

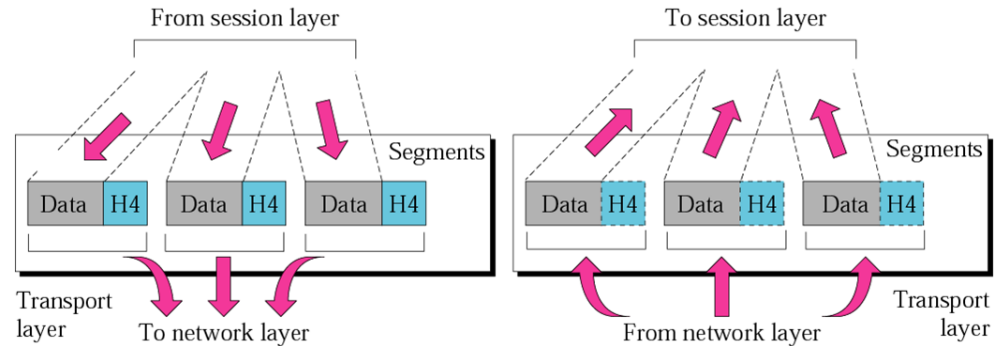
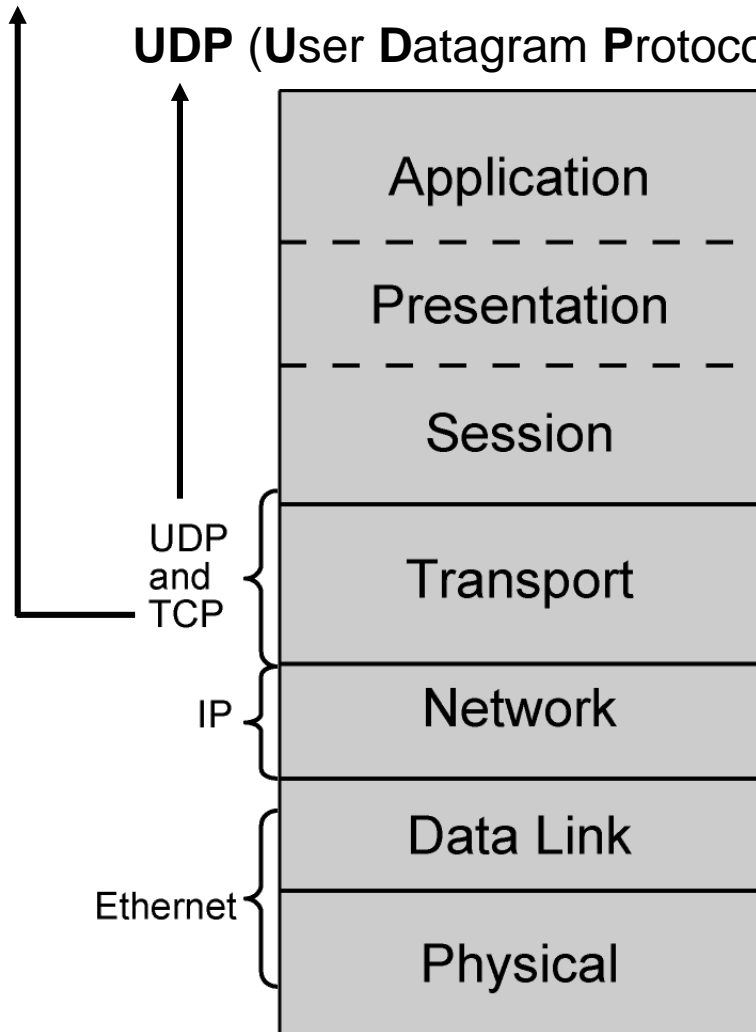


# Transport Layer

# Transport Layer

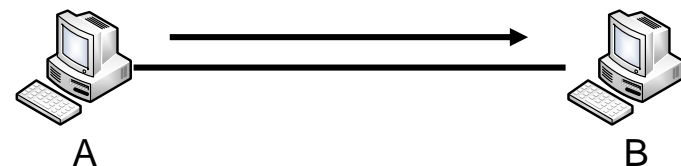
**TCP (Transmission Control Protocol)**

**UDP (User Datagram Protocol)**



## End-to-End Connections

- Session multiplexing
  - Segmentation
  - Flow control (when required)
  - Connection-oriented (when required)
  - Reliability (when required)
- TCP**

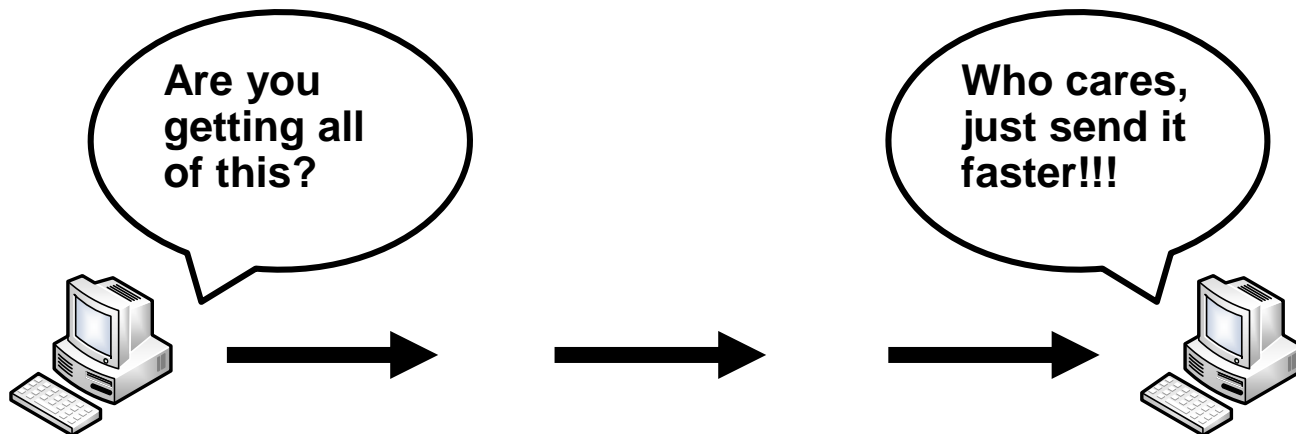


# Reliable vs. Best-Effort Comparison

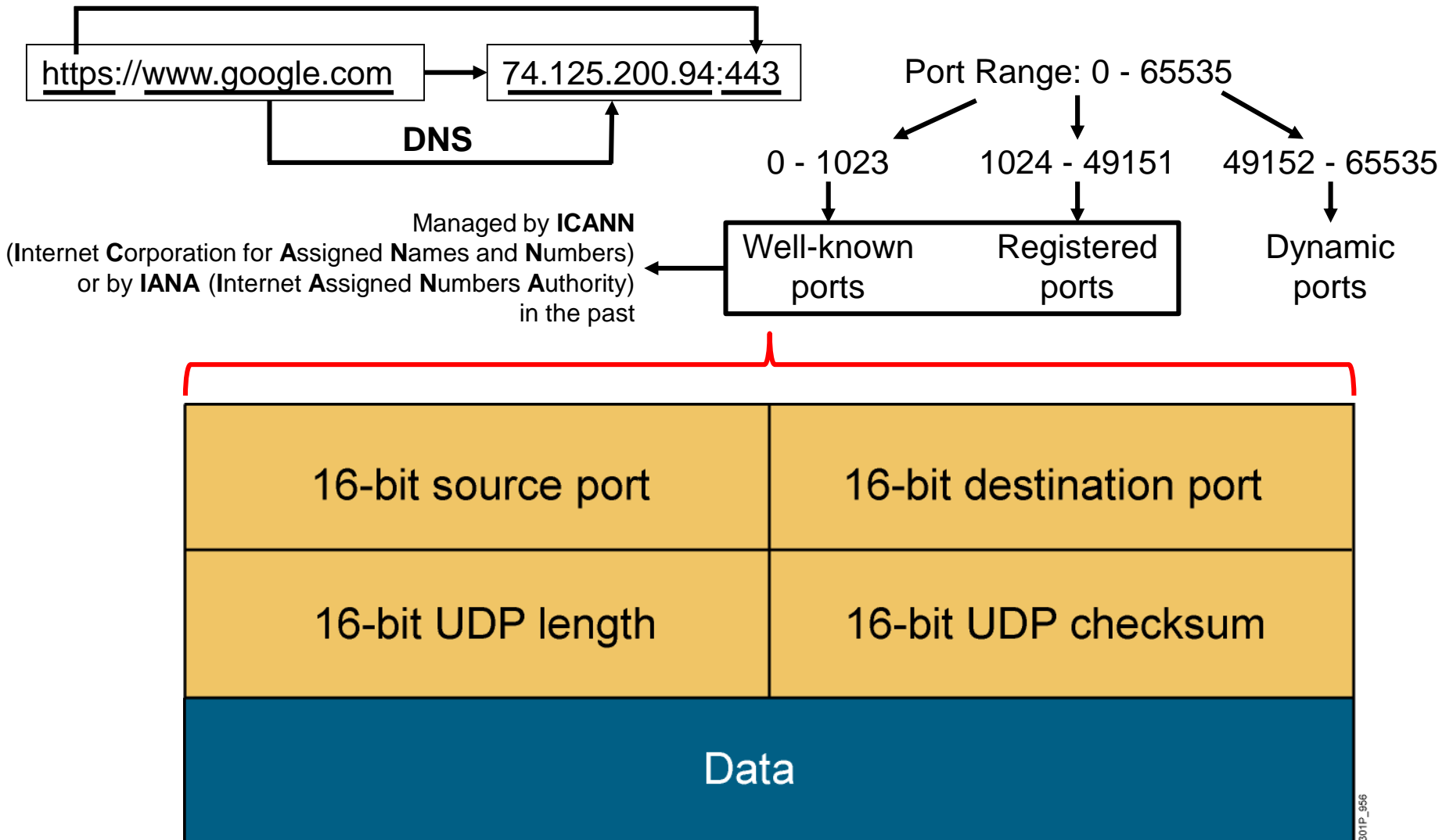
|                 | Reliable  | Best-Effort   |
|-----------------|---|---|
| Connection Type | Connection-oriented   | Connectionless  |
| Protocol        | TCP   | UDP   |
| Sequencing      | Yes   | No  |
| Uses            | <ul style="list-style-type: none"><li>▪ E-mail</li><li>▪ File sharing</li><li>▪ Downloading</li></ul> | <ul style="list-style-type: none"><li>▪ Voice streaming</li><li>▪ Video streaming</li></ul> |

# UDP Characteristics

- Operates at transport layer of OSI and TCP/IP models
- Provides applications with access to the network layer without the overhead of reliability mechanisms
- Is a connectionless protocol
- Provides limited error checking
- Provides best-effort delivery
- Has no data-recovery features

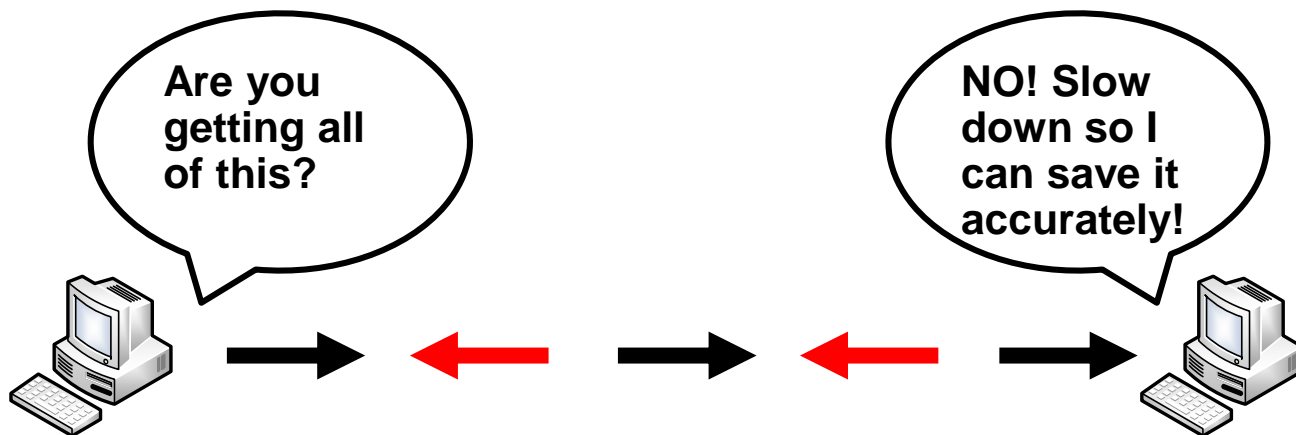
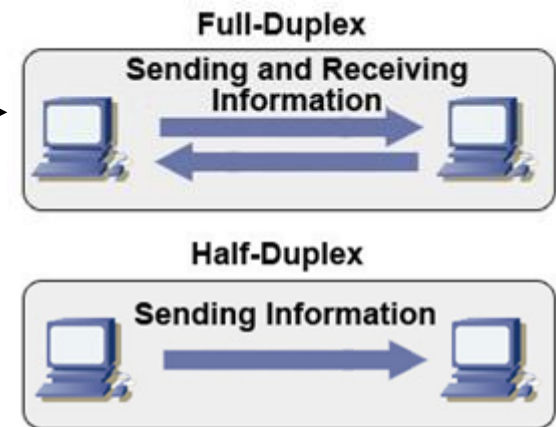


# UDP Header

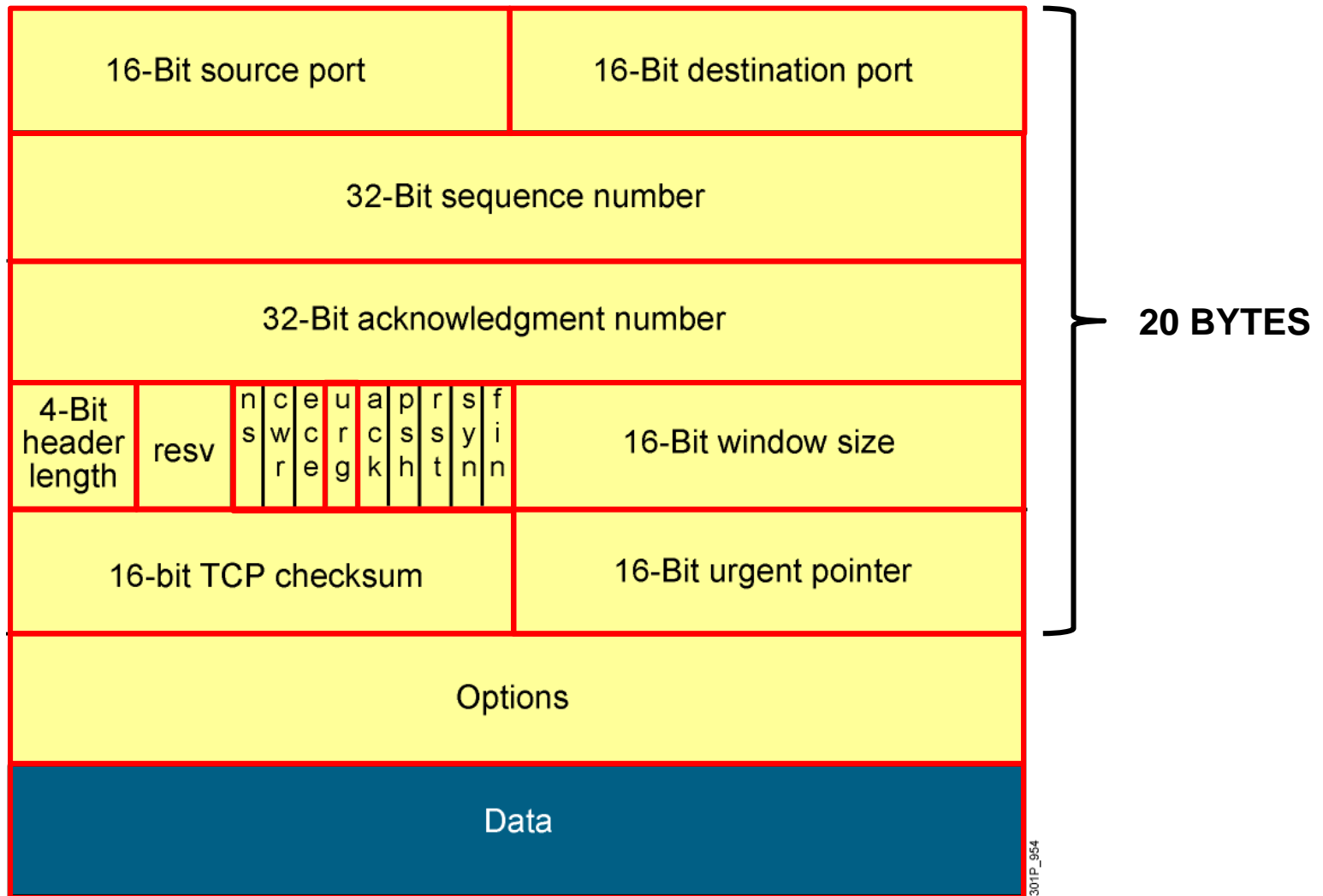


# TCP Characteristics

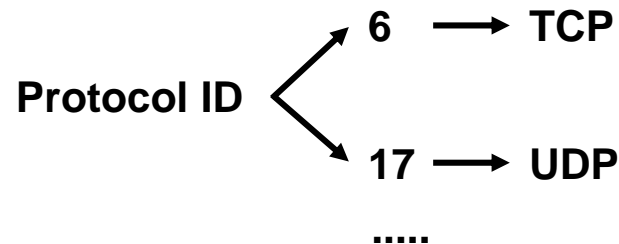
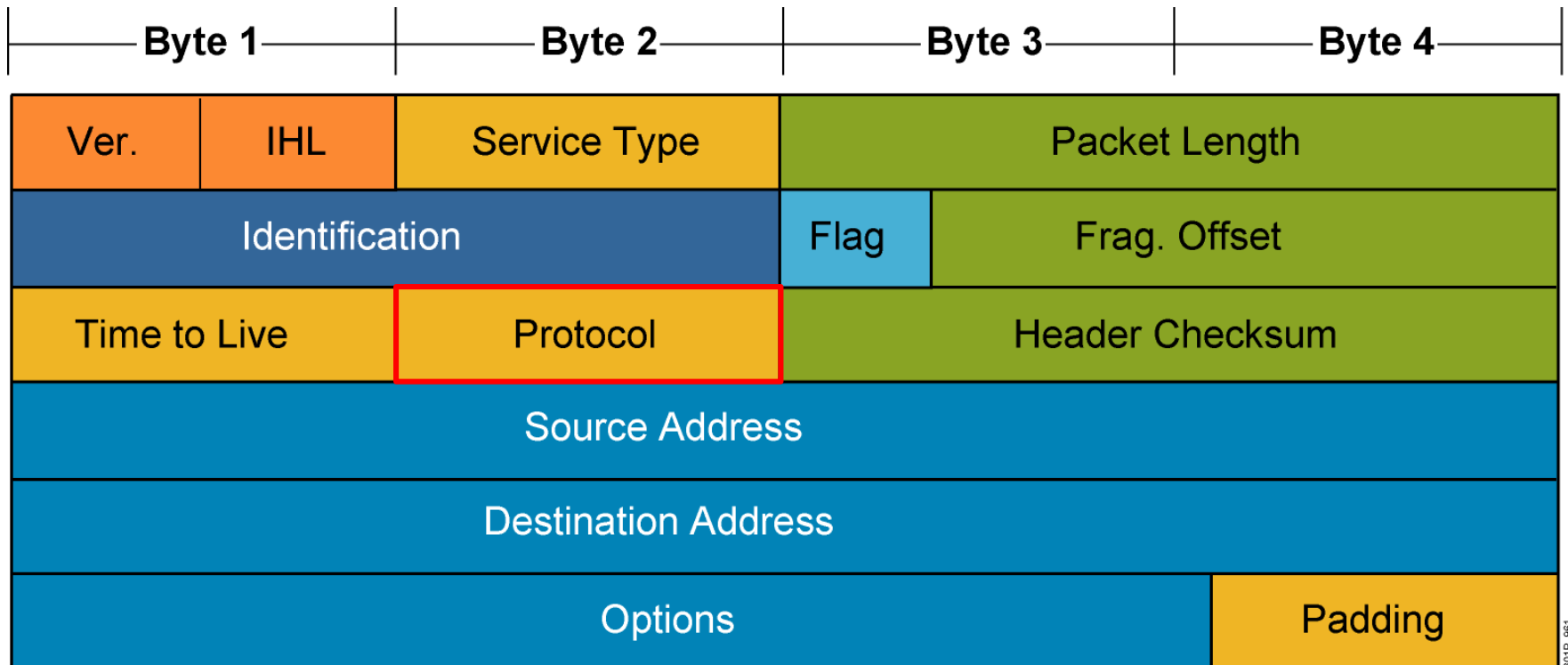
- Transport layer of the TCP/IP stack
- Access to the network layer for applications
- Connection-oriented protocol
- Full-duplex mode operation
- Error checking
- Sequencing of data packets
- Acknowledgement of receipt
- Data-recovery features



# TCP Header

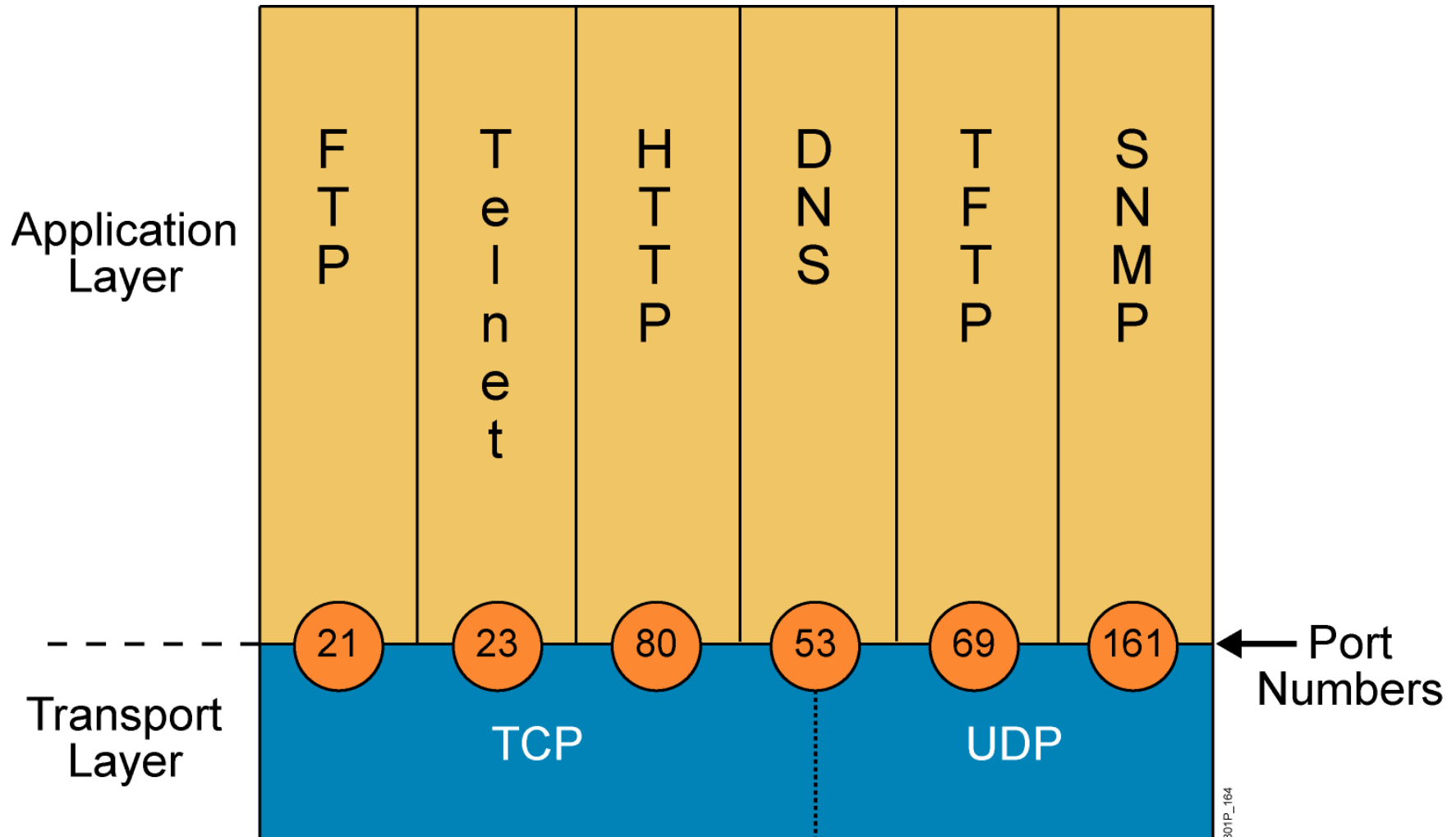


# Mapping Layer 3 to Layer 4

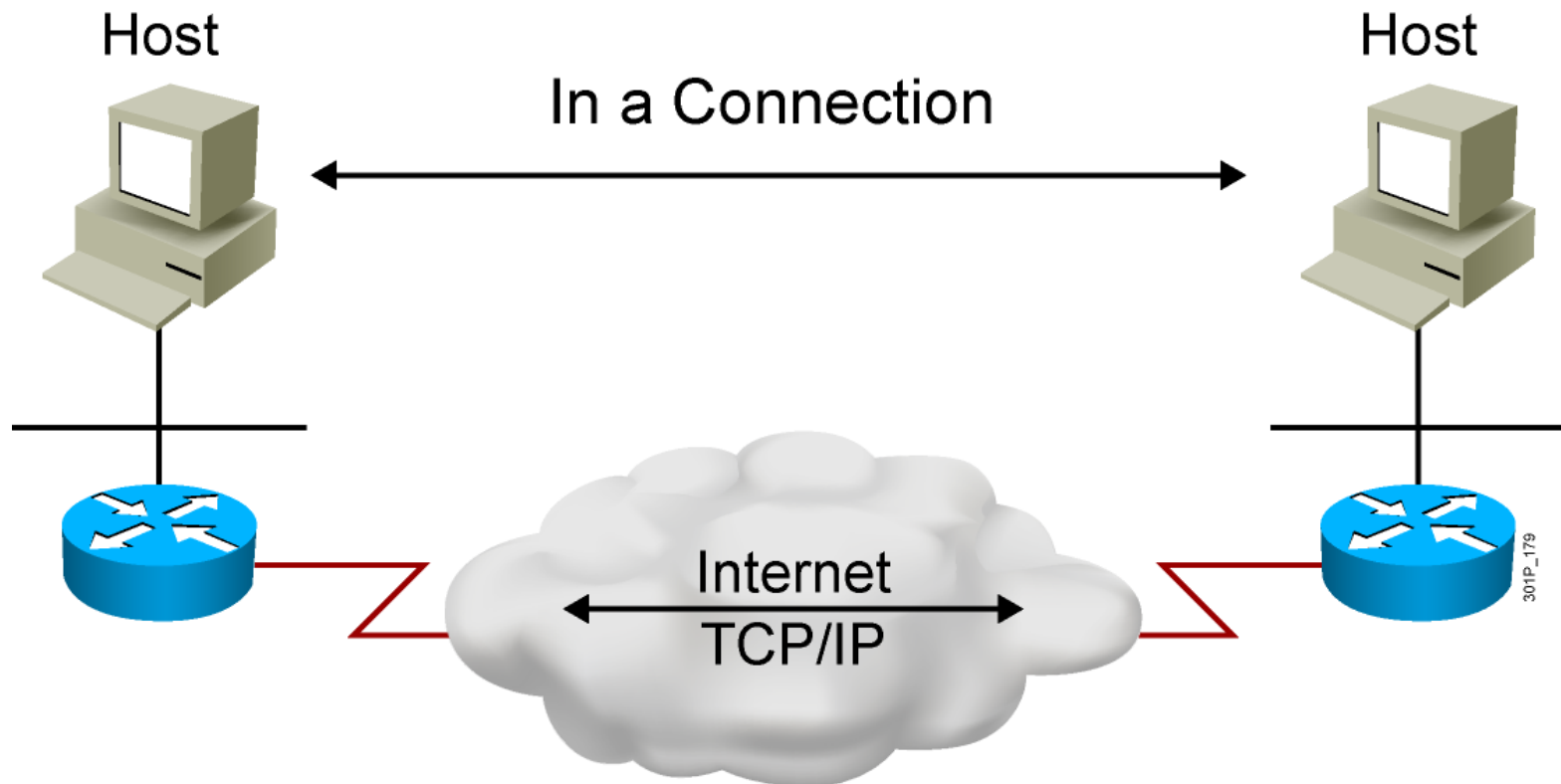




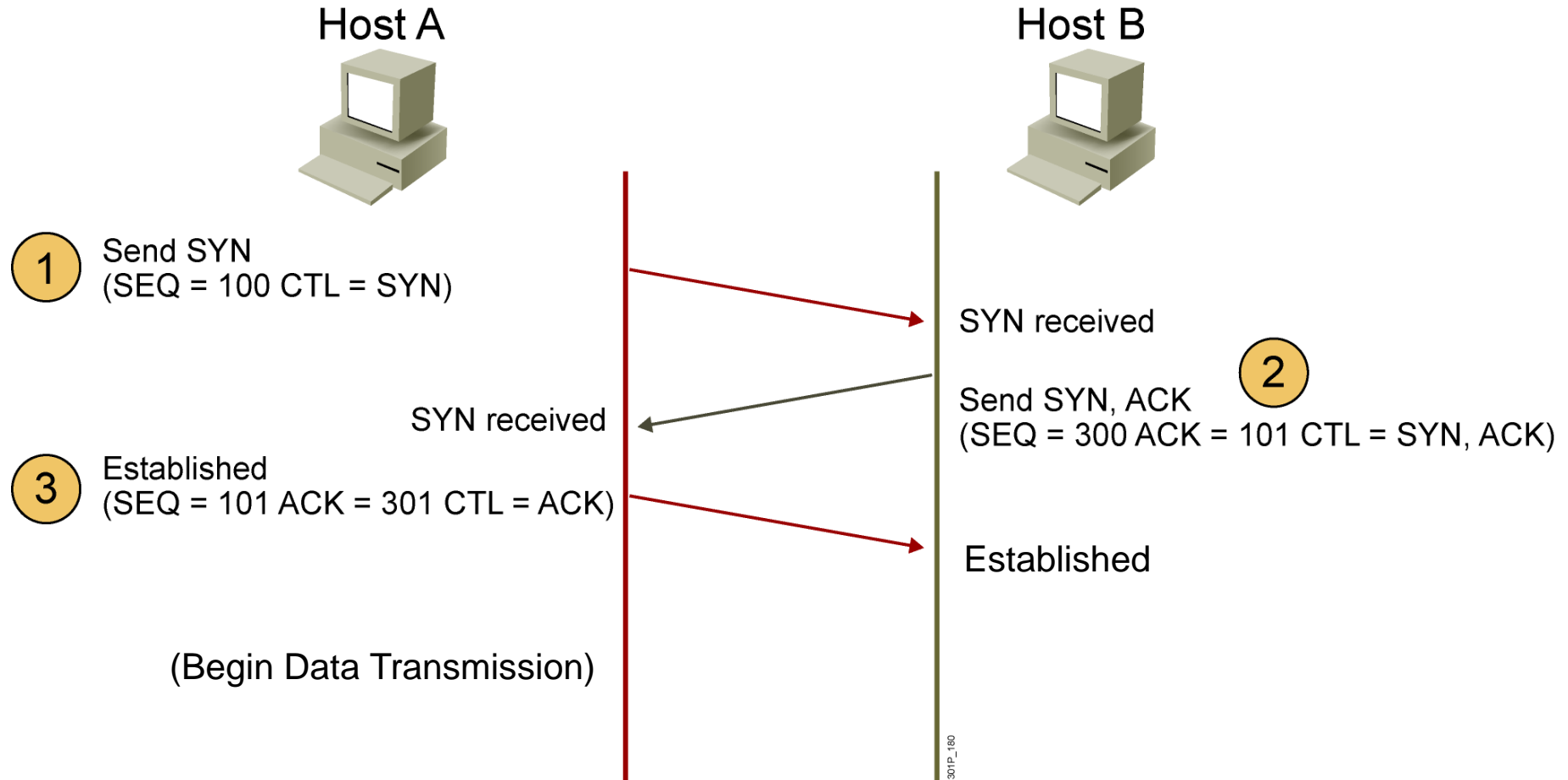
# Mapping Layer 4 to Applications



# Establishing a Connection

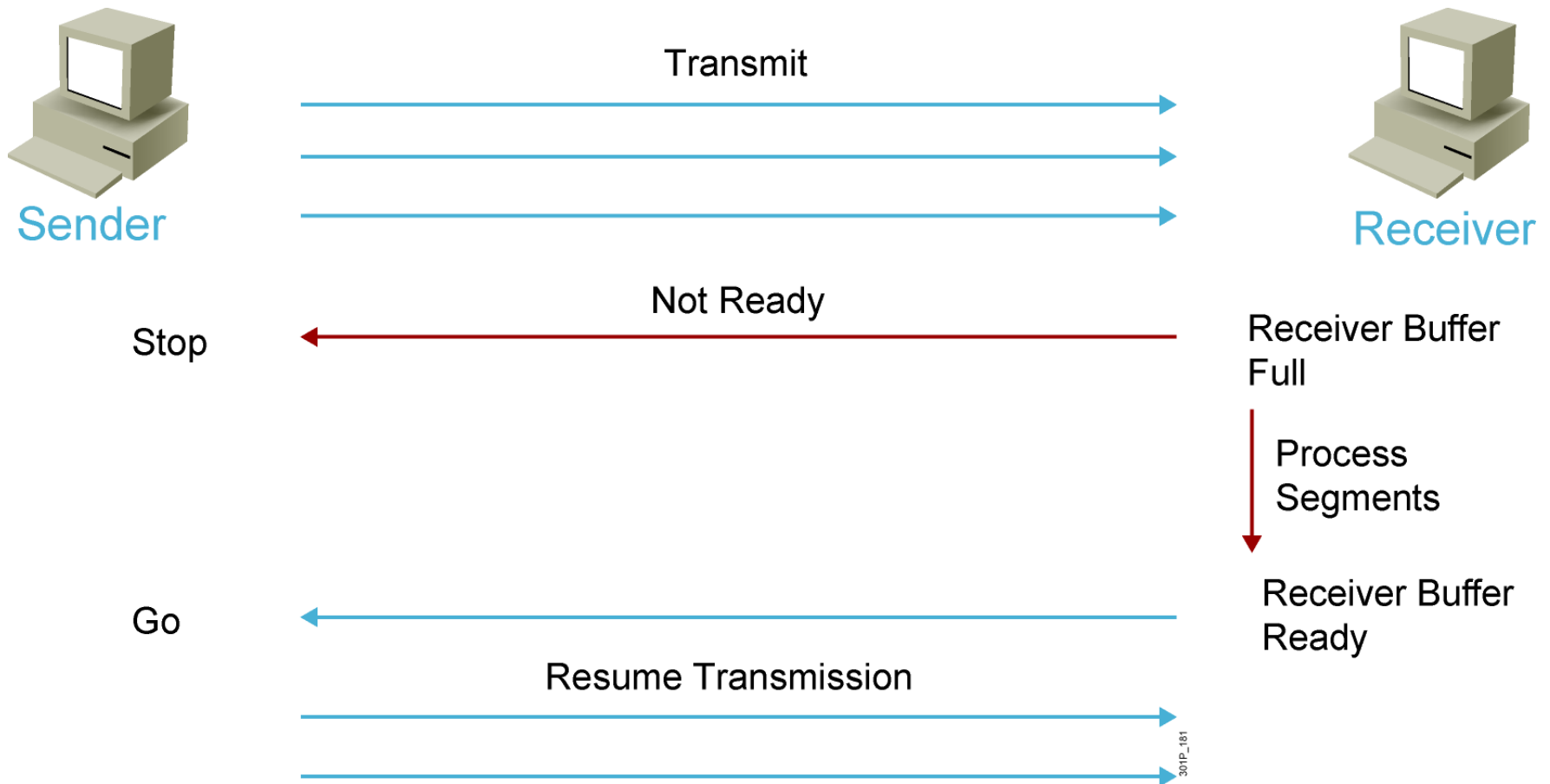


# Three-Way Handshake

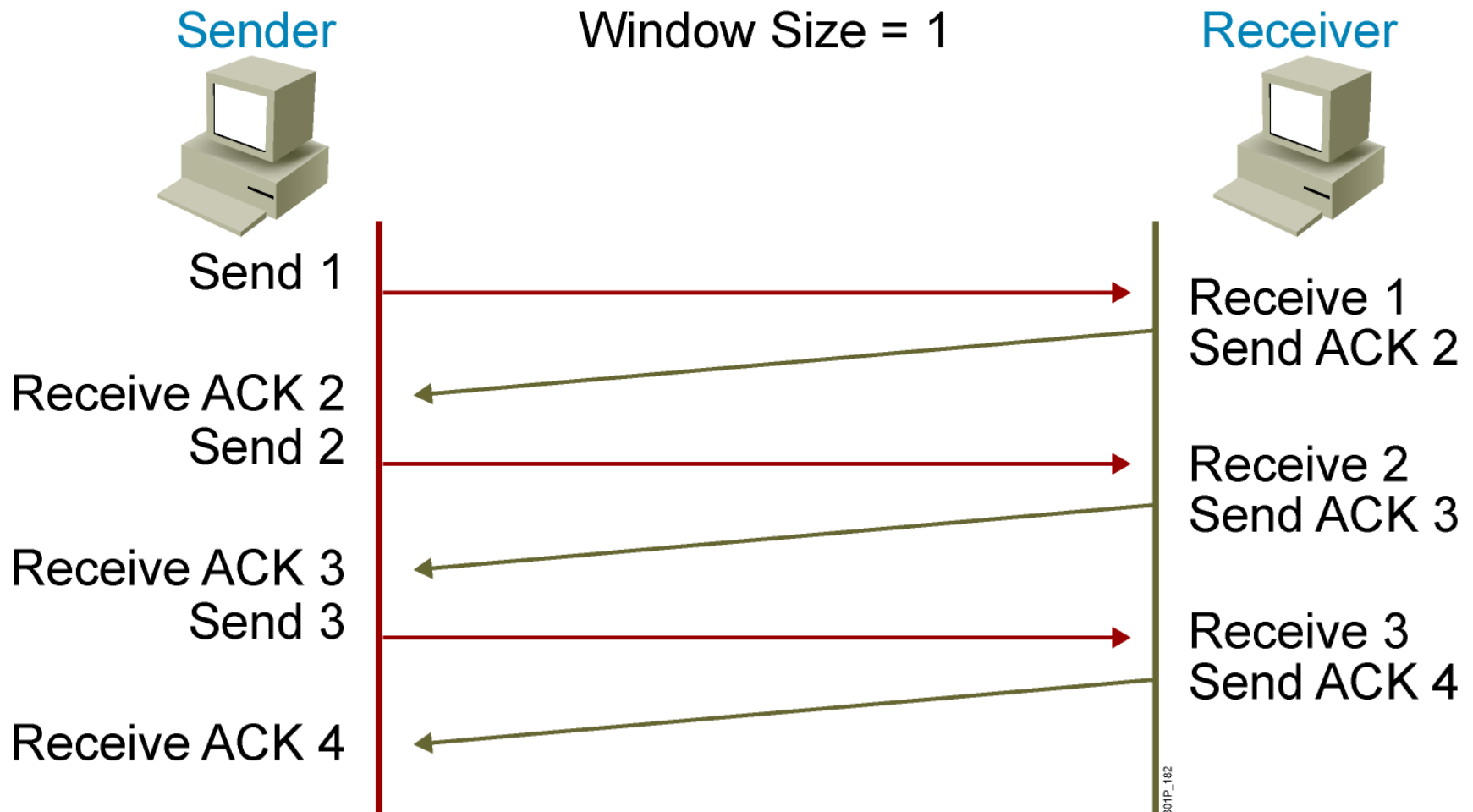


CTL = Which control bits in the TCP header are set to 1

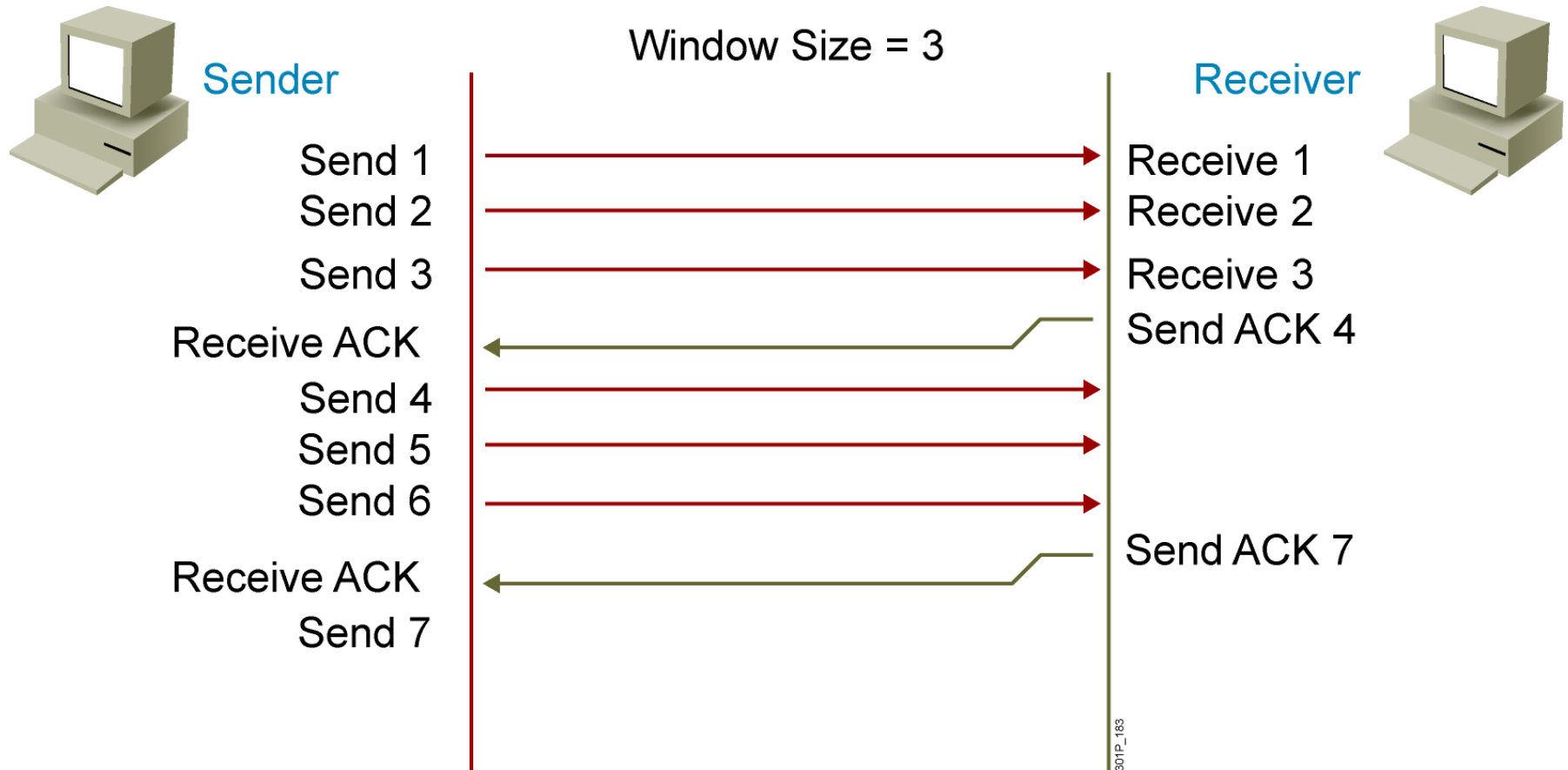
# Flow Control



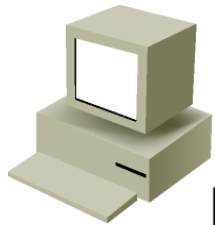
# TCP Acknowledgment



# Fixed Windowing



# TCP Sliding Windowing



Sender

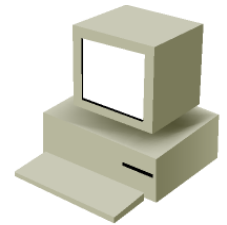
Window Size = 3  
Send 1

Window Size = 3  
Send 2

Window Size = 3  
Send 3

Window Size = 3  
Send 3

Window Size = 3  
Send 4



Receiver

ACK 3  
Window Size = 2

Segment 3 is lost because of the congestion of the receiver.

ACK 5  
Window Size = 2

# TCP Sequence and Acknowledgment Numbers

