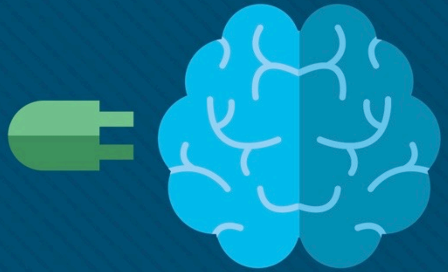


Chapter 3: Network Protocols and Services

Information Security

Dr. Ayman Aljarbouh

3.5 The Transport Layer

Module Objectives

Module Title: The Transport Layer

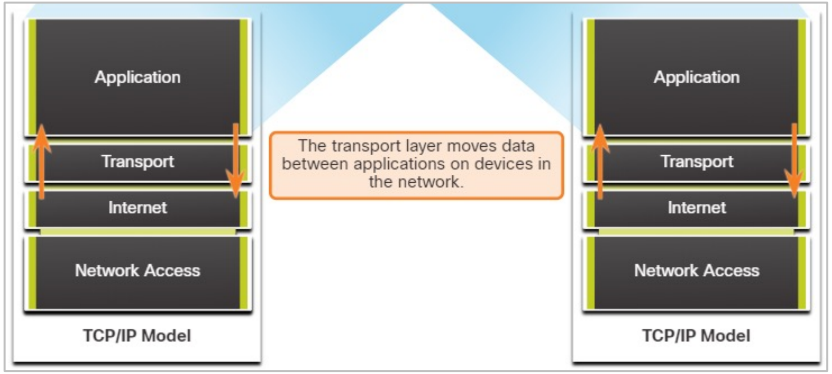
Module Objective: Explain how transport layer protocols support network functionality

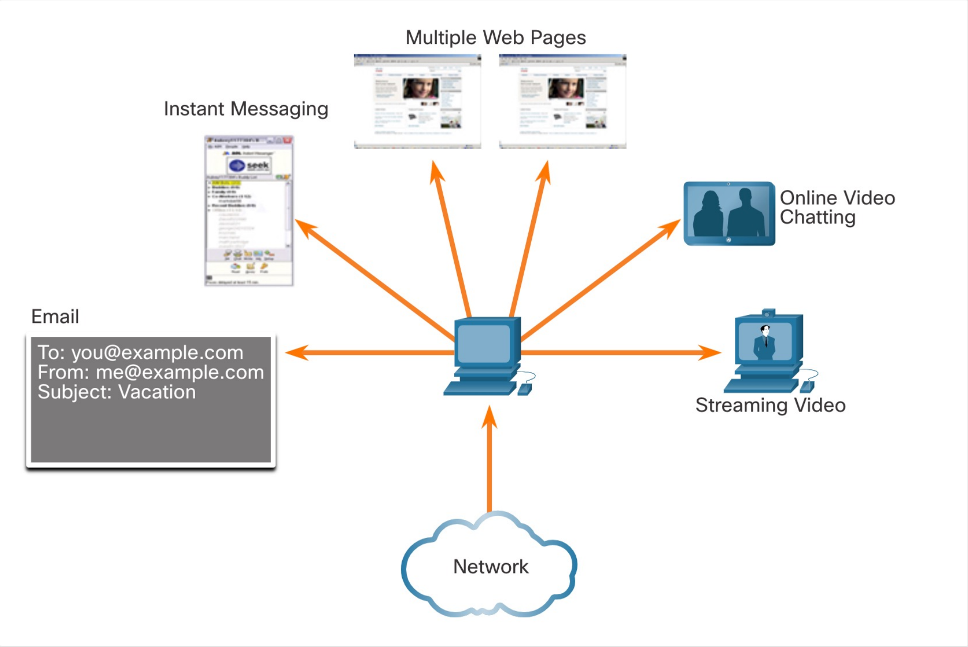
Topic Title	Topic Objective
Transport Layer Characteristics	Explain how transport layer protocols support network communication.
Transport Layer Session Establishment	Explain how the transport layer establishes communication sessions.
Transport Layer Reliability	Explain how the transport layer establishes reliable communications.

Transport Layer Characteristics

Role of the Transport Layer

- Tracks individual conversations.
- Segments data and reassembles segments.
- Add Header Information.
- Identifies applications using a port number.
- Conversation Multiplexing.





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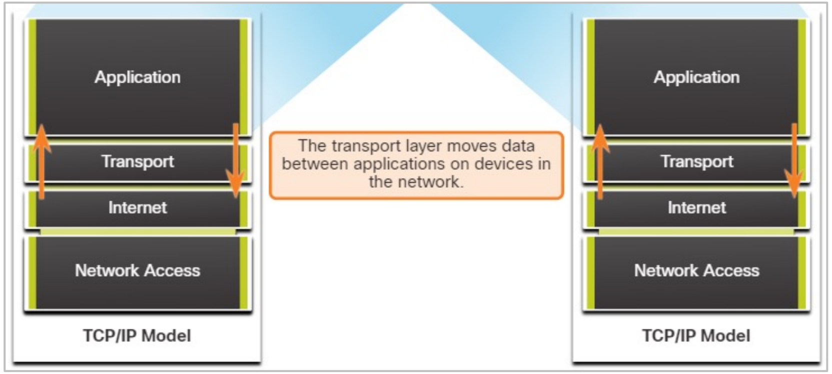
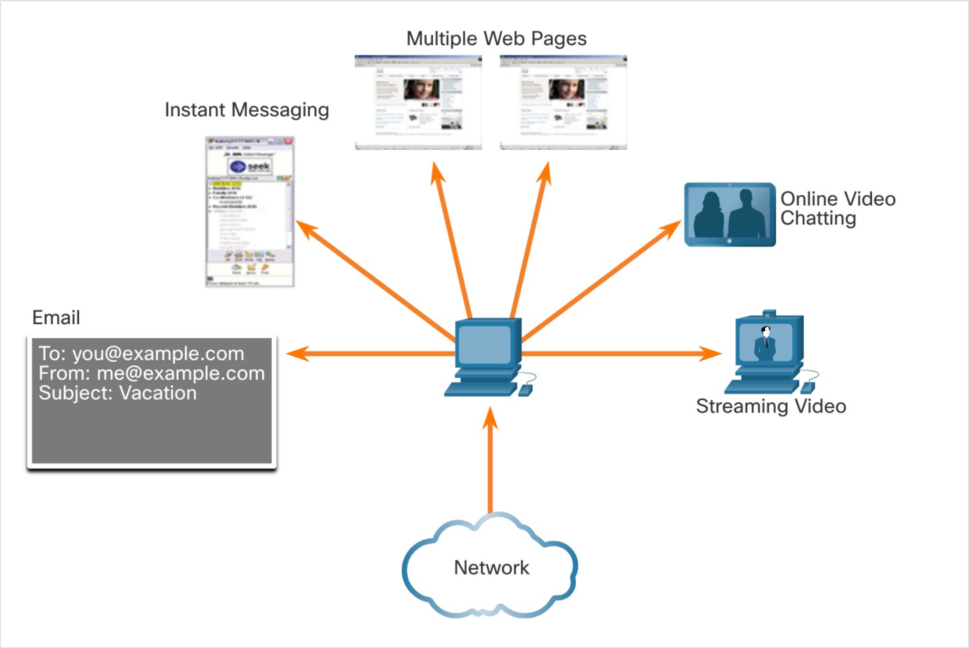

The transport layer moves data between applications on devices in the network.



To: you@example.com
From: me@example.com
Subject: Vacation

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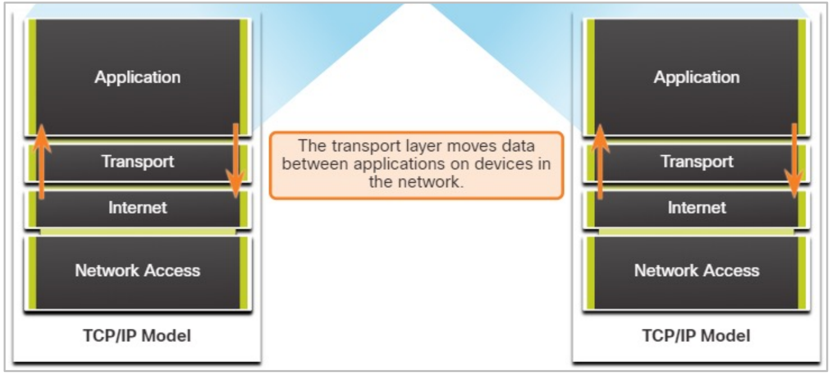

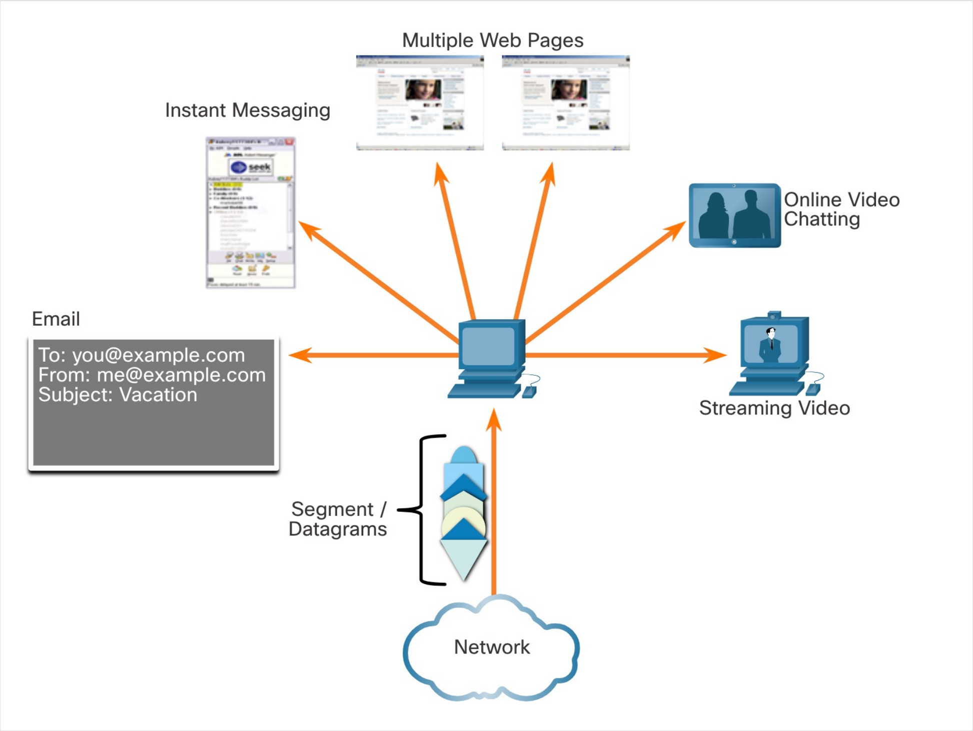

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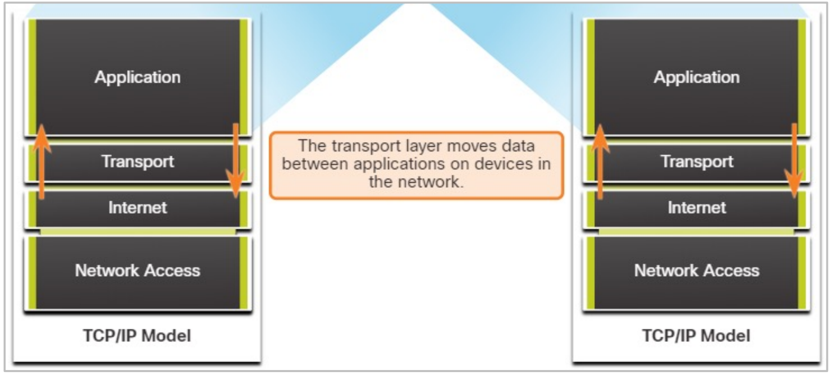

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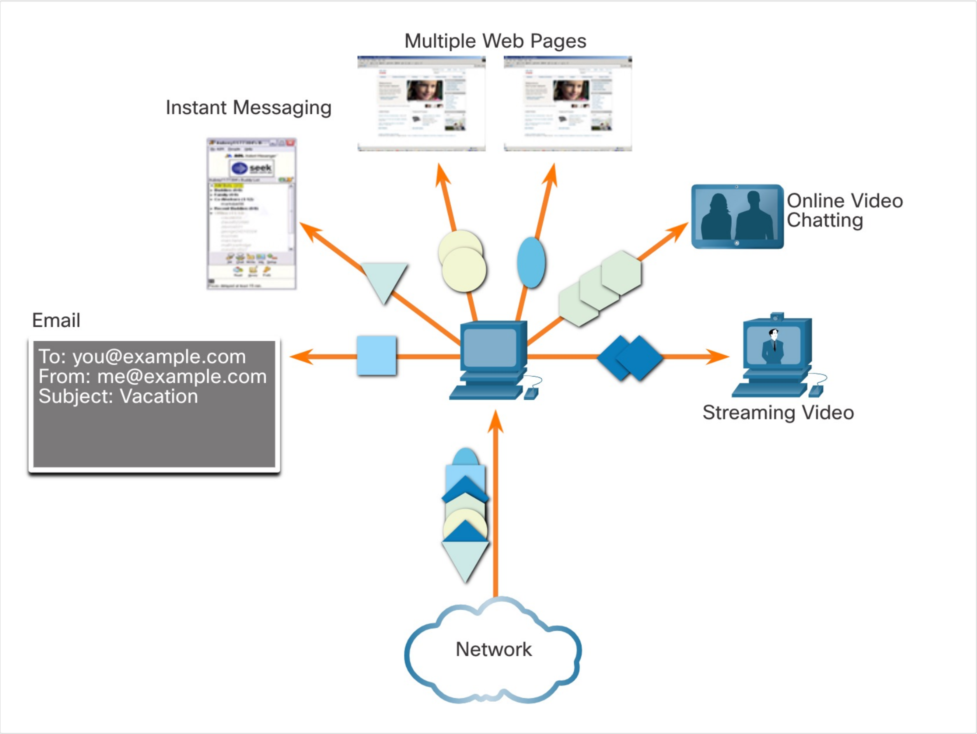

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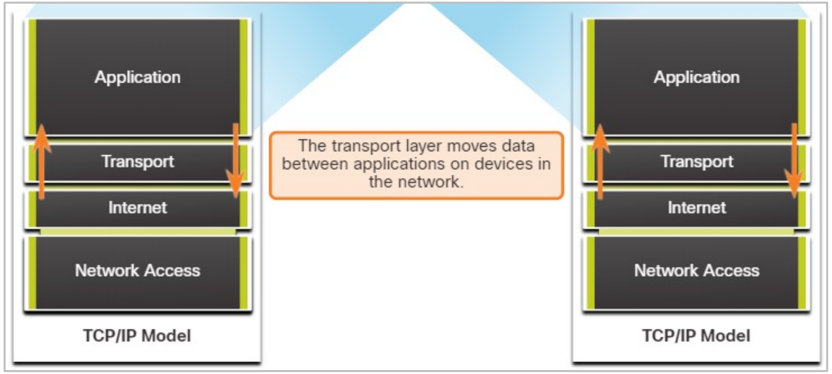

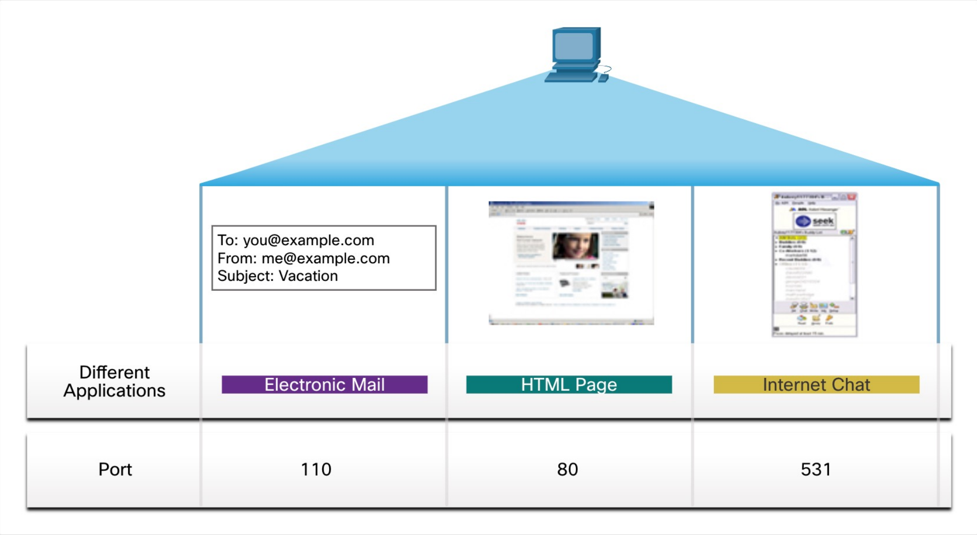

Different Applications	Electronic Mail	HTML Page	Internet Chat
Port	110	80	531

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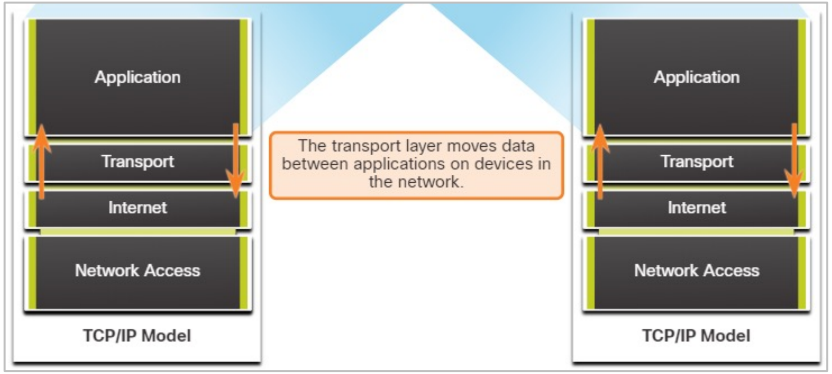

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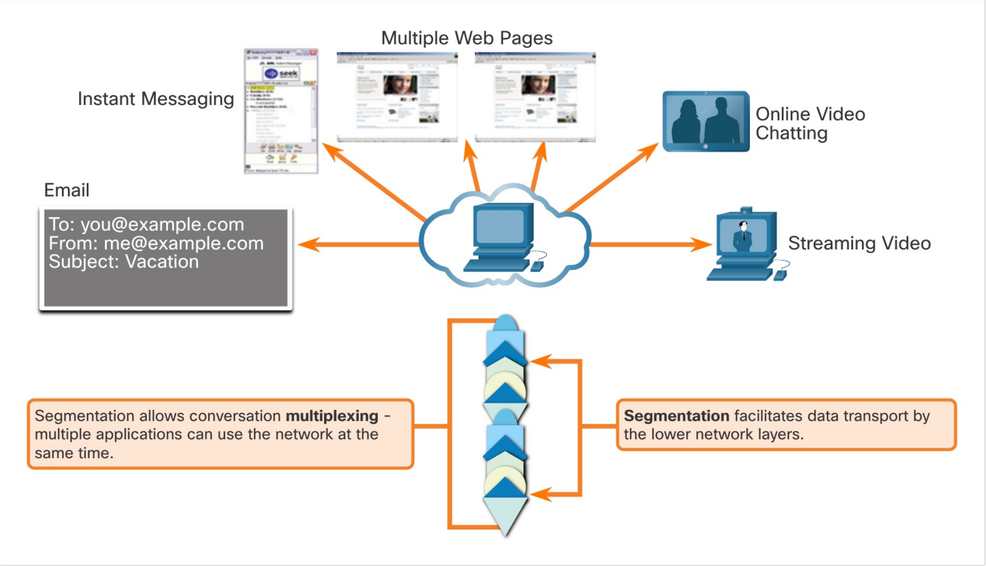

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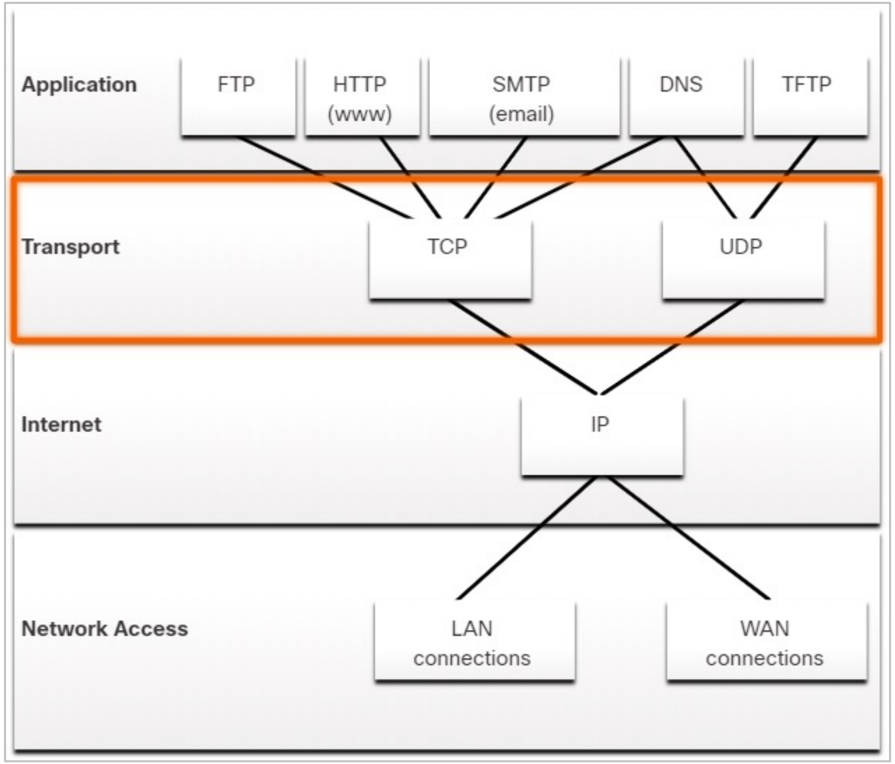
Segmentation allows conversation **multiplexing** - multiple applications can use the network at the same time.

Segmentation facilitates data transport by the lower network layers.

Transport Layer Characteristics

Transport Layer Protocols

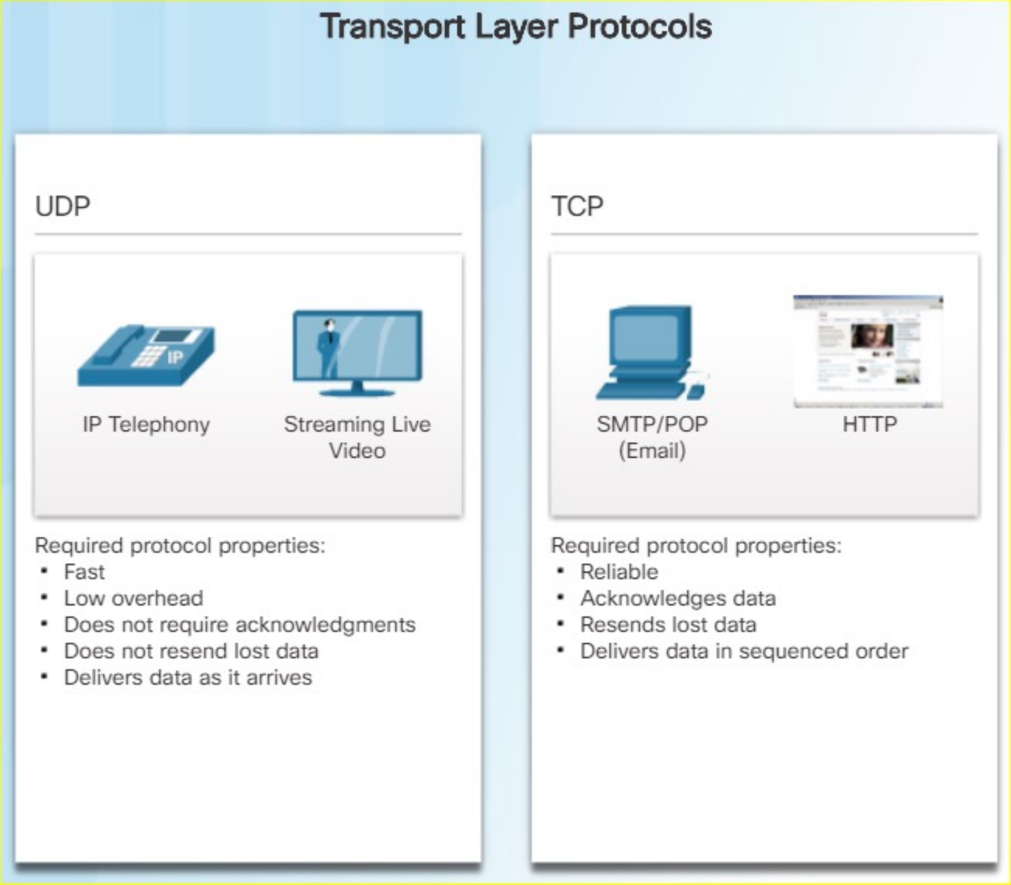
- Segmenting the data into smaller chunks enables many different communications, from many different users, to be interleaved (multiplexed) on the same network.
- The transport layer is also responsible for managing reliability requirements of a conversation.
- TCP/IP provides two transport layer protocols:
  - **Transmission Control Protocol (TCP)**
  - **User Datagram Protocol (UDP)**



Transport Layer Characteristics

TCP versus UDP

- TCP
  - Used for majority of the major TCP/IP protocols.
  - Reliable, acknowledges data, resends lost data, delivers data in sequenced order.
    - Examples: email, HTTP
- UDP
  - Fast, low overhead, does not require acknowledgments, does not resend lost data, delivers data as it arrives.
    - Examples: VoIP, streaming live videos



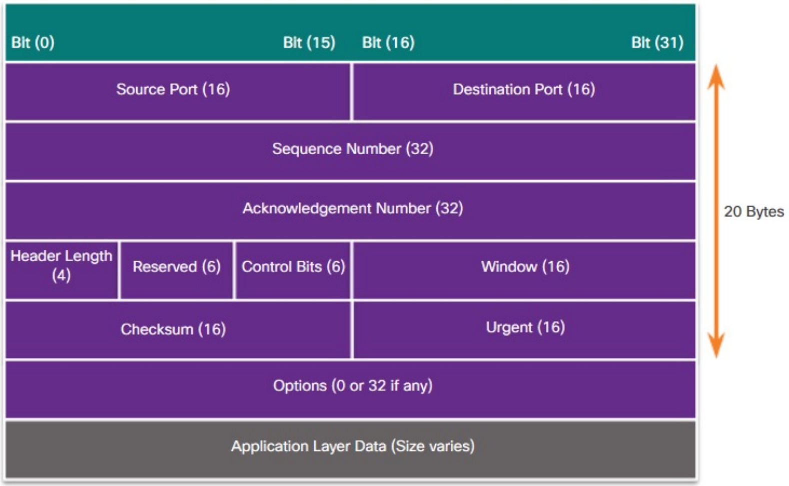
Required protocol properties:
- Fast
- Low overhead
- Does not require acknowledgments
- Does not resend lost data
- Delivers data as it arrives

Required protocol properties:
- Reliable
- Acknowledges data
- Resends lost data
- Delivers data in sequenced order

TCP and UDP Headers

- TCP
  - TCP is a stateful protocol. A stateful protocol is a protocol that keeps track of the state of the communication session.
  - To track the state of a session, TCP records which information it has sent and which information has been acknowledged.
  - The stateful session begins with the session establishment and ends when closed with the session termination.
- UDP
  - UDP is a stateless protocol, meaning neither the client, nor the server, is obligated to keep track of the state of the communication session.
  - If reliability is required when using UDP as the transport protocol, it must be handled by the application.

TCP Segment



Bit (0) Bit (15) Bit (16) Bit (31)

Source Port (16) | Destination Port (16)

Sequence Number (32)

Acknowledgement Number (32)

Header Length (4) | Reserved (6) | Control Bits (6) | Window (16)

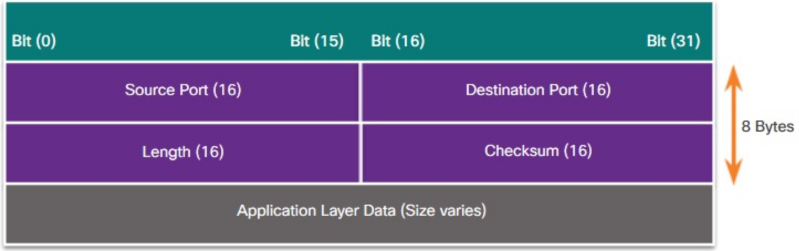
Checksum (16) | Urgent (16)

Options (0 or 32 if any)

Application Layer Data (Size varies)

20 Bytes

UDP Datagram



Bit (0) Bit (15) Bit (16) Bit (31)

Source Port (16) | Destination Port (16)

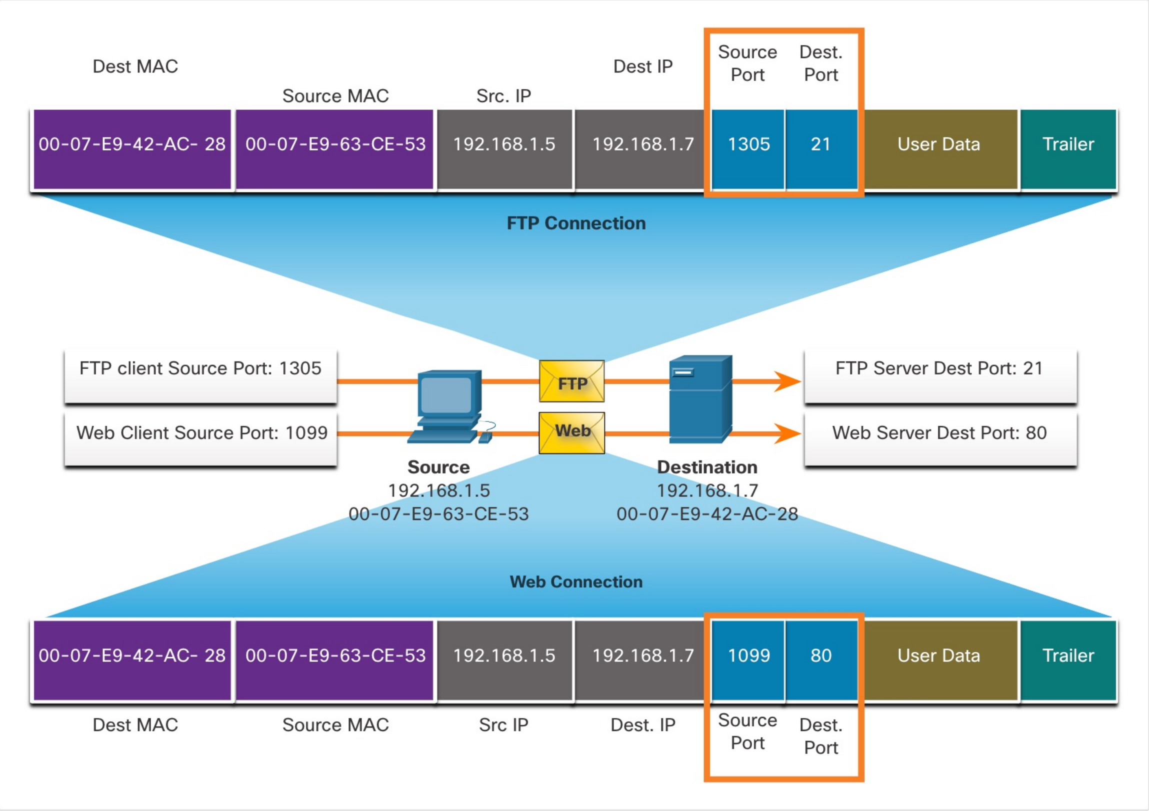
Length (16) | Checksum (16)

Application Layer Data (Size varies)

8 Bytes

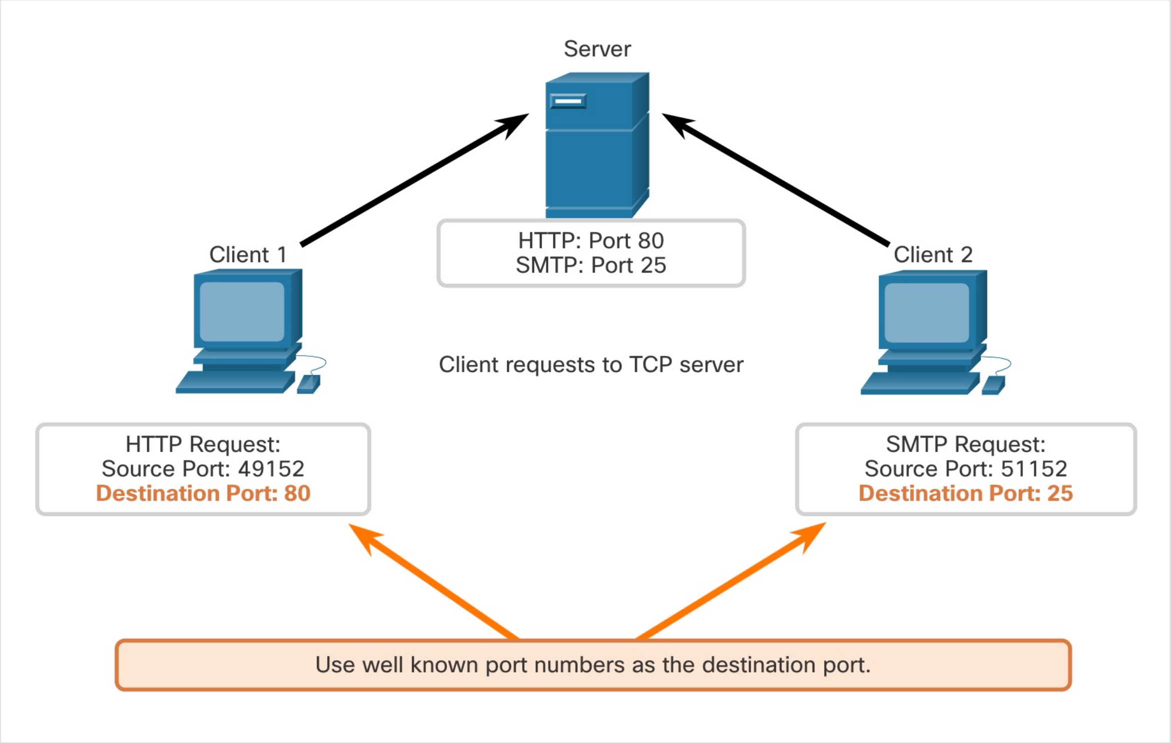
Socket Pairs

- The combination of the source IP address and source port number, or the destination IP address and destination port number is known as a **socket**.
- The socket is used to identify the server and service being requested by the client.
- Sockets enable multiple processes, running on a client, to distinguish themselves from each other, and multiple connections to a server process to be distinguished from each other.



TCP Port Allocation

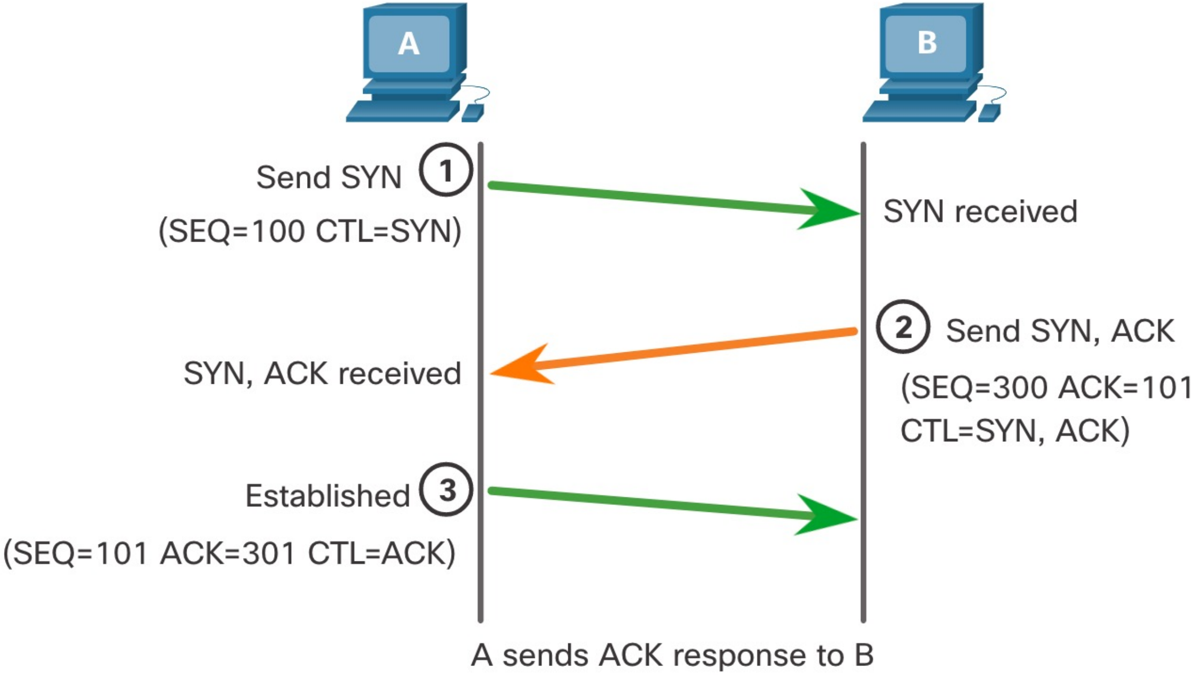
- Destination port numbers:
  - Uses well-known port numbers.
- Source port numbers:
  - Uses dynamic port numbers.
  - When establishing a connection with a server, the transport layer on the client establishes a source port to keep track of data sent from the server.
  - Just as a server can have many ports open for server processes, clients can have many ports open for connections to multiple sockets.



A TCP Session: Connection Establishment

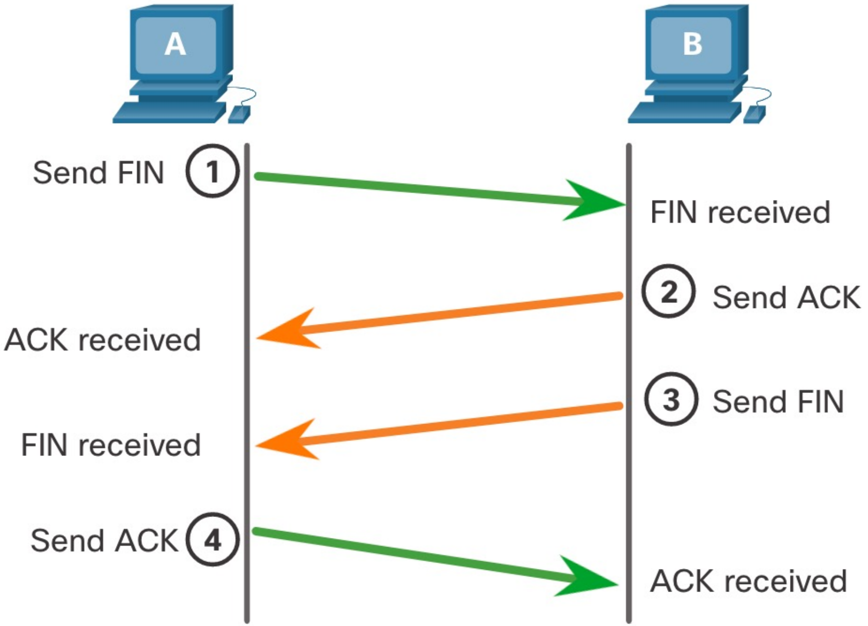
- A TCP connection is established in three steps:

1. The initiating client requests a client-to-server communication session with the server.
2. The server acknowledges the client-to-server communication session and requests a server-to-client communication session.
3. The initiating client acknowledges the server-to-client communication session.



A TCP Session: Session Termination

- To close a connection, the Finish (FIN) control flag must be set in the segment header.
- To end each one-way TCP session, a two-way handshake, consisting of a FIN segment and an Acknowledgement (ACK) segment, is used.
- Therefore, to terminate a single conversation supported by TCP, four exchanges are needed to end both sessions. Either the client or the server can initiate the termination.

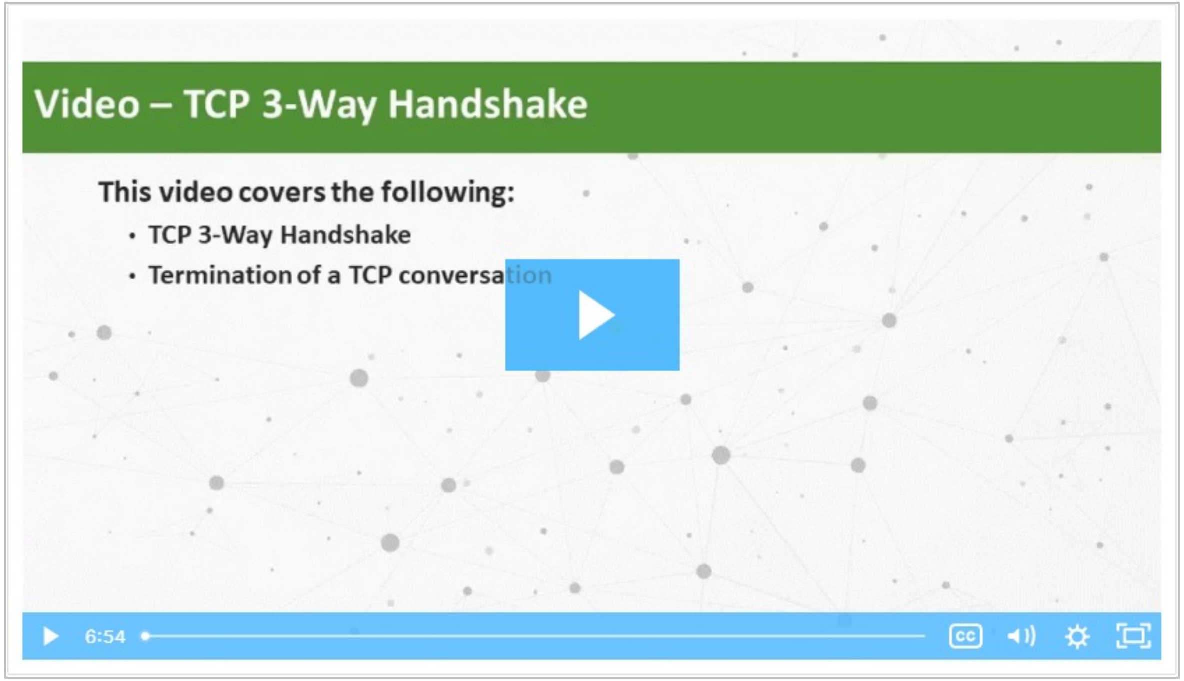


A sends ACK response to B

Transport Layer Session Establishment

Video – TCP 3-Way Handshake

Watch the video to learn more of the TCP 3-way handshake.



Video – TCP 3-Way Handshake

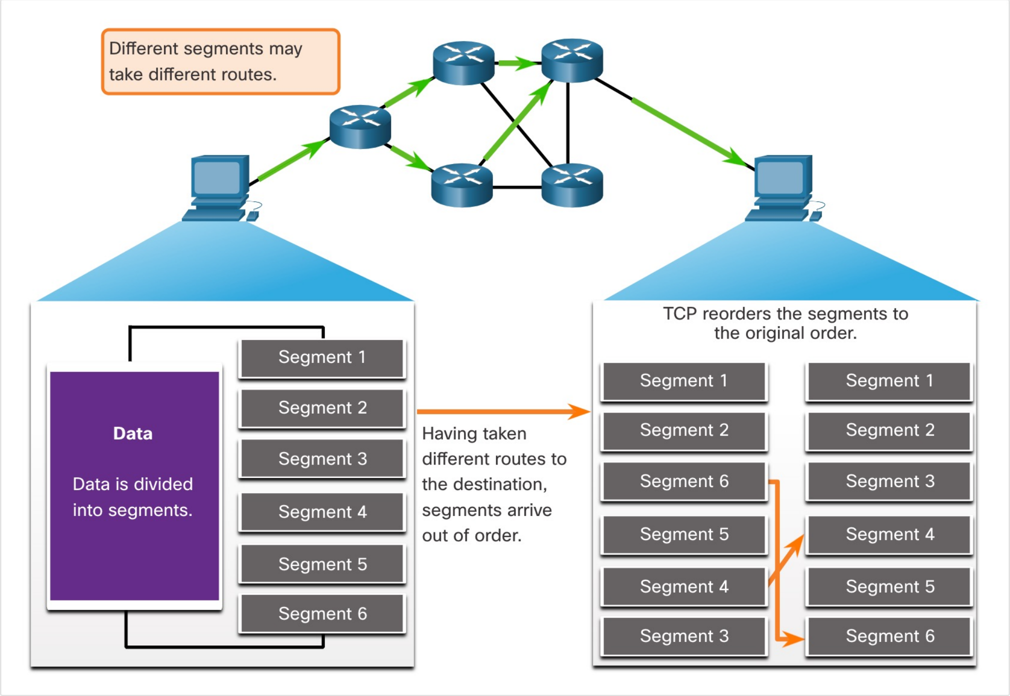
This video covers the following:

- TCP 3-Way Handshake
- Termination of a TCP conversation

https://www.youtube.com/watch?v=k7cgyExzUAE

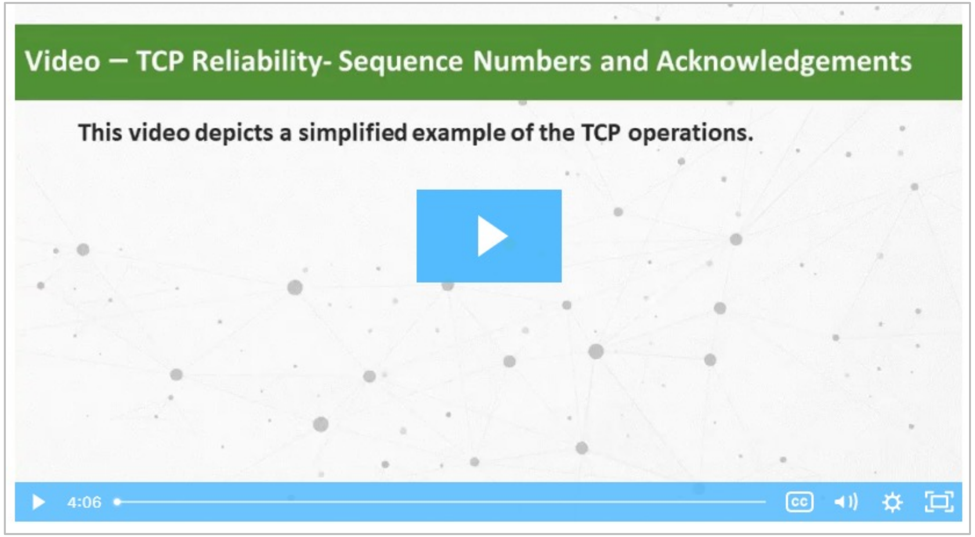
TCP Reliability - Guaranteed and Ordered Delivery

- Segment sequence numbers indicate how to reassemble and reorder received segments, as shown in the figure.
- The receiving TCP process places the data from a segment into a receiving buffer.
- Segments are then placed in the proper sequence order and passed to the application layer when reassembled.
- Any segments that arrive with sequence numbers that are out of order are held for later processing.
- Then, when the segments with the missing bytes arrives, these segments are processed in order.


Different segments may take different routes.
Data
Data is divided into segments.
Segment 1
Segment 2
Segment 3
Segment 4
Segment 5
Segment 6
Having taken different routes to the destination, segments arrive out of order.
TCP reorders the segments to the original order.
Segment 1
Segment 2
Segment 6
Segment 5
Segment 4
Segment 3
Segment 1
Segment 2
Segment 3
Segment 4
Segment 5
Segment 6

Video - TCP Reliability – Sequence Numbers and Acknowledgements

- One of the functions of TCP is to ensure that each segment reaches its destination.
- Click Play in the figure to view a lesson on TCP sequence numbers and acknowledgments.



Video – TCP Reliability- Sequence Numbers and Acknowledgements

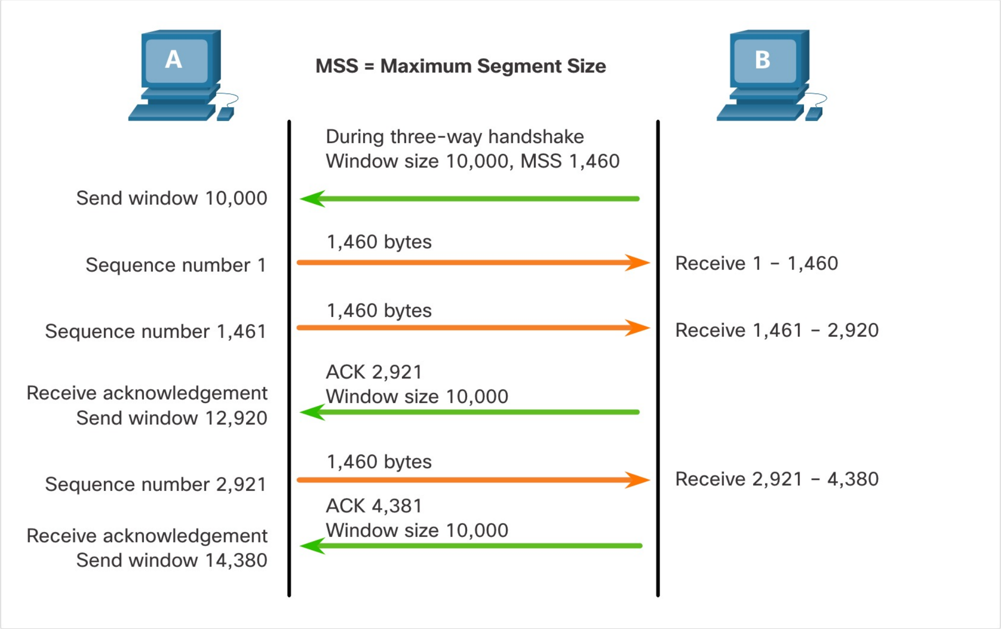
This video depicts a simplified example of the TCP operations.

https://www.youtube.com/watch?v=n779ewu0JJw

Transport Layer Reliability

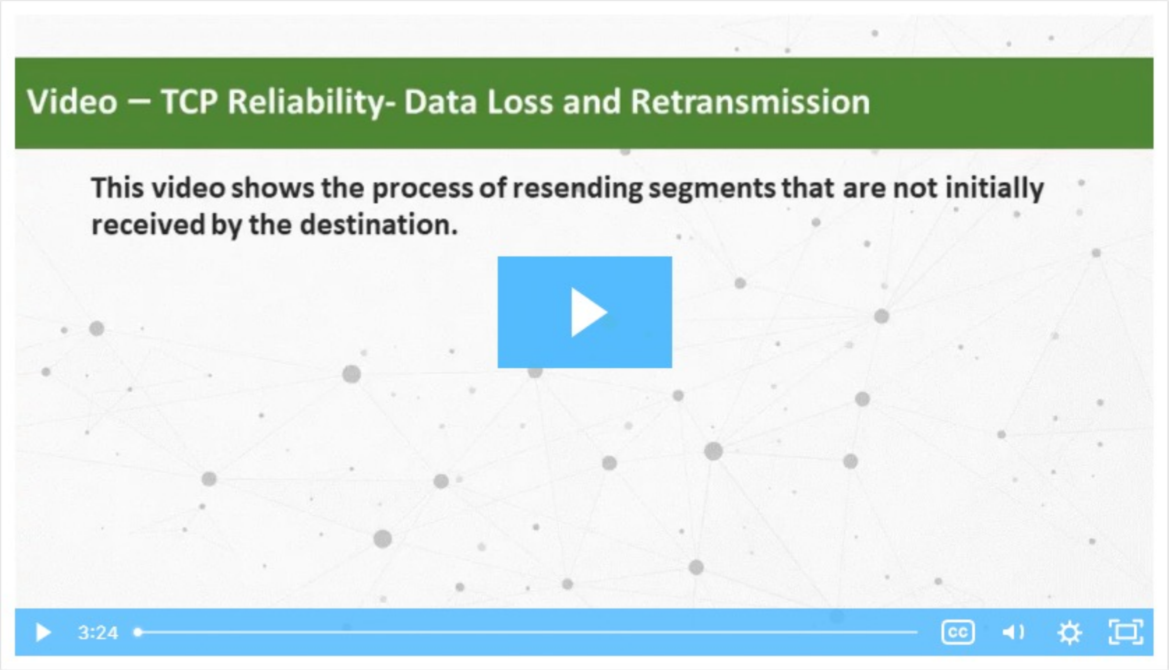
TCP Flow Control - Window Size and Acknowledgments

- **Flow Control:**
  - Flow control helps maintain the reliability of TCP transmission by adjusting the rate of data flow between source and destination for a given session.
  - To accomplish this, the TCP header includes a 16-bit field called the window size.
  - The window size that determines the number of bytes that can be sent before expecting an acknowledgment.
  - The acknowledgment number is the number of the next expected byte.



Video - TCP Reliability - Data Loss and Retransmission

Click Play in the figure to view a lesson on TCP retransmission.



Video – TCP Reliability- Data Loss and Retransmission

This video shows the process of resending segments that are not initially received by the destination.

https://www.youtube.com/watch?v=YVAK6y20oSM

Network Protocols and Services

New Terms and Commands

- Transmission Control Protocol (TCP)
- User Datagram Protocol (UDP)
- Socket Pairs
- Stateless Address

- Multiplexing
- ACK, SYN, FIN
- Transport Layer
- File Transfer Protocol (FTP)

Lab 13 – Using Wireshark to Observe the TCP 3-Way Handshake

In this lab, you will complete the following objectives:

- **Part 1:** Prepare the Hosts to Capture the Traffic
- **Part 2:** Analyze the Packets using Wireshark
- **Part 3:** View the Packets using tcpdump