



UNIVERSITY OF  
CALGARY

# TCP Sequence Number Plots

Carey Williamson

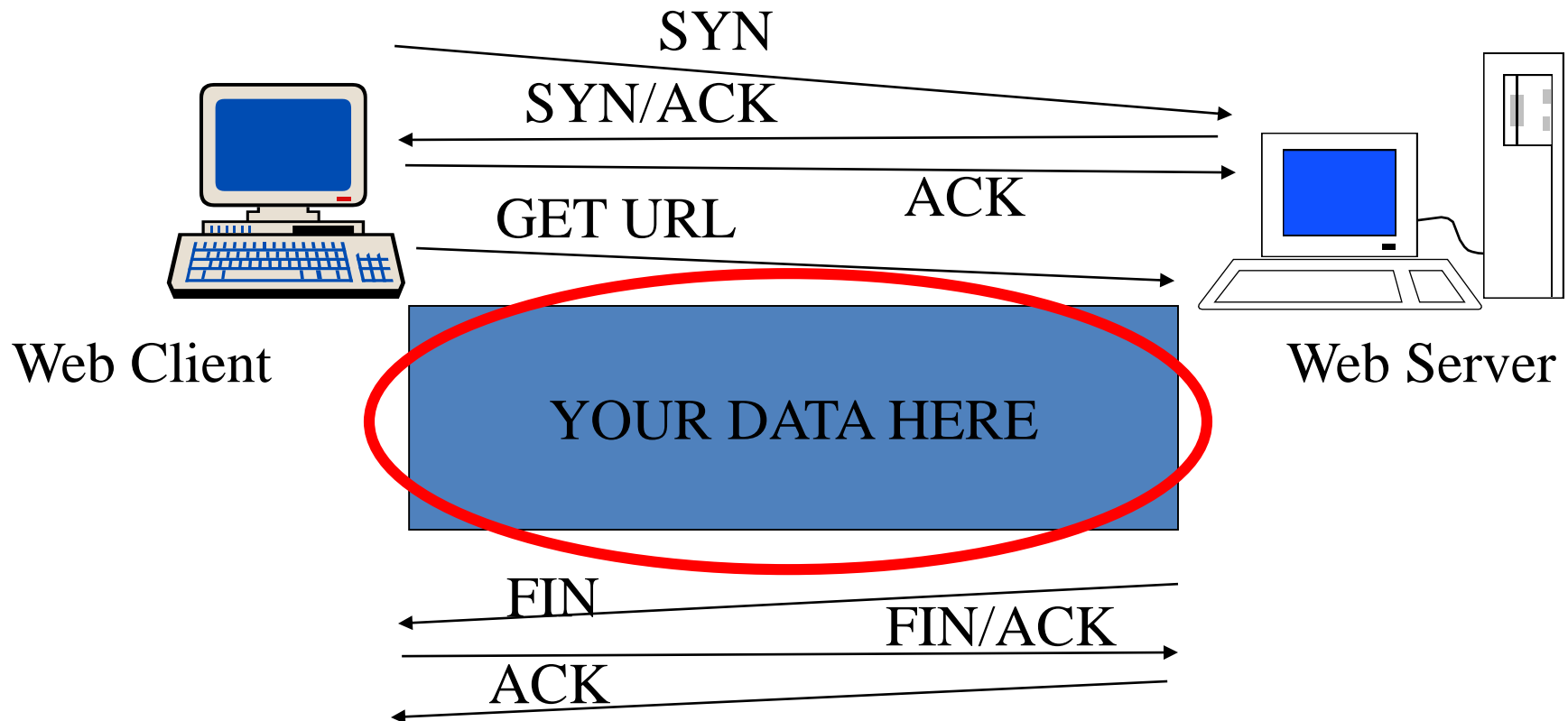
Department of Computer Science

University of Calgary

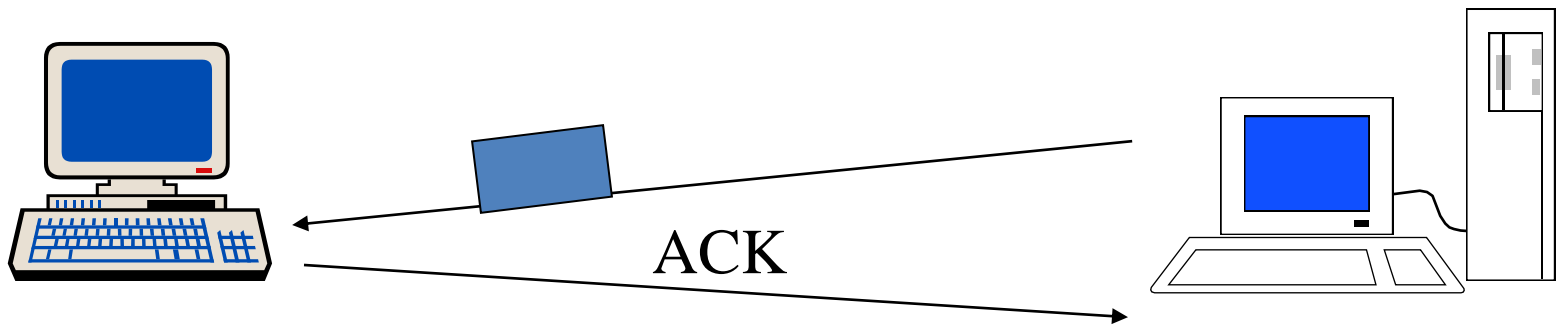
- The Transmission Control Protocol (TCP) is the protocol that sends your data reliably
- Used for email, Web, ftp, telnet, p2p,...
- Makes sure that data is received correctly: right data, right order, exactly once
- Detects and recovers from any problems that occur at the IP network layer
- Mechanisms for reliable data transfer: sequence numbers, acknowledgements, timers, retransmissions, flow control...

“TCP is the four-wheel drive of transport-layer protocols. It can go anywhere, but sometimes it is a pretty bumpy ride!”

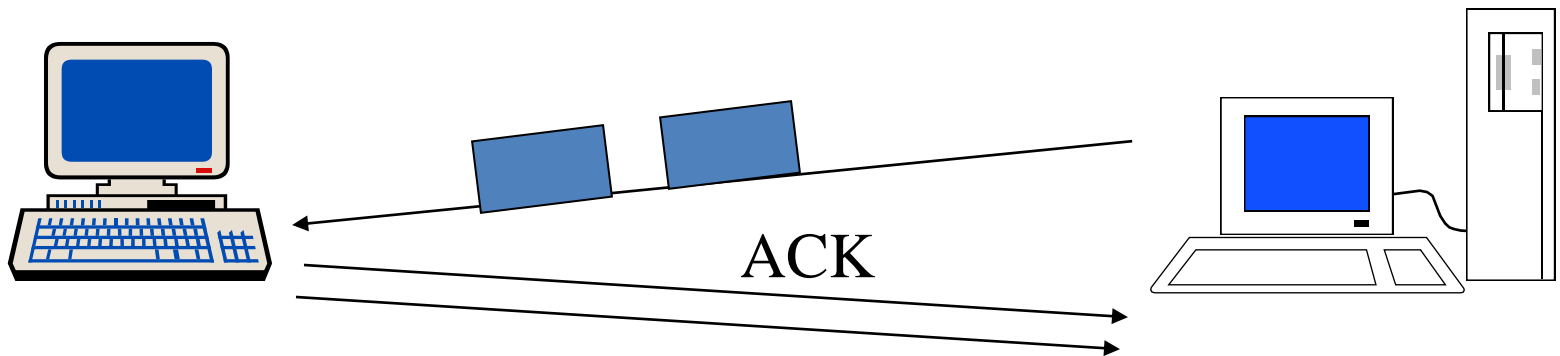
- TCP is a connection-oriented protocol



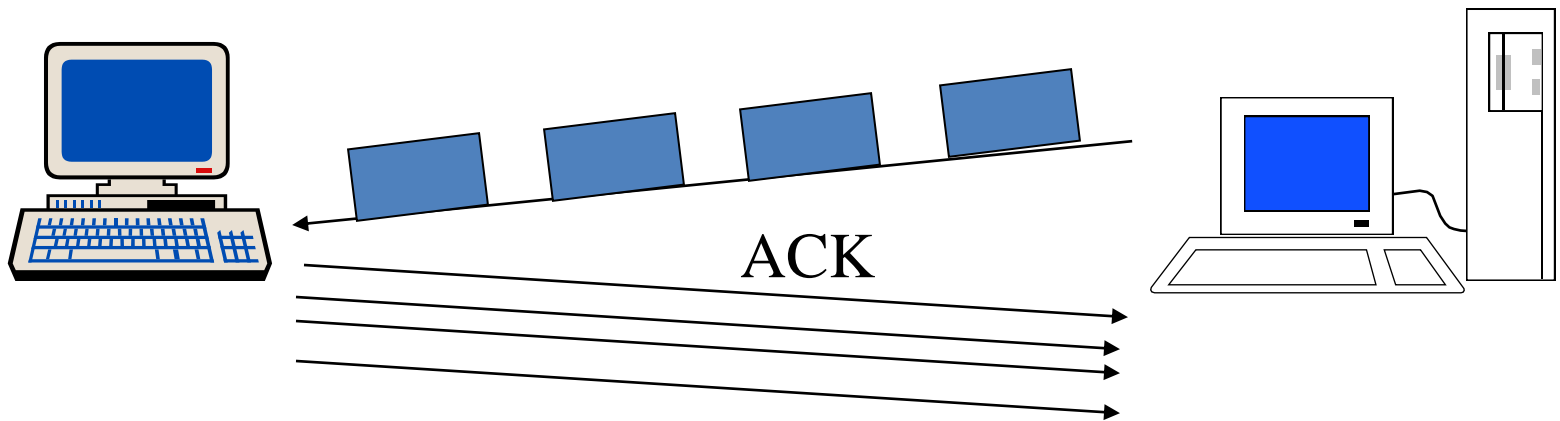
- TCP slow-start and congestion avoidance



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- This (exponential growth) “slow start” process continues until either:
  - **packet loss**: after a brief recovery phase, you enter a (linear growth) “congestion avoidance” phase based on slow-start threshold found
  - **limit reached**: slow-start threshold, or maximum advertised receive window size
  - **all done**: terminate connection and go home

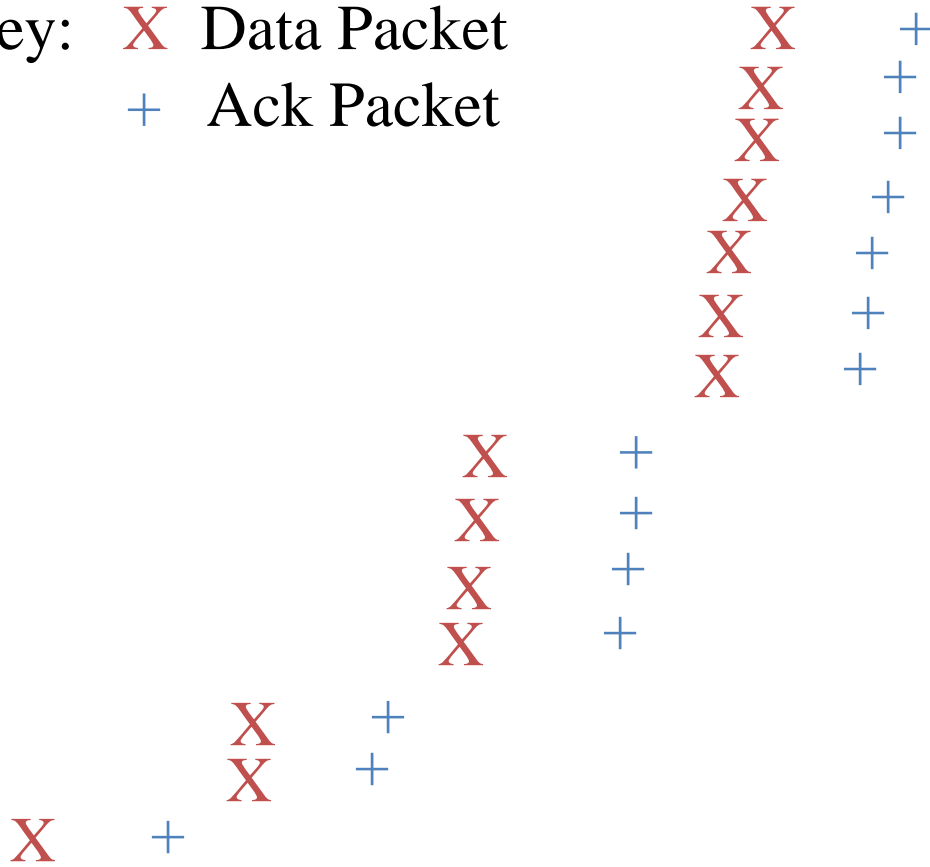
- There is a beautiful way to plot and visualize the dynamics of TCP behaviour
- Called a “TCP Sequence Number Plot”
- Plot packet events (data and acks) as points in 2-D space, with time on the horizontal axis, and sequence number on the vertical axis
- Example: 20 KB Web page (14 packets)...





SeqNum

Key: X Data Packet  
+ Ack Packet



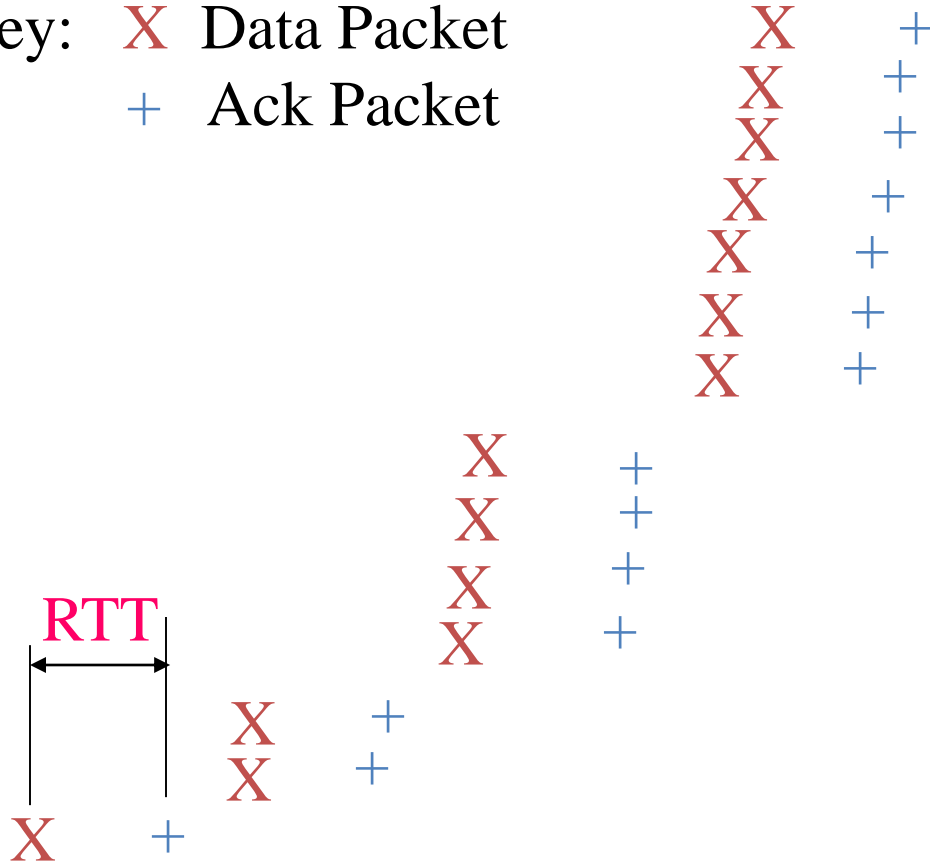
Time





# SeqNum

Key: X Data Packet  
+ Ack Packet

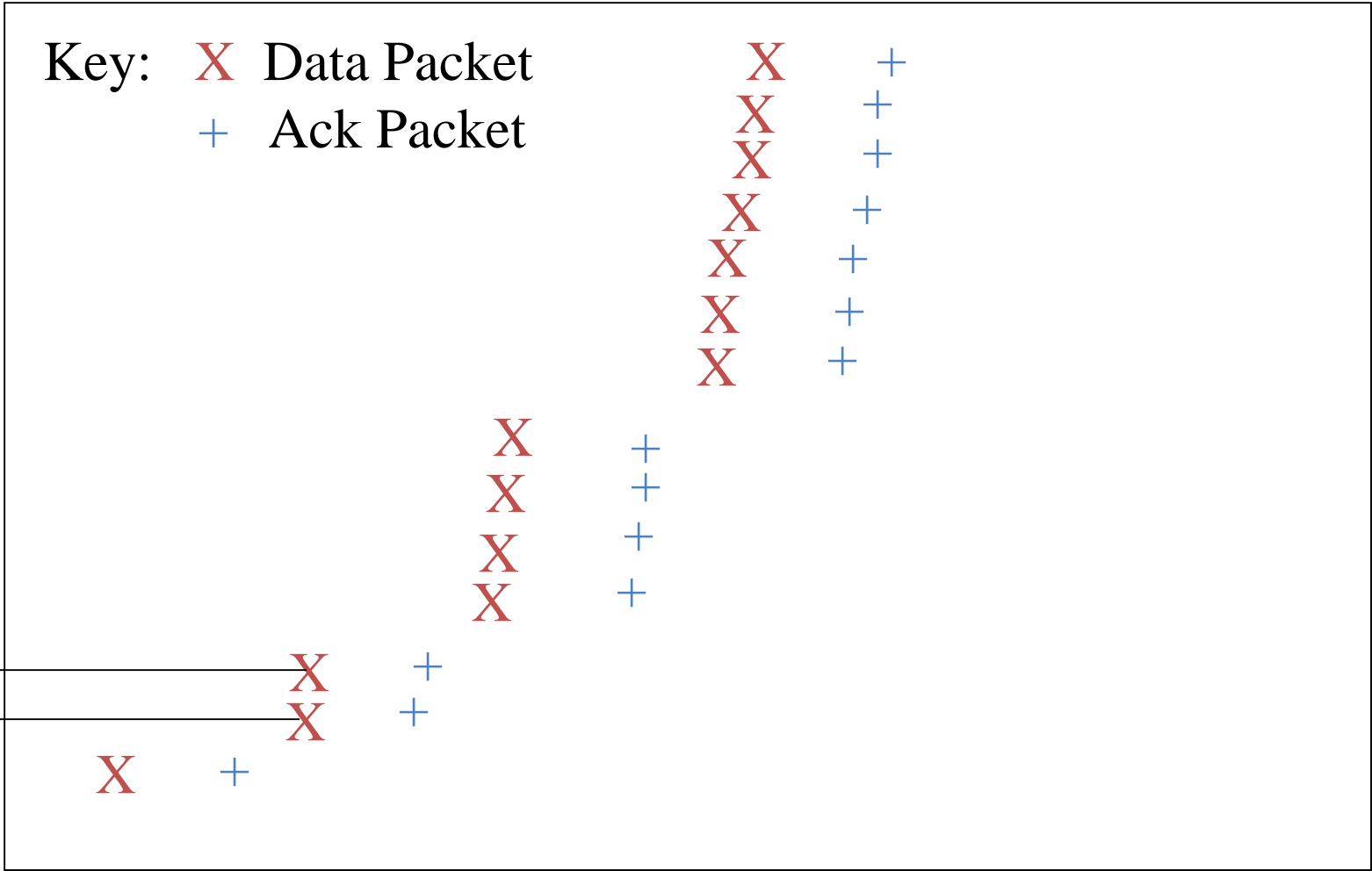




Key: X Data Packet  
+ Ack Packet

SeqNum

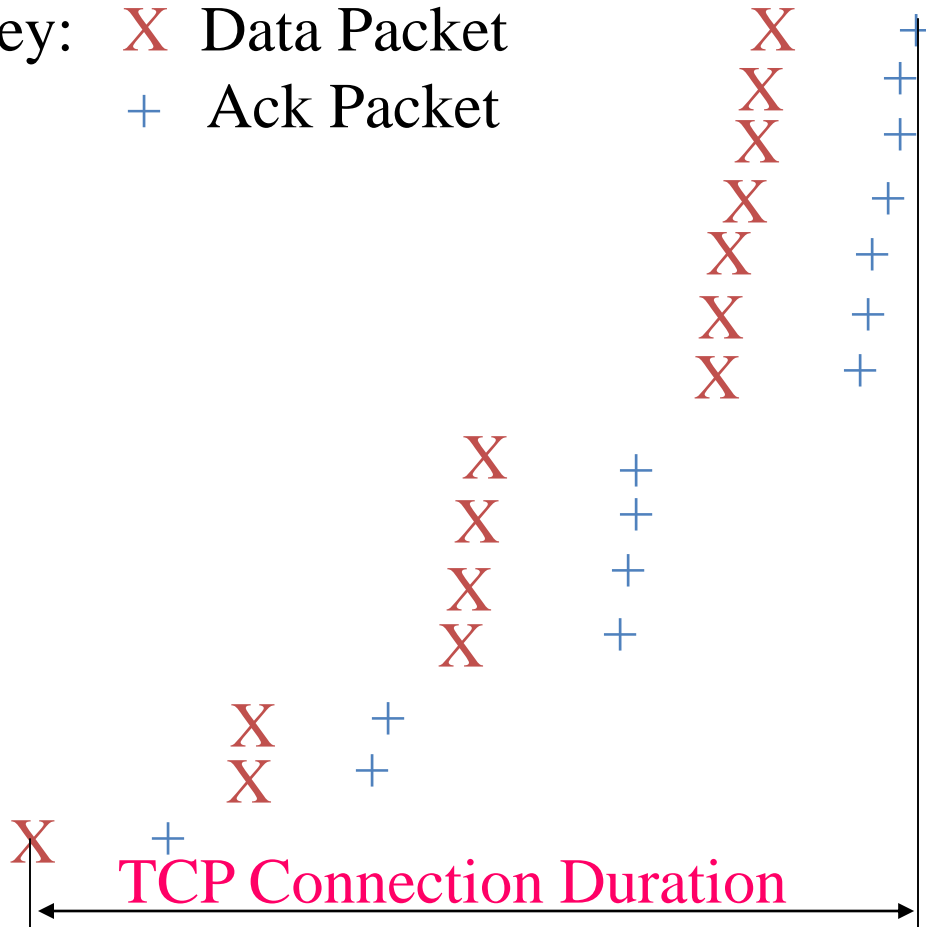
TCP  
Seg.  
Size

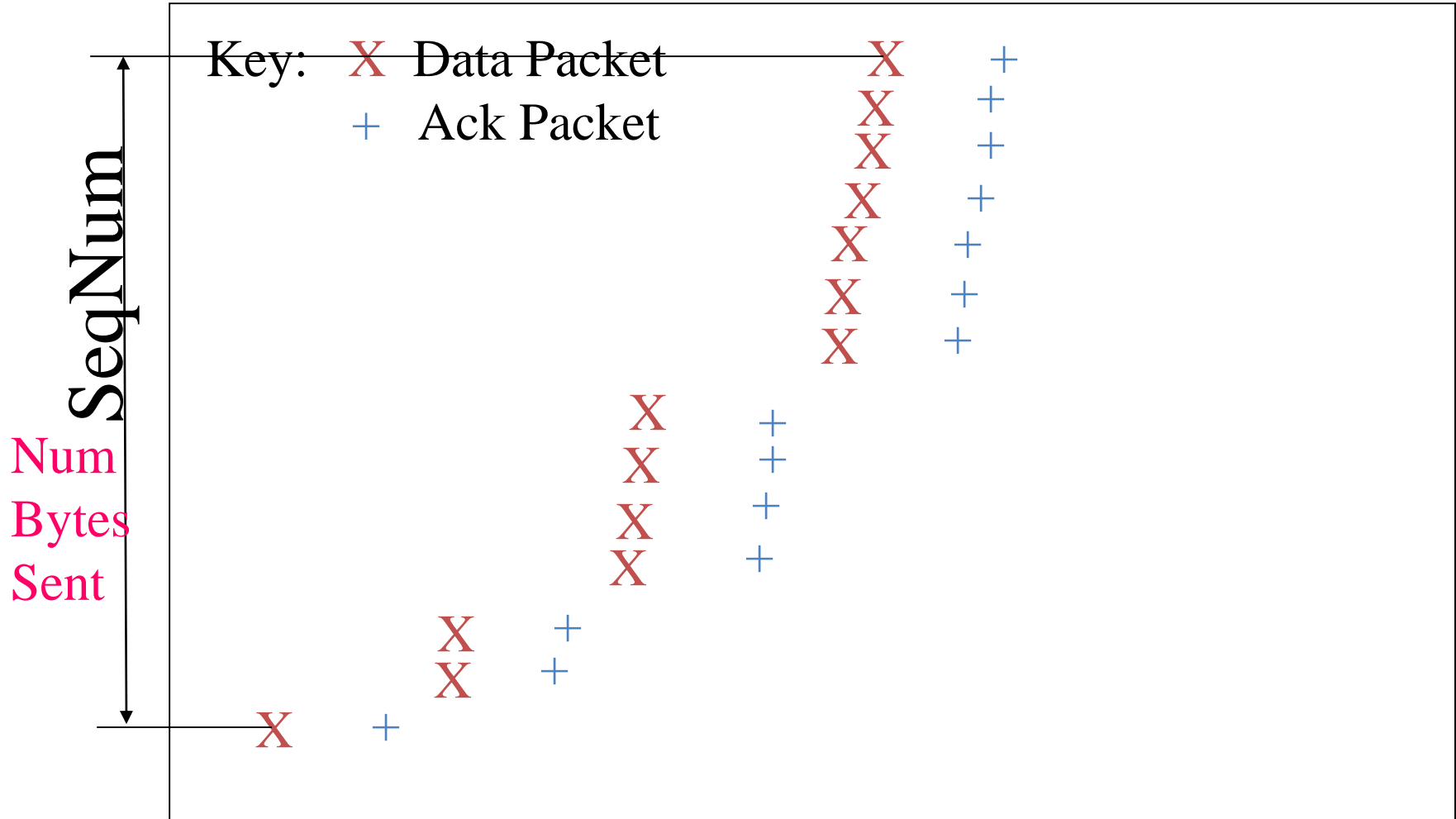




SeqNum

Key: X Data Packet  
+ Ack Packet



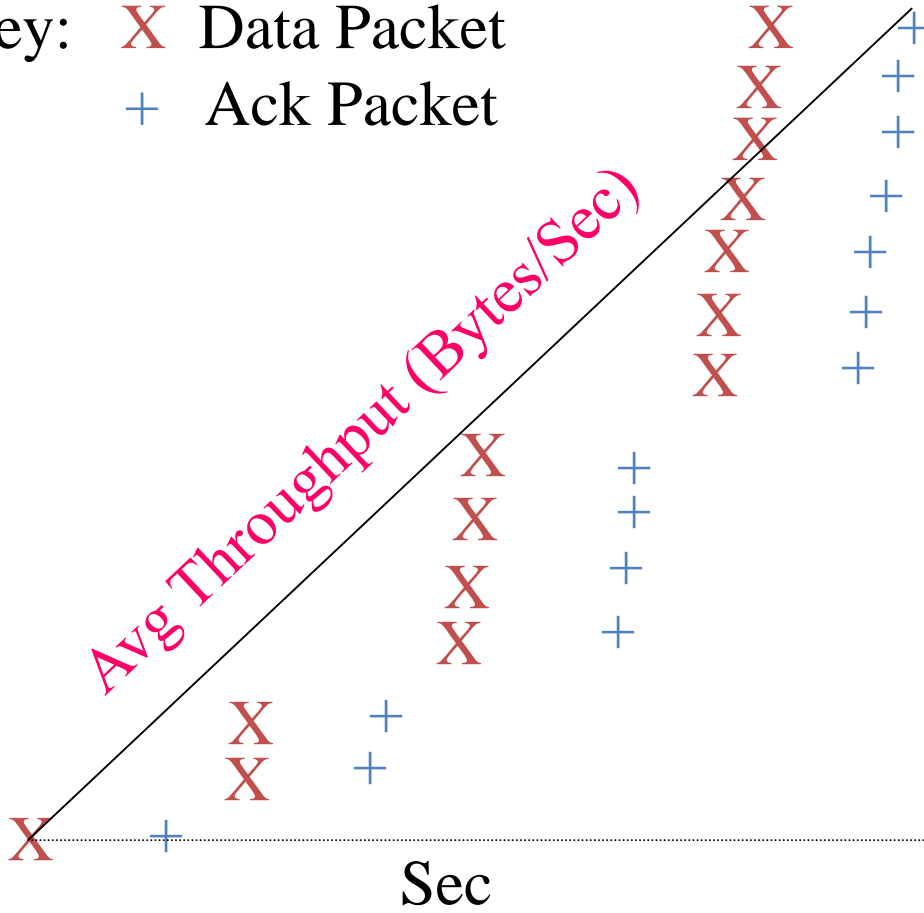




SeqNum

Key: X Data Packet  
+ Ack Packet

Avg Throughput (Bytes/Sec)



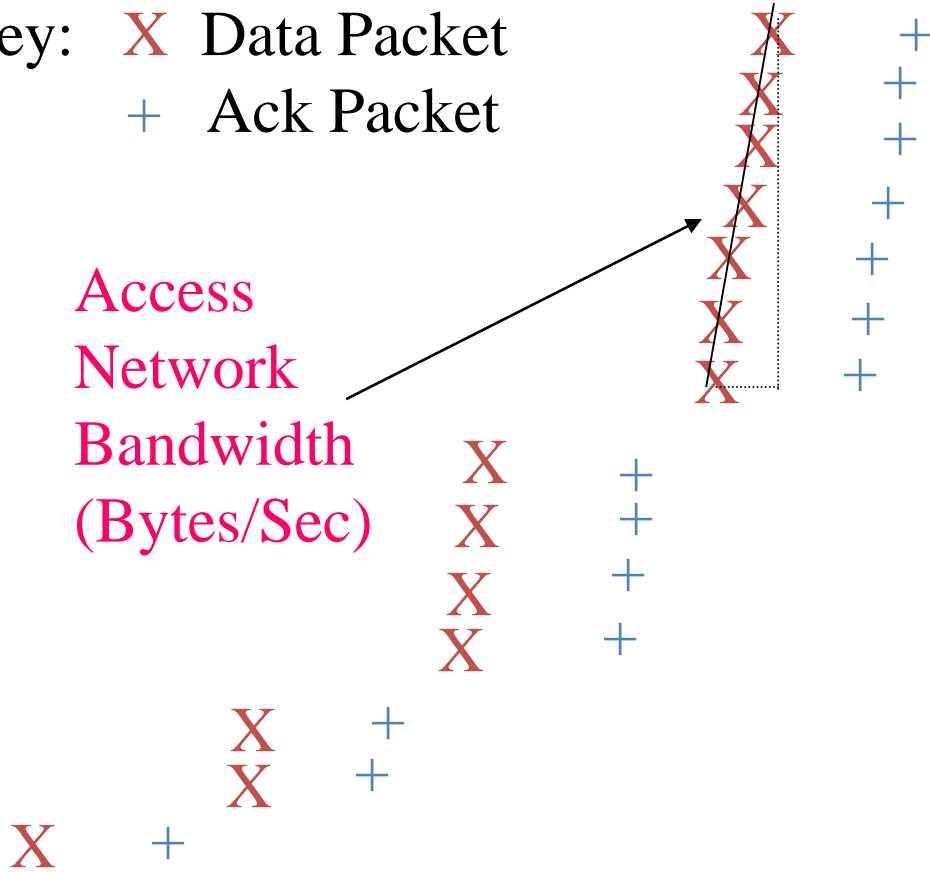
Bytes



# SeqNum

Key: X Data Packet  
+ Ack Packet

Access  
Network  
Bandwidth  
(Bytes/Sec)

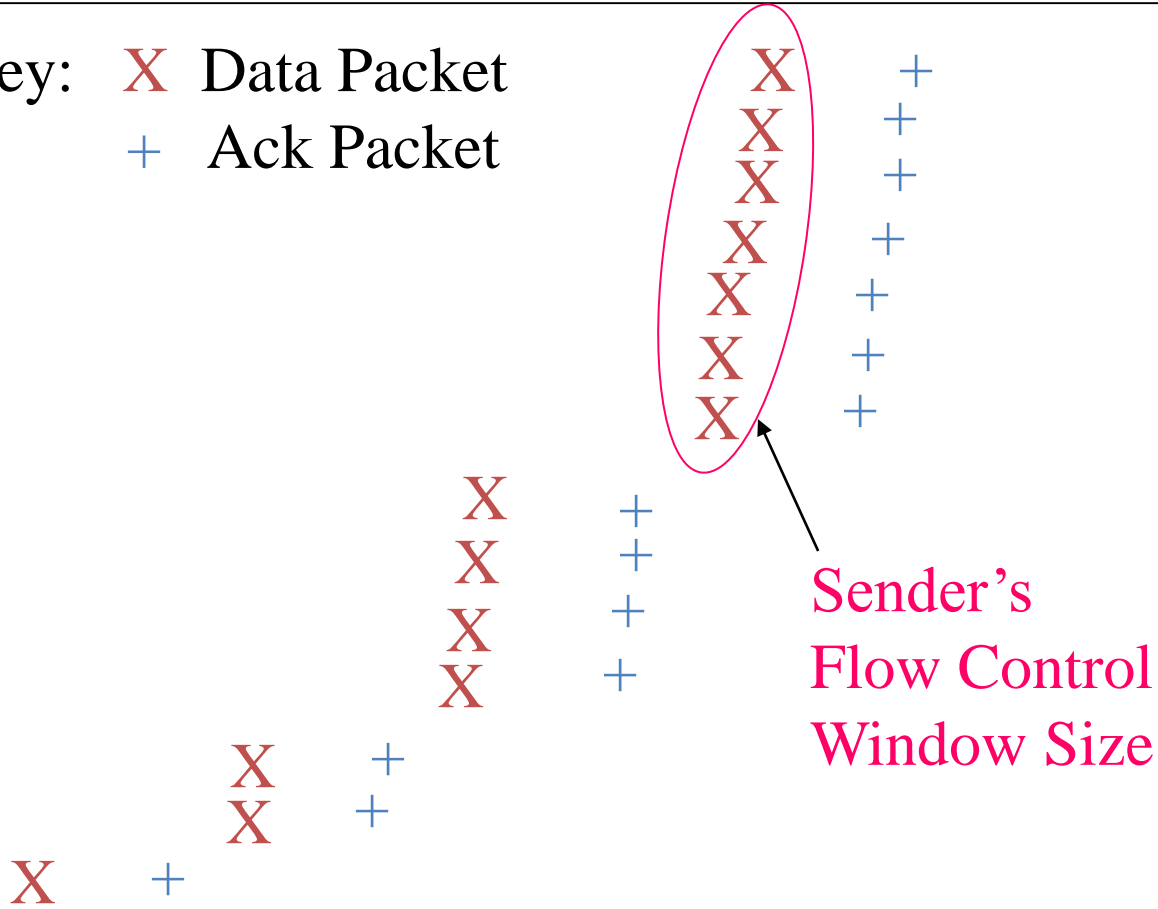






SeqNum

Key: X Data Packet  
+ Ack Packet

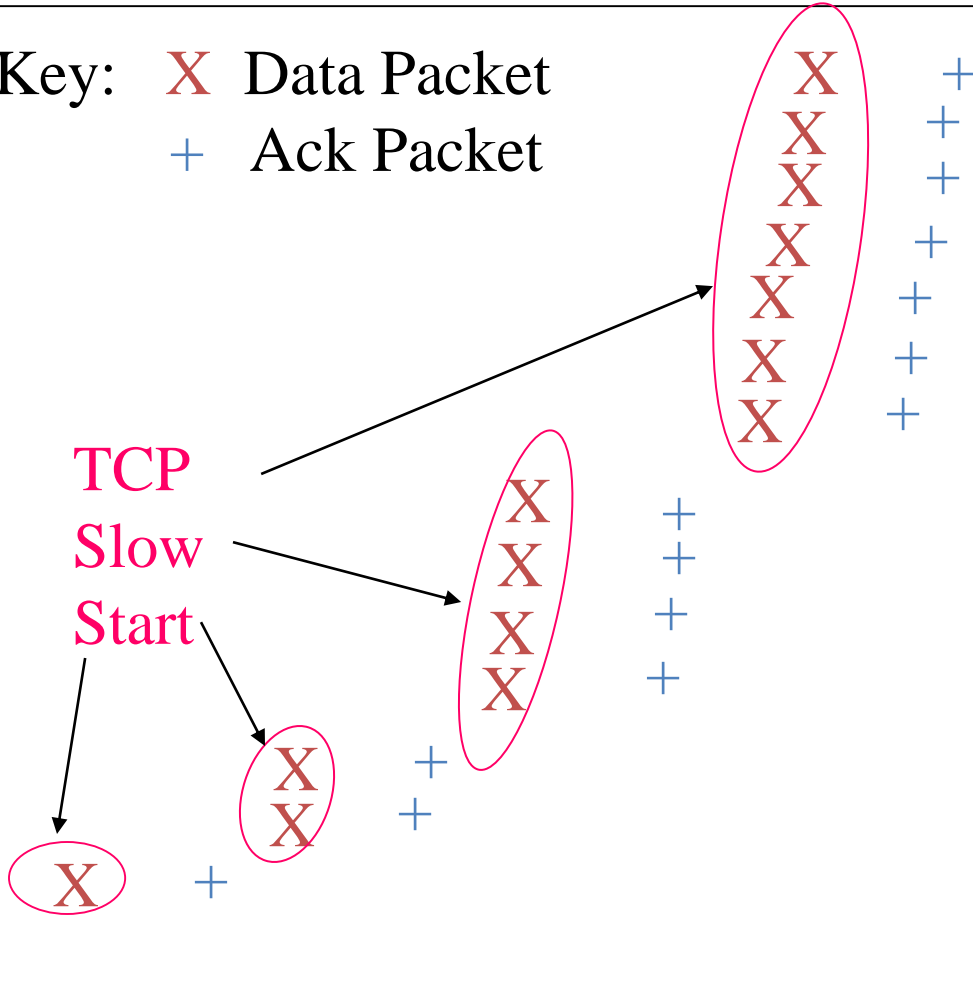




# SeqNum

Key: X Data Packet  
+ Ack Packet

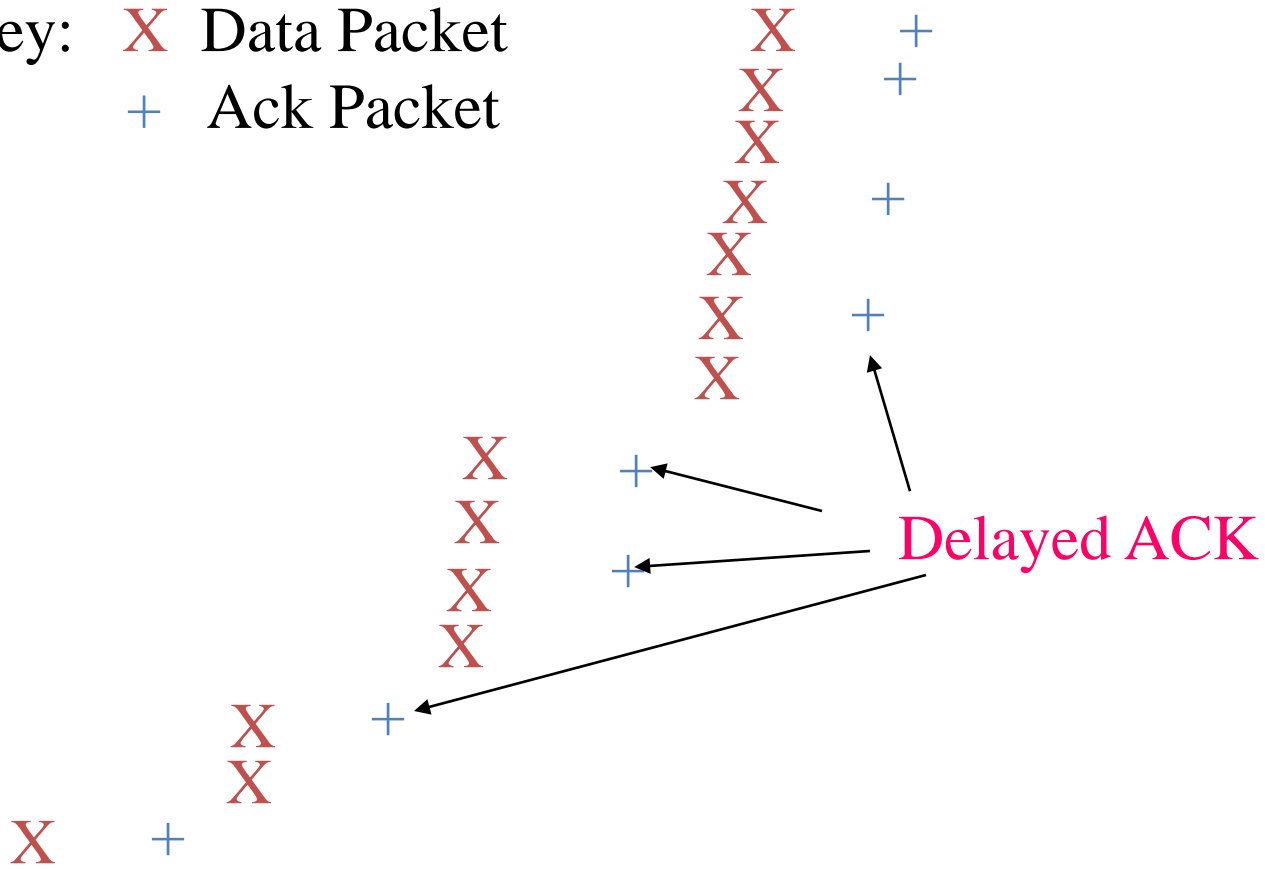
TCP  
Slow  
Start





SeqNum

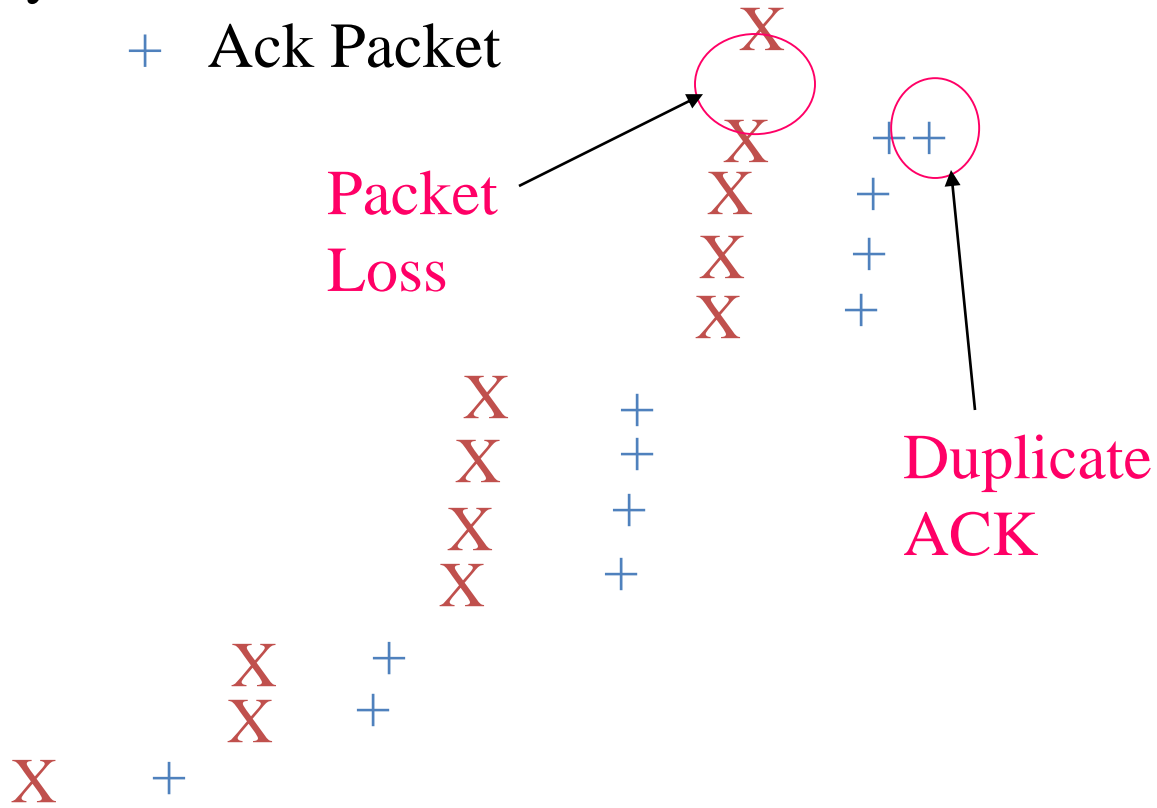
Key: X Data Packet  
+ Ack Packet





SeqNum

Key: X Data Packet  
+ Ack Packet

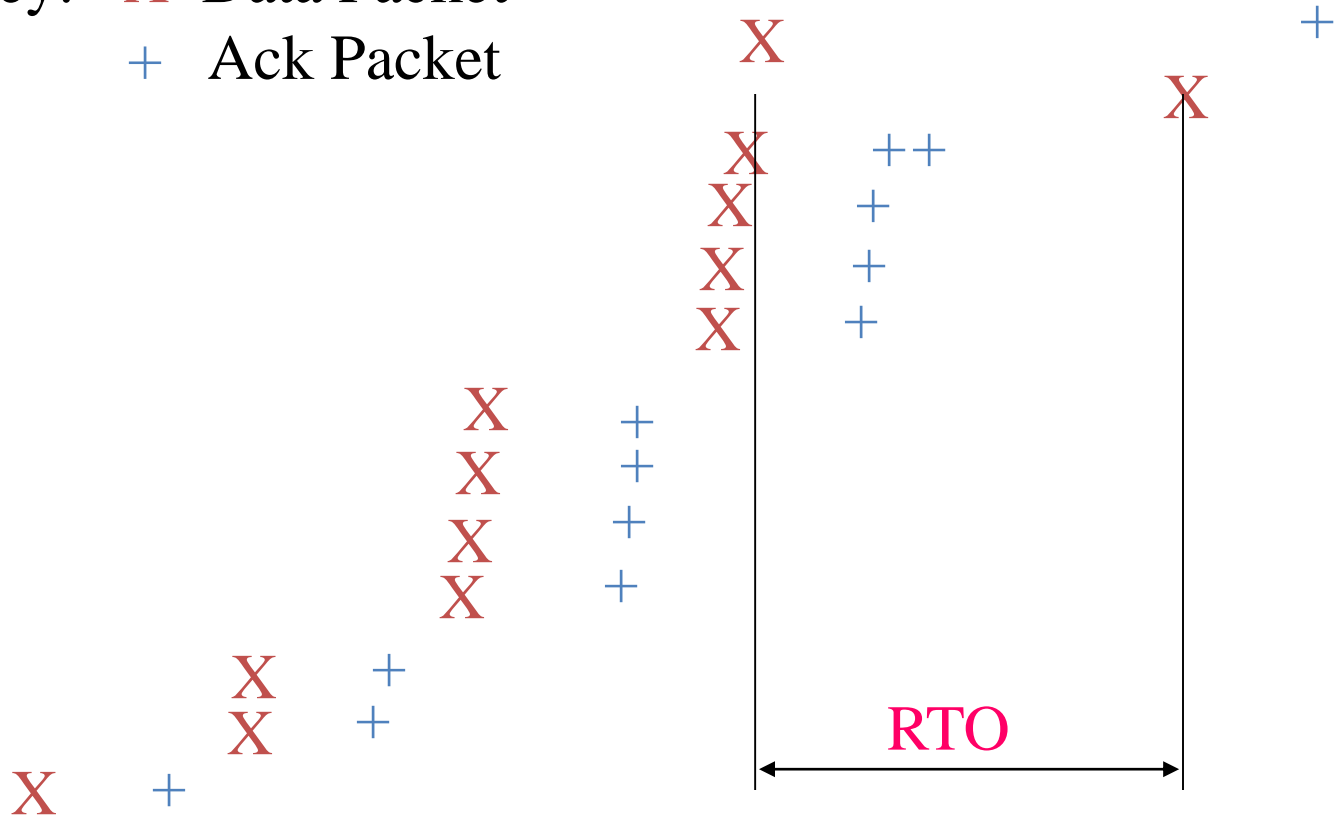






SeqNum

Key: X Data Packet  
+ Ack Packet



- What happens when a packet loss occurs?
- Quiz Time...
  - Consider a 14-packet Web document
  - For simplicity, consider only a single packet loss



SeqNum

Key: X Data Packet  
+ Ack Packet



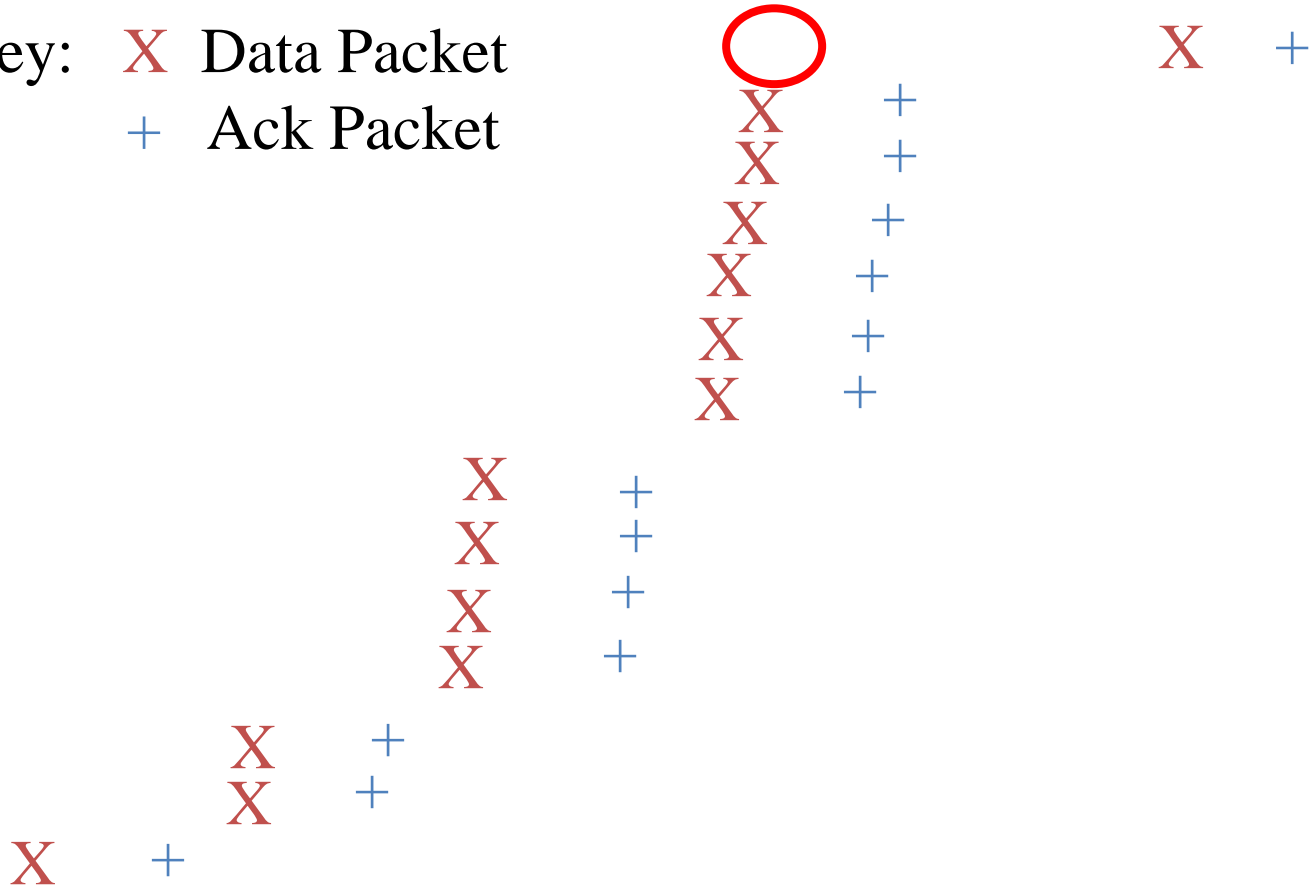






SeqNum

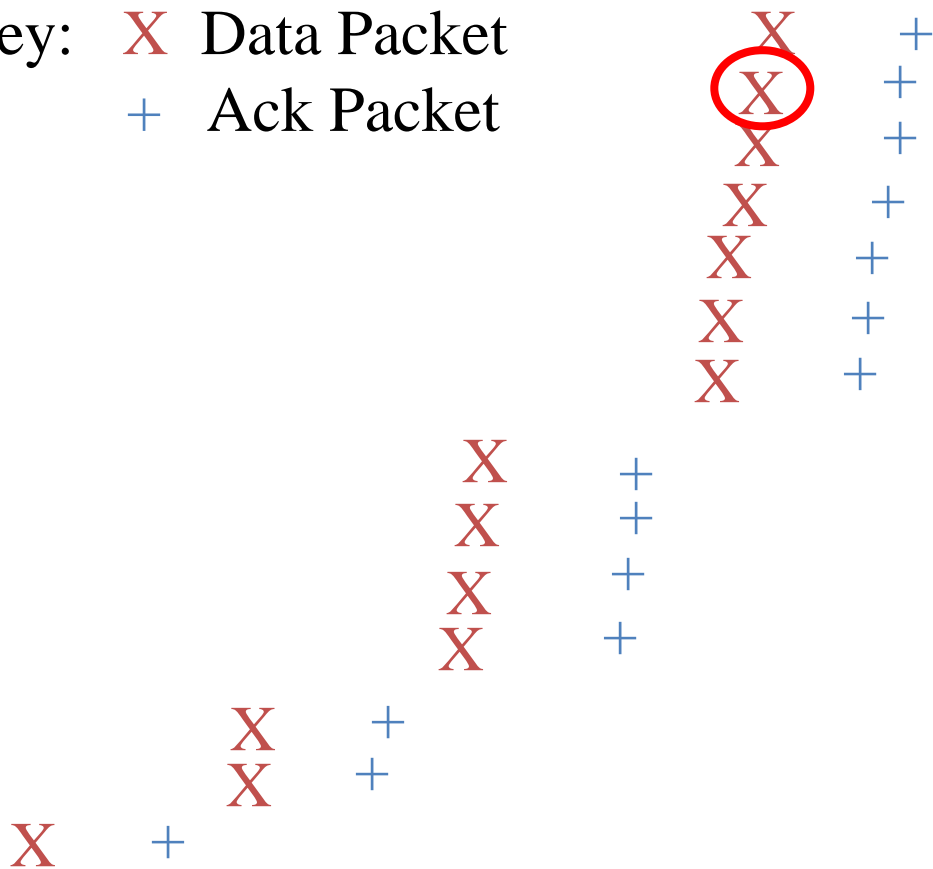
Key: X Data Packet  
+ Ack Packet





SeqNum

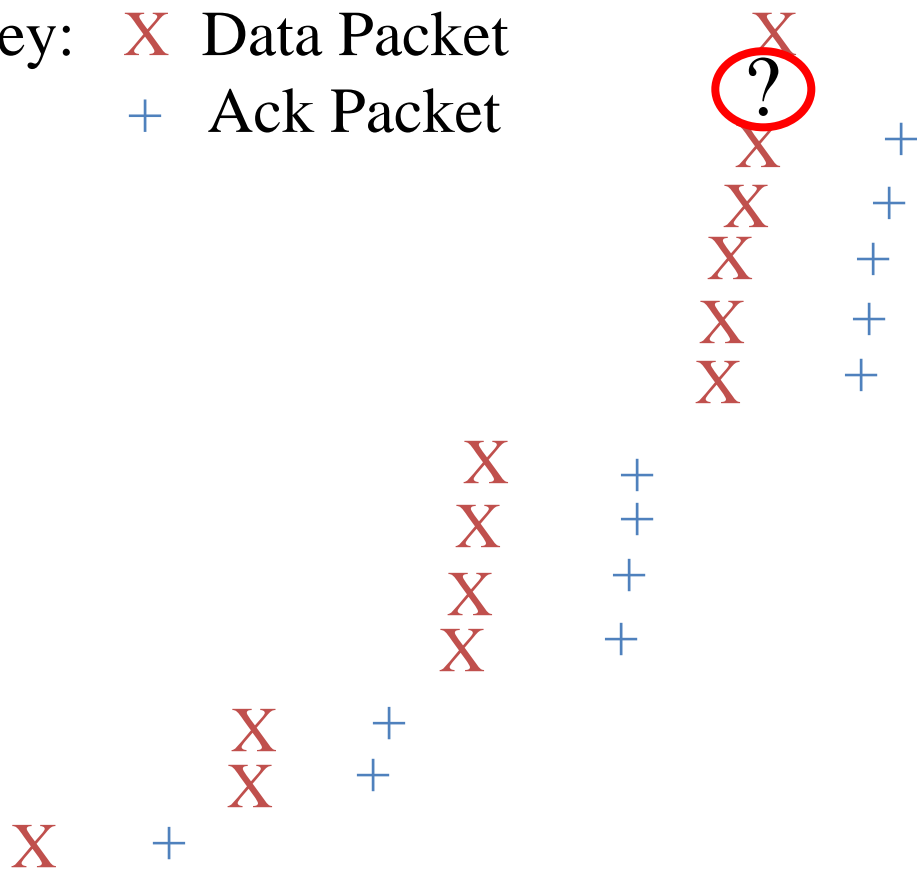
Key: X Data Packet  
+ Ack Packet





SeqNum

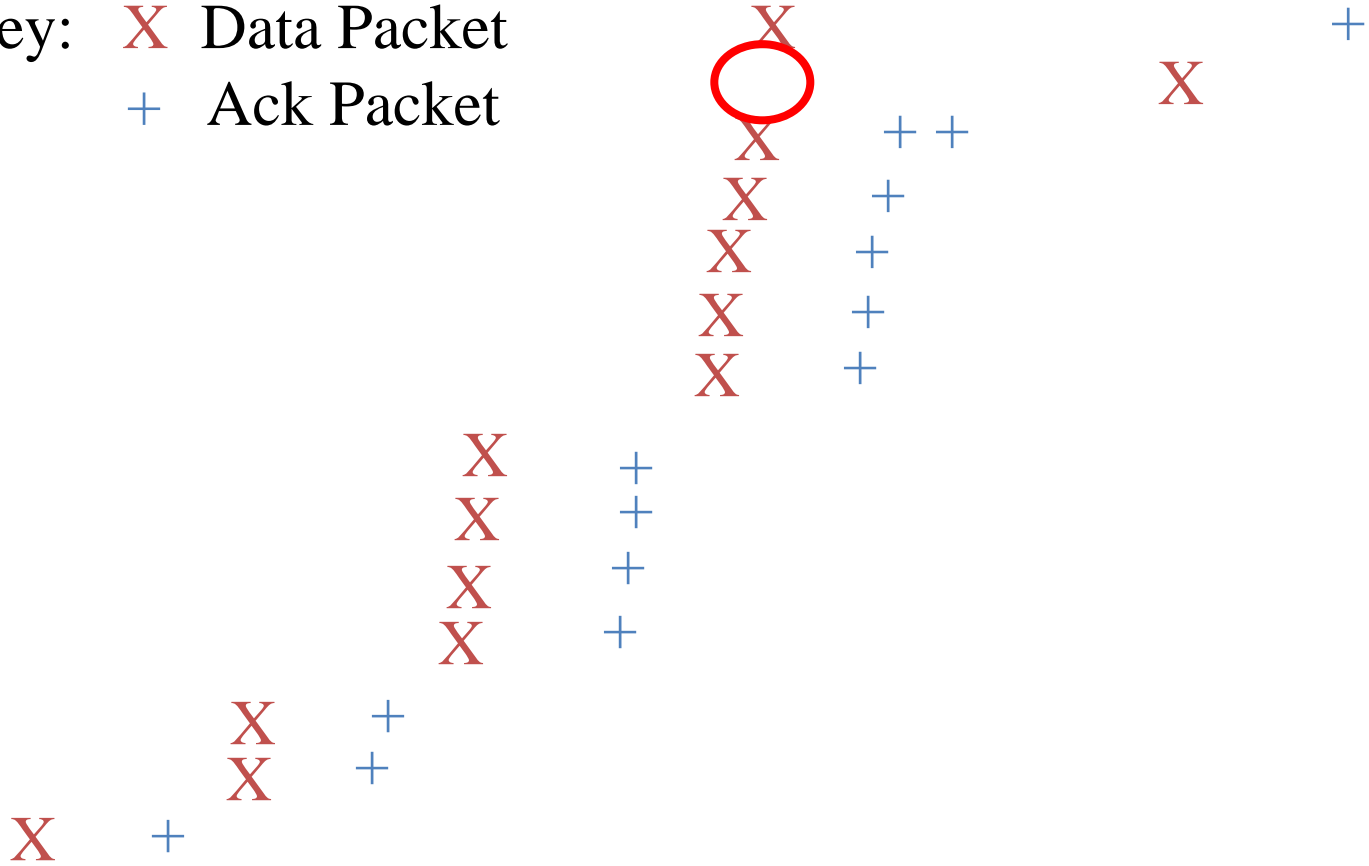
Key: **X** Data Packet  
 + Ack Packet





# SeqNum

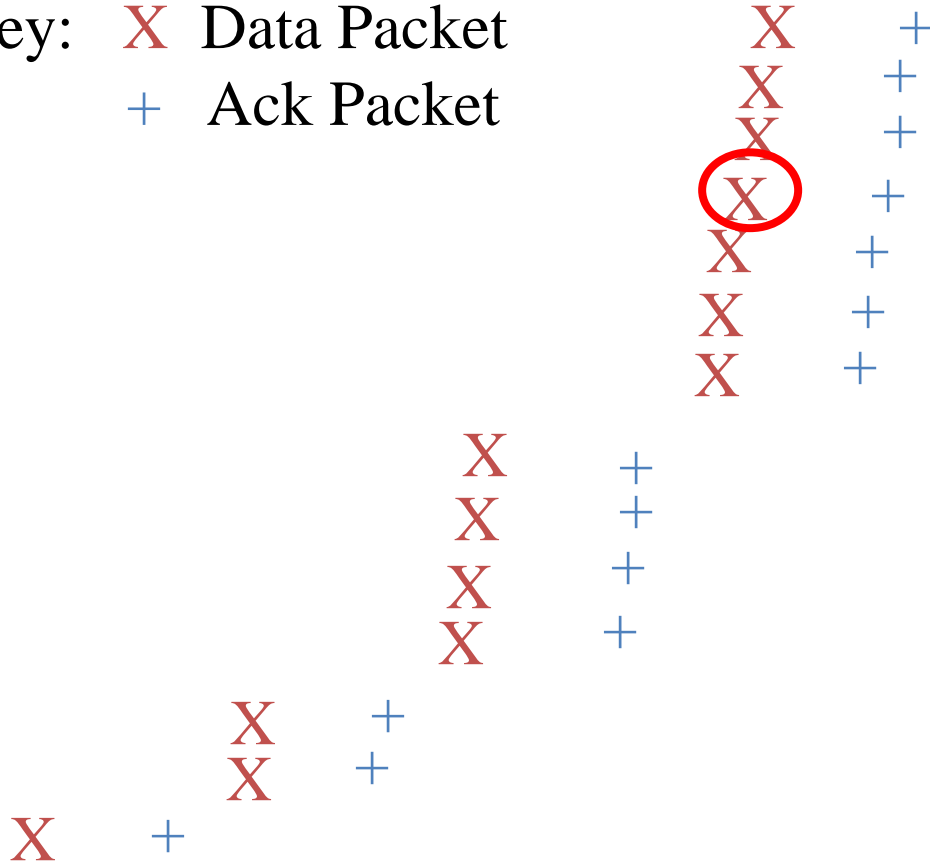
Key: X Data Packet  
+ Ack Packet





SeqNum

Key: X Data Packet  
+ Ack Packet

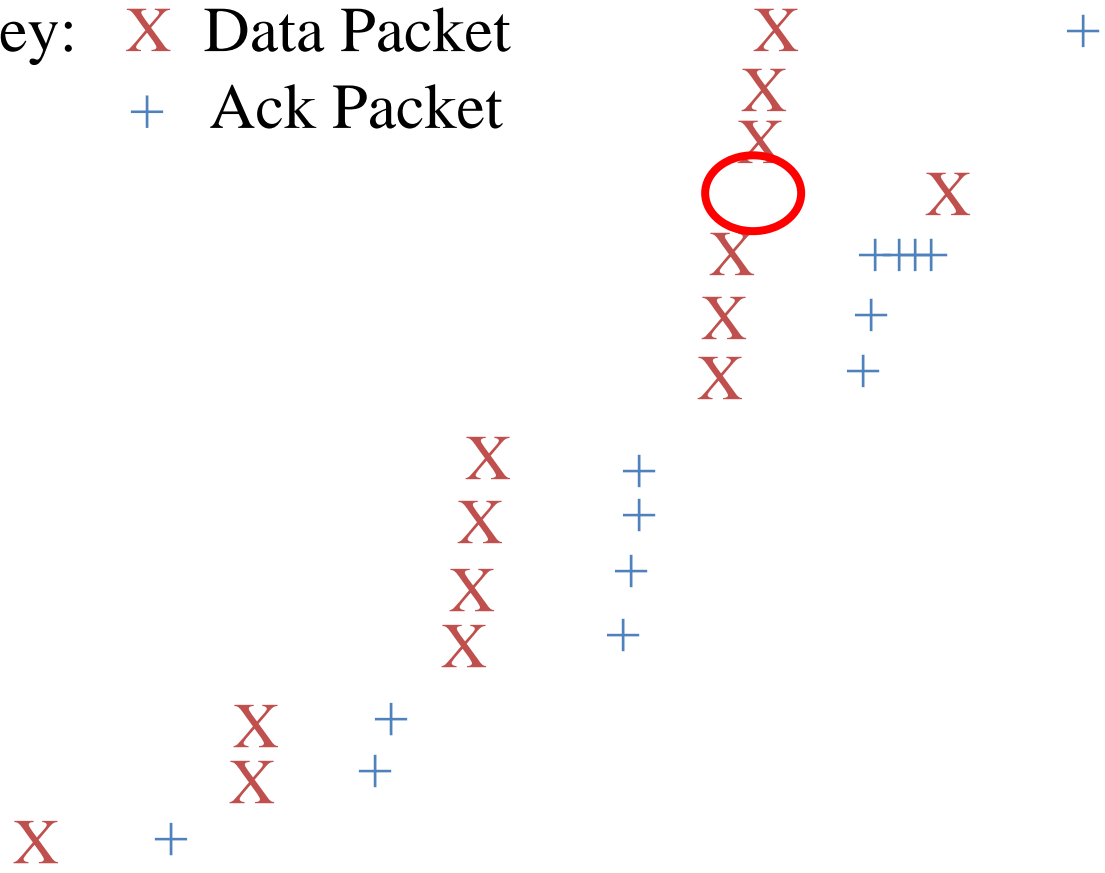






# SeqNum

Key: X Data Packet  
+ Ack Packet

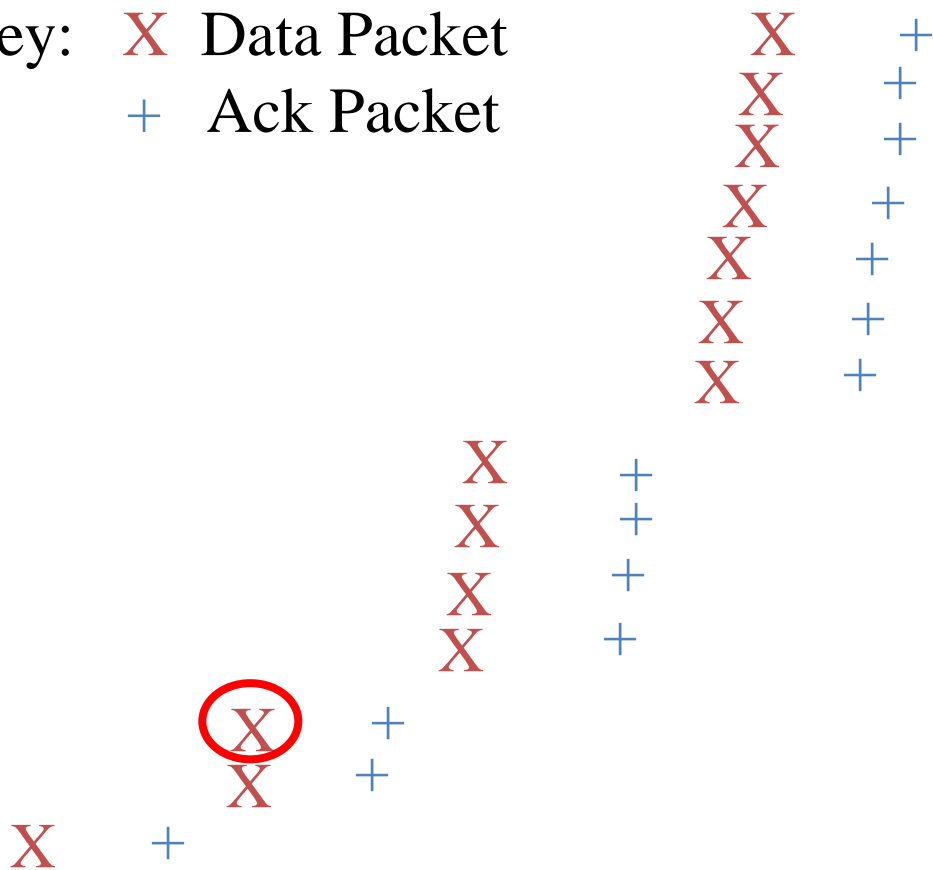






SeqNum

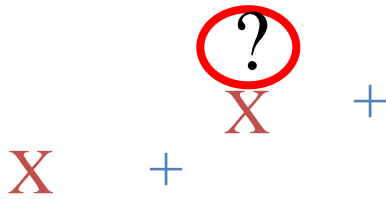
Key: X Data Packet  
+ Ack Packet





SeqNum

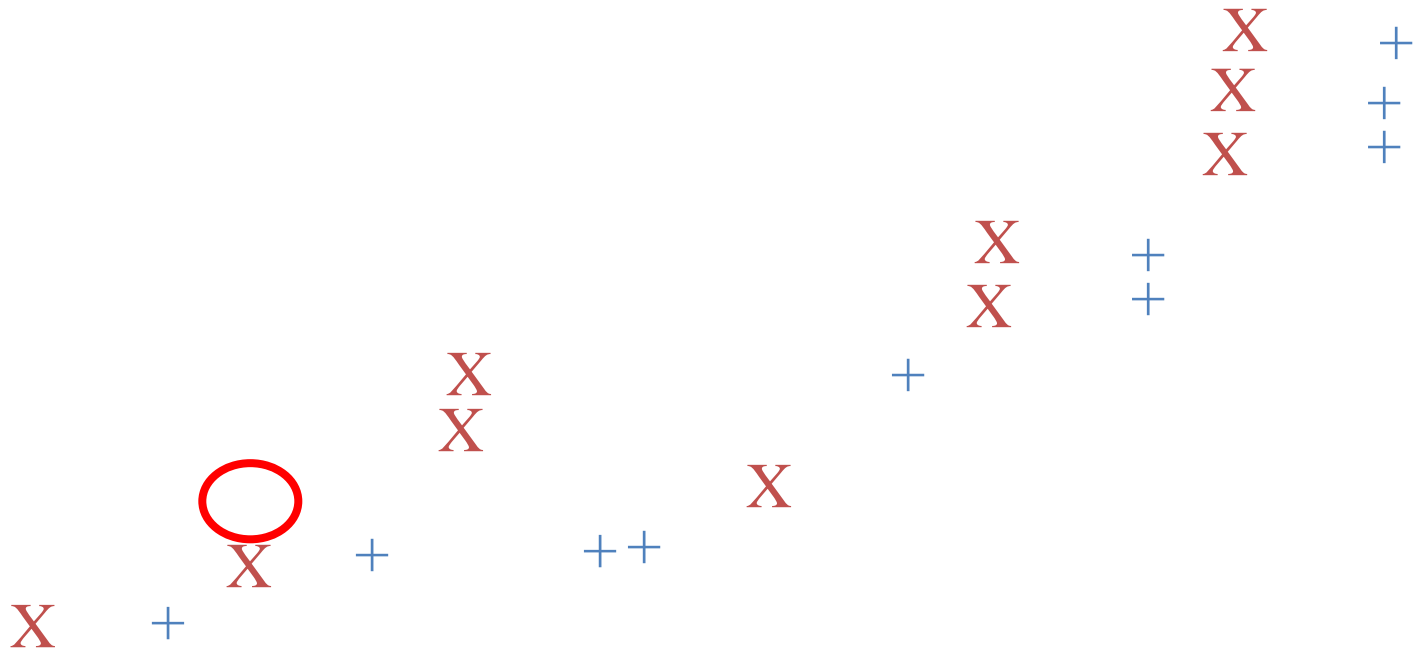
Key: X Data Packet  
+ Ack Packet





SeqNum

Key: X Data Packet  
+ Ack Packet



- Main observation:
  - “Not all packet losses are created equal” - CLW 2002
- Losses early in the transfer have a huge adverse impact on the transfer latency
- Losses near the end of the transfer always cost at least a retransmit timeout
- Losses in the middle may or may not hurt, depending on congestion window size at the time of the loss



- You are now a TCP expert!