Transport Protocols

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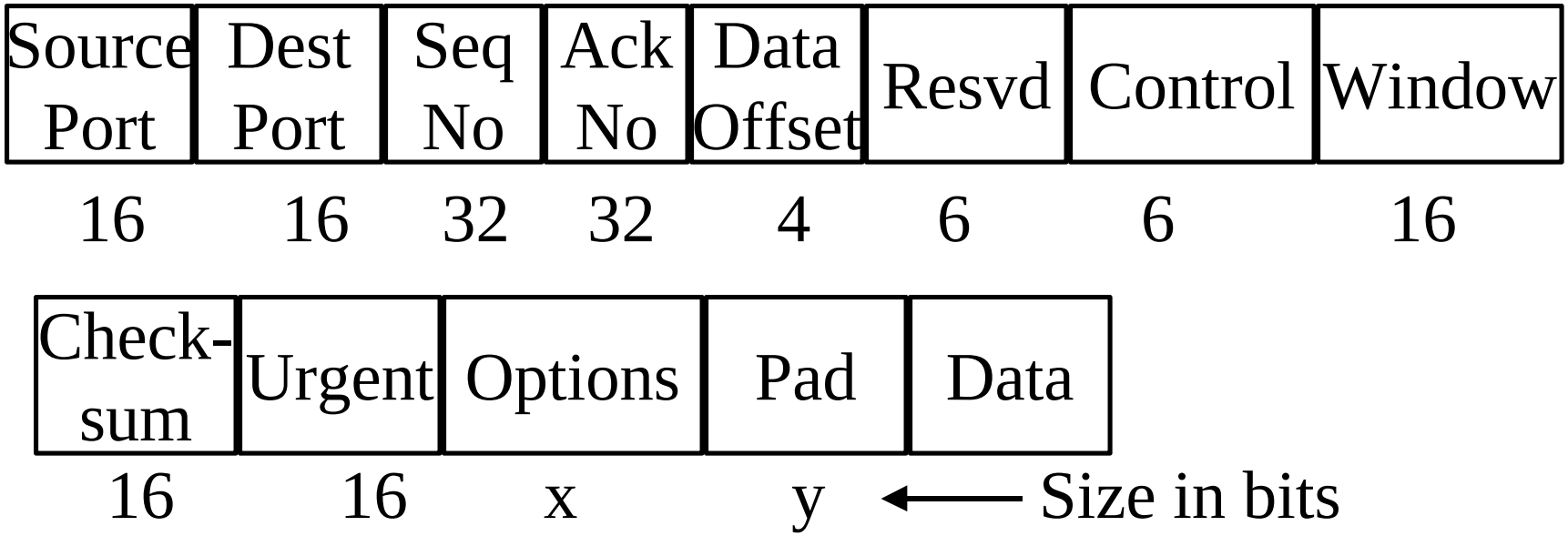
- TCP
  - Key features
  - Header format
  - Mechanisms
  - Implementation choices
  - Slow start congestion avoidance
- UDP

TCP

- Transport Control Protocol
- Key Services:
  - Send: Please send when convenient
  - Data stream push: Please send it all now, if possible.
  - Urgent data signaling: Destination TCP! please give this urgent data to the user
    (Urgent data is delivered in sequence. Push at the should be explicit if needed.)
  - Note: Push has no effect on delivery.
    Urgent requests quick delivery

TCP Header Format



TCP Header

- Source Port (16 bits): Identifies source user process 20 = FTP, 23 = Telnet, 53 = DNS, 80 = HTTP, ...
- Destination Port (16 bits)
- Sequence Number (32 bits): Sequence number of the first byte in the segment. If SYN is present, this is the initial sequence number (ISN) and the first data byte is ISN+1.
- Ack number (32 bits): Next byte expected
- Data offset (4 bits): Number of 32-bit words in the header
- Reserved (6 bits)

TCP Header (Cont)

- Control (6 bits): Urgent pointer field significant,
  Ack field significant,
  Push function,
  Reset the connection,
  Synchronize the sequence numbers,
  No more data from sender

URG	ACK	PSH	RST	SYN	FIN

- Window (16 bits): Will accept [Ack] to [Ack]+[window]

TCP Header (Cont)

- Checksum (16 bits): covers the segment plus a pseudo header. Includes the following fields from IP header: source and dest adr, protocol, segment length. Protects from IP misdelivery.
- Urgent pointer (16 bits): Points to the byte following urgent data. Lets receiver know how much data it should deliver right away.
- Options (variable):
  Max segment size (does not include TCP header, default 536 bytes), Window scale factor, Selective Ack permitted, Timestamp, No-Op, End-of-options

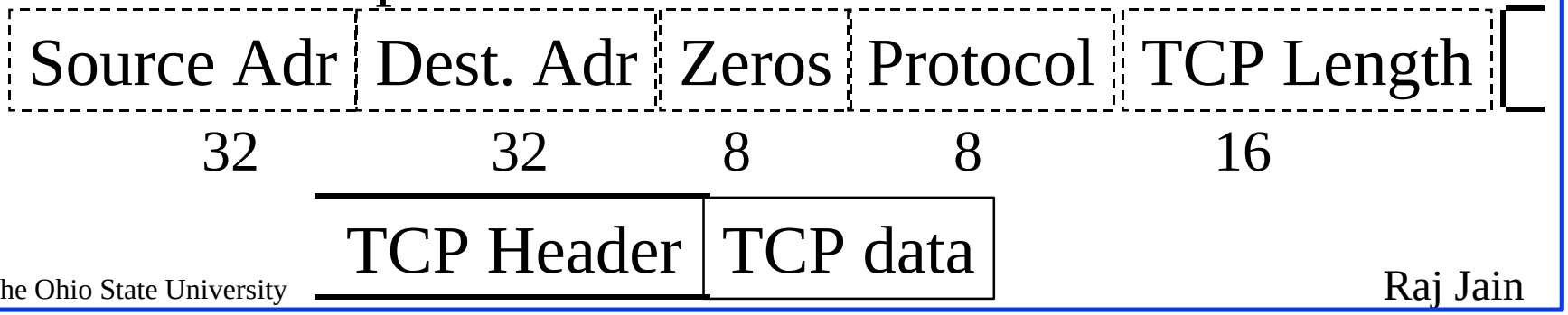
TCP Options

Kind	Length	Meaning
0	1	End of Valid options in header
1	1	No-op
2	4	Maximum Segment Size
3	3	Window Scale Factor
8	10	Timestamp

- End of Options: Stop looking for further option
- No-op: Ignore this byte. Used to align the next option on a 4-byte word boundary
- MSS: Does not include TCP header

TCP Checksum

- Checksum is the 16-bit one's complement of the one's complement sum of a pseudo header of information from the IP header, the TCP header, and the data, padded with zero octets at the end (if necessary) to make a multiple of two octets.
- Checksum field is filled with zeros initially
- TCP length (in octet) is not transmitted but used in calculations.
- Efficient implementation in RFC1071.



TCP Service Requests

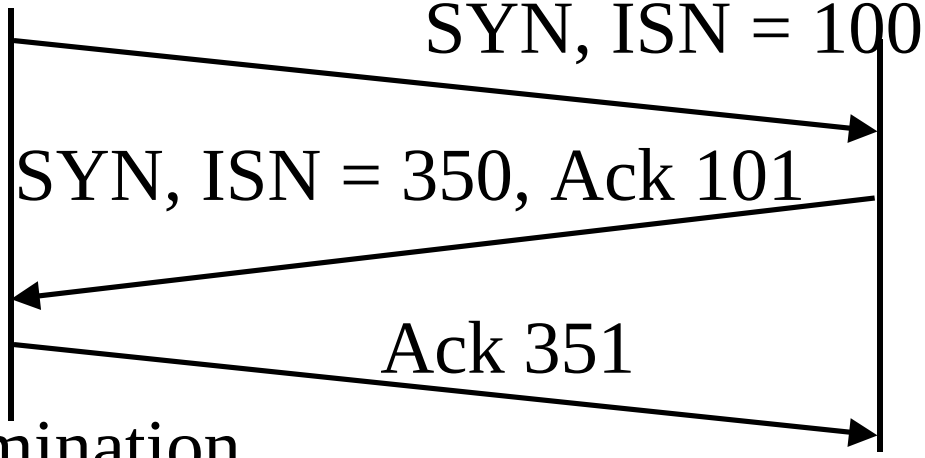
- Unspecified passive open:
  Listen for connection requests from any user (port)
- Full passive open:
  Listen for connection requests from specified port
- Active open: Request connection
- Active open with data: Request connection and transmit data
- Send: Send data
- Allocate: Issue incremental allocation for receive data
- Close: Close the connection gracefully
- Abort: Close the connection abruptly
- Status: Report connection status

TCP Service Responses

- Open ID: Informs the name assigned to the pending request
- Open Failure: Your open request failed
- Open Success: Your open request succeeded
- Deliver: Reports arrival of data
- Closing: Remote TCP has issued a close request
- Terminate: Connection has been terminated
- Status Response: Here is the connection status
- Error: Reports service request or internal error

TCP Mechanisms

- Connection Establishment
  - Three way handshake
  - SYN flag set ⇒ Request for connection



- Connection Termination
  - Close with FIN flag set
  - Abort

Data Transfer

- Stream: Every byte is numbered modulo 2^{32}.
- Header contains the sequence number of the first byte
- Flow control: Credit = number of bytes
- Data transmitted at intervals determined by TCP
  Push $\Rightarrow$ Send now
- Urgent: Send this data in ordinary data stream with urgent pointer
- If TPDU not intended for this connection is received, the "reset" flag is set in the outgoing segment

Implementation Policies (Choices)

- Send Policy:

  Too little ⇒ More overhead. Too large ⇒ Delay

  Push ⇒ Send now, if possible.

- Delivery Policy:

  May store or deliver each in-order segment.

  Urgent ⇒ Deliver now, if possible.

- Accept Policy:

  May or May not discard out-of-order segments

Implementation Policies (Cont)

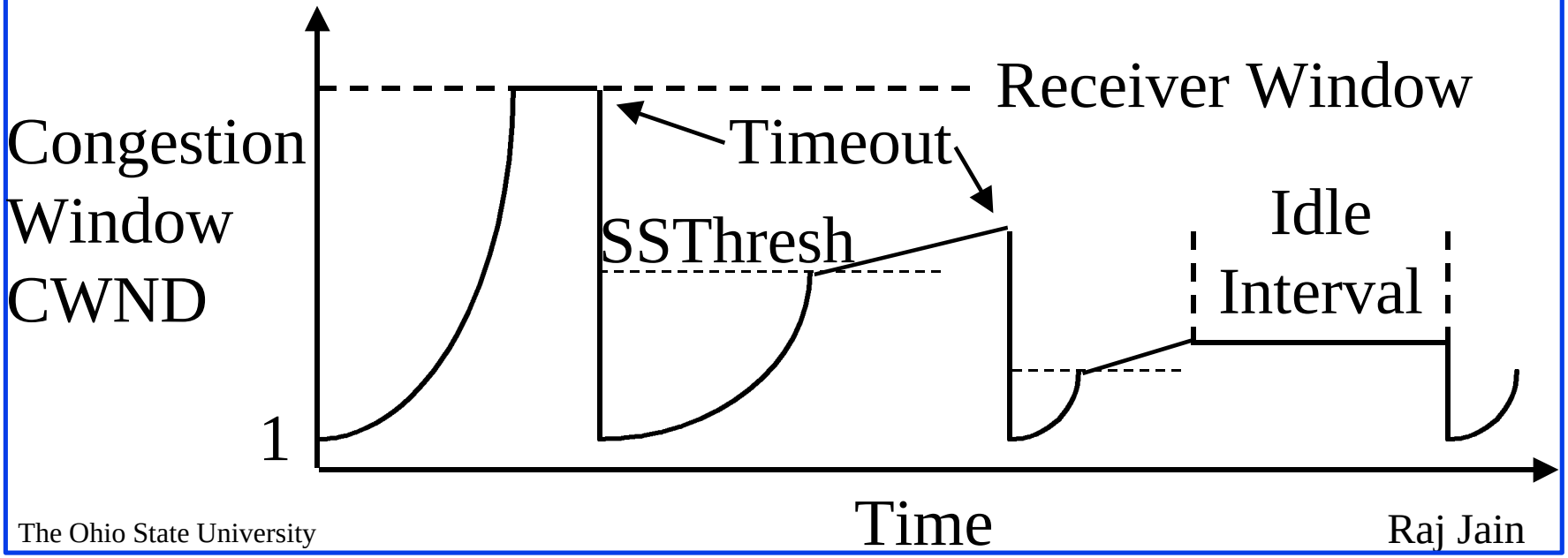
- Retransmit Policy:
  - First only
  - Retransmit all
  - Retransmit individual
  - (maintain separate timer for each segment)
- Ack Policy:
  - Immediate (no piggybacking)
  - Cumulative (wait for outgoing data or timeout)

Slow Start Flow Control

- Window = Flow Control Avoids receiver overrun
- Need congestion control to avoid network overrun
- The sender maintains two windows:
  Credits from the receiver
  Congestion window from the network
  Congestion window is always less than the receiver window
- Starts with a congestion window (CWND) of 1 segment (one max segment size)
  $\Rightarrow$ Do not disturb existing connections too much.
- Increase CWND by 1 every time an ack is received

Slow Start (Cont)

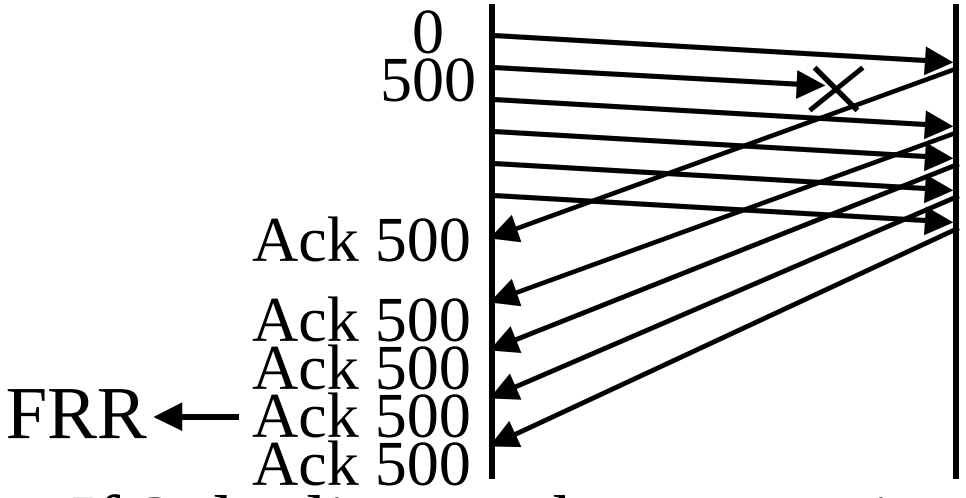
- If packets lost, remember slow start threshold (SSThresh) to CWND/2
  Set CWND to 1
  Increment by 1 per ack until SSthresh
  Increment by 1/CWND per ack afterwards



Slow Start (Cont)

- At the beginning, SSThresh = Receiver window
- After a long idle period (exceeding one round-trip time), reset the congestion window to one.
- Exponential growth phase is also known as "Slow start" phase
- The linear growth phase is known as "congestion avoidance phase"

Fast Retransmit and Recovery



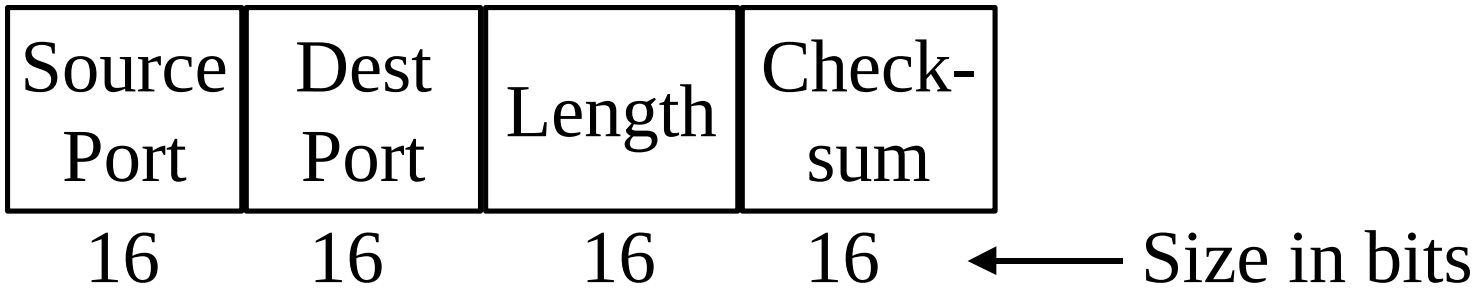
- If 3 duplicate acks are received for the same packet, assume that the next packet has been last. Retransmit it right away. Retransmit only one packet.
- Helps if a single packet is lost.
  Does not help if multiple packets lost.
- Ref: Stevens, Internet draft

FRR (Cont)

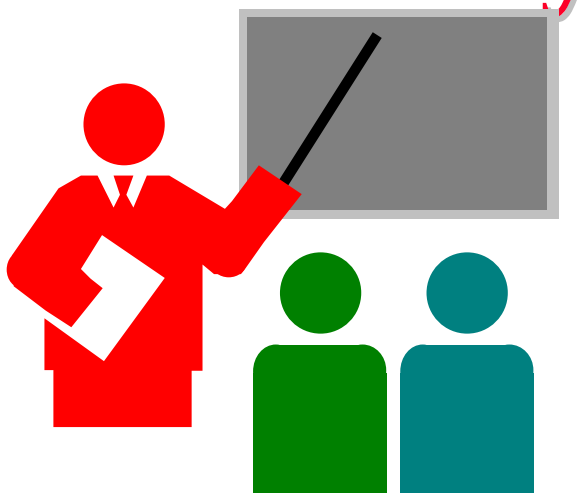
- Upon receiving the third duplicate Ack:
  - Set SSThresh to 1/2 of current CWND
  - Retransmit the missing segment
  - Set CWND to SSthresh+3
- For each successive duplicate Ack:
  - Increment CWND by 1 MSS
  - New packets are transmitted if allowed by CWND
- Upon receiving the next (non-duplicate) Ack:
  - Set CWND to SSthresh ⇒ Enter linear growth phase
- Receiver caches out-of-order data.

User Datagram Protocol (UDP)

- Connectionless end-to-end service
- No flow control. No error recovery (no acks)
- Provides port addressing
- Error detection (Checksum) optional. Applies to pseudo-header (same as TCP) and UDP segment. If not used, it is set to zero.
- Used by network management



Summary



- TCP provides reliable full-duplex connections.
- TCP Streams, credit flow control
- Slow-start, Fast retransmit/recovery
- UDP is connectionless and simple.
  No flow/error control.

Homework

- Read RFCs 0768 (UDP) 0793 (TCP), 2001 (Slow start and FRR)
  All RFCs can be found on ftp://ftp.isi.edu/in-notes/
- Read Sections 17.3 and 17.4 of Stallings' book
- Submit answers to problem 17.15