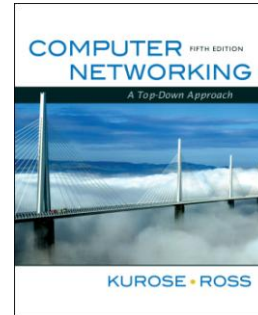


# RSC

## Part III: Transport Layer

### 3. TCP



**Redes y Servicios de Comunicaciones**  
**Universidad Carlos III de Madrid**

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*Computer Networking:  
A Top Down Approach  
5<sup>th</sup> edition.*

Jim Kurose, Keith Ross  
Addison-Wesley, April  
2009.

Network Layer II-1

## RSC Part III: Transport Layer

- III. 1 Basic Transport layer concepts
  - Transport layer Principles
  - Transport layer Services
  - Multiplexing and Demultiplexing
- III.3 TCP
  - TCP connection
  - TCP Segment, sequence and ack numbers
  - RTT Estimation and Timeout
  - Reliable Data Transfer
  - Flow Control
  - TCP connection

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# TCP: Overview

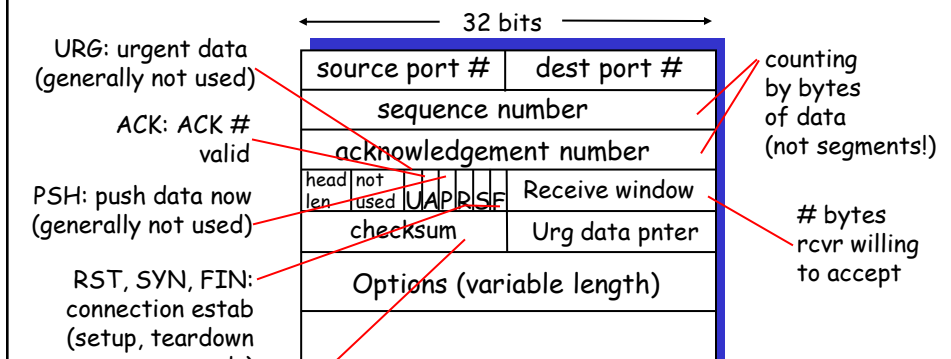
RFCs: 793, 1122, 1323, 2018, 2581

- ❑ **point-to-point:**
  - one sender, one receiver
- ❑ **reliable, in-order byte stream:**
  - no "message boundaries"
- ❑ **pipelined:**
  - TCP congestion and flow control set window size
- ❑ **send & receive buffers**
- ❑ **full duplex data:**
  - bi-directional data flow in same connection
  - MSS: maximum segment size
- ❑ **connection-oriented:**
  - handshaking (exchange of control msgs) init's sender, receiver state before data exchange
- ❑ **flow controlled:**
  - sender will not overwhelm receiver



Transport Layer 3-3

# TCP segment structure



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## TCP seq. #'s and ACKs

### Seq. #'s:

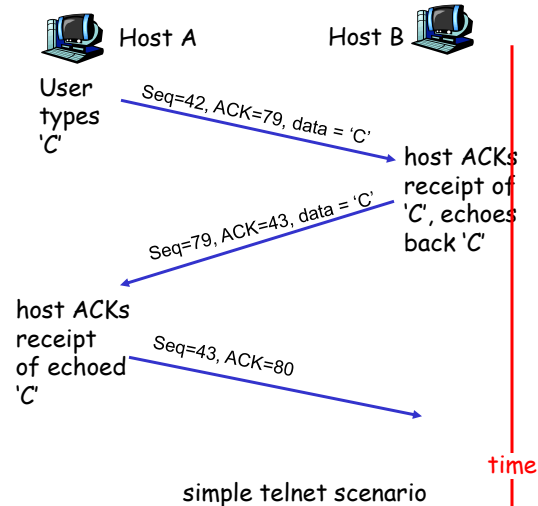
- byte stream "number" of first byte in segment's data

### ACKs:

- seq # of next byte expected from other side
- cumulative ACK

**Q:** how receiver handles out-of-order segments

- A: TCP spec doesn't say, - up to implementor



Transport Layer 3-5

## TCP reliable data transfer

- TCP creates rdt service on top of IP's unreliable service
- Pipelined segments
- Cumulative acks
- TCP uses single retransmission timer
- Retransmissions are triggered by:
  - timeout events
  - duplicate acks
- Initially consider simplified TCP sender:
  - ignore duplicate acks
  - ignore flow control,

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## TCP sender events:

### data rcvd from app:

- ❑ Create segment with seq #
- ❑ seq # is byte-stream number of first data byte in segment
- ❑ start timer if not already running (think of timer as for oldest unacked segment)
- ❑ expiration interval: TimeoutInterval

### timeout:

- ❑ retransmit segment that caused timeout
- ❑ restart timer

### Ack rcvd:

- ❑ If acknowledges previously unacked segments
  - update what is known to be acked
  - start timer if there are outstanding segments

Transport Layer 3-7

```
NextSeqNum = InitialSeqNum  
SendBase = InitialSeqNum
```

```
loop (forever) {  
  switch(event)
```

```
  event: data received from application above  
    create TCP segment with sequence number NextSeqNum  
    if (timer currently not running)  
      start timer  
    pass segment to IP  
    NextSeqNum = NextSeqNum + length(data)
```

```
  event: timer timeout  
    retransmit not-yet-acknowledged segment with  
      smallest sequence number  
    start timer
```

## TCP sender (simplified)

### Comment:

- SendBase-1: last cumulatively ack'ed byte

### Example:

- SendBase-1 = 71;  
y = 73, so the rcvr

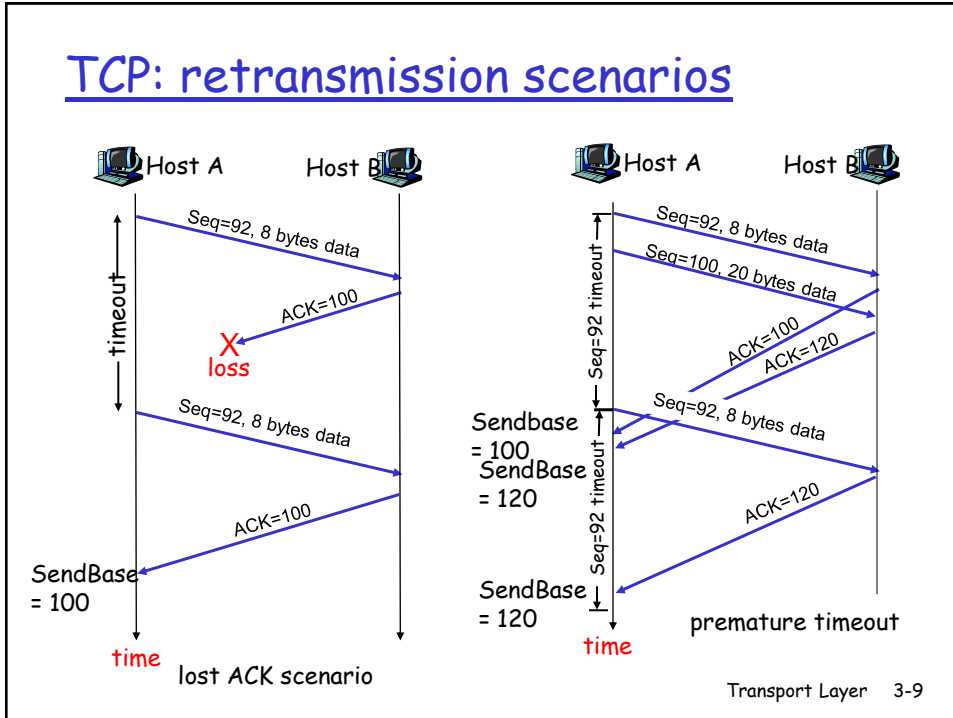
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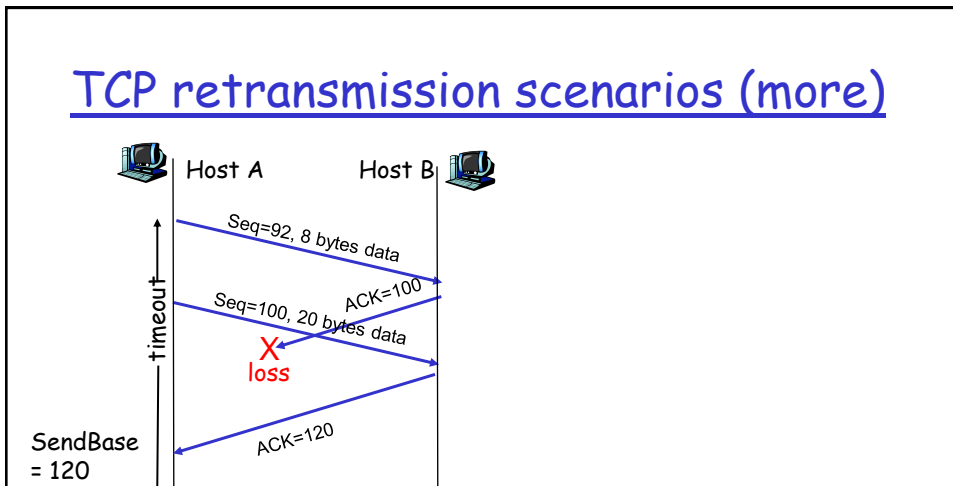
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## TCP: retransmission scenarios



## TCP retransmission scenarios (more)



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## TCP ACK generation [RFC 1122, RFC 2581]

Event at Receiver	TCP Receiver action
Arrival of in-order segment with expected seq #. All data up to expected seq # already ACKed	Delayed ACK. Wait up to 500ms for next segment. If no next segment, send ACK
Arrival of in-order segment with expected seq #. One other segment has ACK pending	Immediately send single cumulative ACK, ACKing both in-order segments
Arrival of out-of-order segment higher-than-expected seq. # . Gap detected	Immediately send <i>duplicate ACK</i> , indicating seq. # of next expected byte
Arrival of segment that partially or completely fills gap	Immediate send ACK, provided that segment starts at lower end of gap

Transport Layer 3-11

## Fast Retransmit

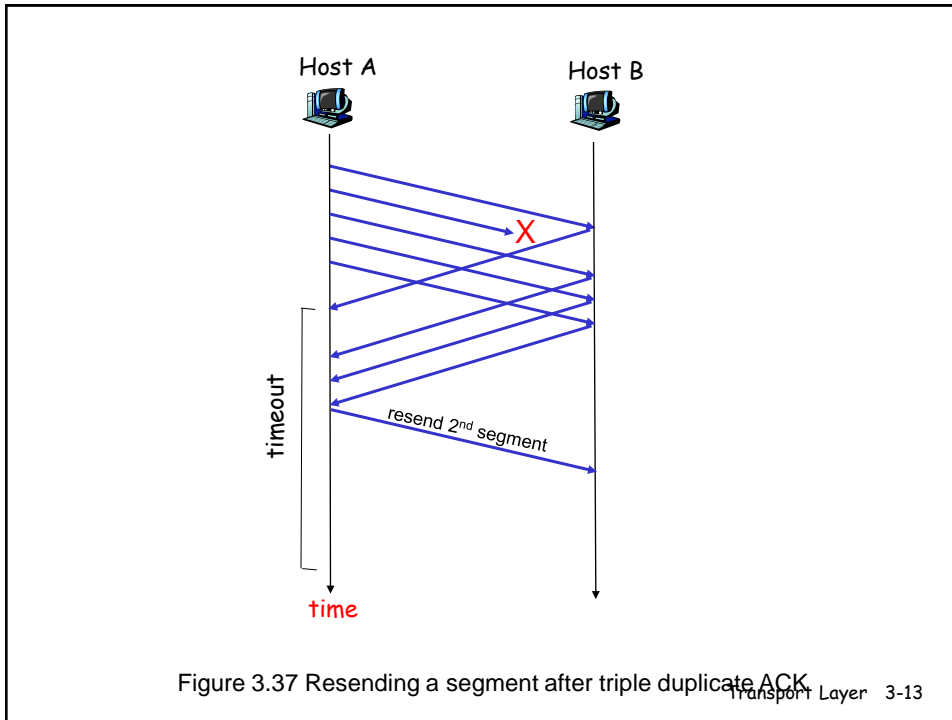
- ❑ Time-out period often relatively long:
  - long delay before resending lost packet
- ❑ Detect lost segments via duplicate ACKs.
  - Sender often sends many segments back-to-
- ❑ If sender receives 3 ACKs for the same data, it supposes that segment after ACKed data was lost:
  - **fast retransmit**: resend segment before timer expires

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## Fast retransmit algorithm:

```

event: ACK received, with ACK field value of y
  if (y > SendBase) {
    SendBase = y
    if (there are currently not-yet-acknowledged segments)
      start timer
  }
  else {
    increment count of dup ACKs received for y
    if (count of dup ACKs received for y = 3) {
      resend segment with sequence number y
    }
  }

```

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