# CSCI 466: Networks

UDP and TCP

Reese Pearsall

Fall 2023

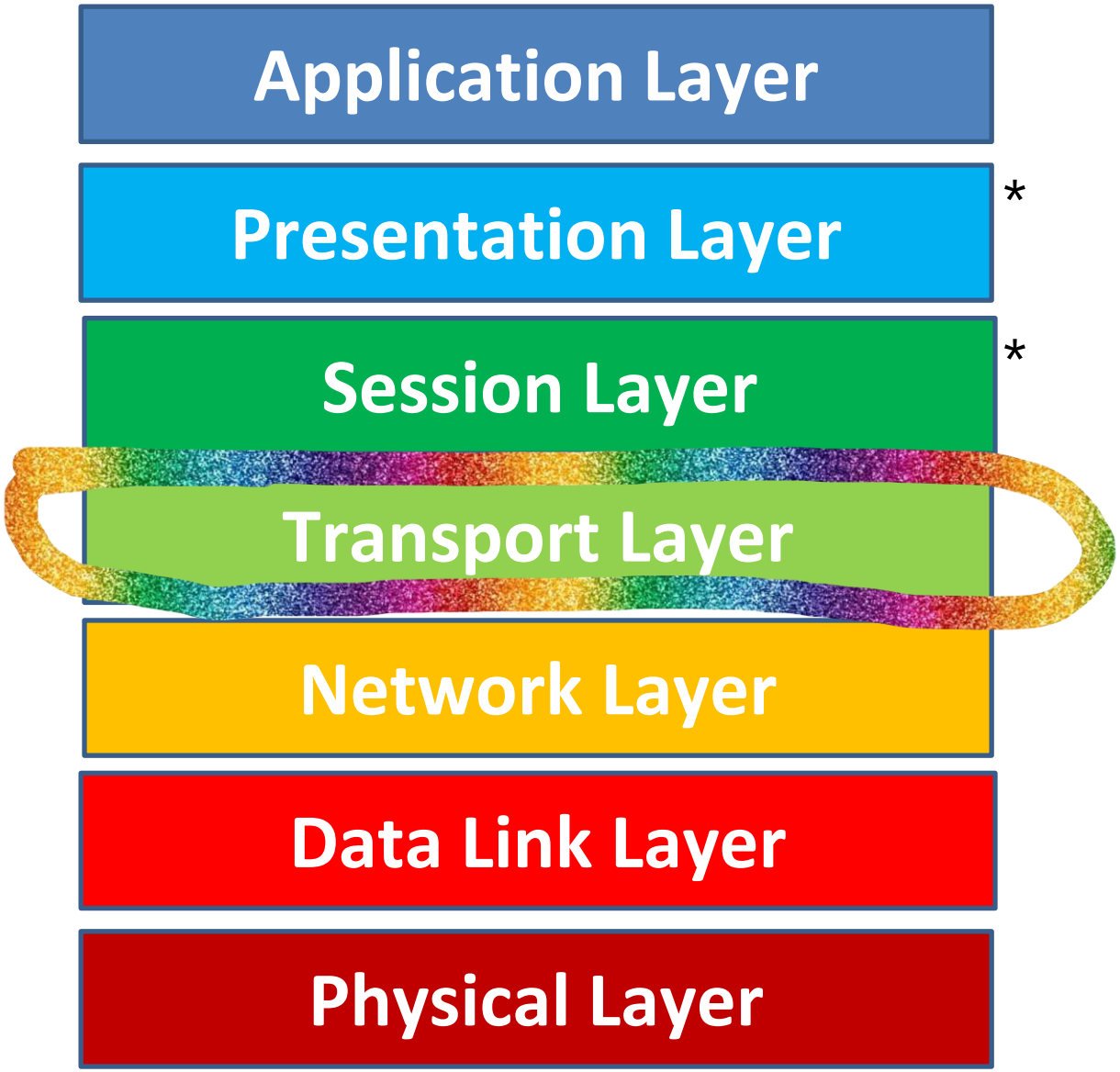


*All images are stolen from the internet

## Announcements

PA 2 Posted. Due Wednesday October 18th

# OSI Model




**Application Layer**

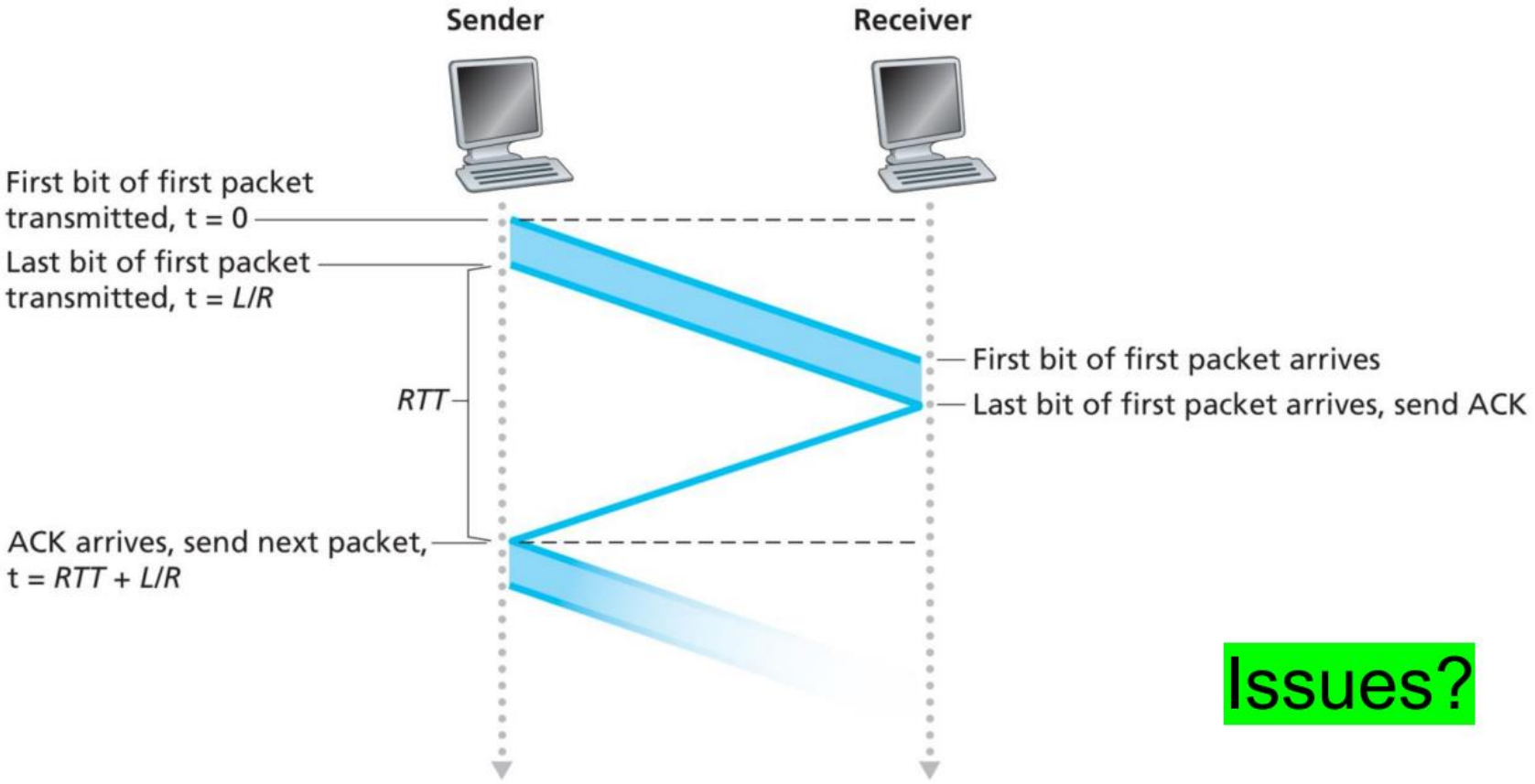
Messages from Network Applications

**Physical Layer**

Bits being transmitted over some medium

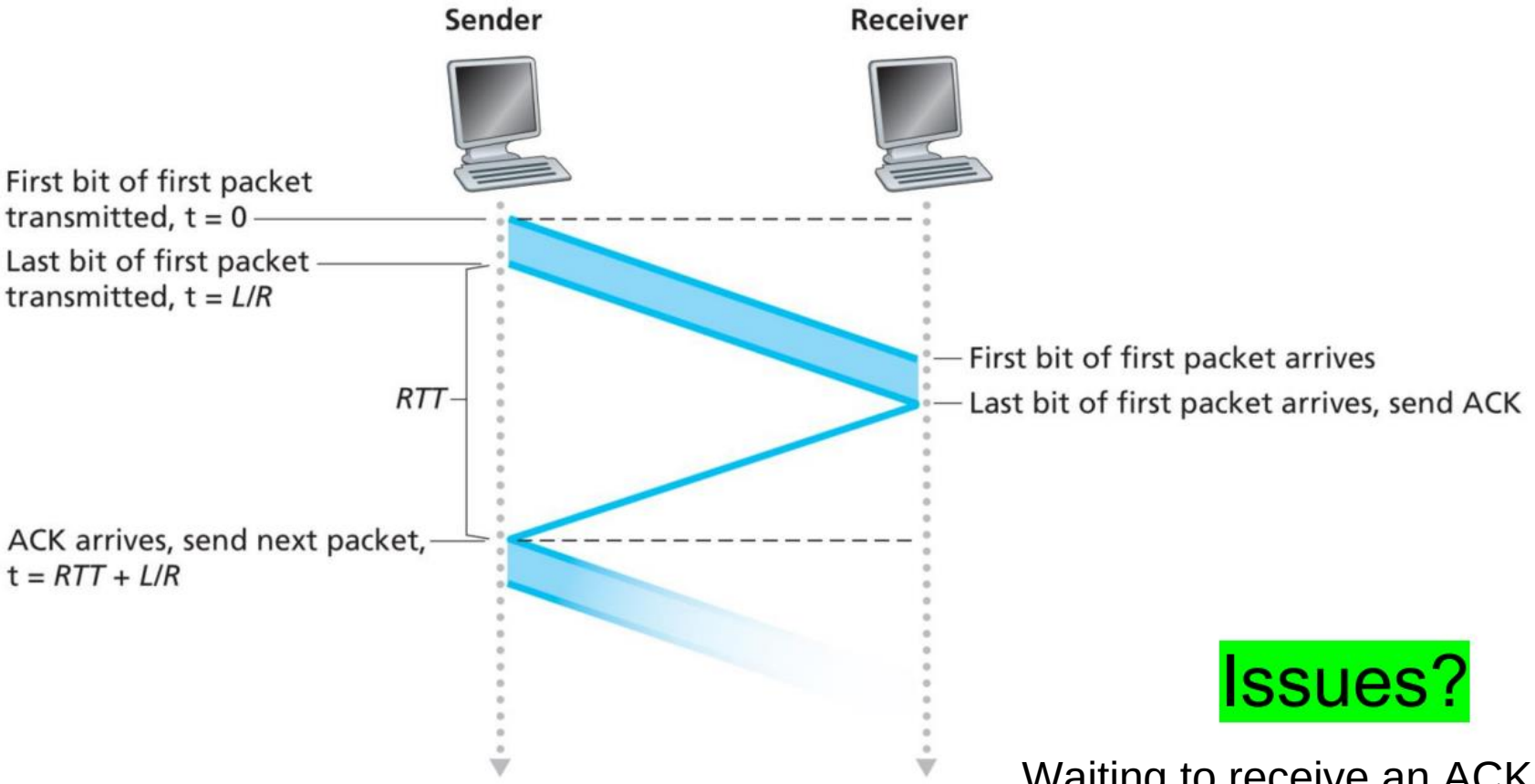
**In the textbook, they condense it to a 5-layer model, but 7 layers is what is most used*

So far, our reliable data transfer protocols have been **stop-and-wait**




Issues?

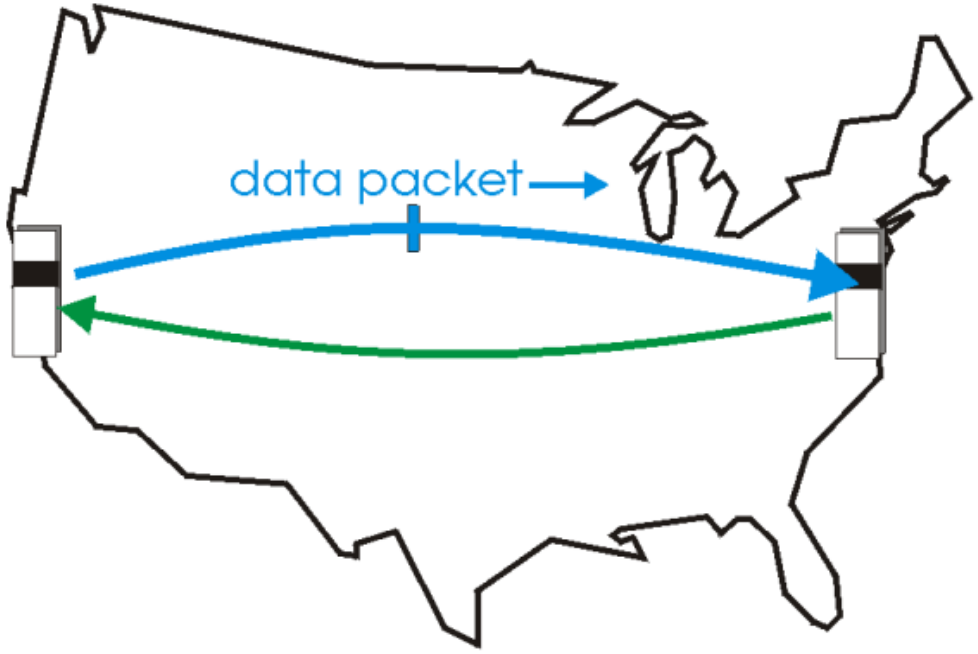
So far, our reliable data transfer protocols have been **stop-and-wait**



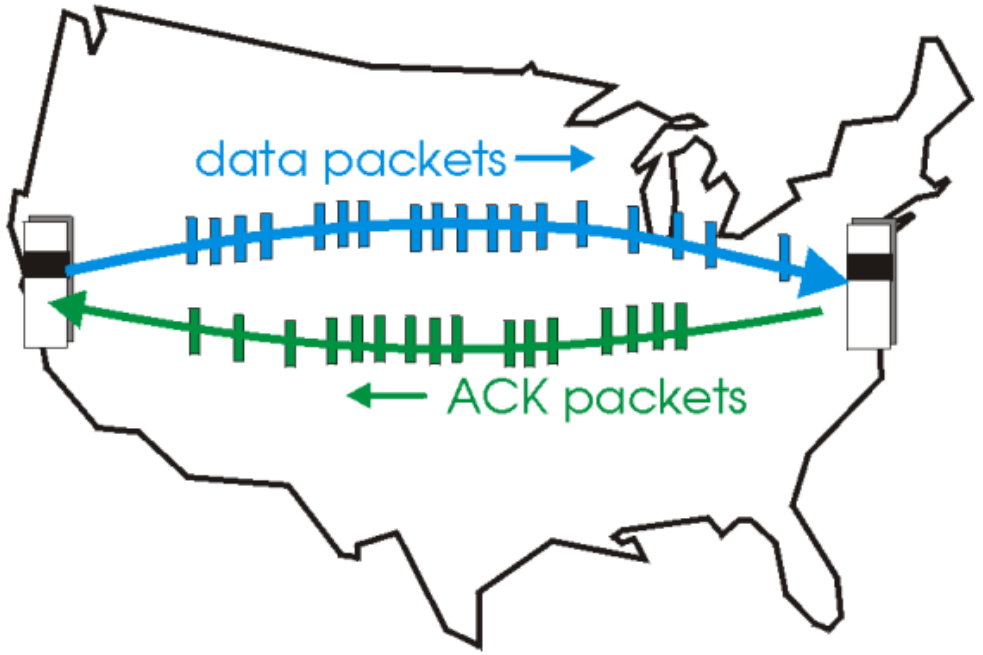

Issues?

Waiting to receive an ACK is inefficient
We spend *a lot* of time waiting

**Pipelining**: sender allows multiple, “in-flight”, yet-to-be acknowledged packets

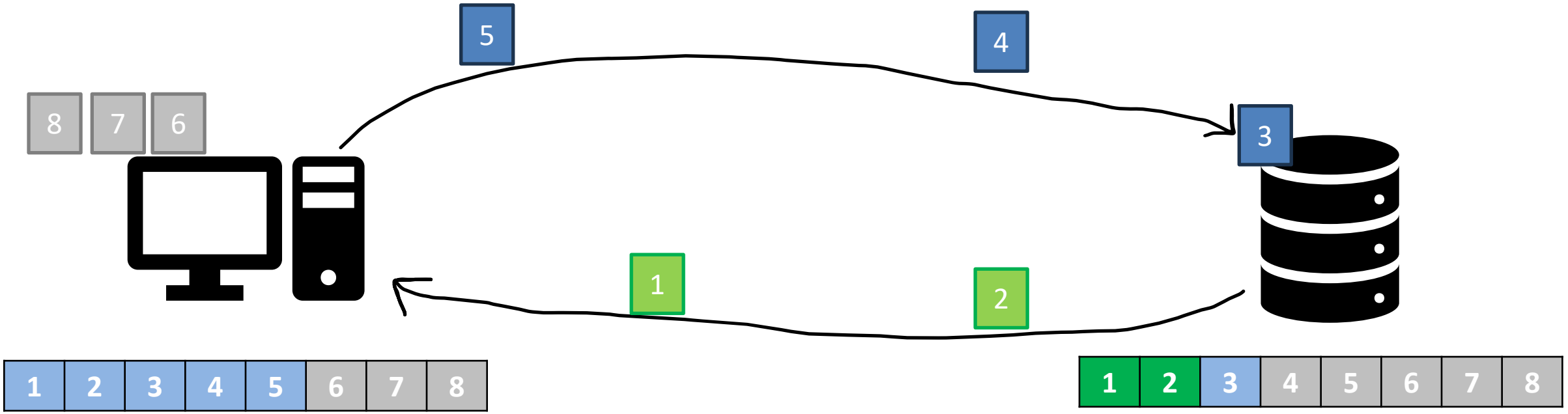



(a) a stop-and-wait protocol in operation




(b) a pipelined protocol in operation

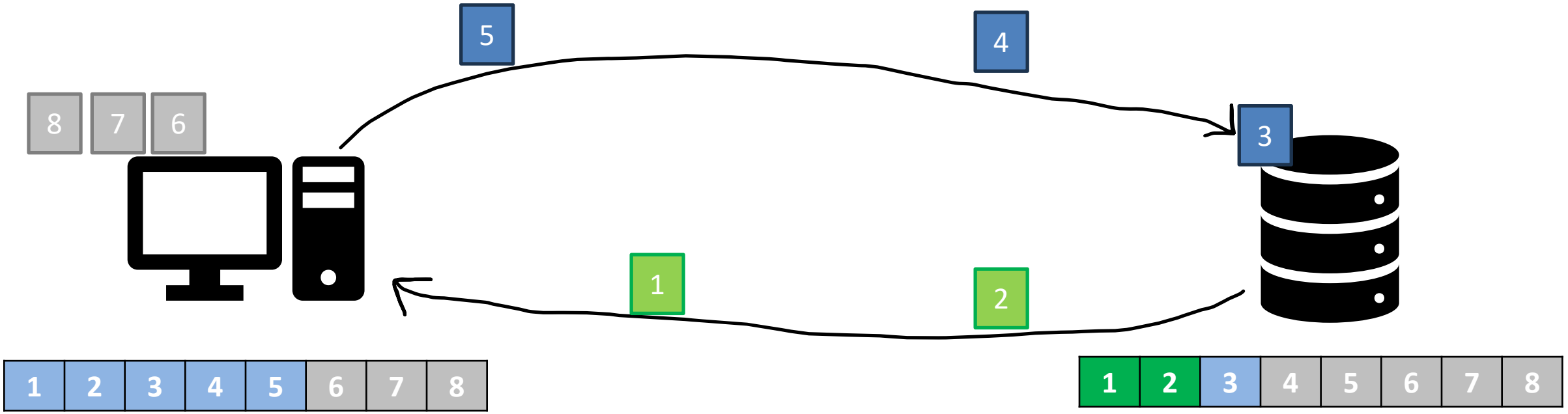
**Pipelining**: sender allows multiple, “in-flight”, yet-to-be acknowledged packets




Consequences:

- Need to use a wider range of sequence numbers

**Pipelining**: sender allows multiple, “in-flight”, yet-to-be acknowledged packets

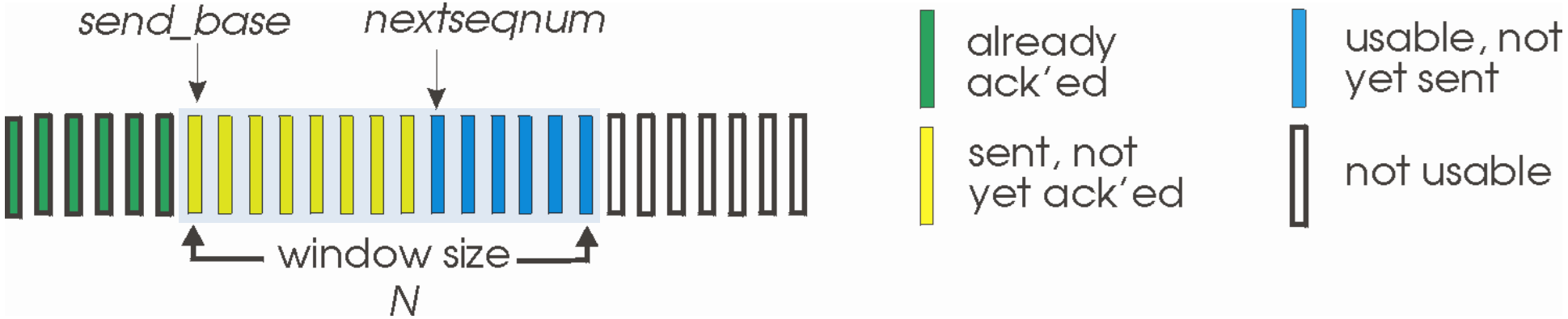



Consequences:

- Need to use a wider range of sequence numbers
- Sender and receiver may need to **buffer** more than one packet

# Go-Back-N: sender

- sender: "window" of up to N, consecutive transmitted but unACKed pkts
  - k-bit seq # in pkt header

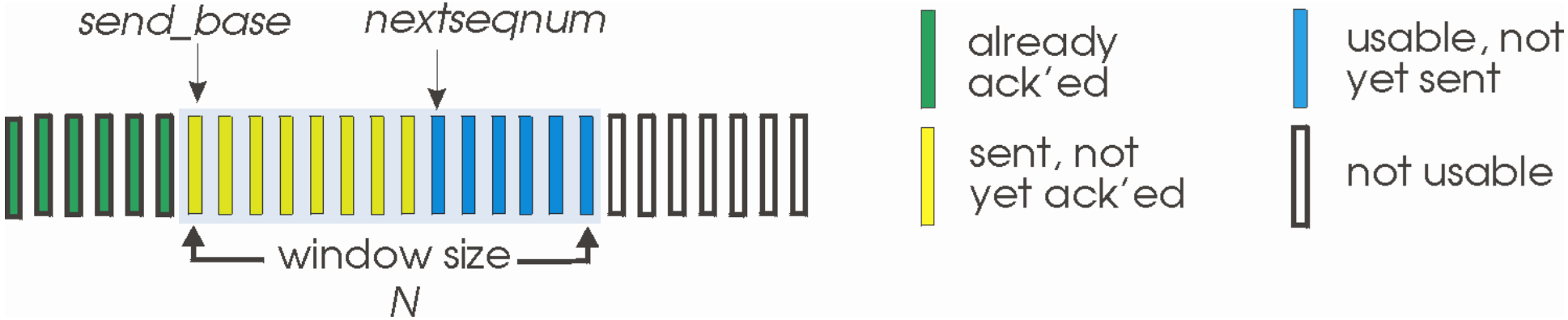



- *cumulative ACK:* ACK(*n*): ACKs all packets up to, including seq # *n*
  - on receiving ACK(*n*): move window forward to begin at *n+1*
- timer for oldest in-flight packet
- *timeout(n):* retransmit packet n and all higher seq # packets in window

# Go-Back-N: sender

*(Why not have an infinite window size?)*

- sender: "window" of up to N, consecutive transmitted but unACKed pkts
  - k-bit seq # in pkt header

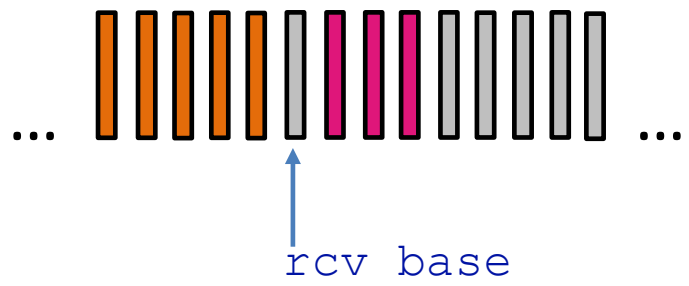


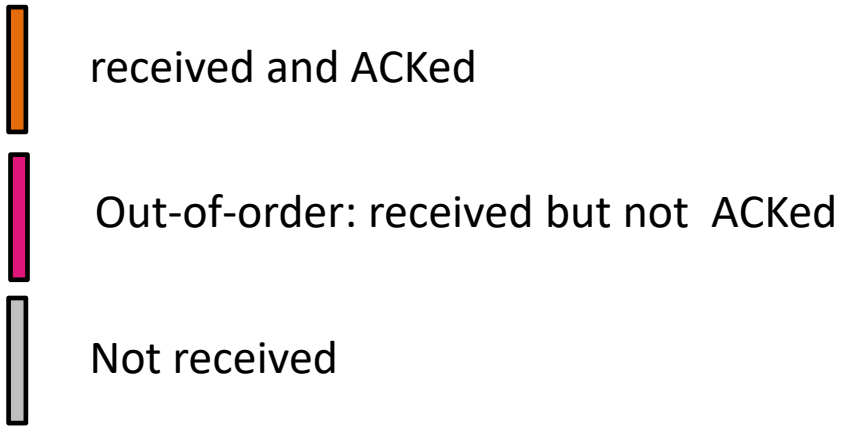

- *cumulative ACK:* ACK(*n*): ACKs all packets up to, including seq # *n*
  - on receiving ACK(*n*): move window forward to begin at *n+1*
- timer for oldest in-flight packet
- *timeout(n):* retransmit packet n and all higher seq # packets in window

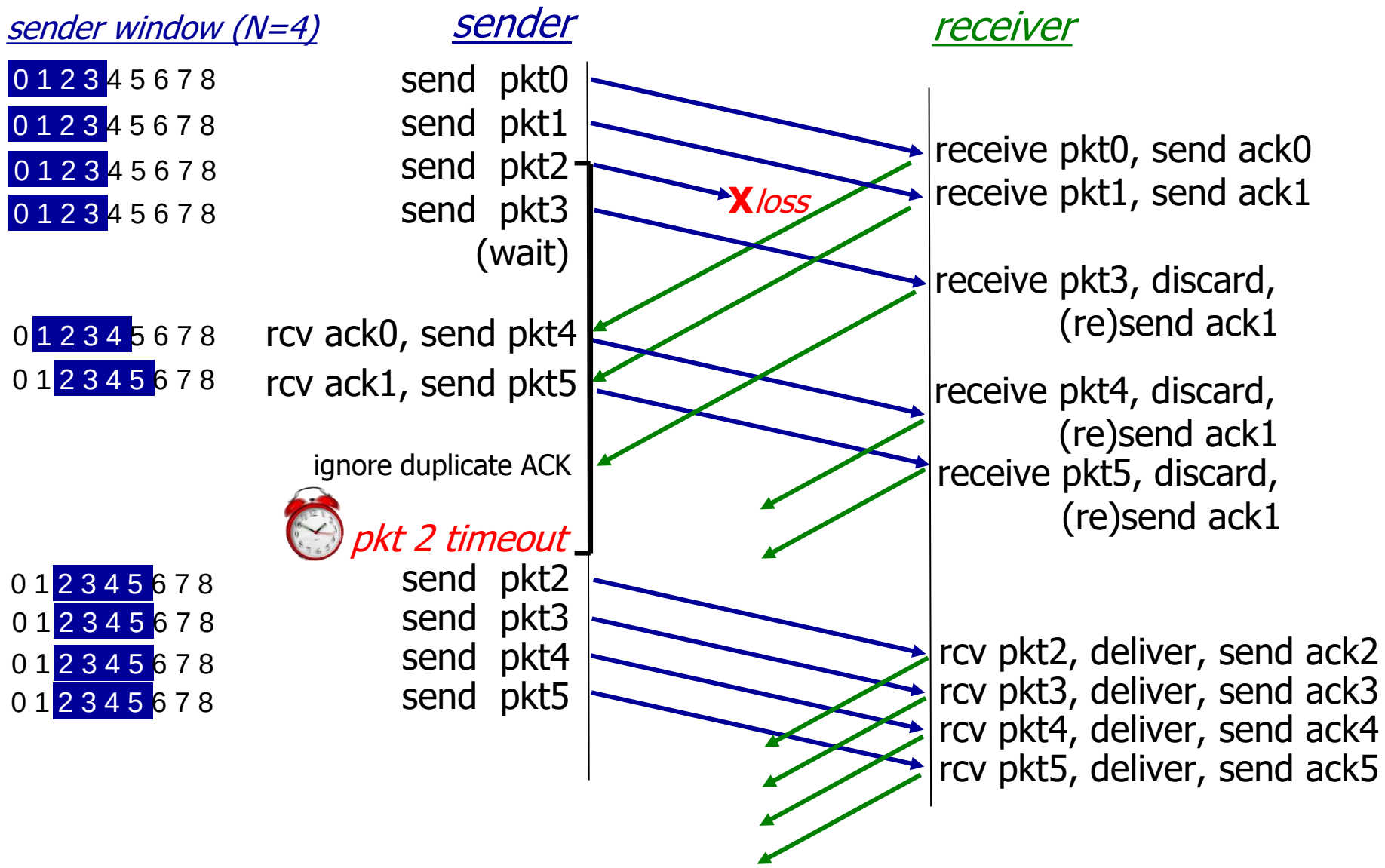
# Go-Back-N: receiver

- ACK-only: always send ACK for correctly-received packet so far, with highest *in-order* seq #
  - may generate duplicate ACKs
  - need only remember `rcv_base`
- on receipt of out-of-order packet:
  - can discard (don't buffer) or buffer: an implementation decision
  - re-ACK pkt with highest in-order seq #

Receiver view of sequence number space:




sender window (N=4)
sender
receiver
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
send pkt0
send pkt1
send pkt2
send pkt3
(wait)
X loss
receive pkt0, send ack0
receive pkt1, send ack1
receive pkt3, discard,
(re)send ack1
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
rcv ack0, send pkt4
rcv ack1, send pkt5
receive pkt4, discard,
(re)send ack1
receive pkt5, discard,
(re)send ack1
ignore duplicate ACK
pkt 2 timeout
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
0 1 2 3 4 5 6 7 8
send pkt2
send pkt3
send pkt4
send pkt5
rcv pkt2, deliver, send ack2
rcv pkt3, deliver, send ack3
rcv pkt4, deliver, send ack4
rcv pkt5, deliver, send ack5

https://www2.tkn.tu-berlin.de/teaching/rn/animations/gbn_sr/

# Selective repeat: the approach

- *pipelining*: *multiple* packets in flight
- *receiver individually ACKs* all correctly received packets
  - buffers packets, as needed, for in-order delivery to upper layer
- sender:
  - maintains (conceptually) a timer for each unACKed pkt
    - timeout: retransmits single unACKed packet associated with timeout
  - maintains (conceptually) "window" over *N* consecutive seq #s
    - limits pipelined, "in flight" packets to be within this window

https://www2.tkn.tu-berlin.de/teaching/rn/animations/gbn_sr/

# Selective repeat: sender and receiver

## sender

data from above:

- if next available seq # in window, send packet

timeout(*n*):

- resend packet *n*, restart timer

ACK(*n*) in [sendbase,sendbase+N-1]:

- mark packet *n* as received
- if n smallest unACKed packet, advance window base to next unACKed seq #

## receiver

packet *n* in [rcvbase, rcvbase+N-1]

- send ACK(*n*)
- out-of-order: buffer
- in-order: deliver (also deliver buffered, in-order packets), advance window to next not-yet-received packet

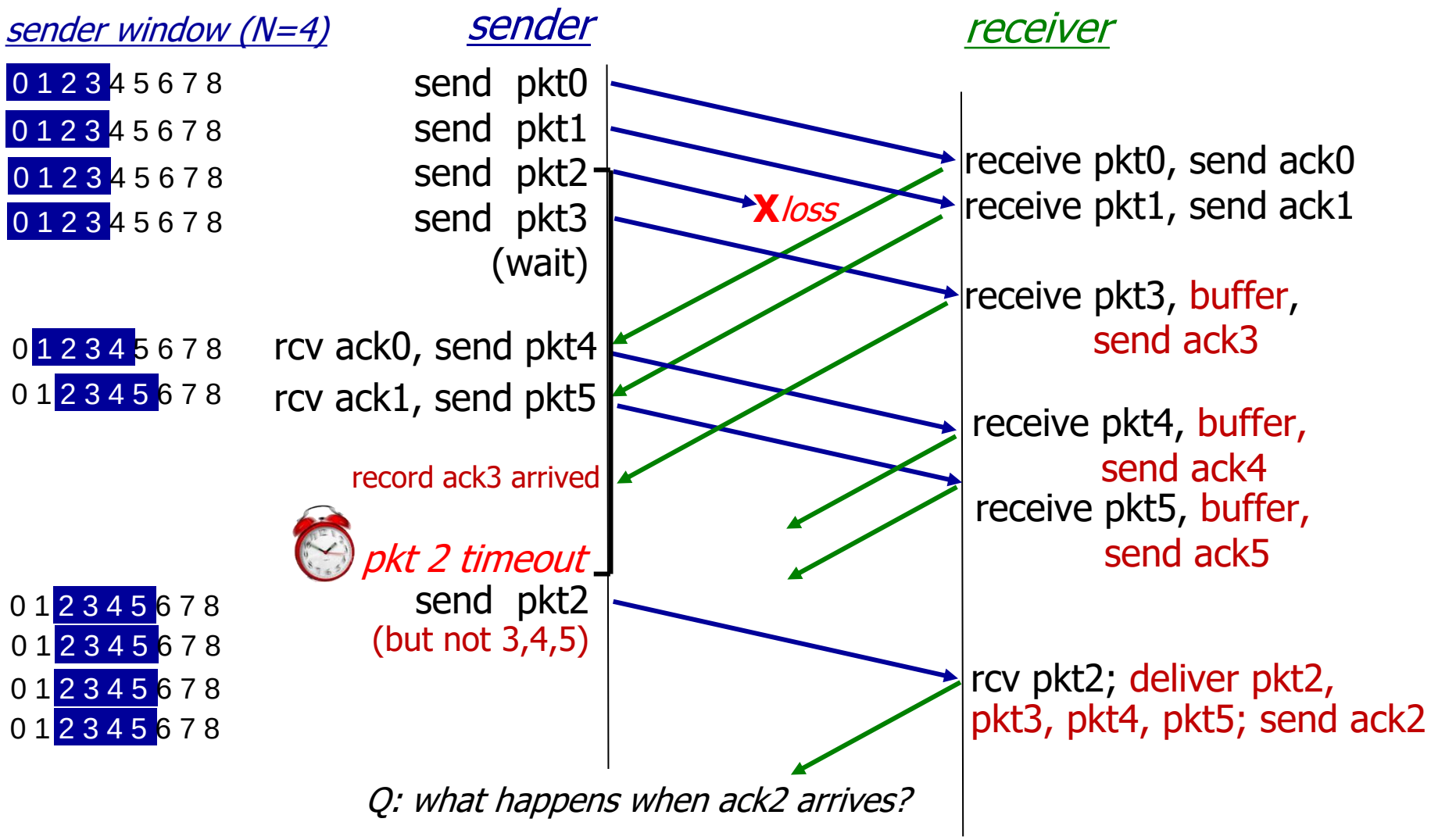
packet *n* in [rcvbase-N,rcvbase-1]

- ACK(*n*)

otherwise:

- ignore

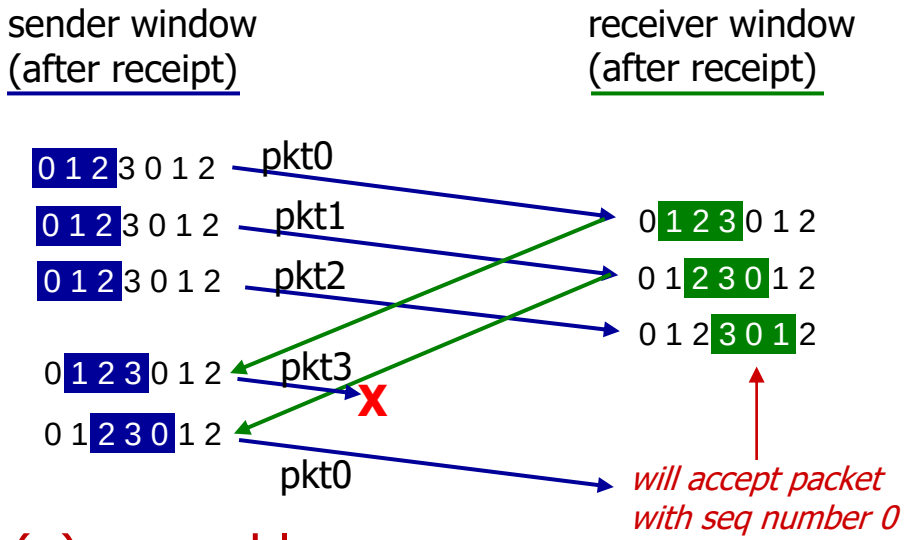
# Selective Repeat in action



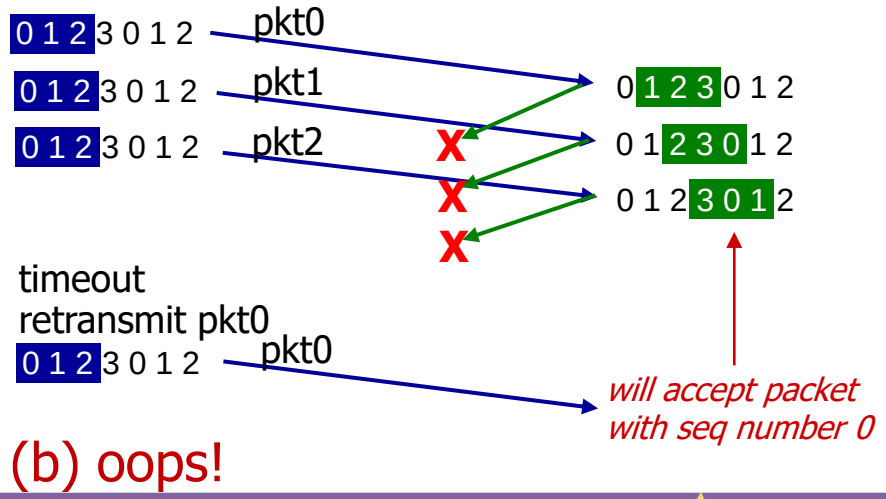
# Selective repeat: a dilemma!

example:

- seq #s: 0, 1, 2, 3 (base 4 counting)
- window size=3




(a) no problem



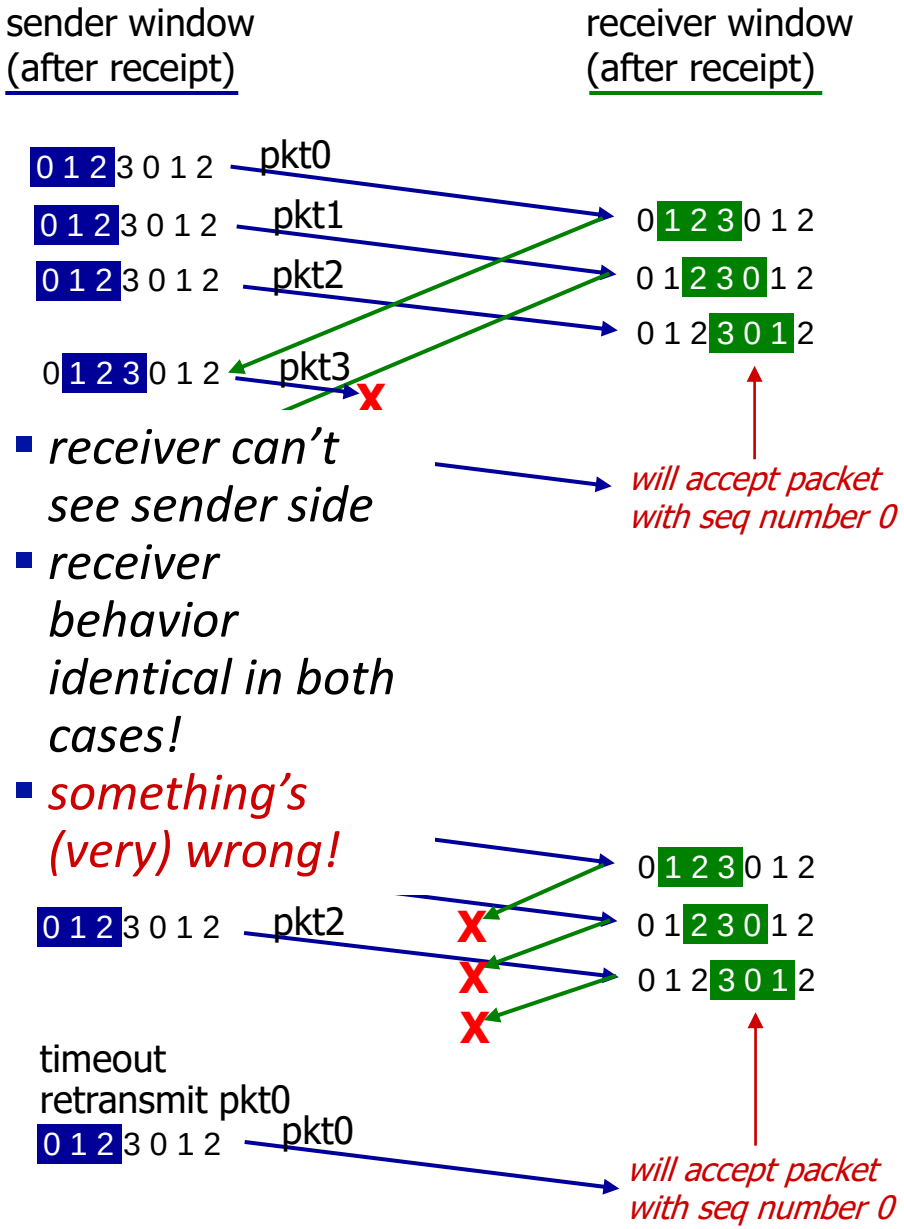

(b) oops!

# Selective repeat: a dilemma!

example:

- seq #s: 0, 1, 2, 3 (base 4 counting)
- window size=3

Q: what relationship is needed between sequence # size and window size to avoid problem in scenario (b)?



# RDT Principles

**Checksum-** Used to detect bit errors in transmitted packets

# RDT Principles

**Checksum-** Used to detect bit errors in transmitted packets

**Timer-** Used to timeout/retransmit a packet, possibly because the packet (or its ACK) was lost within a channel

# RDT Principles

**Checksum-** Used to detect bit errors in transmitted packets

**Timer-** Used to timeout/retransmit a packet, possibly because the packet (or its ACK) was lost within a channel

**Sequence Number**- Used for sequential numbering of packets of data flowing form sender to receiver. Gaps in sequence number of packets allow the receiver to detect a lost or duplicate packet

# RDT Principles

**Checksum-** Used to detect bit errors in transmitted packets

**Timer-** Used to timeout/retransmit a packet, possibly because the packet (or its ACK) was lost within a channel

**Sequence Number**- Used for sequential numbering of packets of data flowing form sender to receiver. Gaps in sequence number of packets allow the receiver to detect a lost or duplicate packet

**Acknowledgement**- Used by the receiver to tell the sender that a packet or set of packets has been received correctly. ACKs will typically carry the sequence # of the packet being acknowledged

# RDT Principles

**Checksum-** Used to detect bit errors in transmitted packets

**Timer-** Used to timeout/retransmit a packet, possibly because the packet (or its ACK) was lost within a channel

**Sequence Number**- Used for sequential numbering of packets of data flowing form sender to receiver. Gaps in sequence number of packets allow the receiver to detect a lost or duplicate packet

**Acknowledgement**- Used by the receiver to tell the sender that a packet or set of packets has been received correctly. ACKs will typically carry the sequence # of the packet being acknowledged

**Negative Acknowledgement**- Used by the receiver to tell the sender that a packet has not been received correctly. Negative acknowledgements will typically carry the sequence number of the packet that was not received correctly

# RDT Principles

**Checksum-** Used to detect bit errors in transmitted packets

**Timer-** Used to timeout/retransmit a packet, possibly because the packet (or its ACK) was lost within a channel

**Sequence Number**- Used for sequential numbering of packets of data flowing form sender to receiver. Gaps in sequence number of packets allow the receiver to detect a lost or duplicate packet

**Acknowledgement**- Used by the receiver to tell the sender that a packet or set of packets has been received correctly. ACKs will typically carry the sequence # of the packet being acknowledged

**Negative Acknowledgement**- Used by the receiver to tell the sender that a packet has not been received correctly. Negative acknowledgements will typically carry the sequence number of the packet that was not received correctly

**Window, pipelining**- The sender may be restricted to sending only packets with sequence numbers that fall within a given range. By allowing multiple packets to be transmitted but not yet acknowledged, sender utilization can be increased over a stop-and-wait mode of operation

## Transport Layer Protocols:

1. Transmission Control Protocol (TCP)
2. User Datagram Protocol (UDP)

# UDP

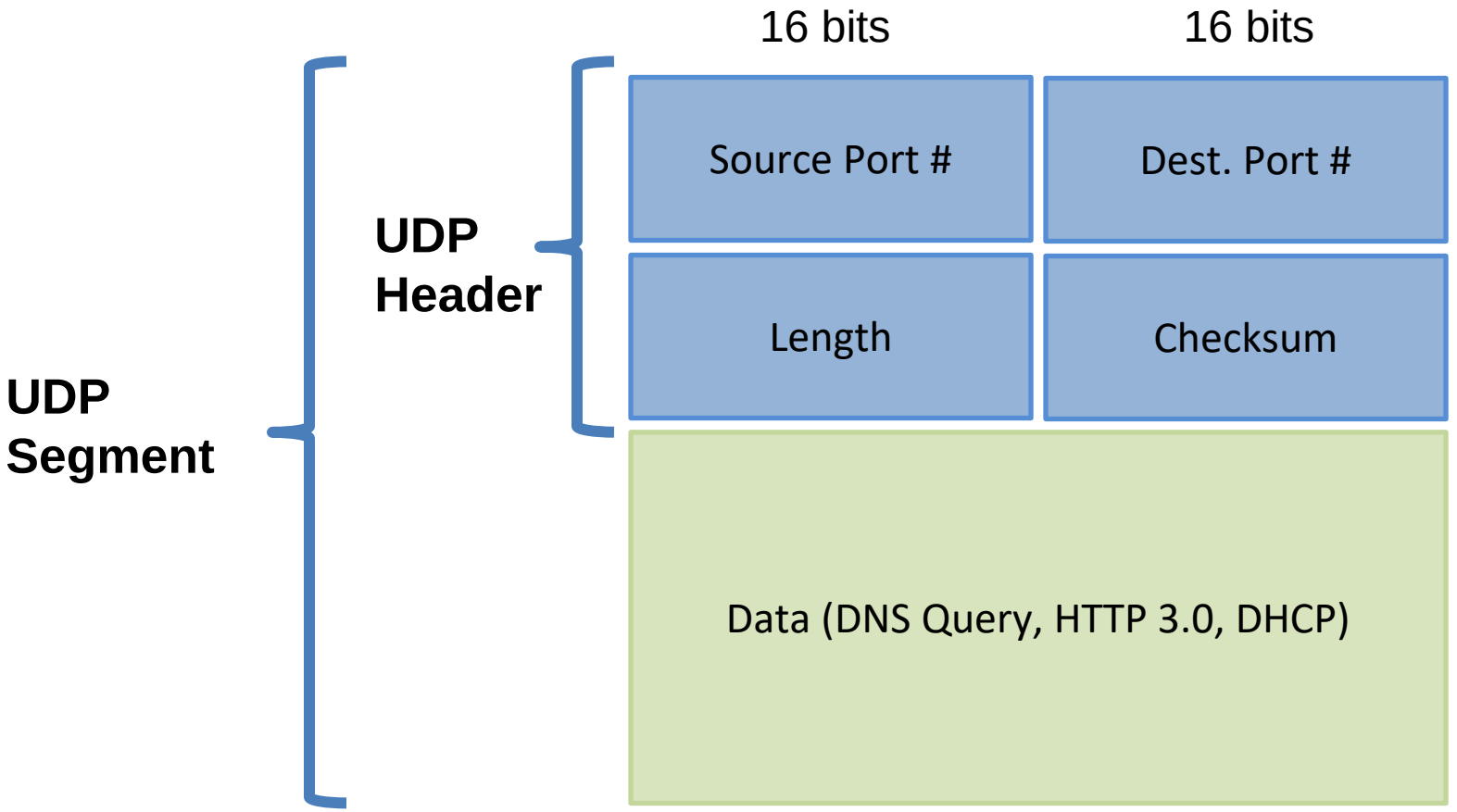
- "no frills," "bare bones" Internet transport protocol
- "best effort" service, UDP segments may be:
  - lost
  - delivered out-of-order to app
- *connectionless:*
  - no handshaking between UDP sender, receiver
  - each UDP segment handled independently of others

## Why is there a UDP?

- no connection establishment (which can add RTT delay)
- simple: no connection state at sender, receiver
- small header size
- no congestion control
  - UDP can blast away as fast as desired!
  - can function in the face of congestion

# UDP

The UDP header is very small!! (4 bytes, 32 bits)

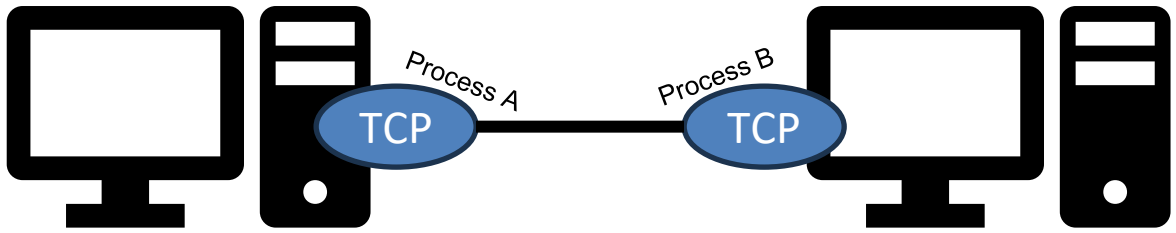


# TCP

- Connection oriented, point-to-point (1 to 1)

→ **TCP Handshake** must occur before data is being transmitted

A *logical* connection




- Reliable, in order, data transfer
- Cumulative ACKs
- Pipelining

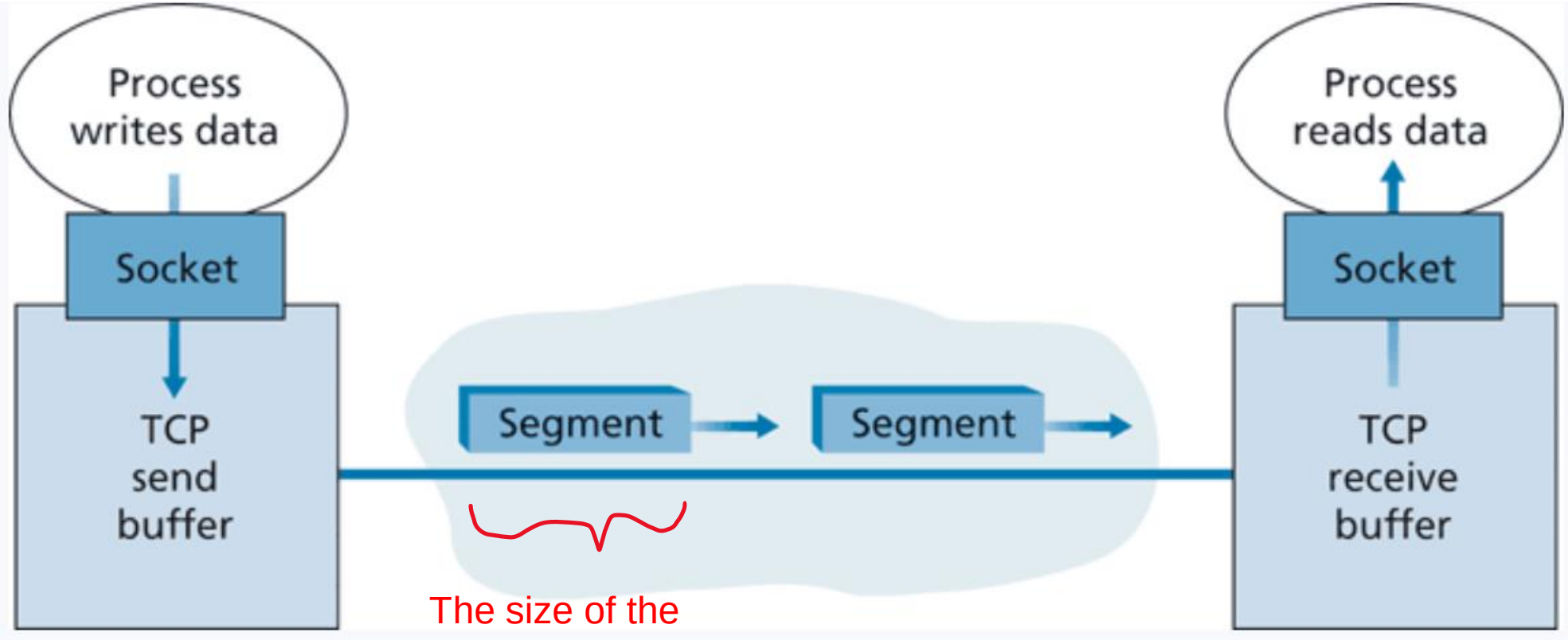
→ TCP Congestion and flow control set window size

- Flow controlled

→ Sender will not overwhelm receiver

- Full-duplex service

# TCP



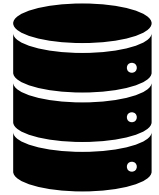

The size of the segment is determined by the maximum segment size (MSS)

*(Roughly 1500 bytes– size of a link layer frame)*

# TCP Sequence Numbers

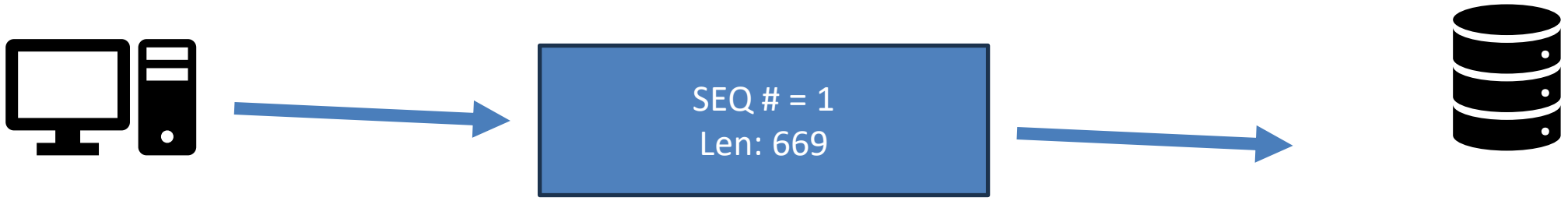
A TCP connection is transmitting a **byte stream**

Sequence numbers are based on *how much data has been sent*
Acknowledgement numbers are based on *how much data has been successfully received*



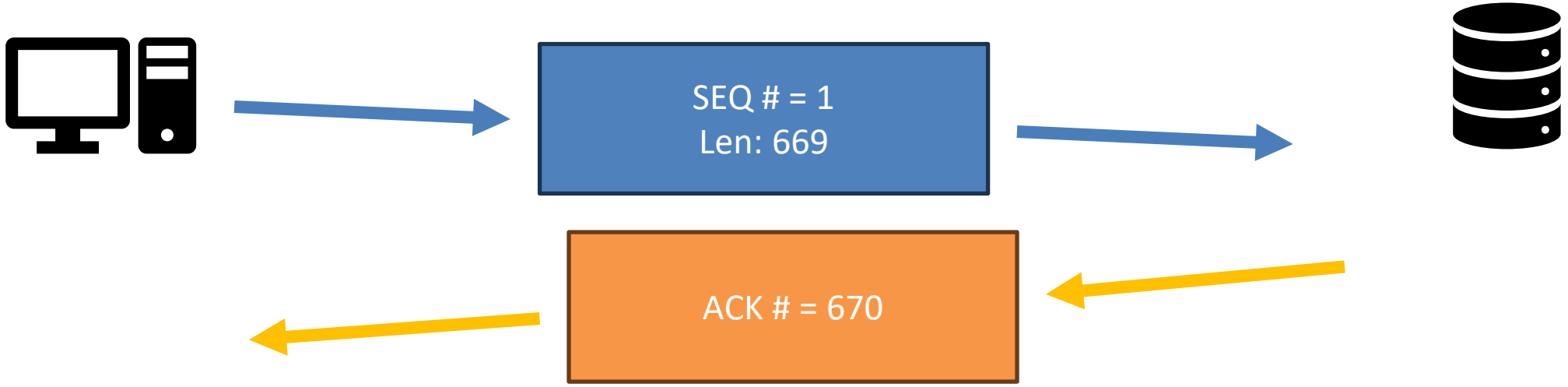
# TCP Sequence Numbers

A TCP connection is transmitting a **byte stream**



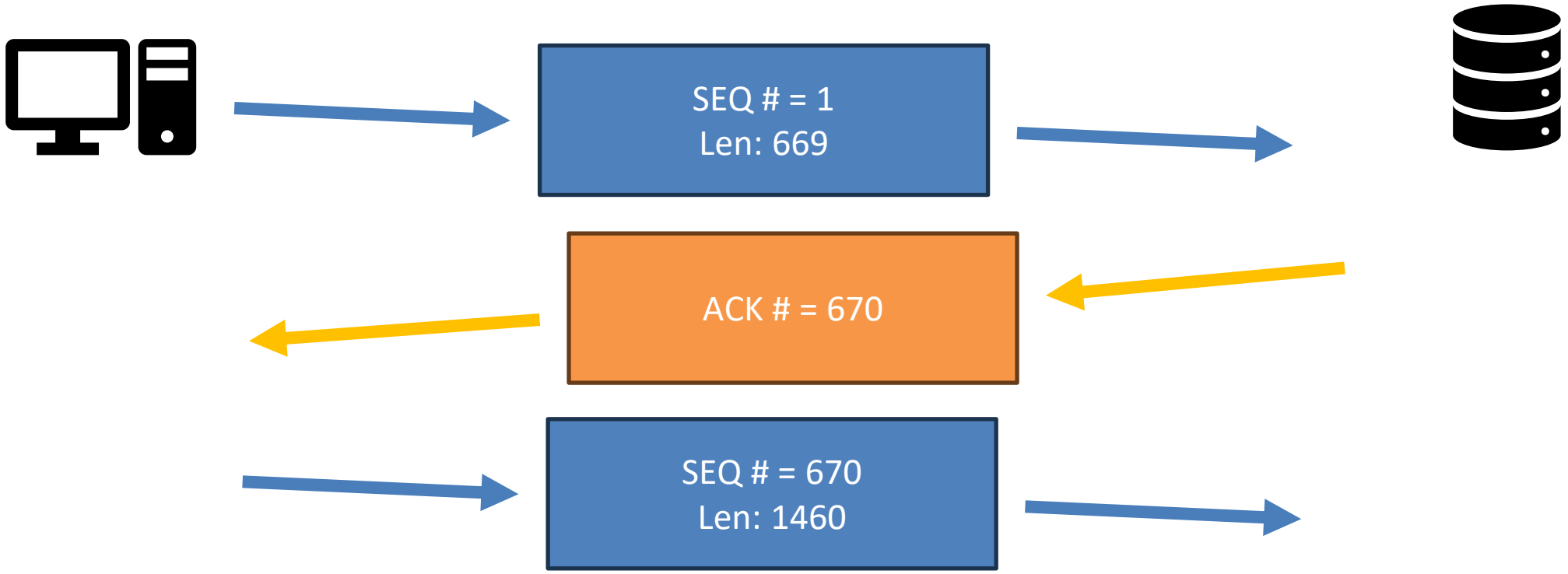
# TCP Sequence Numbers

A TCP connection is transmitting a **byte stream**



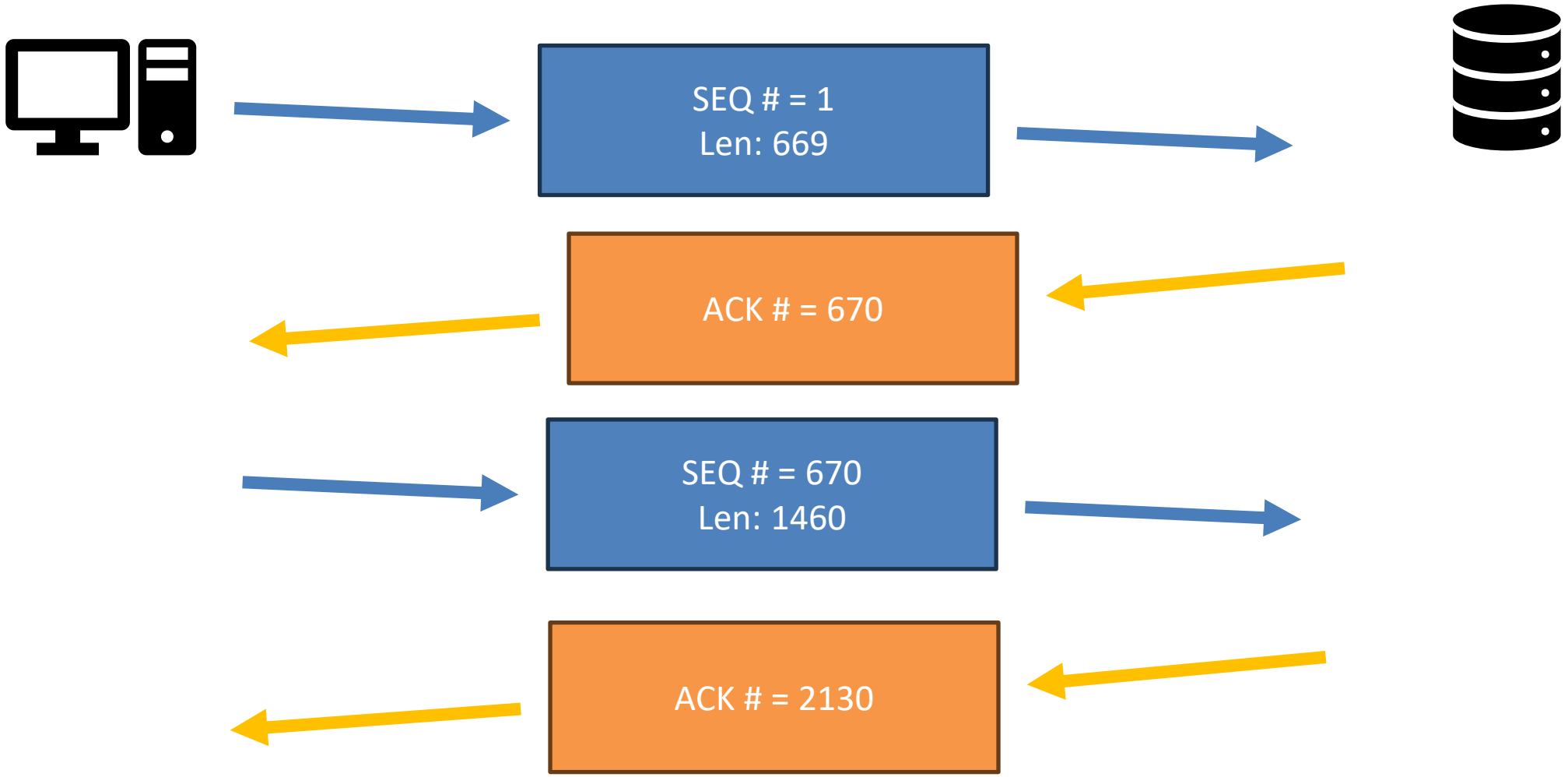
# TCP Sequence Numbers

A TCP connection is transmitting a **byte stream**



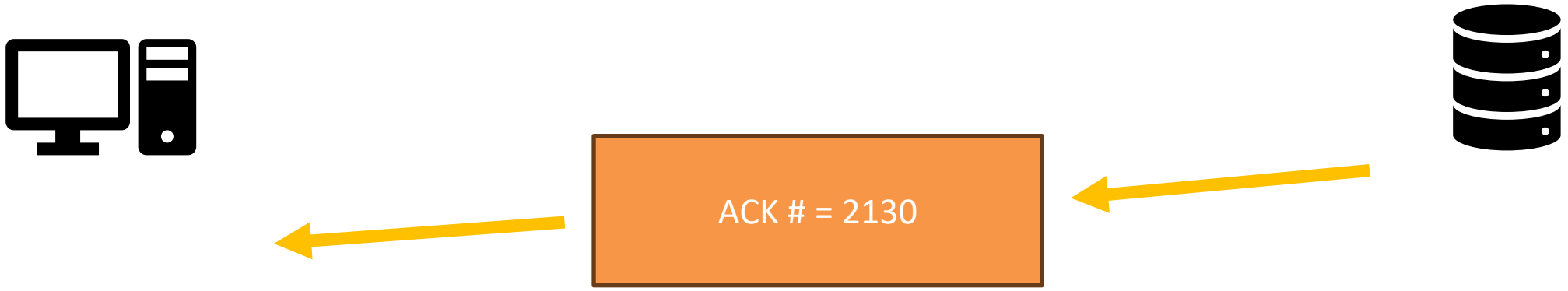
# TCP Sequence Numbers

A TCP connection is transmitting a **byte stream**



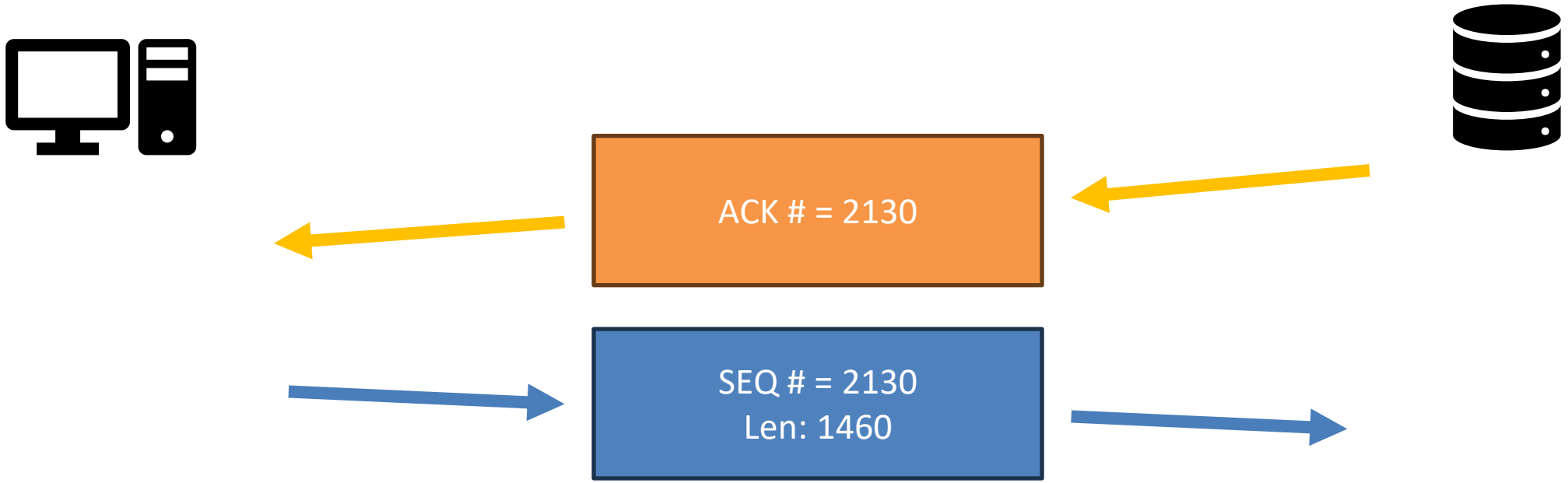
# TCP Sequence Numbers

A TCP connection is transmitting a **byte stream**



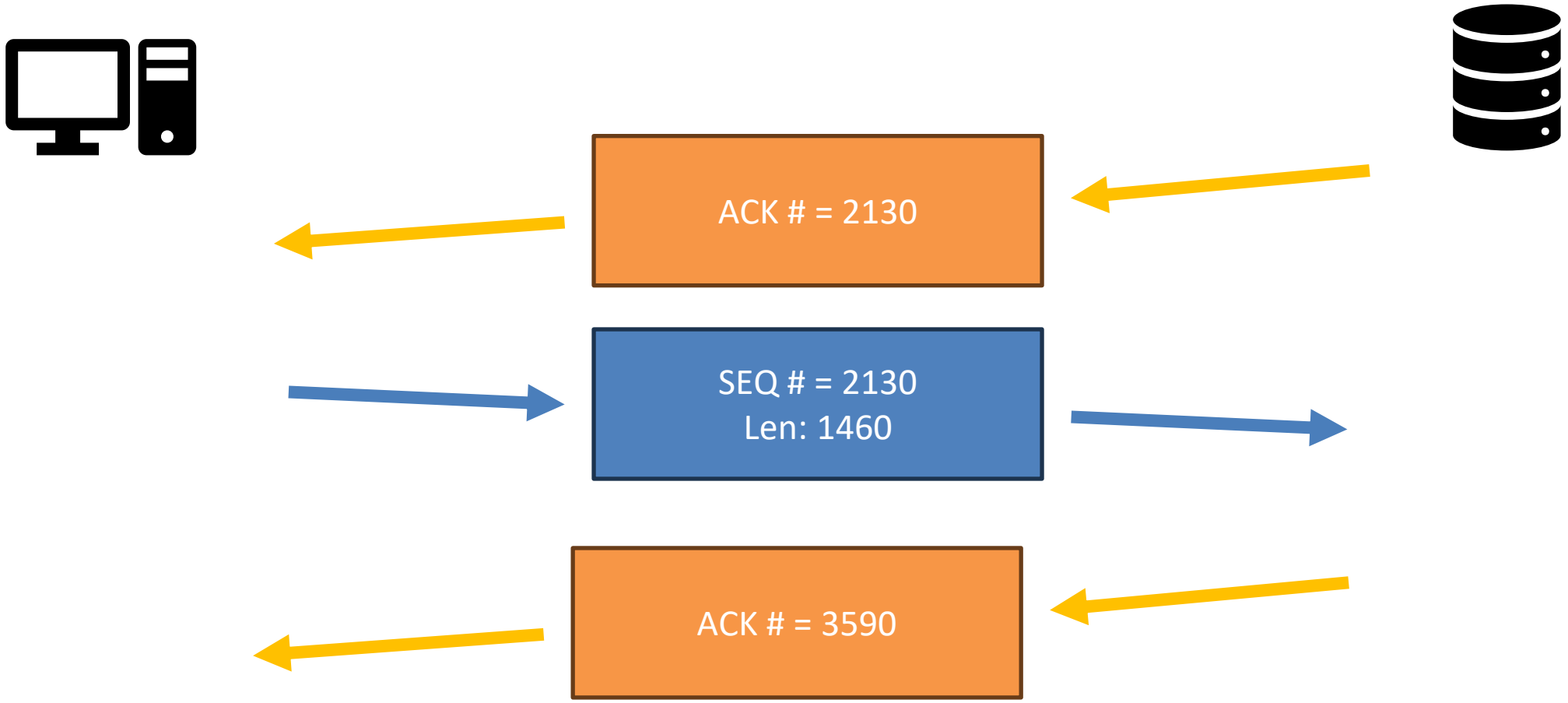
# TCP Sequence Numbers

A TCP connection is transmitting a **byte stream**



# TCP Sequence Numbers

A TCP connection is transmitting a **byte stream**



# TCP Sequence Numbers