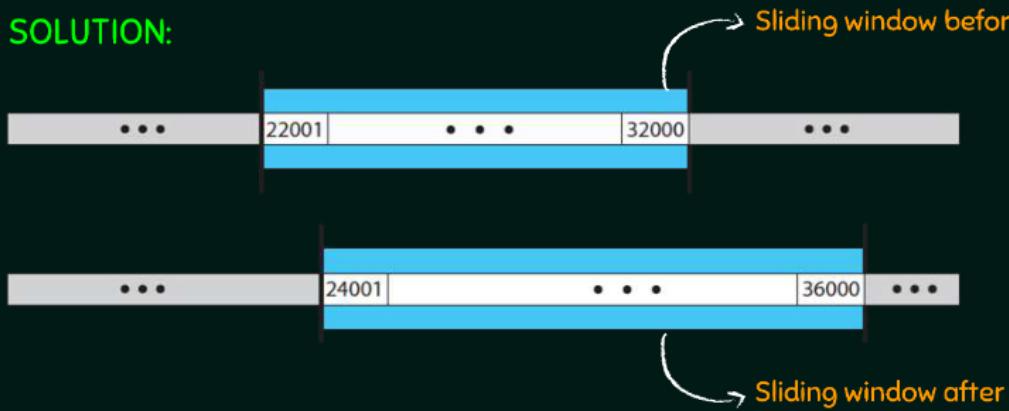


Question 4Neso Academy

QUESTION 4

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SOLUTION:



Question 4Neso Academy

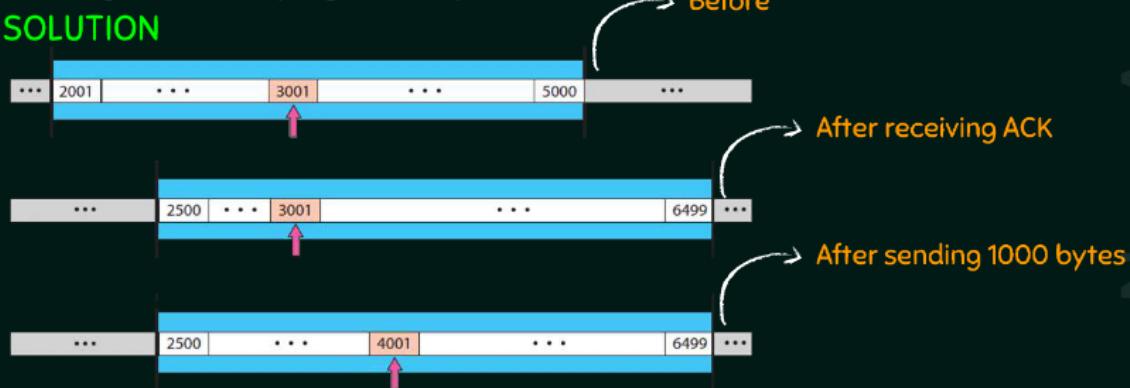
QUESTION 5

A window holds bytes 2001 to 5000. The next byte to be sent is 3001. Draw a figure to show the situation of the window after the following two events.

- An ACK segment with the acknowledgment number 2500 and window size advertisement 4000 is received.

- A segment carrying 1000 bytes is sent.

SOLUTION



Question 5 Neso Academy

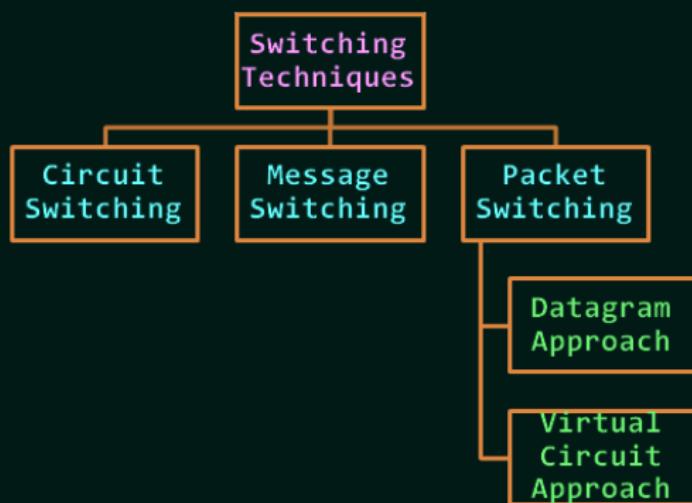
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand congestion in computer networks.
- ★ Know various congestion control categories.

Outcomes ★★ Neso Academy

SWITCHING TECHNIQUES



Neso Academy

Switching TechniquesNeso Academy

CONGESTION – ANALOGY

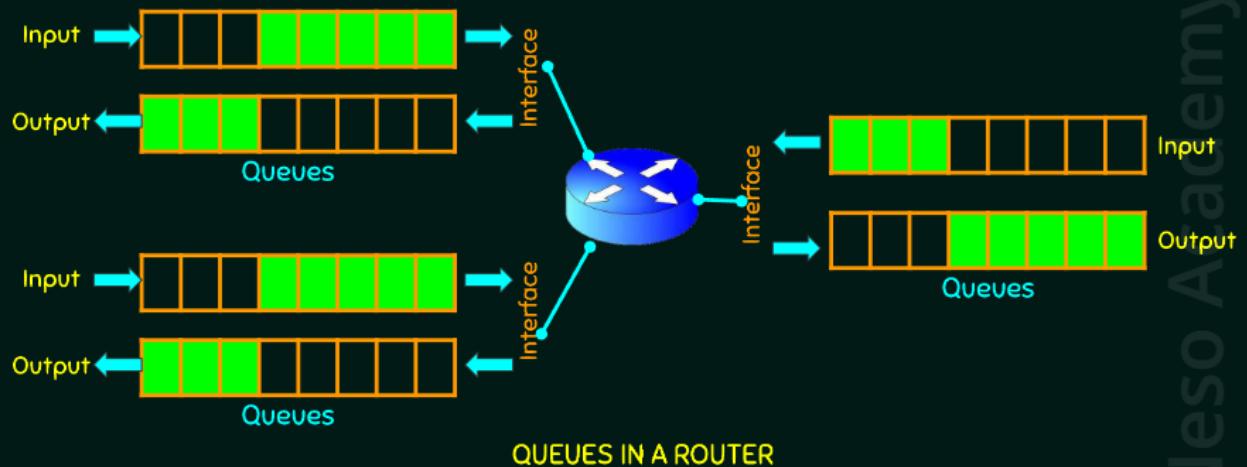
What do you do when you have more people than seats?



Neso Academy

Congestion -AnalogyNeso Academy proudly presents....Neso Academy

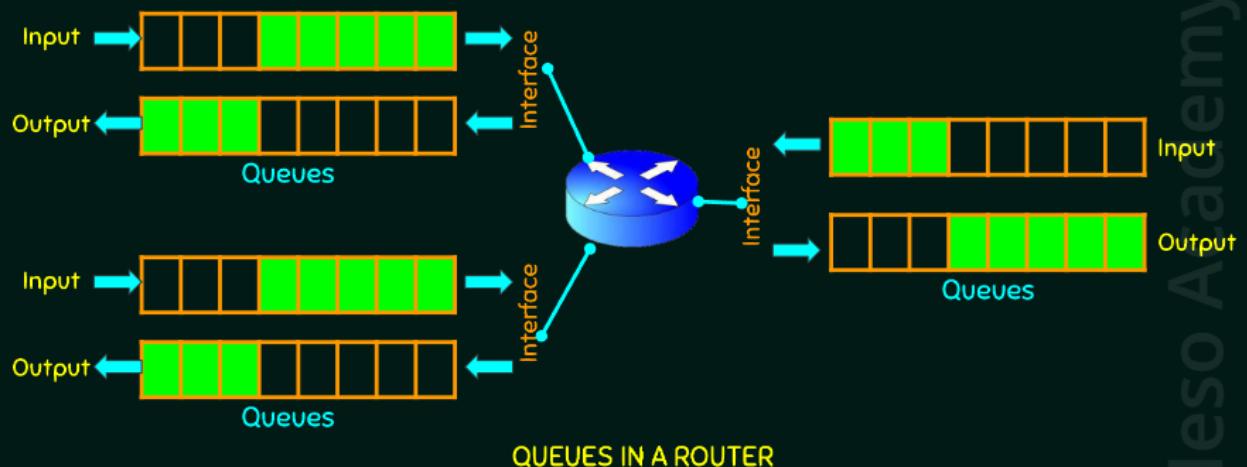
CONGESTION



Neso Academy

CongestionNeso Academy

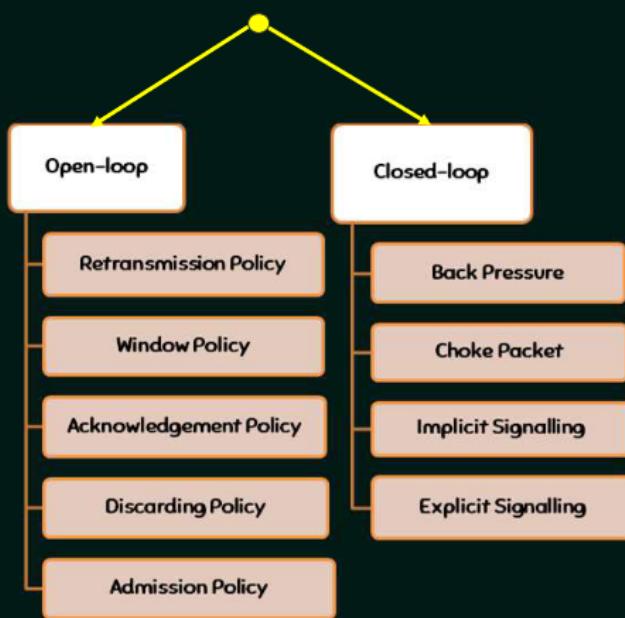
WHEN PACKET ARRIVES AT INCOMING INTERFACE?



Neso Academy

When packet arrives at incoming interface?Neso Academy

Congestion Control



Congestion Control Neso Academy

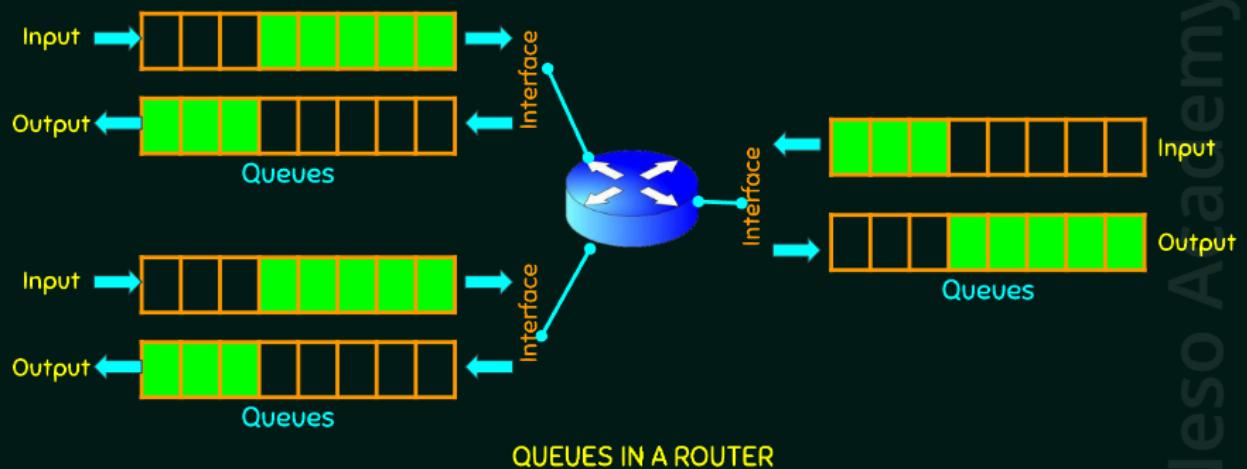
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know various congestion control categories.
- ★ Understand various open loop congestion control mechanisms.

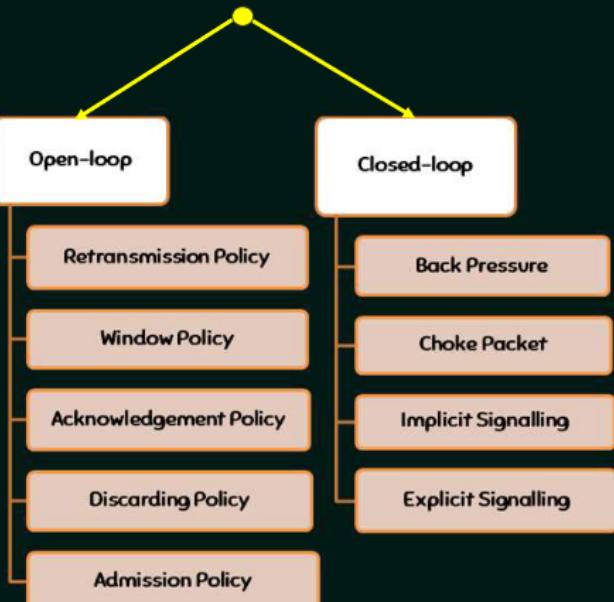
Outcomes ★★ Neso Academy

CONGESTION



CongestionNeso Academy

CONGESTION CONTROL



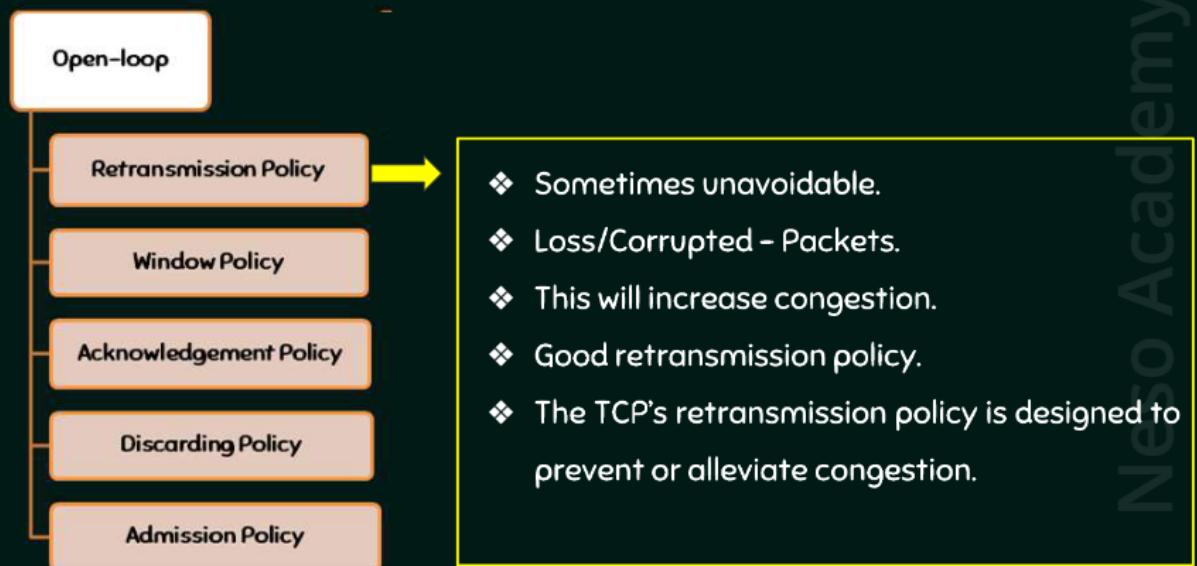
Congestion ControlNeso Academy

Congestion Control



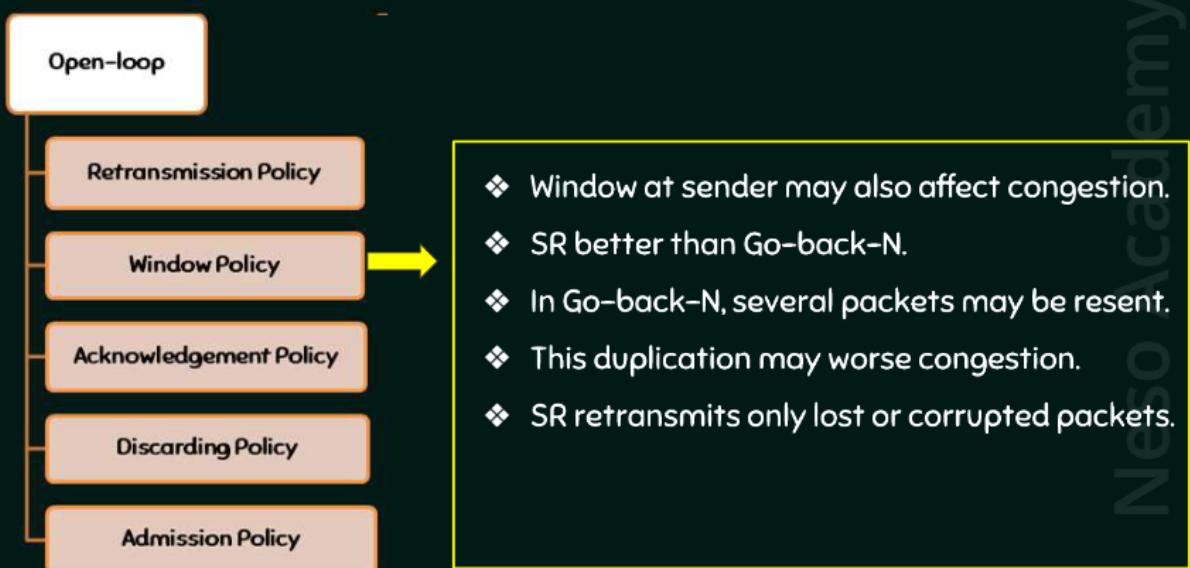
Congestion Control Neso Academy

Congestion Control



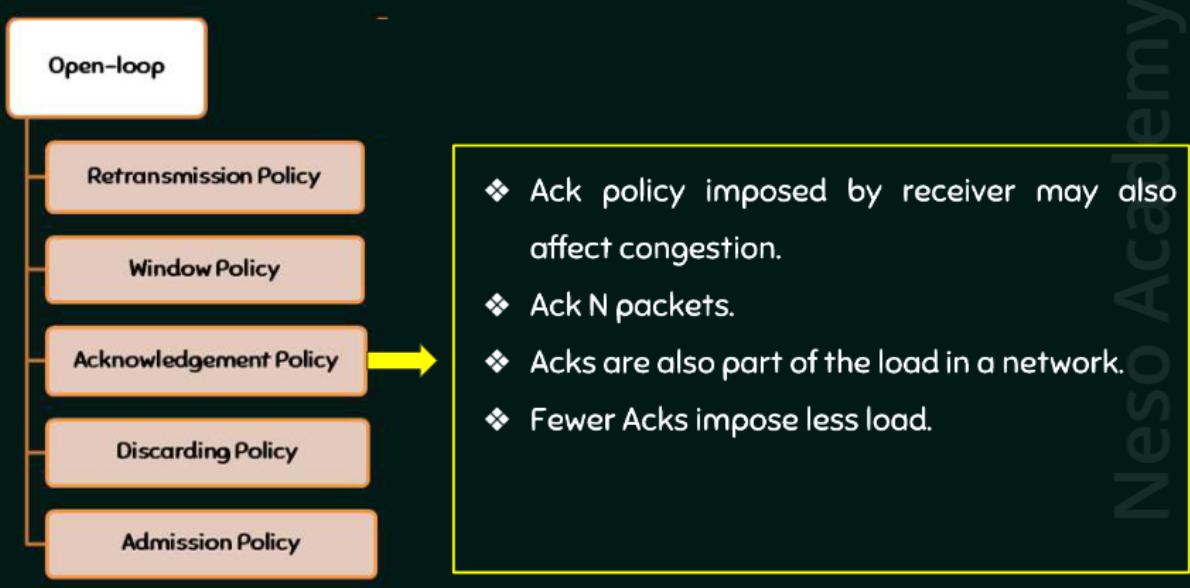
Congestion Control ♦♦♦♦♦ Neso Academy

CONGESTION CONTROL



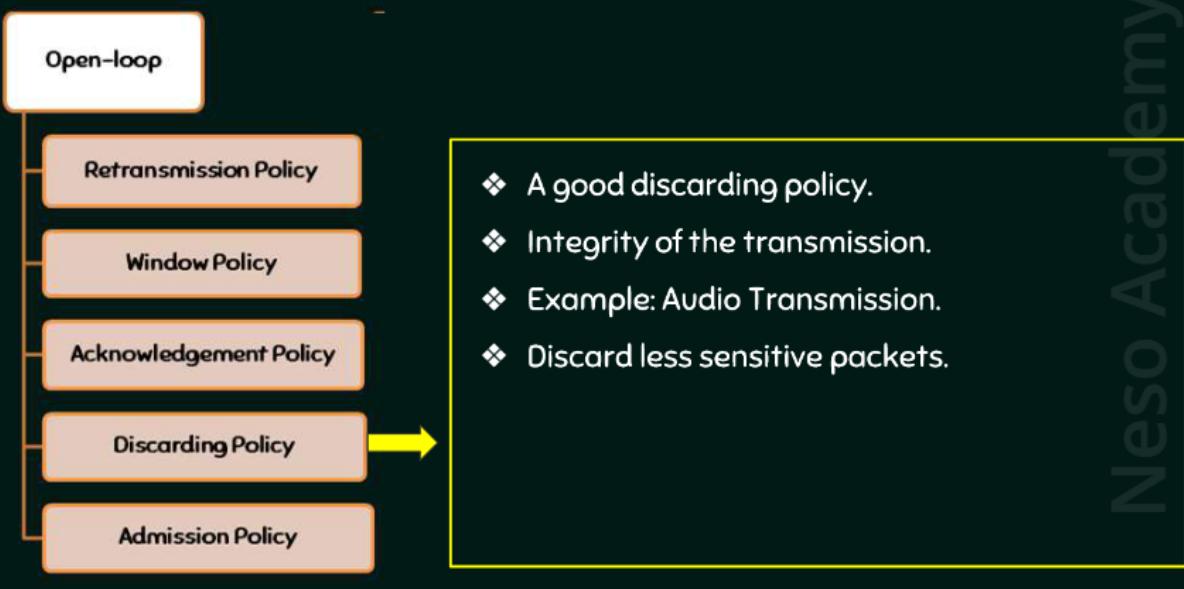
Congestion Control❖❖❖❖❖ Neso Academy

CONGESTION CONTROL



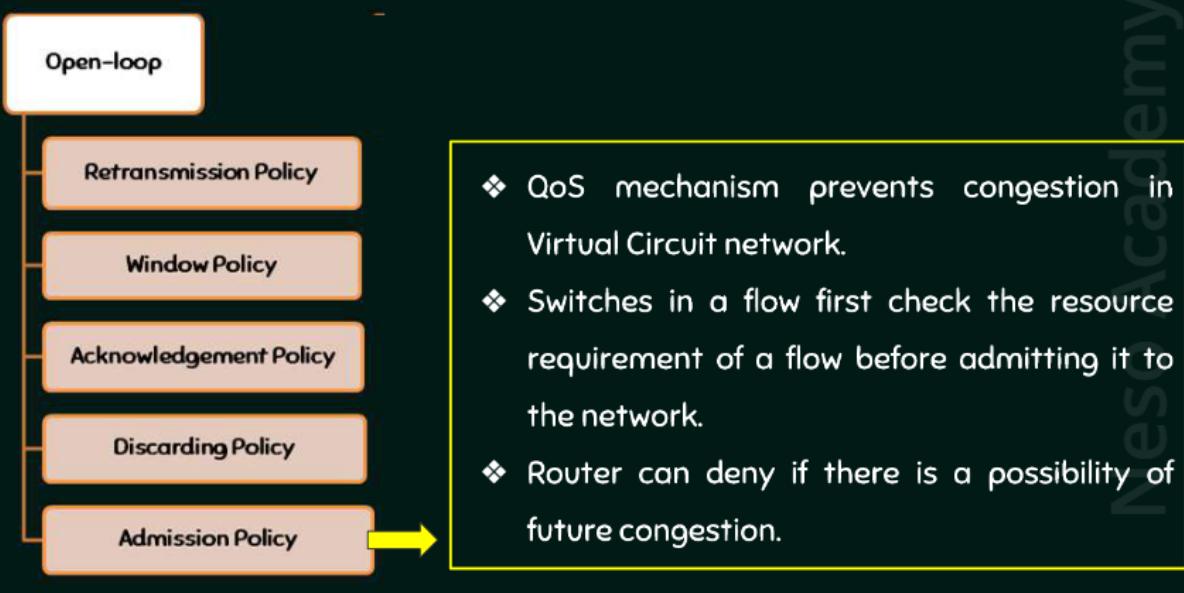
Congestion Control❖❖❖❖ Neso Academy

CONGESTION CONTROL



Congestion Control❖❖❖❖Neso Academy

CONGESTION CONTROL



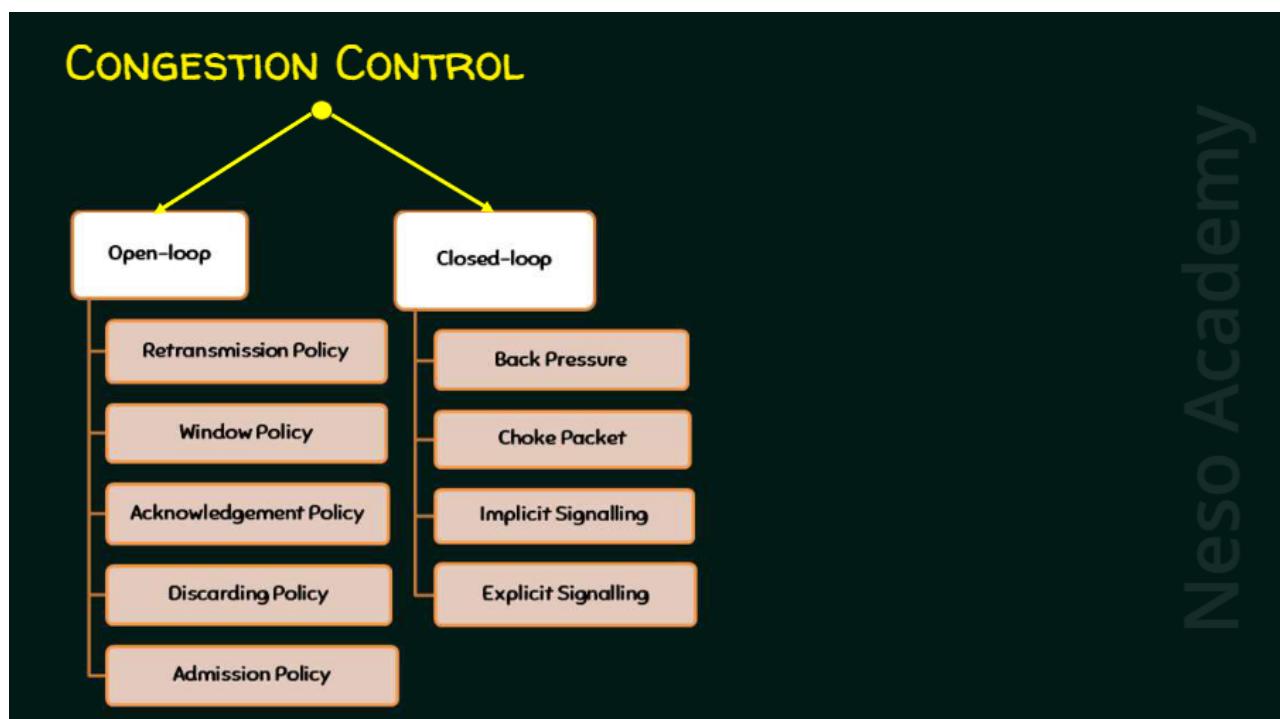
Congestion Control❖❖❖Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

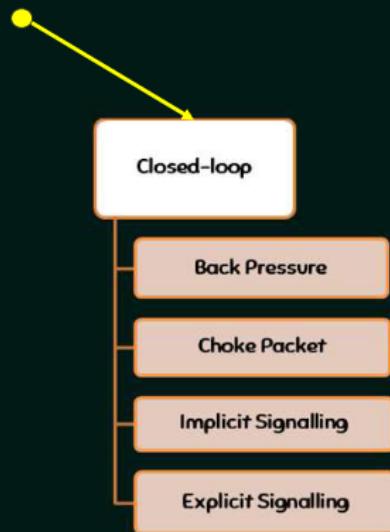
- ★ Know various congestion control categories.
- ★ Know the difference between open loop and closed loop congestion control mechanisms.
- ★ Understand various closed loop congestion control mechanisms.

Outcomes ★★★ Neso Academy



Congestion Control Neso Academy

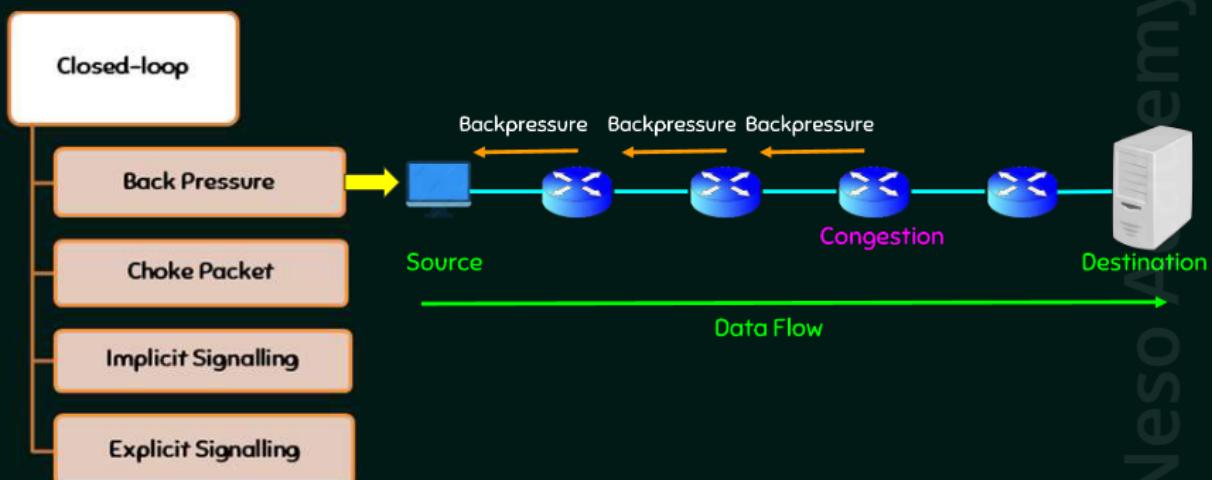
Congestion Control



Neso Academy

Congestion Control Neso Academy

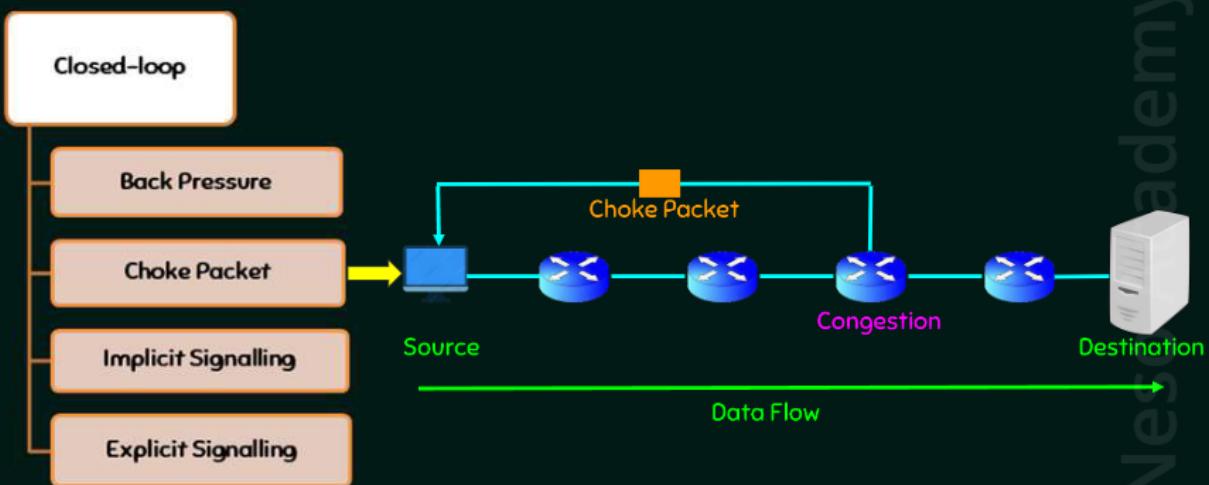
Congestion Control



Neso Academy

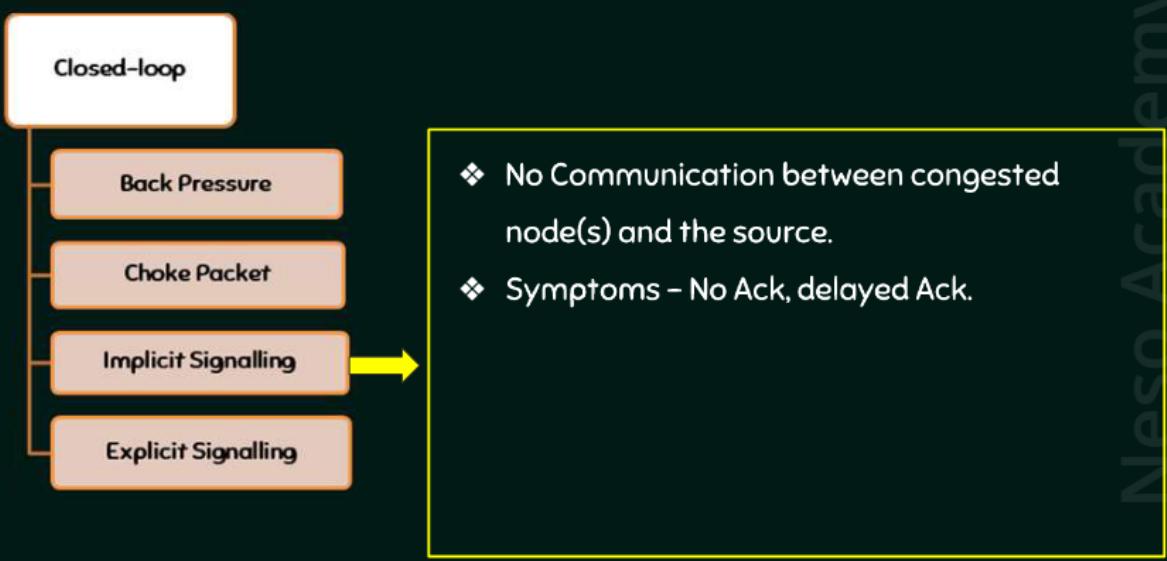
Congestion Control Neso Academy

Congestion Control



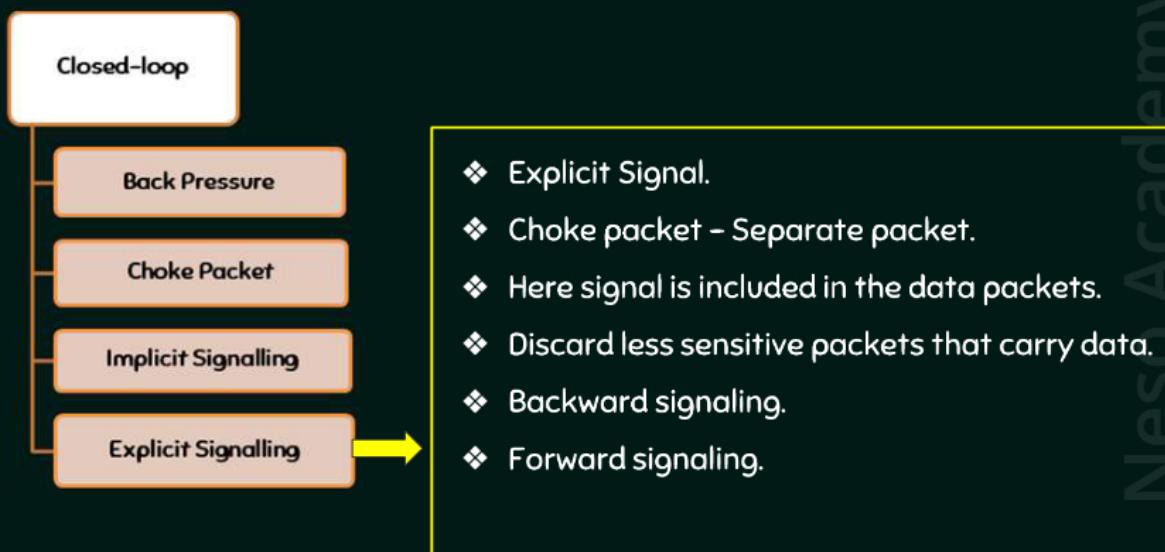
Congestion Control Neso Academy

Congestion Control



Congestion Control ♦♦ Neso Academy

Congestion Control



Congestion Control❖❖❖❖❖❖ Neso Academy

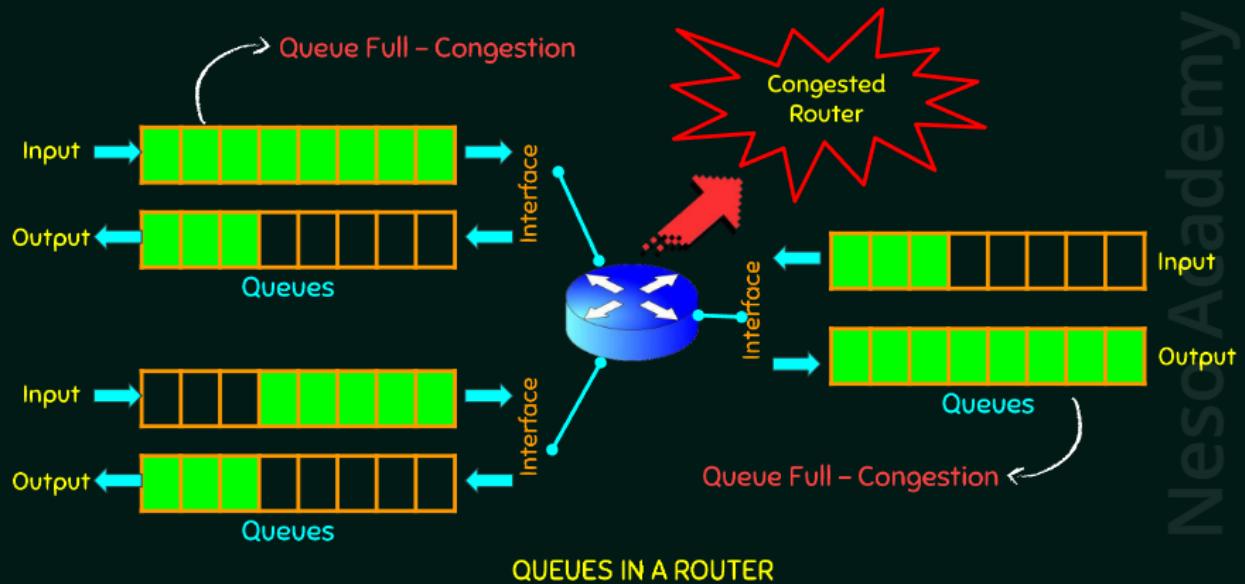
OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand congestion control in TCP.
- ★ Know how TCP uses congestion control to avoid congestion or alleviate congestion in the network.

Outcomes★★Neso Academy

CONGESTION



CongestionNeso Academy

CONGESTION CONTROL IN TCP

Who decides the window size?



Congestion Control in TCPNeso Academy

CONGESTION CONTROL IN TCP

Who decides the window size?



Congestion Control in TCP
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CONGESTION CONTROL IN TCP

- ★ Congestion Window
- ★ Congestion Policy

Congestion Control in TCP ★★ Neso Academy

CONGESTION CONTROL IN TCP

Congestion Window

- ★ The sender window size is determined by the available buffer space in the receiver (rwnd).
- ★ In other words, we assumed that it is only the receiver that can dictate to the sender the size of the sender's window.
- ★ Did we ignore any entity here?
- ★ If the network cannot deliver the data as fast as they are created by the sender, it must tell the sender to slow down.
- ★ The sender's window size is determined not only by the receiver but also by congestion in the network.

Actual window size = Minimum (rwnd, cwnd)

Congestion Control in TCP★★★★★Neso Academy

CONGESTION CONTROL IN TCP

Congestion Policy

- ★ TCP's general policy for handling congestion is based on three phases: slow start, congestion avoidance, and congestion detection.
- ★ In the slow-start phase, the sender starts with a very slow rate of transmission, but increases the rate rapidly to reach a threshold.
- ★ When the threshold is reached, the data rate is reduced to avoid congestion.
- ★ Finally if congestion is detected, the sender goes back to the slow-start or congestion avoidance phase based on how the congestion is detected.

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Congestion Control in TCP

Congestion Policy

1. Slow Start
2. Additive Increase
3. Multiplicative Decrease

Congestion Control in TCP Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the various phases of congestion control in TCP.
- ★ Know about slow start algorithm in TCP.

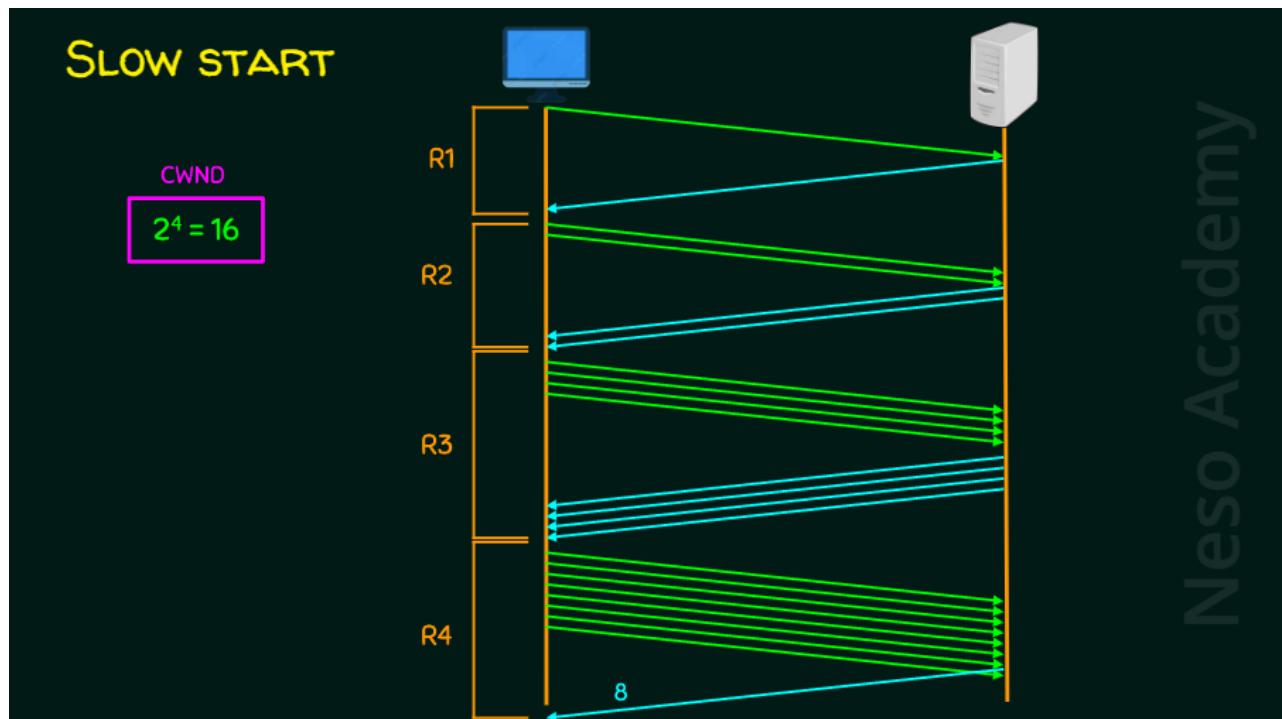
Outcomes ★★ Neso Academy

Congestion Control in TCP

1. Slow Start
2. Additive Increase
3. Multiplicative Decrease

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Slow startNeso Academy

SLOW START

Round	Value of cwnd
Start	$2^0 = 1$
After Round 1	$2^1 = 2$
After Round 2	$2^2 = 4$
After Round 3	$2^3 = 8$
After Round 4	$2^4 = 16$
After Round 5	$2^5 = 32$
After Round 6	$2^6 = 64$
:	:

Slow start Neso Academy

SLOW START

- ★ Slow start cannot continue indefinitely.
- ★ There must be a threshold to stop this exponential growth.
- ★ The sender keeps track of a variable named ssthresh (slow-start threshold).
- ★ When the size of window in bytes reaches this threshold, slow start stops and the next phase starts.
- ★ In most implementations, the value of ssthresh is 65,535 bytes.

Slow start ★★★★★ Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand congestion control in TCP.
- ★ Know about additive increase congestion avoidance algorithm in TCP.

Outcomes ★ Neso Academy

CONGESTION CONTROL IN TCP

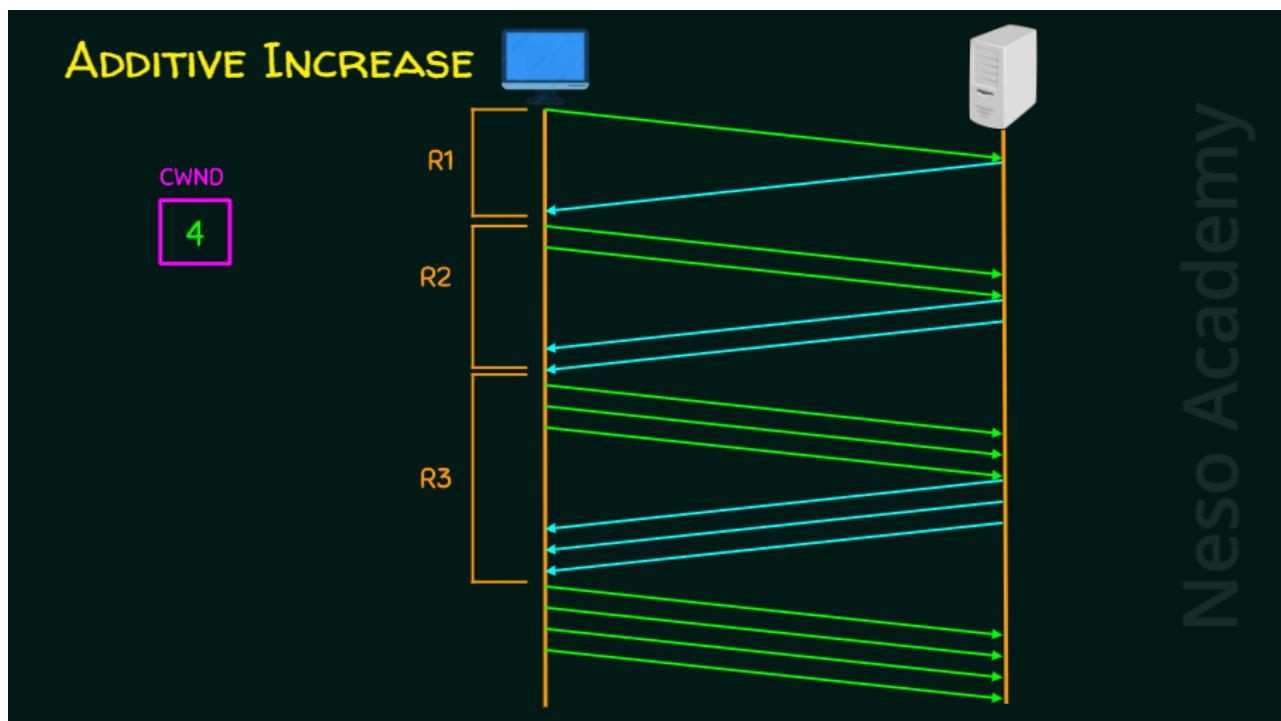
1. Slow Start
2. Additive Increase (Congestion Avoidance)
3. Multiplicative Decrease (Congestion Detection)

Congestion Control in TCP Neso Academy

2. ADDITIVE INCREASE

- ★ Slow start – cwnd increases exponentially.
- ★ This exponential growth must be slowed down, to avoid congestion before it happens.
- ★ Congestion Avoidance: Additive Increase.
- ★ When cwnd reaches the threshold, the slow-start phase stops and the additive phase begins.
- ★ In this algorithm, each time the whole window of segments is acknowledged (one round), the size of the congestion window is increased by 1.
- ★ In the congestion avoidance algorithm, the size of the congestion window increases additively until congestion is detected.

2. Additive Increase★★★★★Neso Academy



Additive IncreaseNeso Academy

ADDITIVE INCREASE

Round	Value of cwnd
Start	1
After Round 1	2
After Round 2	3
After Round 3	4
After Round 4	5
After Round 5	6
After Round 6	7
:	:

Additive Increase Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand congestion control in TCP.
- ★ Know about multiplicative decrease congestion detection algorithm in TCP.
- ★ Understand fast transmission and fast recovery.

Outcomes ★★★ Neso Academy

Congestion Control in TCP

1. Slow Start
2. Additive Increase (Congestion Avoidance)
3. Multiplicative Decrease (Congestion Detection)

Congestion Control in TCP Neso Academy

3. MULTIPLICATIVE DECREASE

- ★ Slow start – Exponential increase.
- ★ Additive increase – Linear increase.
- ★ The cwnd must be decreased, if there is a congestion.
- ★ Sender can guess that congestion.
- ★ Retransmission of segment.
- ★ Retransmission can occur in one of two cases:
 - When a timer times out or
 - When three ACKs are received
- ★ Threshold is dropped to one-half, a multiplicative decrease.

3. Multiplicative Decrease ★★★★★○★ Neso Academy

3. MULTIPLICATIVE DECREASE

TCP implementations have two reactions:

Reaction 1

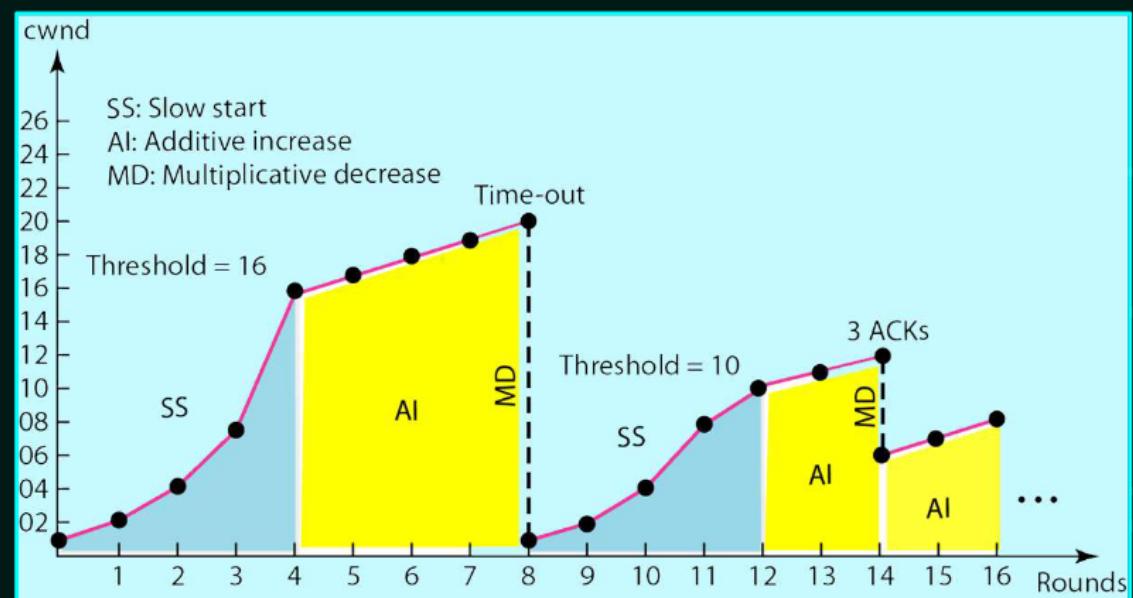
1. It sets the value of the threshold to one-half of the current window size.
2. It sets cwnd to the size of one segment.
3. It starts the slow-start phase again.

Reaction 2

1. It sets the value of the threshold to one-half of the current window size.
2. It sets cwnd to the value of the threshold.
3. It starts the congestion avoidance phase.

3. Multiplicative DecreaseNeso Academy

MULTIPLICATIVE DECREASE



Multiplicative DecreaseNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand QoS with an analogy.
- ★ Know about flow characteristics.

Outcomes ★ Neso Academy

ANALOGY



Analogy Neso Academy

THE INTERNET



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The InternetNeso Academy

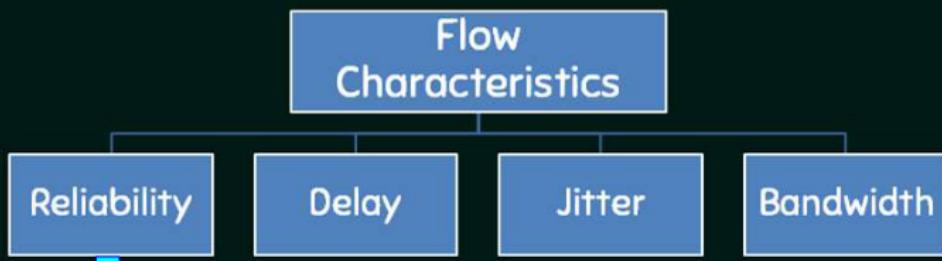
QoS

- ★ Packet Switched Networks – Multimedia applications.
 - ★ However, there is more to transmitting audio and video over a network than just providing sufficient bandwidth.
 - ★ Applications that are sensitive to the timeliness of data : real-time applications.
 - ★ VoIP conversation, Video conferencing, Remote login etc.,
 - ★ Email, Surfing the internet, Uploading a file to the cloud etc,
 - ★ Informally: QoS – A flow seeks to attain.
 - ★ Flow characteristics.

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QoS ★★★★★★★★ Neso Academy

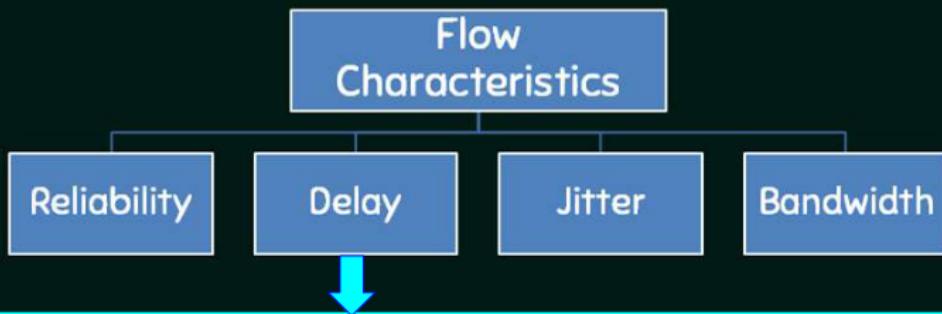
FLOW CHARACTERISTICS



- ★ Lack of reliability = Losing a packet or Ack.
- ★ The sensitivity of application programs to reliability is not the same.
- ★ **Reliability:** Email, File transfer, surfing the internet > Telephony or Audio conferencing.

Flow characteristics ★★★ Neso Academy

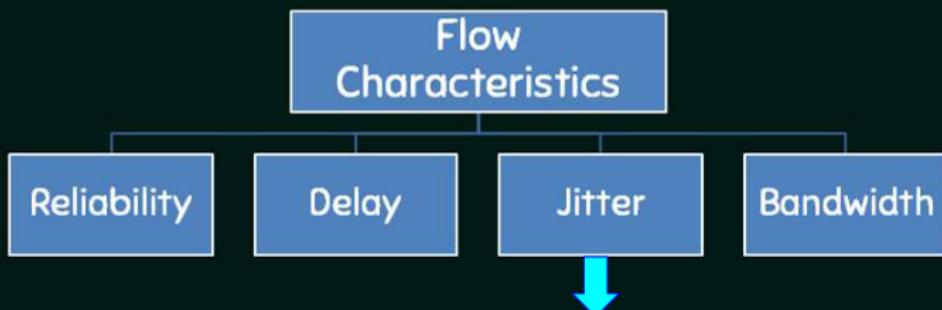
FLOW CHARACTERISTICS



- ★ Source-to-Destination delay.
- ★ Applications can tolerate delay in different degrees.
- ★ **Delay:** Email, File transfer, and surfing the internet > Telephony, Audio conferencing, and Remote login.

Flow characteristics ★★★ Neso Academy

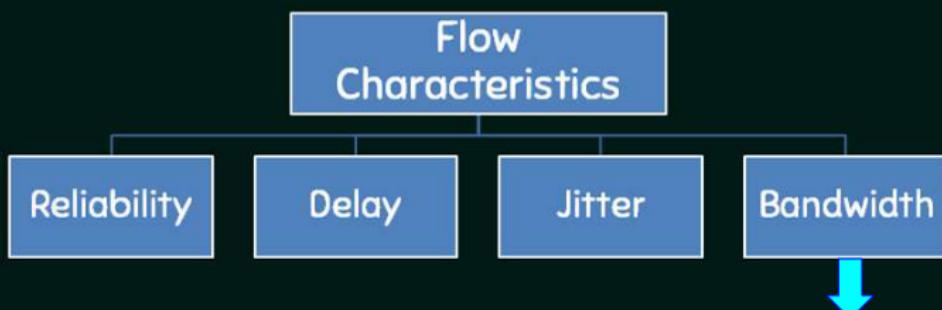
FLOW CHARACTERISTICS



- ★ Variation in delay for packets belonging to the same flow.
- ★ Example 1: 0, 1, 2, 3 → 20, 21, 22, 23 (Same delay: 20).
- ★ Example 2: 0, 1, 2, 3 → 21, 23, 21, 28 (Different delays: 21, 22, 19 and 24).
- ★ High jitter and Low jitter.

Flow characteristics ★★★★ Neso Academy

FLOW CHARACTERISTICS



- ★ Different application – Different bandwidths.
- ★ Bandwidth: Video Conferencing > Email.

Flow characteristics ★★ Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Understand QoS.
- ★ Know about flow characteristics.

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Outcomes ★ Neso Academy

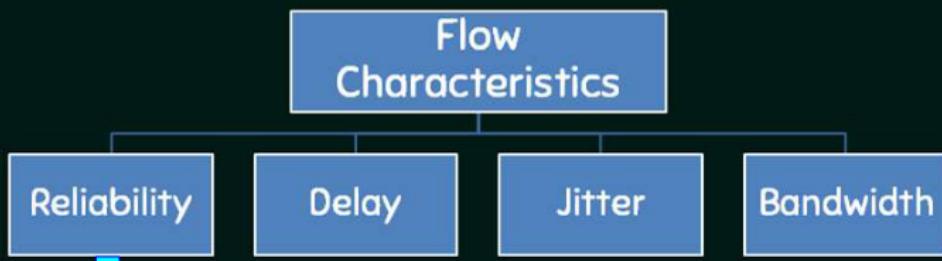
ANALOGY



Neso Academy

Analogy Neso Academy

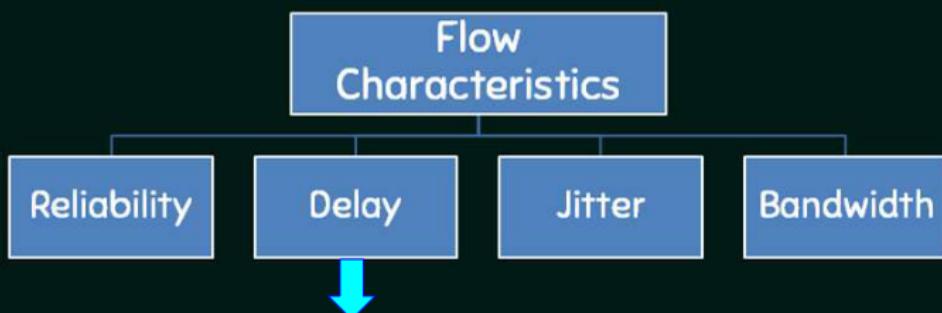
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Flow characteristics ★★★ Neso Academy

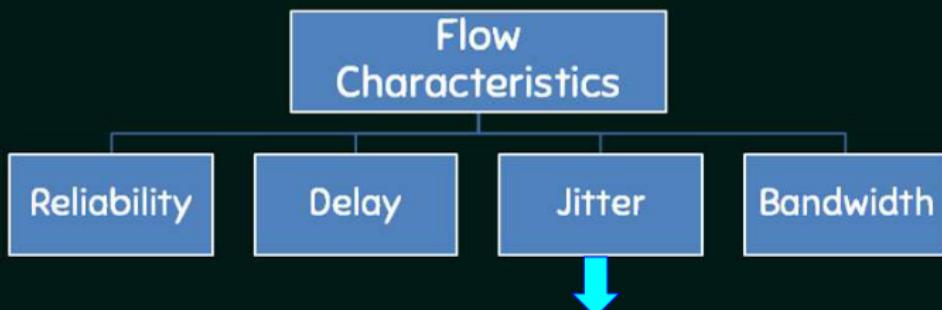
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Flow characteristics ★★★ Neso Academy

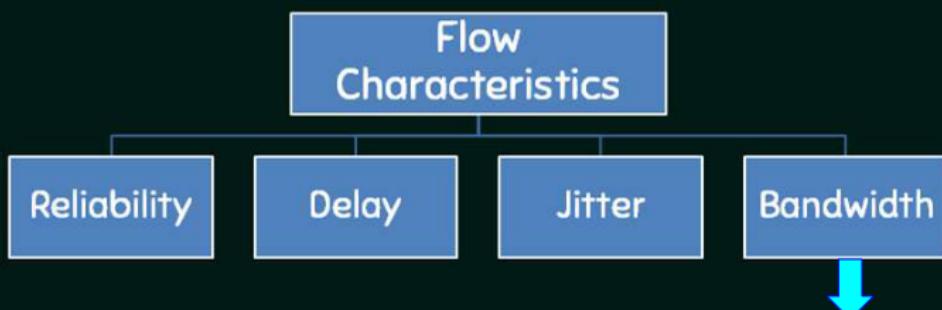
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Flow characteristics ★★★★ Neso Academy

FLOW CHARACTERISTICS



- ★ Different application – Different bandwidths.
- ★ Bandwidth: Video Conferencing > Email.

Flow characteristics ★★ Neso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the techniques to improve QoS.
- ★ Understand scheduling techniques such as FIFO Queuing, Priority Queuing, and Weighted Fair Queuing.

Outcomes ★ Neso Academy

TECHNIQUES TO IMPROVE QoS

1. Scheduling
2. Traffic shaping
3. Admission control
4. Resource reservation

Techniques to improve QoS Neso Academy

TECHNIQUES TO IMPROVE QoS

1. Scheduling
2. Traffic shaping
3. Admission control
4. Resource reservation

Techniques to improve QoS Neso Academy

SCHEDULING

- ★ Packets from different flows – Switch or Router.
- ★ Good scheduling technique.

Scheduling Techniques

1. FIFO Queuing
2. Priority Queuing
3. Weighted Fair Queuing

★★Scheduling Neso Academy

SCHEDULING

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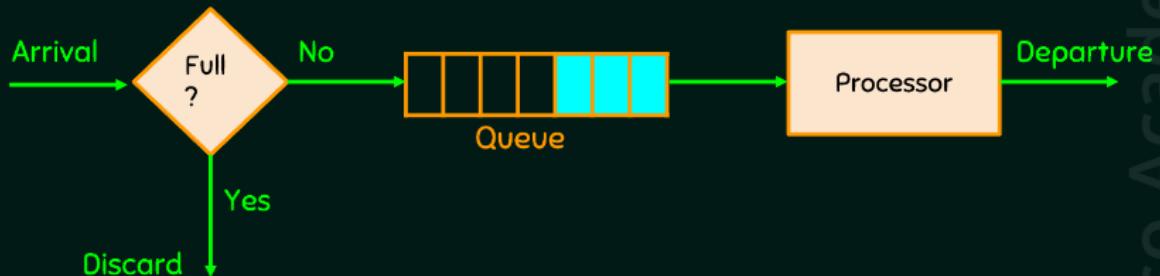
Scheduling Techniques

1. FIFO Queuing
2. Priority Queuing
3. Weighted Fair Queuing

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FIFO QUEUING



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FIFO QueuingNeso Academy

SCHEDULING

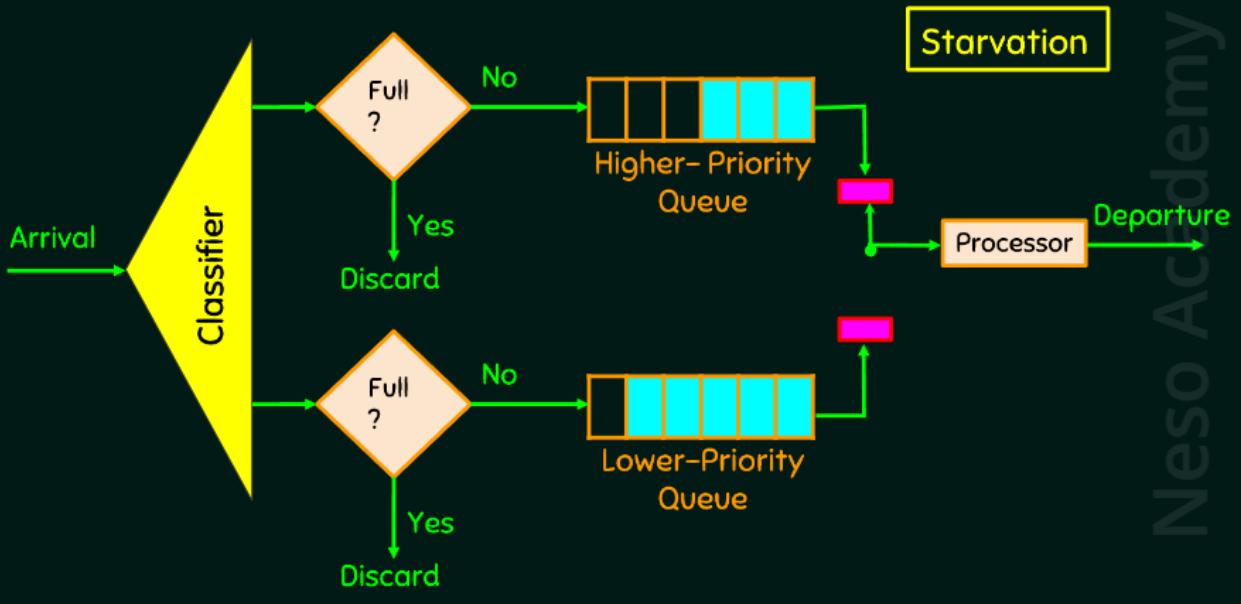
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Scheduling Techniques

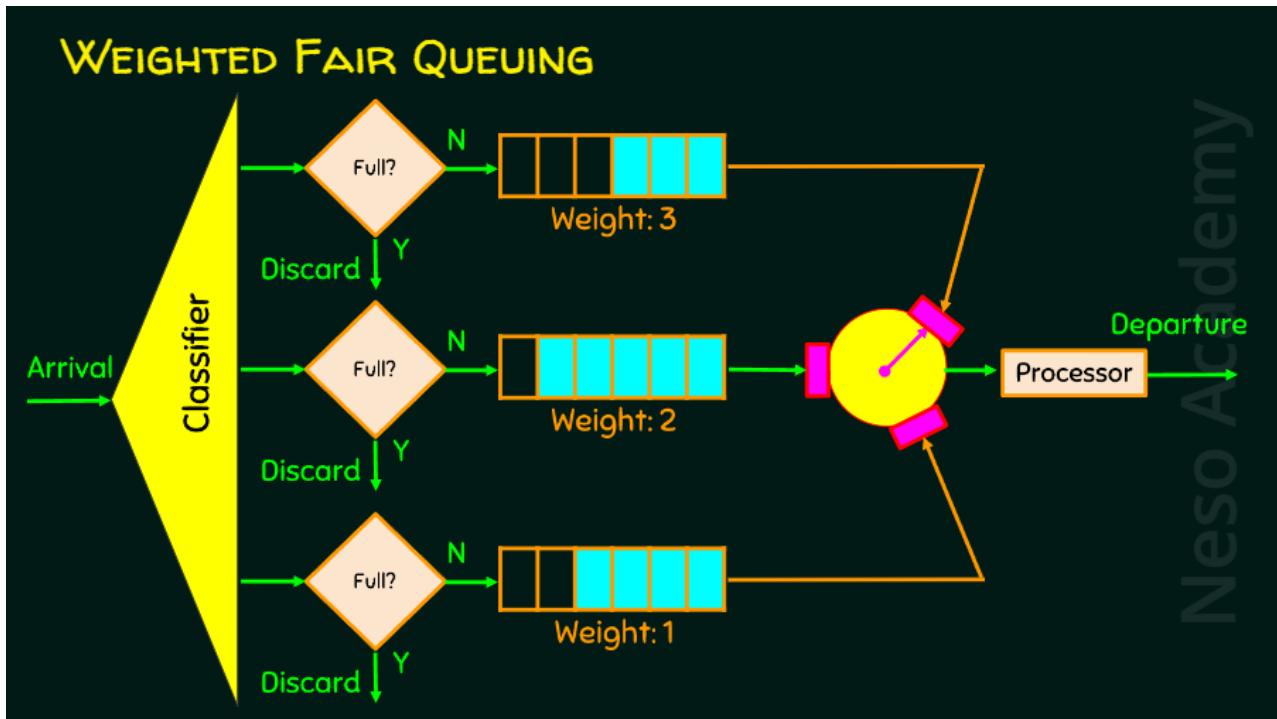
1. FIFO Queuing
2. Priority Queuing
3. Weighted Fair Queuing

★★SchedulingNeso Academy

PRIORITY QUEUING



Priority QueuingNeso Academy



Weighted Fair QueuingNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the techniques to improve QoS.
- ★ Understand traffic shaping such as leaky bucket and token bucket algorithms.

★★OutcomesNeso Academy

TECHNIQUES TO IMPROVE QoS

1. Scheduling
2. Traffic Shaping
3. Admission Control
4. Resource Reservation

Techniques to improve QoS Neso Academy

TECHNIQUES TO IMPROVE QoS

1. Scheduling
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Techniques to improve QoS Neso Academy

TRAFFIC SHAPING

- ★ Controls the amount of traffic sent to the network.
- ★ Controls the rate of traffic sent to the network.

Traffic Shaping Techniques

1. Leaky Bucket
2. Token Bucket

★★Traffic shapingNeso Academy

TRAFFIC SHAPING

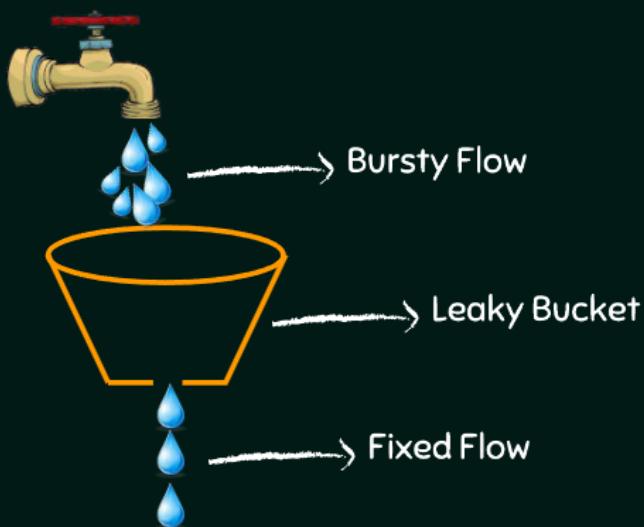
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Traffic Shaping Techniques

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★★Traffic shapingNeso Academy

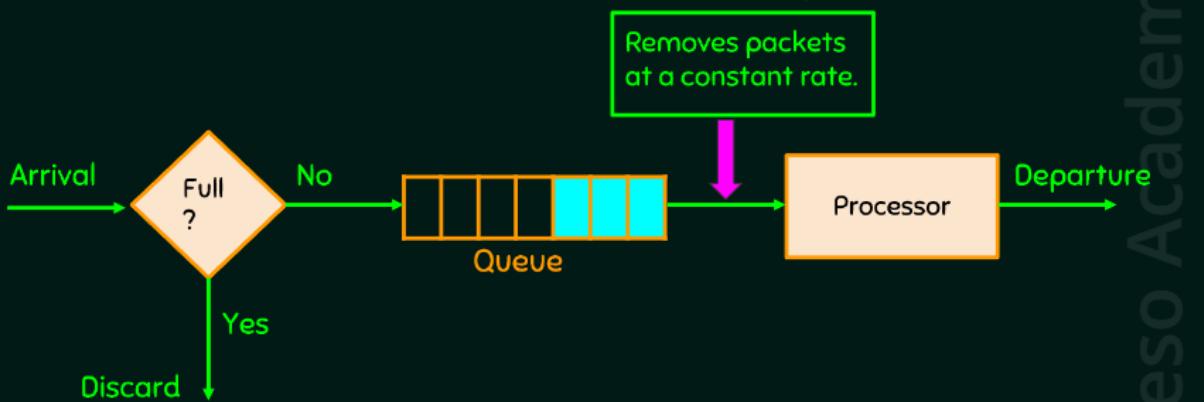
LEAKY BUCKET



Leaky BucketNeso Academy

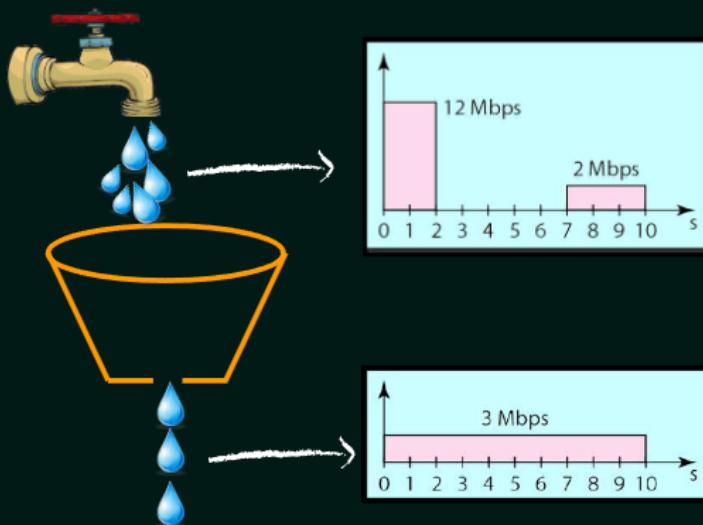
LEAKY BUCKET

Leaky Bucket Algorithm



Leaky BucketNeso Academy

LEAKY BUCKET



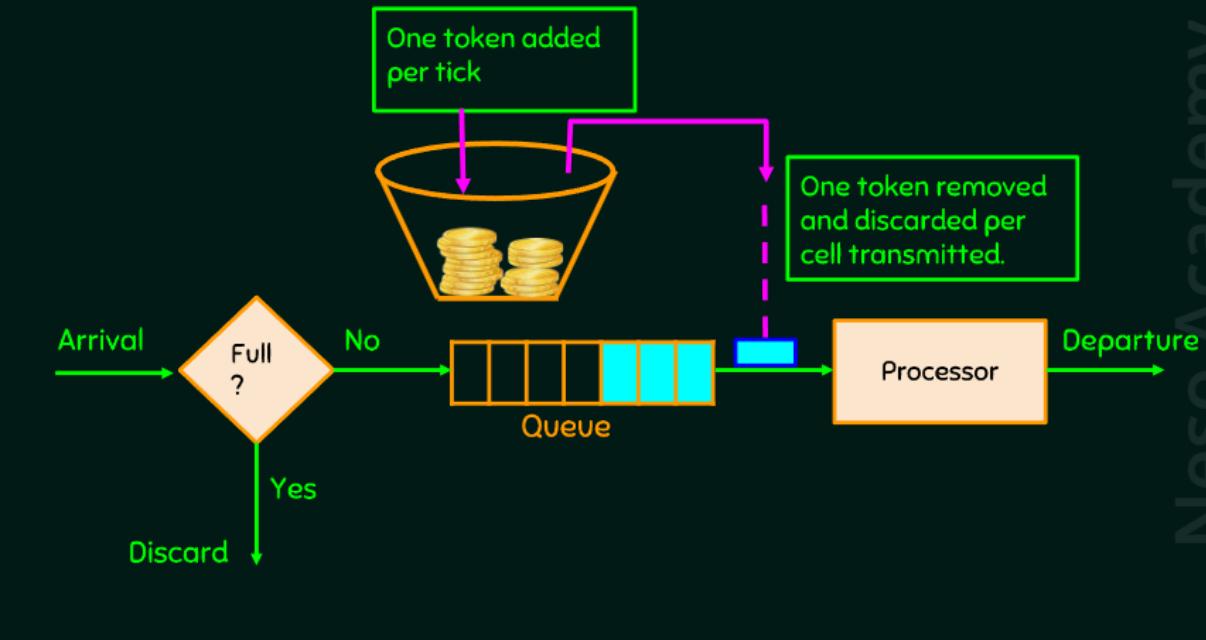
Leaky Bucket Neso Academy

LEAKY BUCKET

- ★ A leaky bucket algorithm shapes bursty traffic into fixed-rate traffic by averaging the data rate.
- ★ Fixed and variable size packets.
- ★ Counter.

★★★Leaky Bucket Neso Academy

TOKEN BUCKET



Token BucketNeso Academy

TOKEN BUCKET

- ★ The token bucket allows bursty traffic at a regulated maximum rate.
- ★ Host accumulate credit for the future in form of tokens.
- ★ For each tick of the clock, the system sends 'n' tokens to the bucket.
- ★ Example:
 - n = 100, host is idle for 100 ticks, the bucket collects 10,000 tokens.
- ★ Counter.
- ★ Token = 0.
- ★ Token ++, Counter ++
- ★ Each time a unit of data is sent, counter = counter - 1
- ★ If counter = 0, host cannot send data.

★★★★★★★★★Token BucketNeso Academy

OUTCOMES

Upon the completion of this session, the learner will be able to

- ★ Know the techniques to improve QoS.
- ★ Know the advantages of combining leaky and token bucket methods.
- ★ Know about admission control.
- ★ Know about resource reservation.
- ★ Know the two models to provide QoS in the Internet.

★★★★★OutcomesNeso Academy

TECHNIQUES TO IMPROVE QoS

1. Scheduling
2. Traffic Shaping
3. Admission Control
4. Resource Reservation

Techniques to improve QoSNeso Academy

TECHNIQUES TO IMPROVE QoS

1. Scheduling
2. Traffic Shaping
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4. Resource Reservation

Techniques to improve QoS Neso Academy

TRAFFIC SHAPING

- ★ Controls the amount of traffic sent to the network.
- ★ Controls the rate of traffic sent to the network.

Traffic Shaping Techniques

1. Leaky Bucket
2. Token Bucket

★★Traffic shaping Neso Academy

TRAFFIC SHAPING

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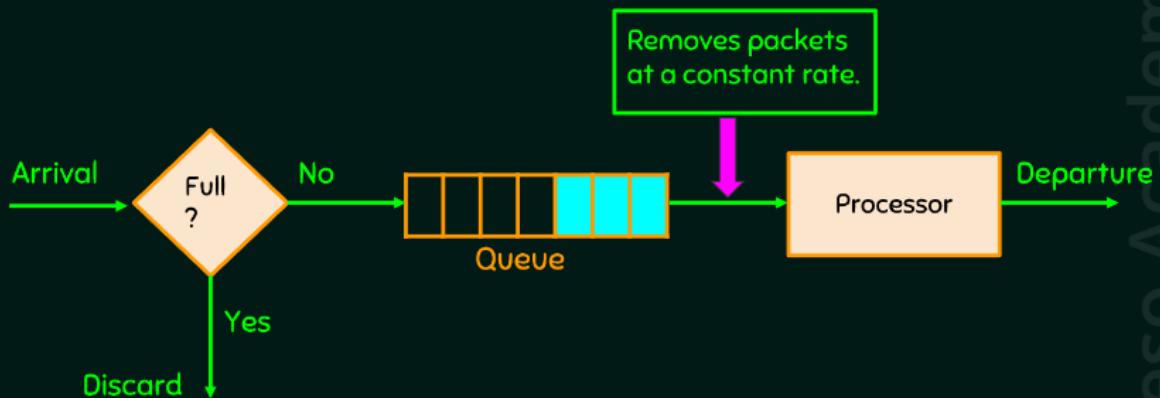
Traffic Shaping Techniques

1. Leaky Bucket
2. Token Bucket

★★Traffic shapingNeso Academy

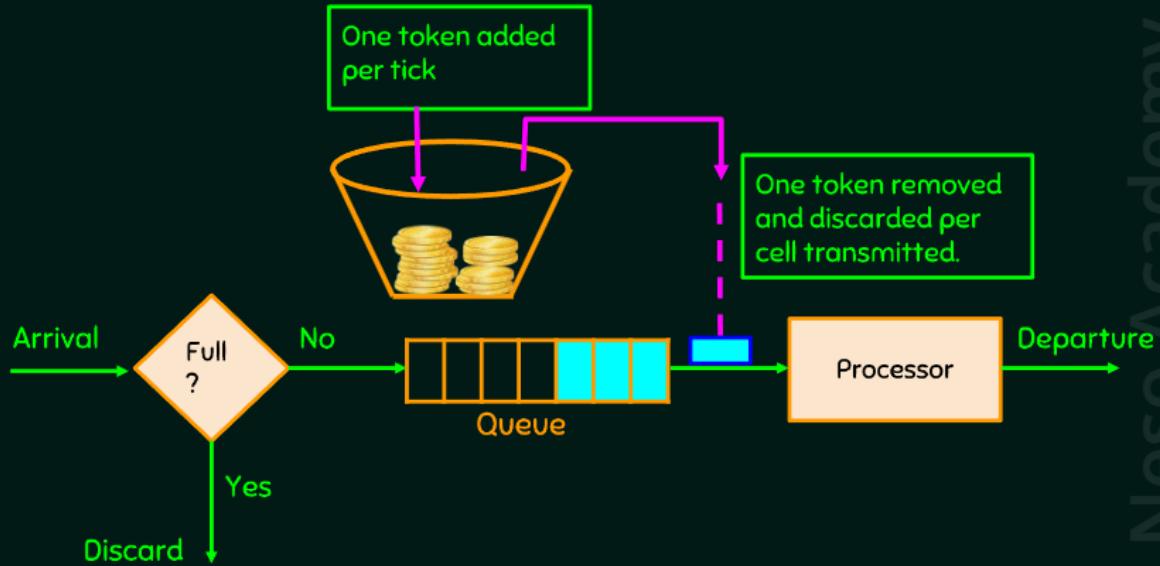
LEAKY BUCKET

Leaky Bucket Algorithm



Leaky BucketNeso Academy

TOKEN BUCKET



Token BucketNeso Academy

COMBINING LEAKY AND TOKEN BUCKETS

- ★ Both can be combined to regulate the traffic.
- ★ The leaky bucket is applied after the token bucket.
- ★ The rate of the leaky bucket needs to be higher than the rate of tokens dropped in the bucket.

★★★Combining Leaky and Token BucketsNeso Academy

TECHNIQUES TO IMPROVE QoS

1. Scheduling
2. Traffic Shaping
3. Admission Control
4. Resource Reservation

Techniques to improve QoS Neso Academy

ADMISSION CONTROL

- ★ Admission control used by router/switch.
- ★ To accept or reject a flow based on predefined parameters called flow specifications.
- ★ It checks the flow specifications to see its capacity.
- ★ Capacity in terms of bandwidth, buffer size, CPU speed, etc.

★★★★★ Admission Control Neso Academy

TECHNIQUES TO IMPROVE QoS

1. Scheduling
2. Traffic Shaping
3. Admission Control
4. Resource Reservation

Techniques to improve QoS Neso Academy

RESOURCE RESERVATION

- ★ Flow of data needs resources.
- ★ Resources include buffer, bandwidth, CPU time, and so on.
- ★ QoS can be improved, if these resources are reserved beforehand.
- ★ Two models
 - **Integrated Services** : A flow-based QoS model designed for IP.
 - **Differentiated Services**: A class-based QoS model designed for IP.
- ★ At network layer.

★★★★○★Resource Reservation Neso Academy