TCP Sequence Number Plots

Carey Williamson
Department of Computer Science
University of Calgary
Winter 2018

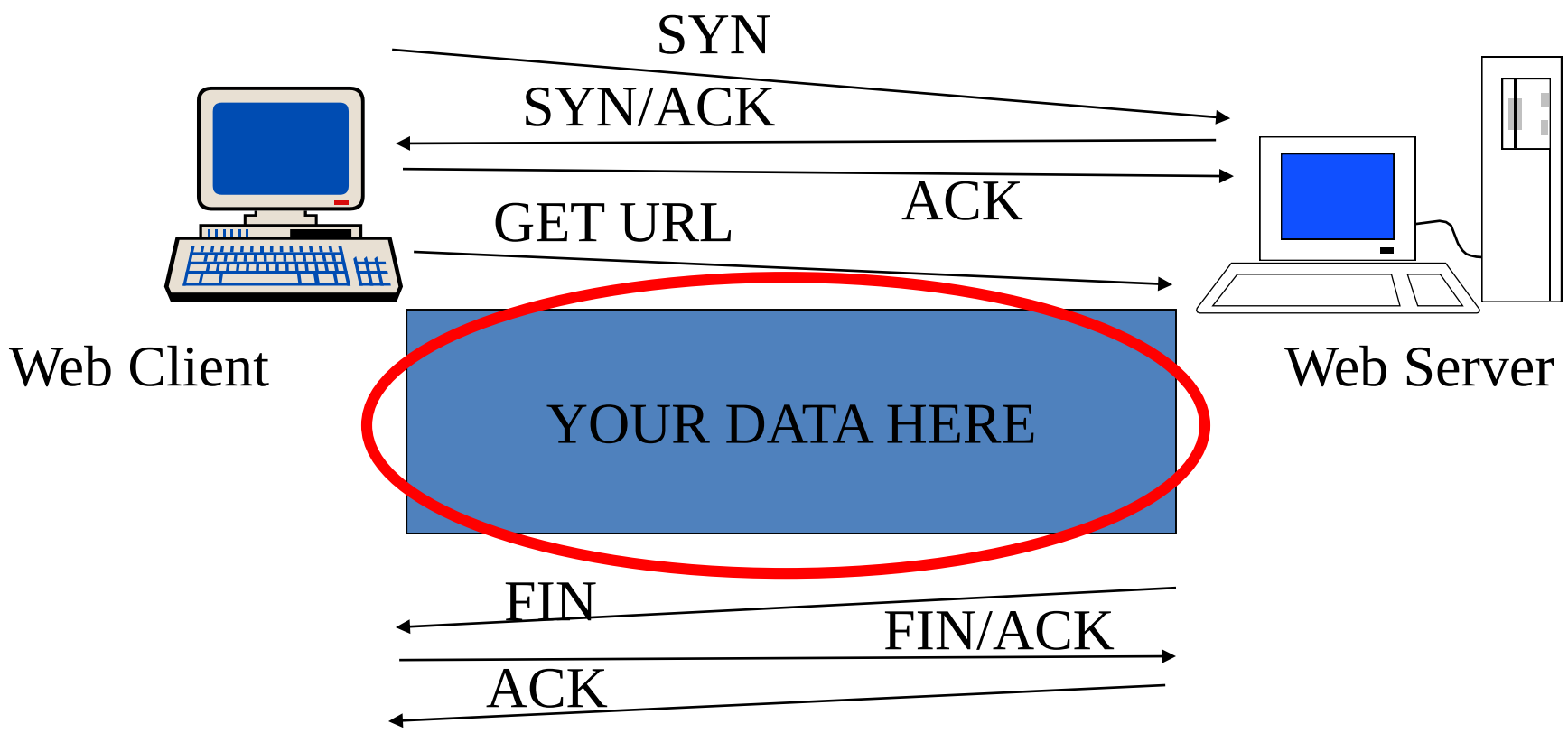
Tutorial: TCP 101

- 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!"

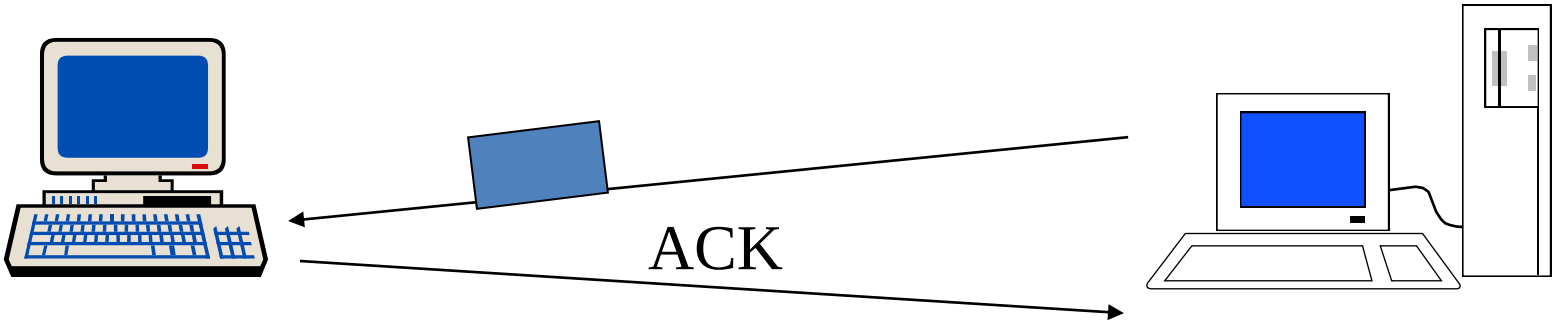
TCP 101 (Cont'd)

- TCP is a connection-oriented protocol



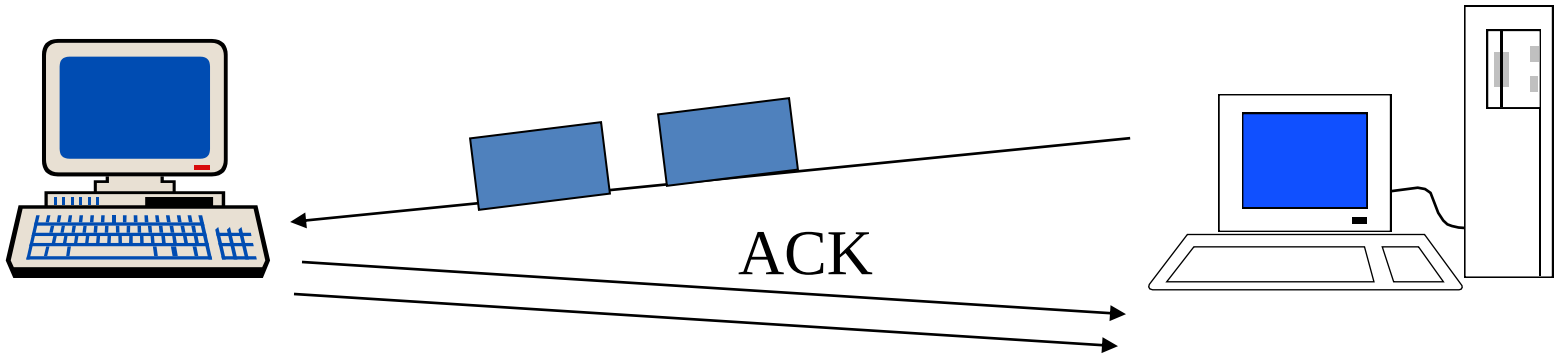
TCP 101 (Cont'd)

- TCP slow-start and congestion avoidance



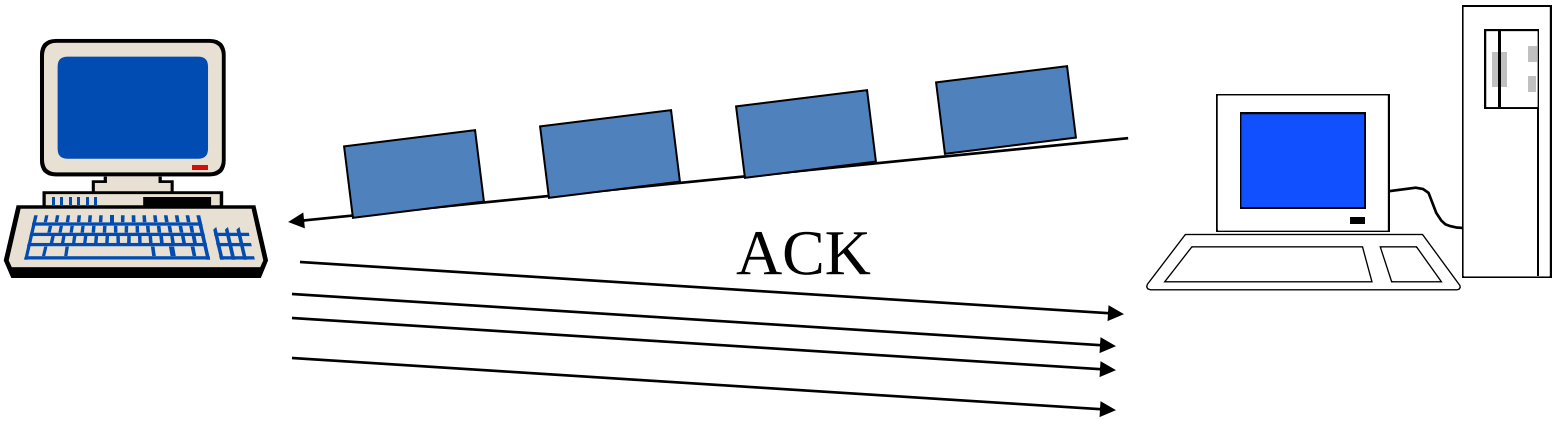
TCP 101 (Cont'd)

- TCP slow-start and congestion avoidance



TCP 101 (Cont'd)

- TCP slow-start and congestion avoidance

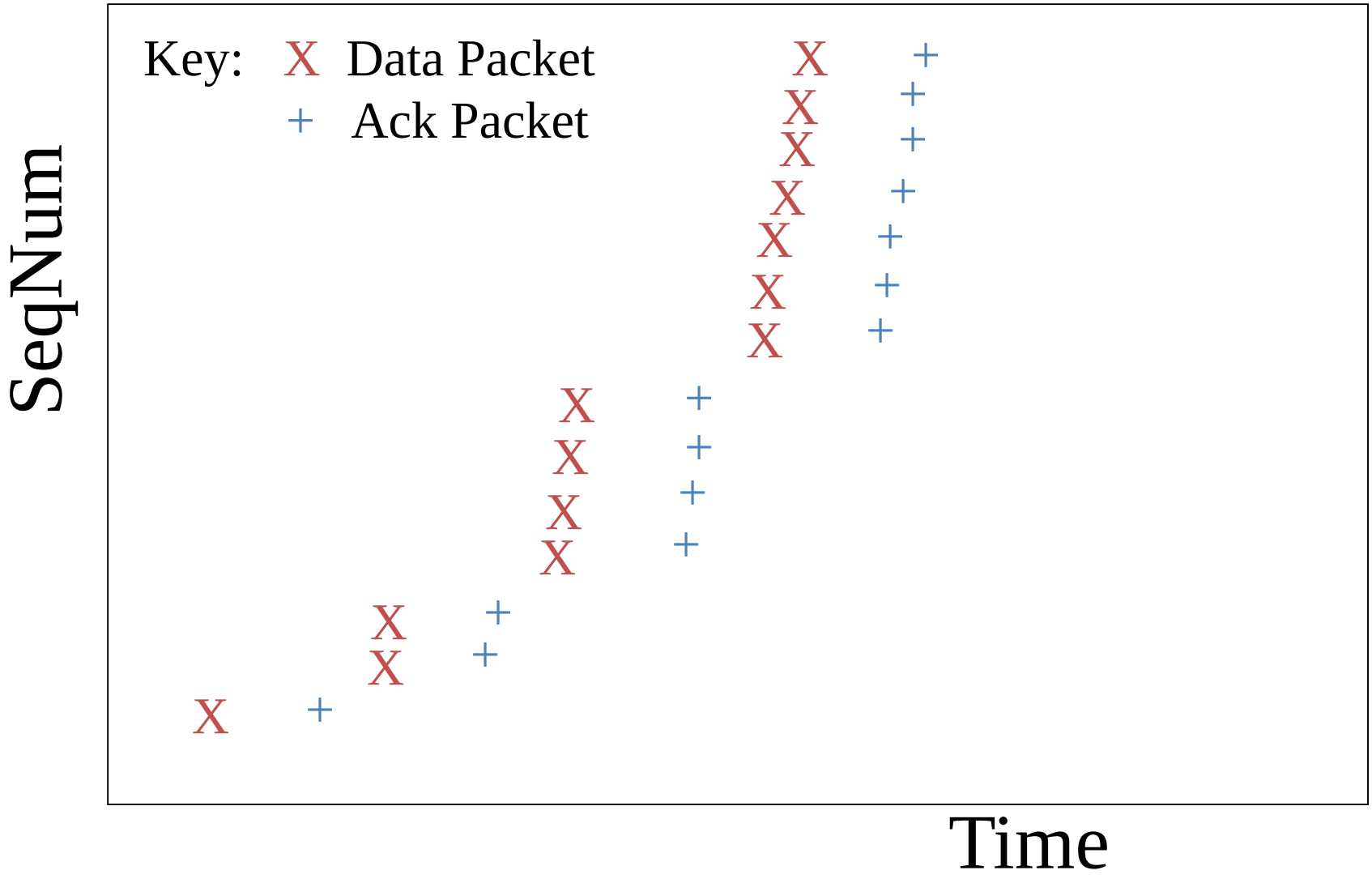


TCP 101 (Cont'd)

- 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

Tutorial: TCP 201

- 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)…

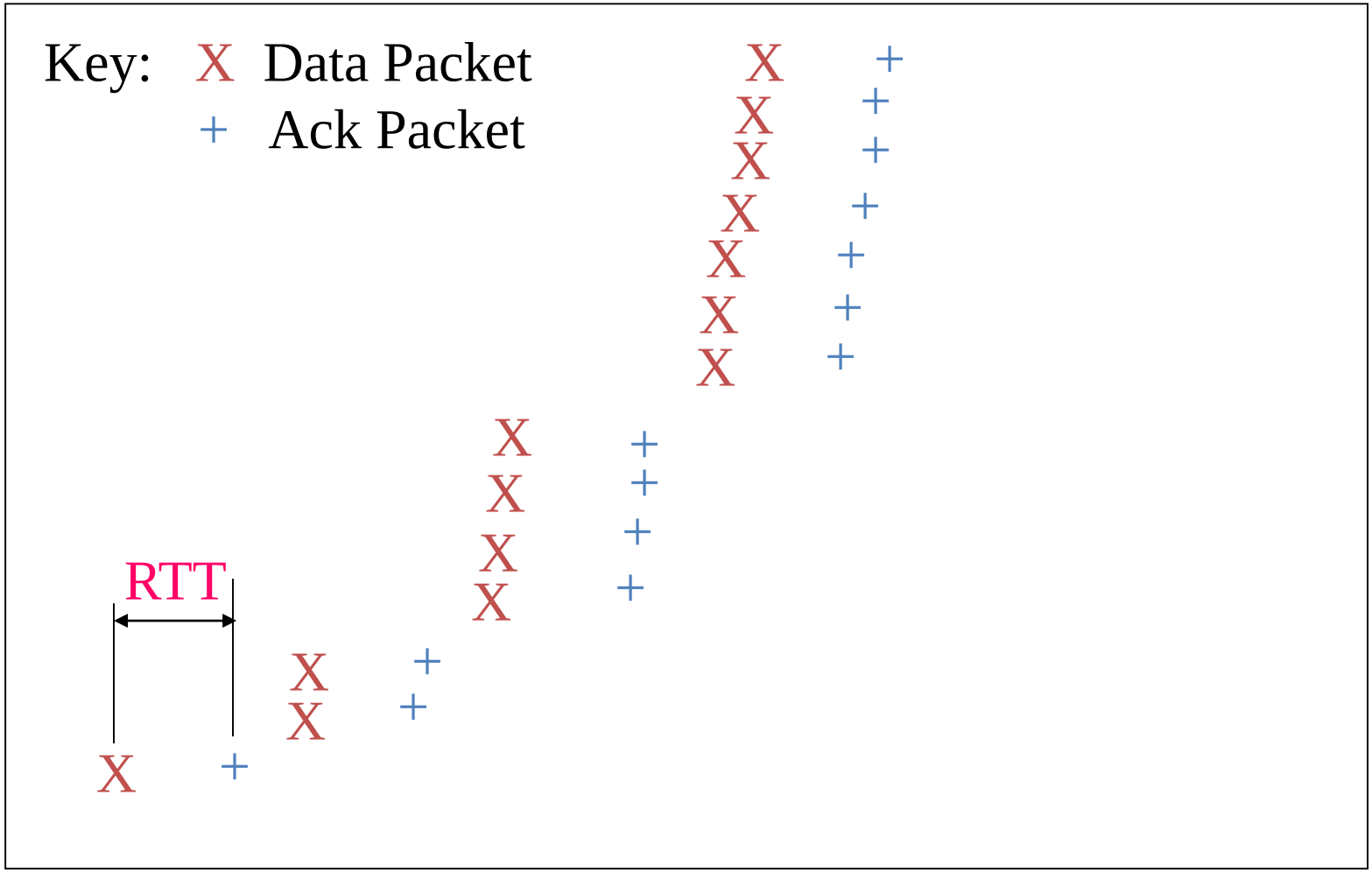

Key:
X Data Packet
+ Ack Packet
SeqNum
Time

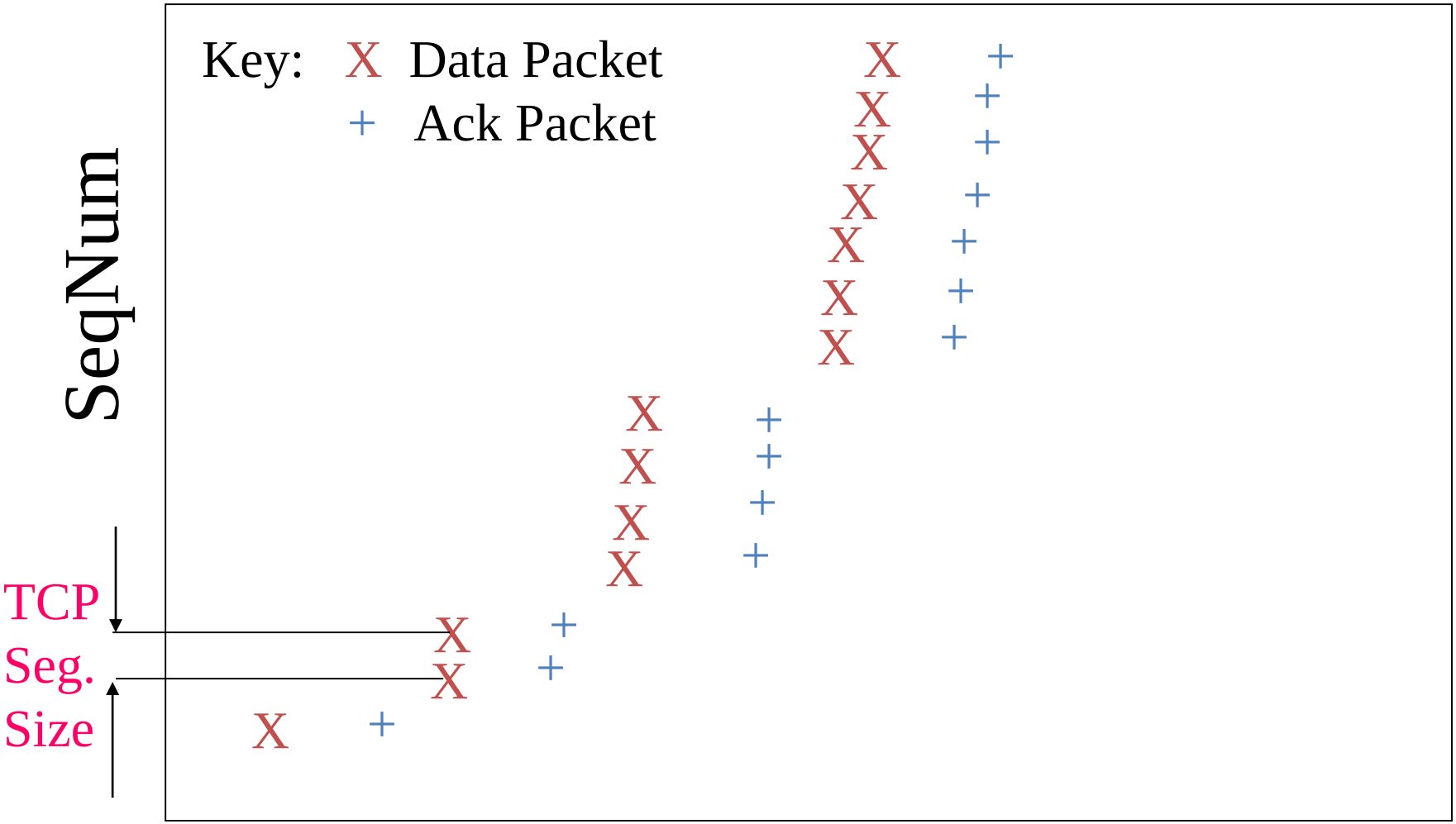
UNIVERSITY OF CALGARY

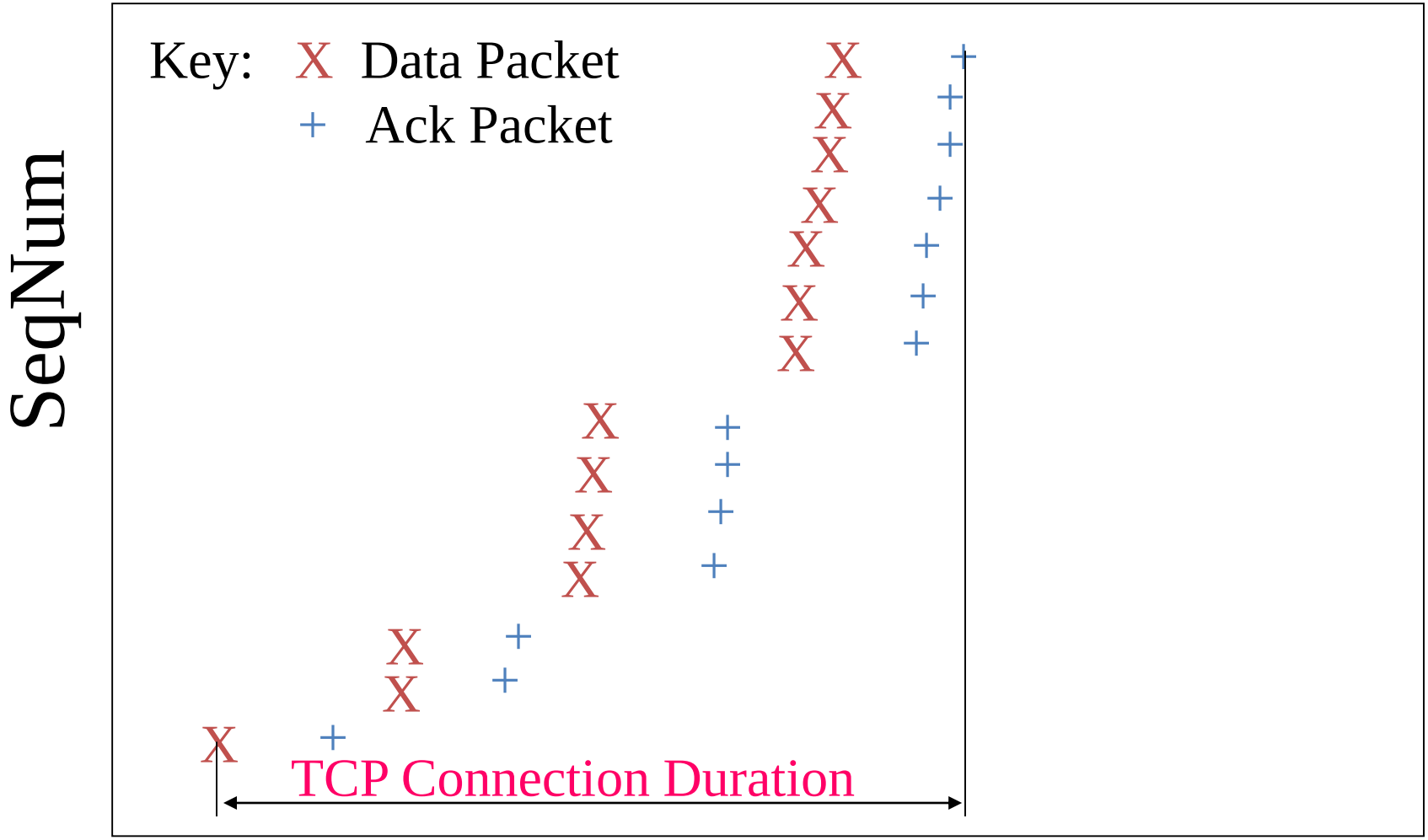
So What?

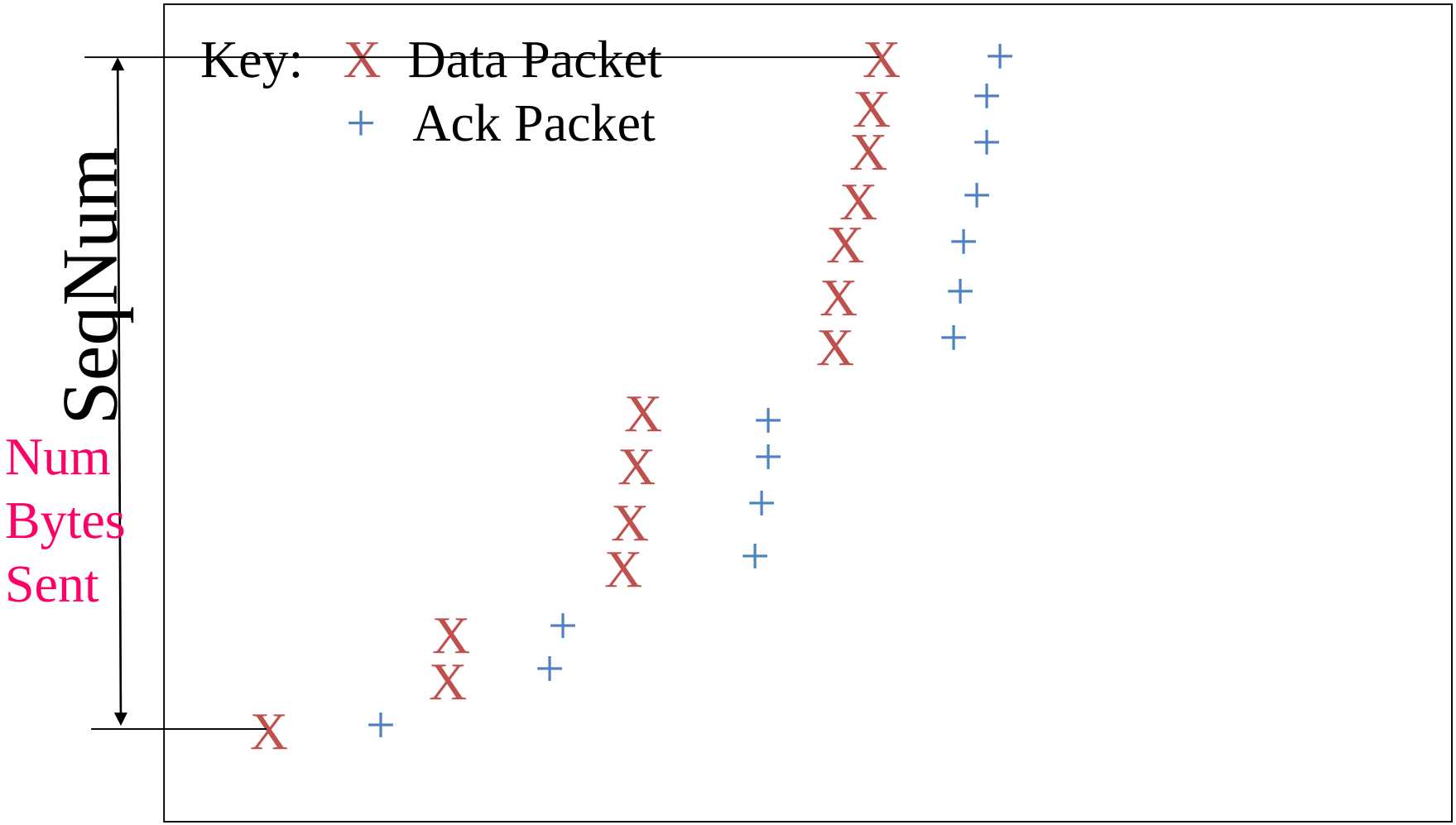
- What can it tell you?

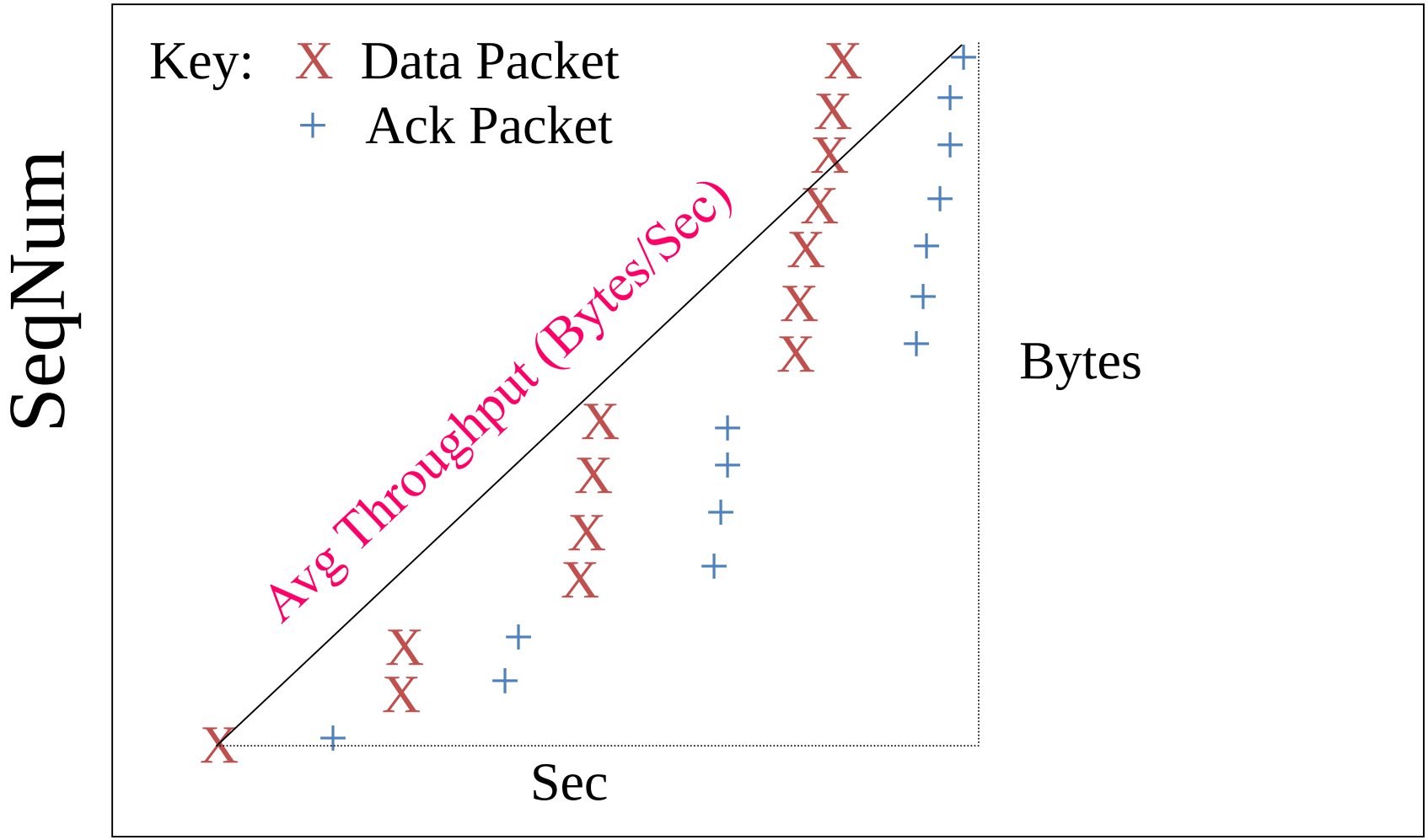
- Everything!!!

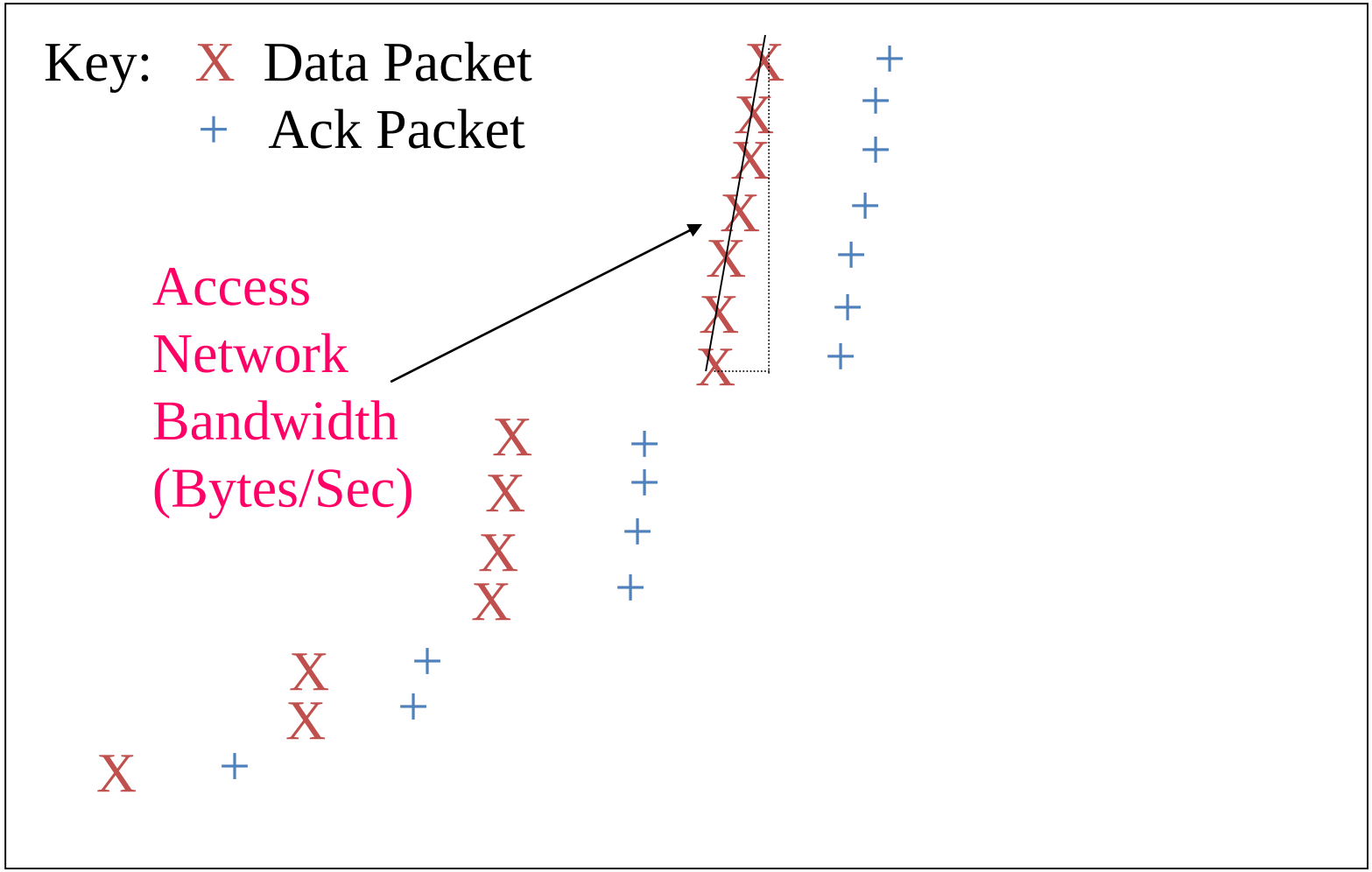

SeqNum
Key:
X Data Packet
+ Ack Packet
RTT

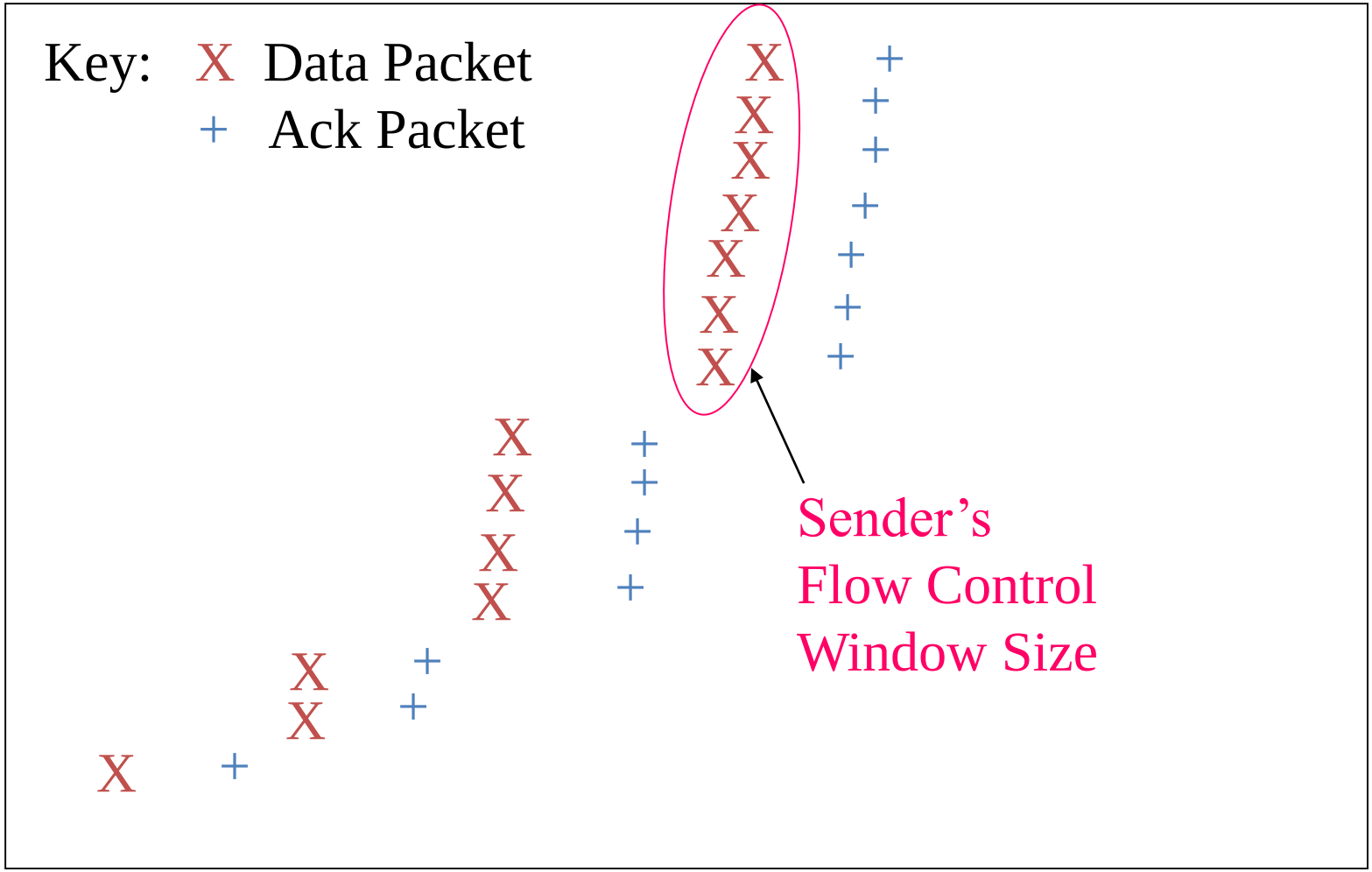

Key:
X Data Packet
+ Ack Packet
SeqNum
TCP
Seg.
Size

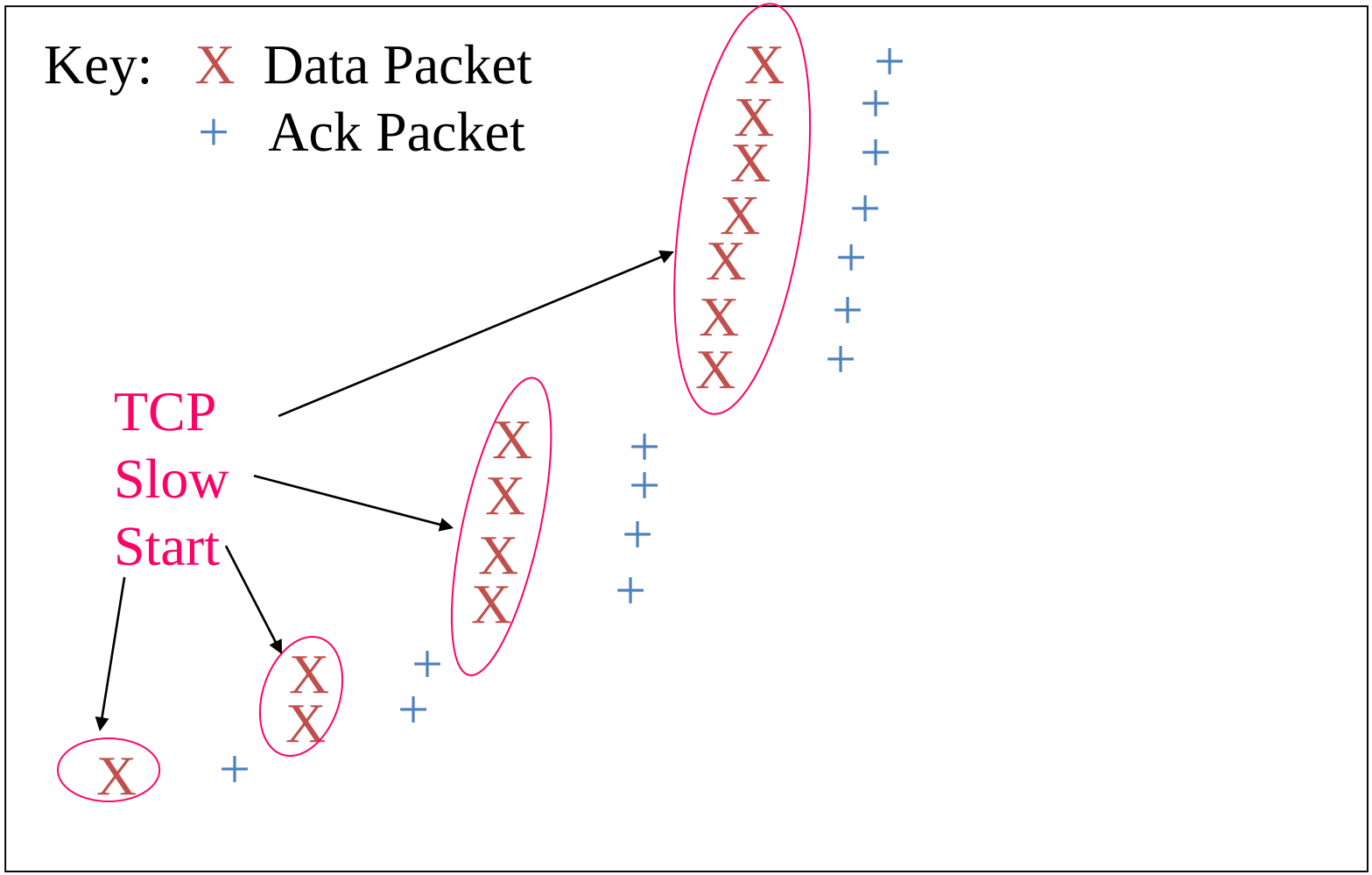

SeqNum
Key:
X Data Packet
+ Ack Packet
TCP Connection Duration

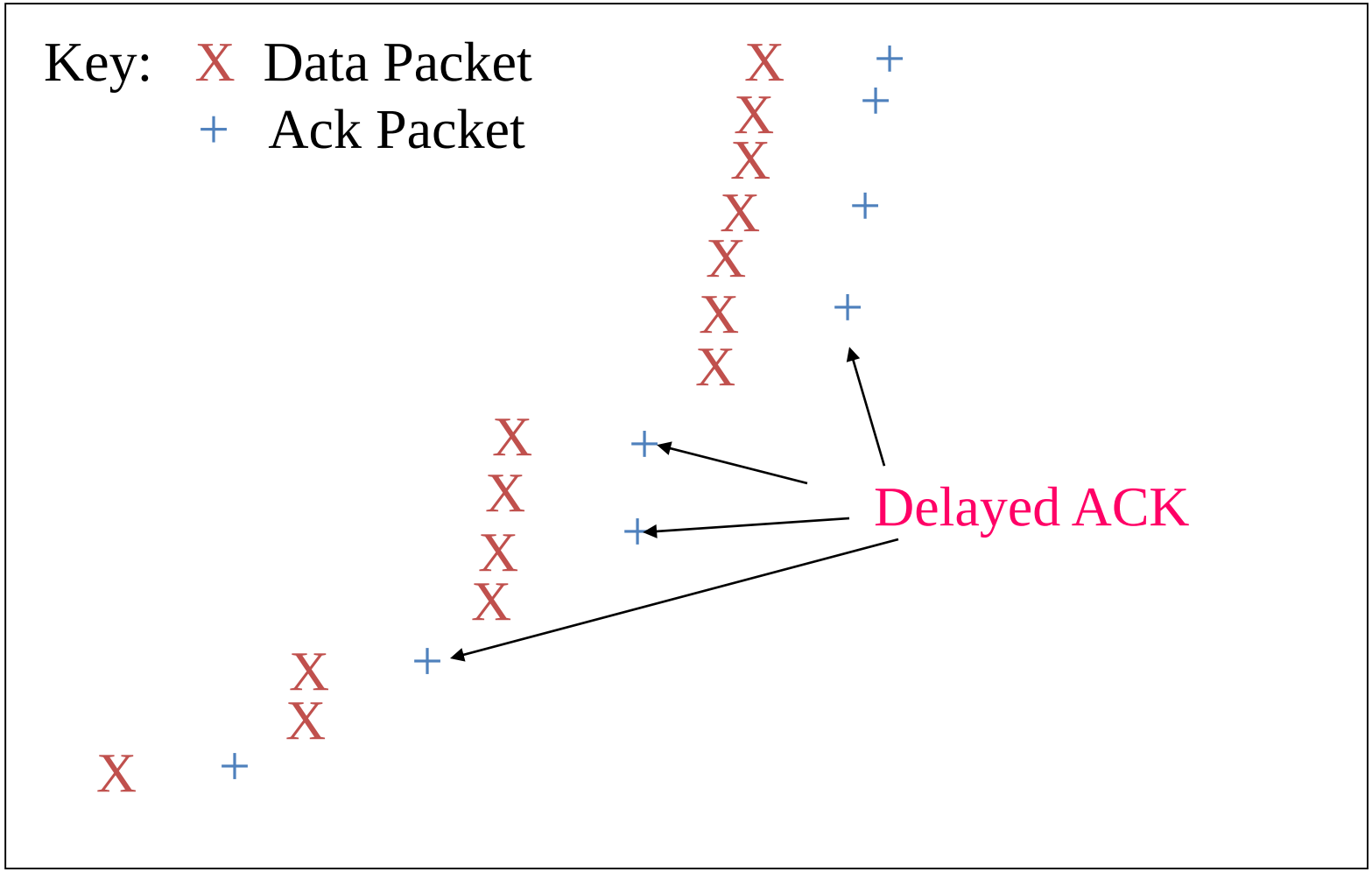

Key: X Data Packet
+ Ack Packet
SeqNum
Num Bytes Sent

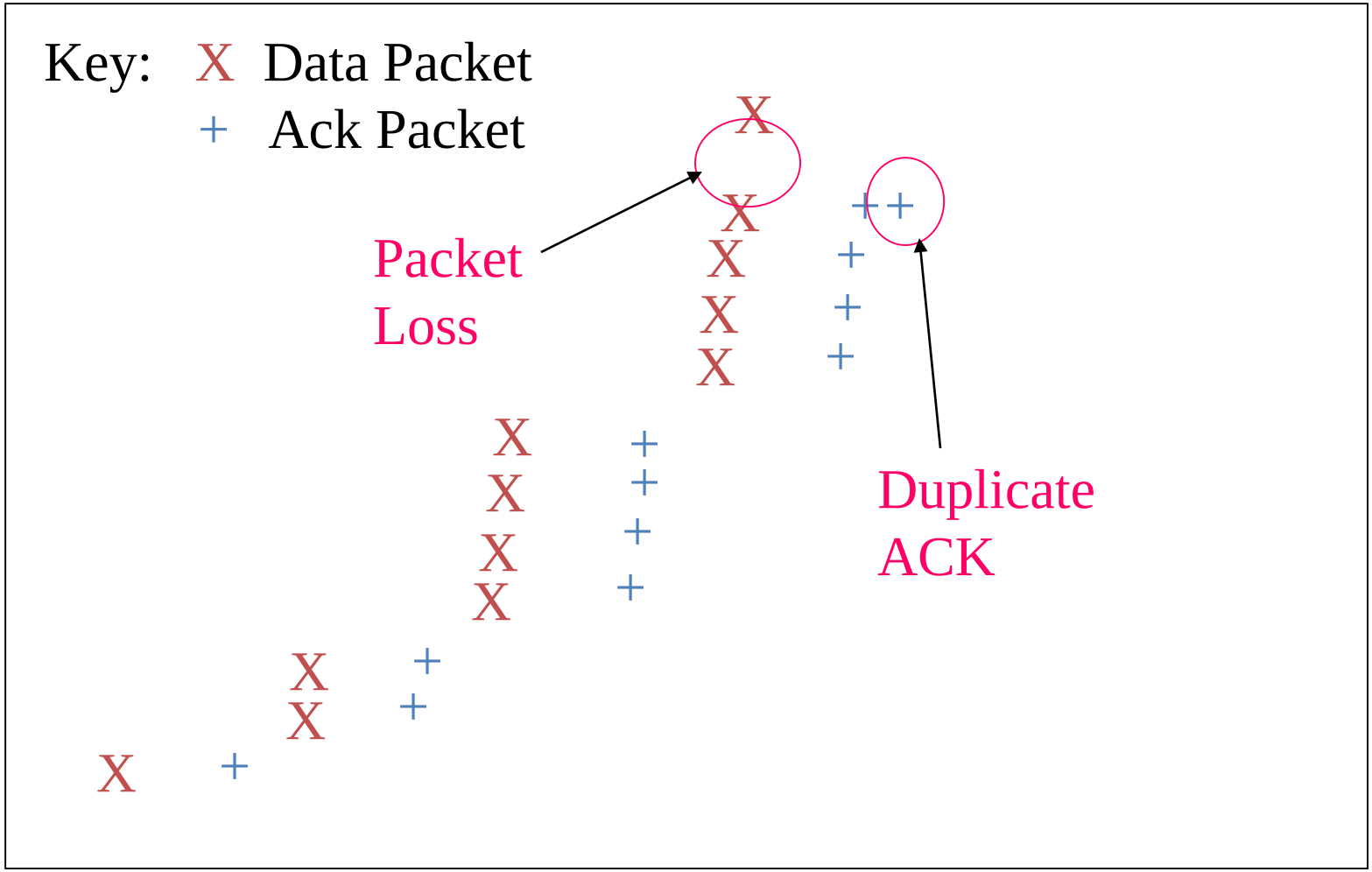

Key:
X Data Packet
+ Ack Packet
SeqNum
Bytes
Sec
Avg Throughput (Bytes/Sec)

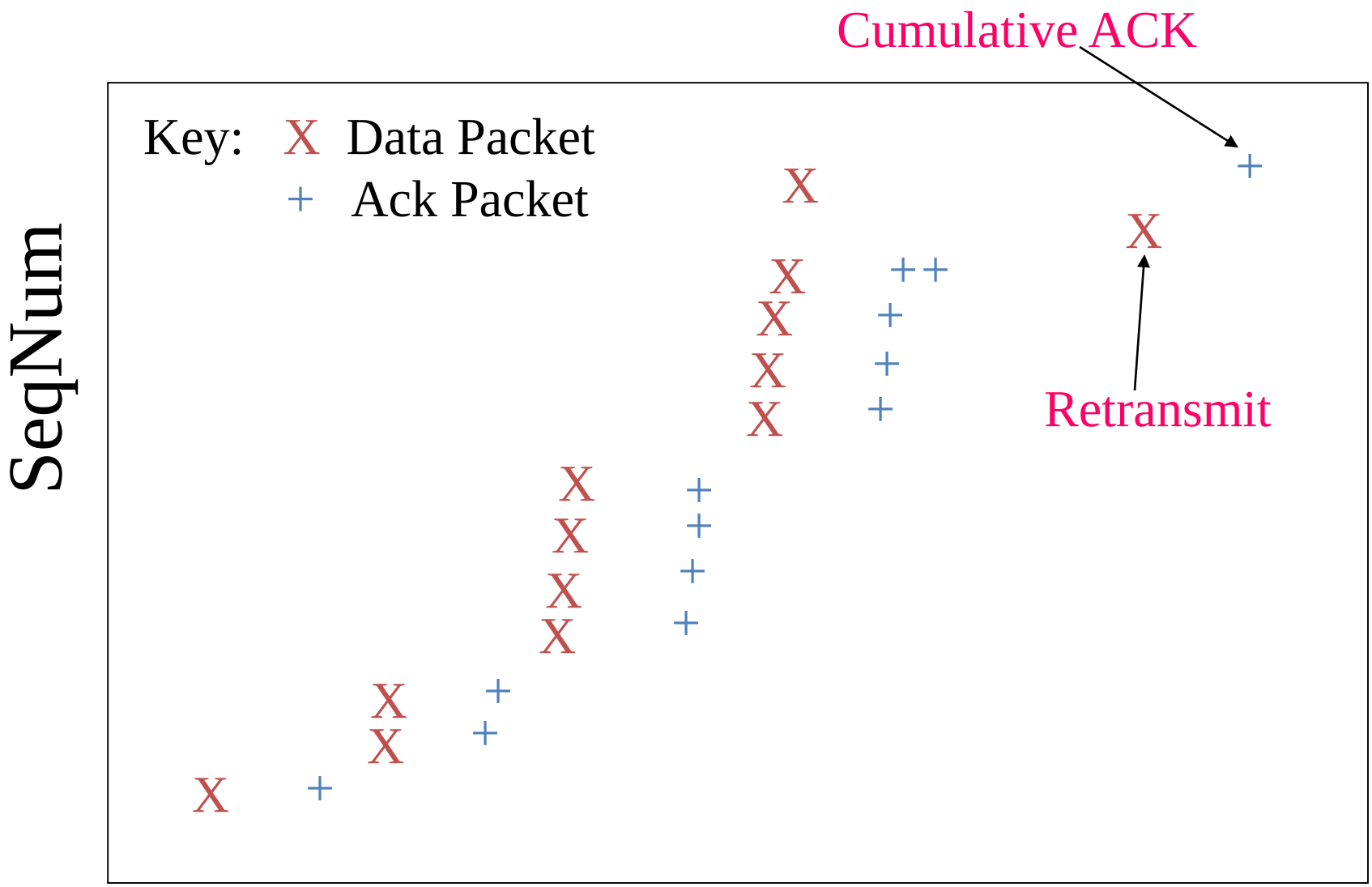

SeqNum
Key:
X Data Packet
+ Ack Packet
Access
Network
Bandwidth
(Bytes/Sec)

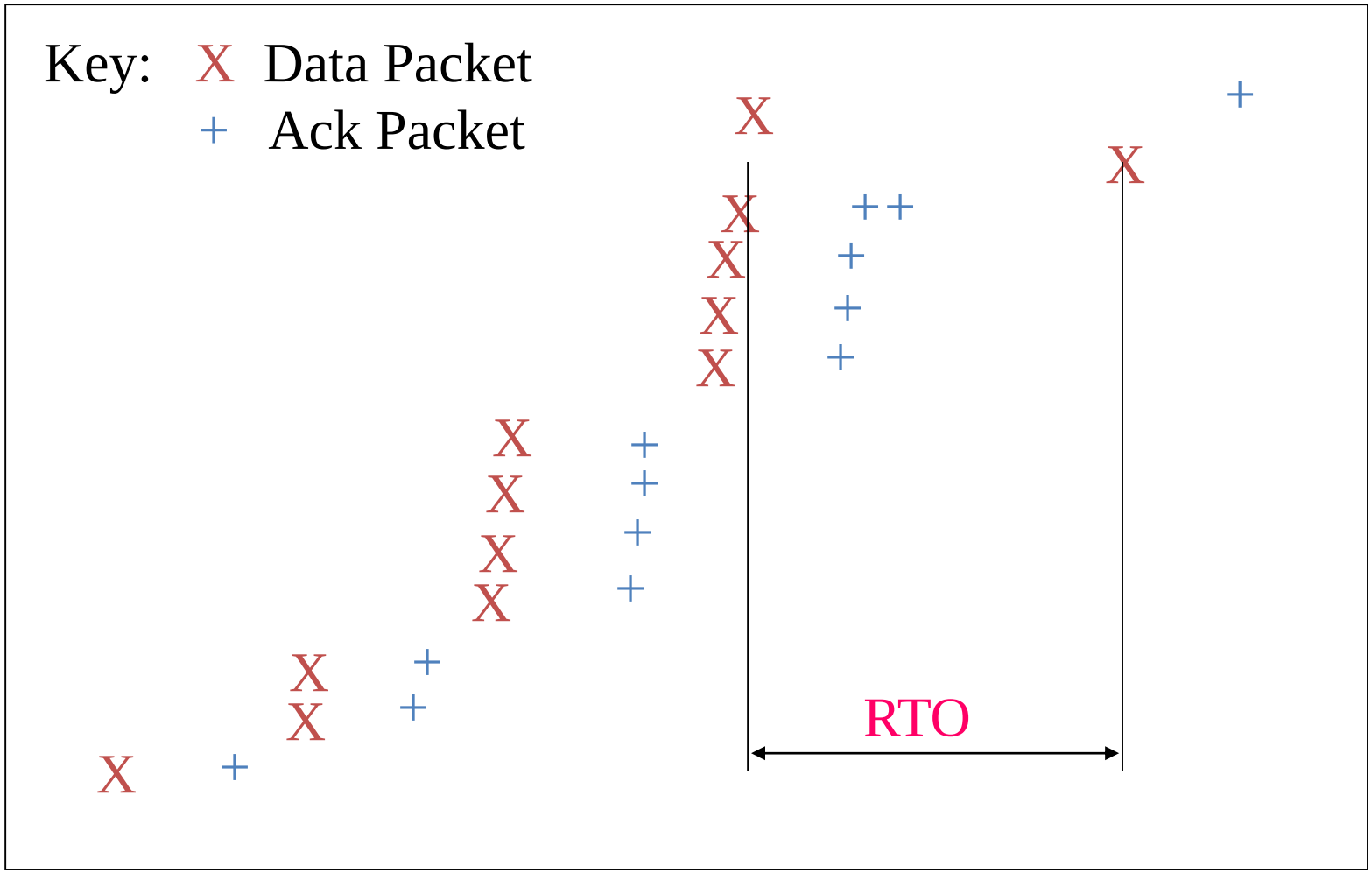

SeqNum
Key:
X Data Packet
+ Ack Packet
Sender's
Flow Control
Window Size


SeqNum
Key: X Data Packet
+ Ack Packet
TCP
Slow
Start


Key:
X Data Packet
+ Ack Packet
SeqNum
Delayed ACK


Key:
X Data Packet
+ Ack Packet
SeqNum
Packet Loss
Duplicate ACK

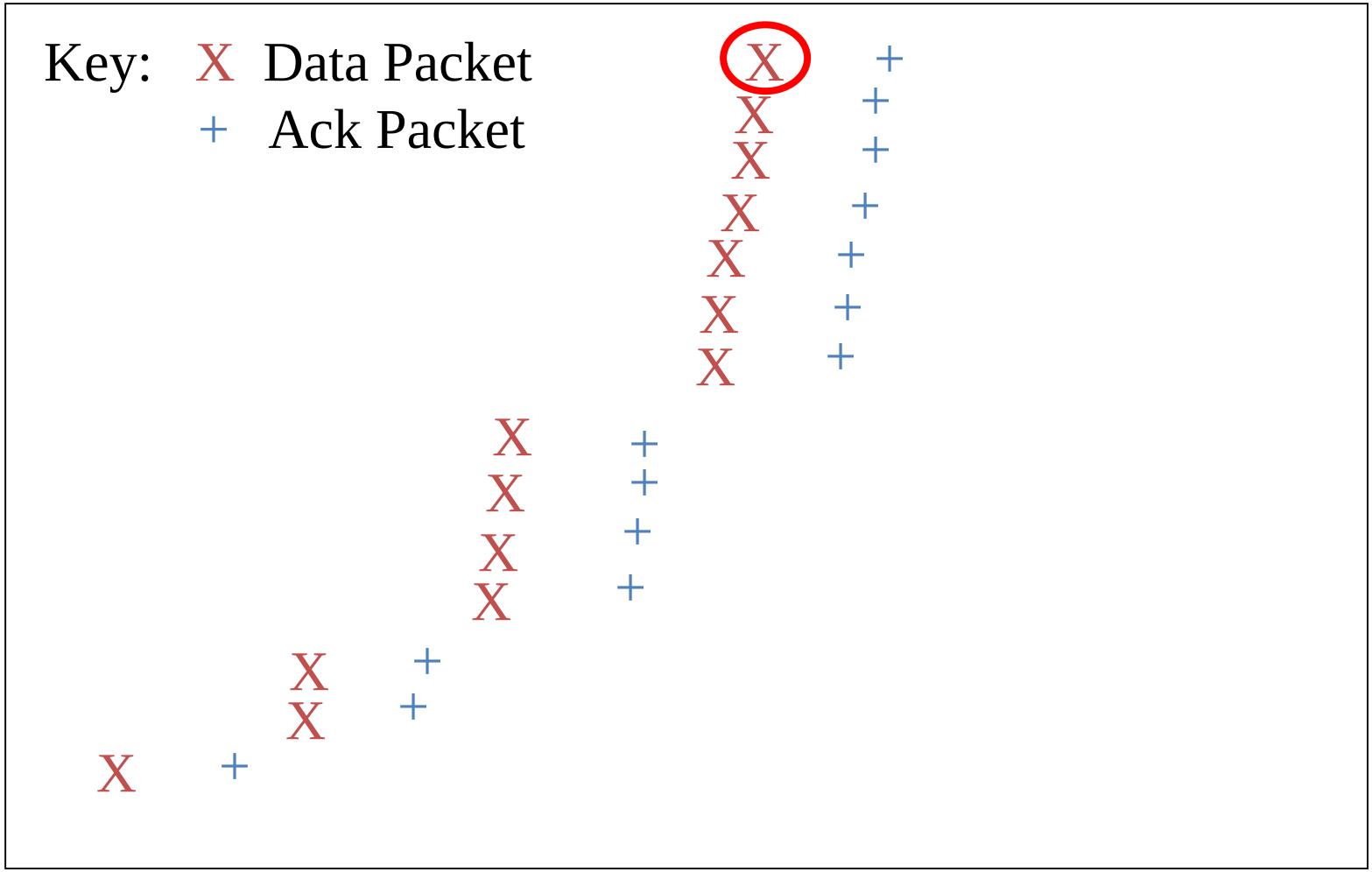

Cumulative ACK
Key: X Data Packet
+ Ack Packet
SeqNum
Retransmit

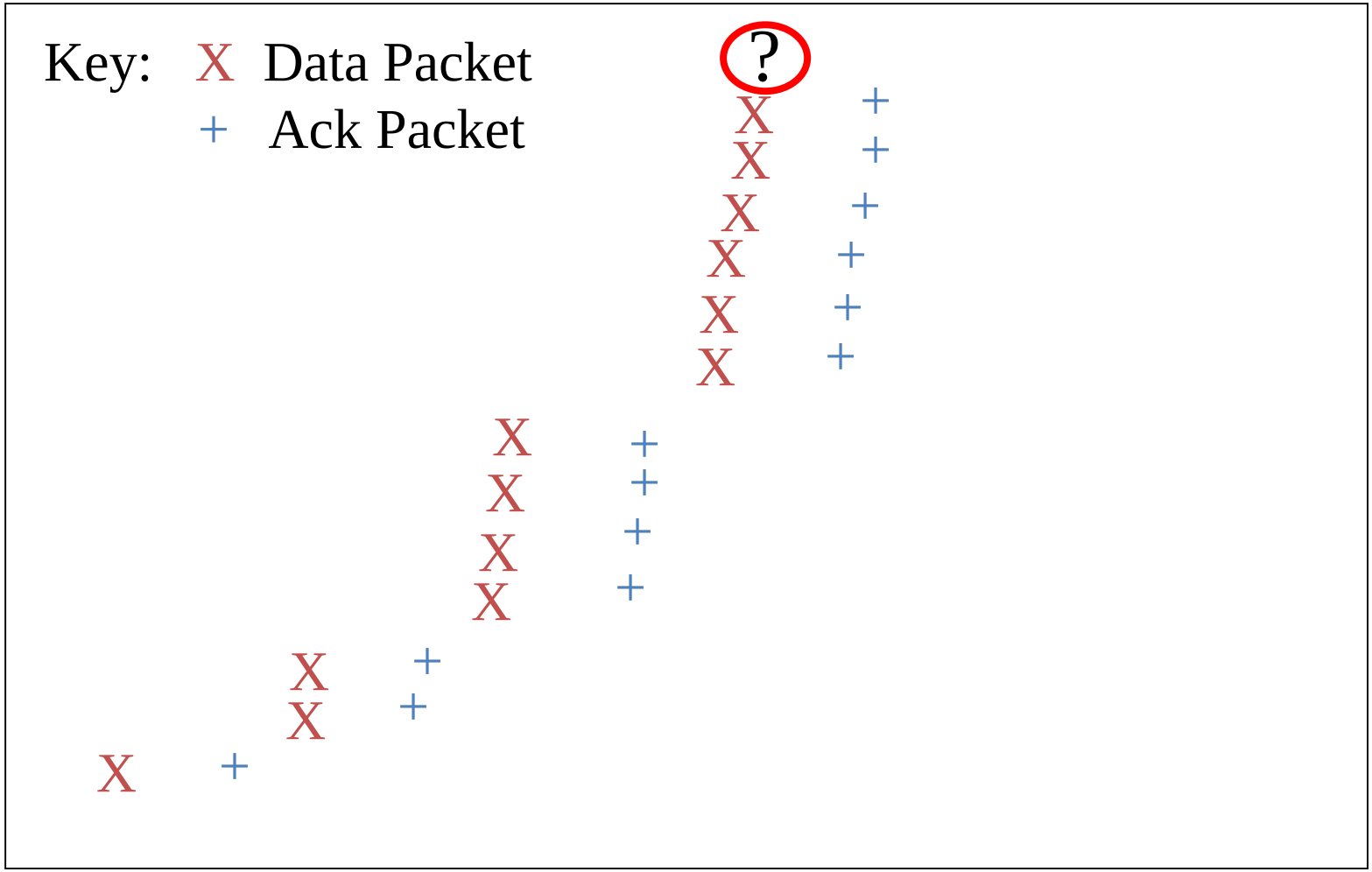

Key: X Data Packet
+ Ack Packet
SeqNum
RTO

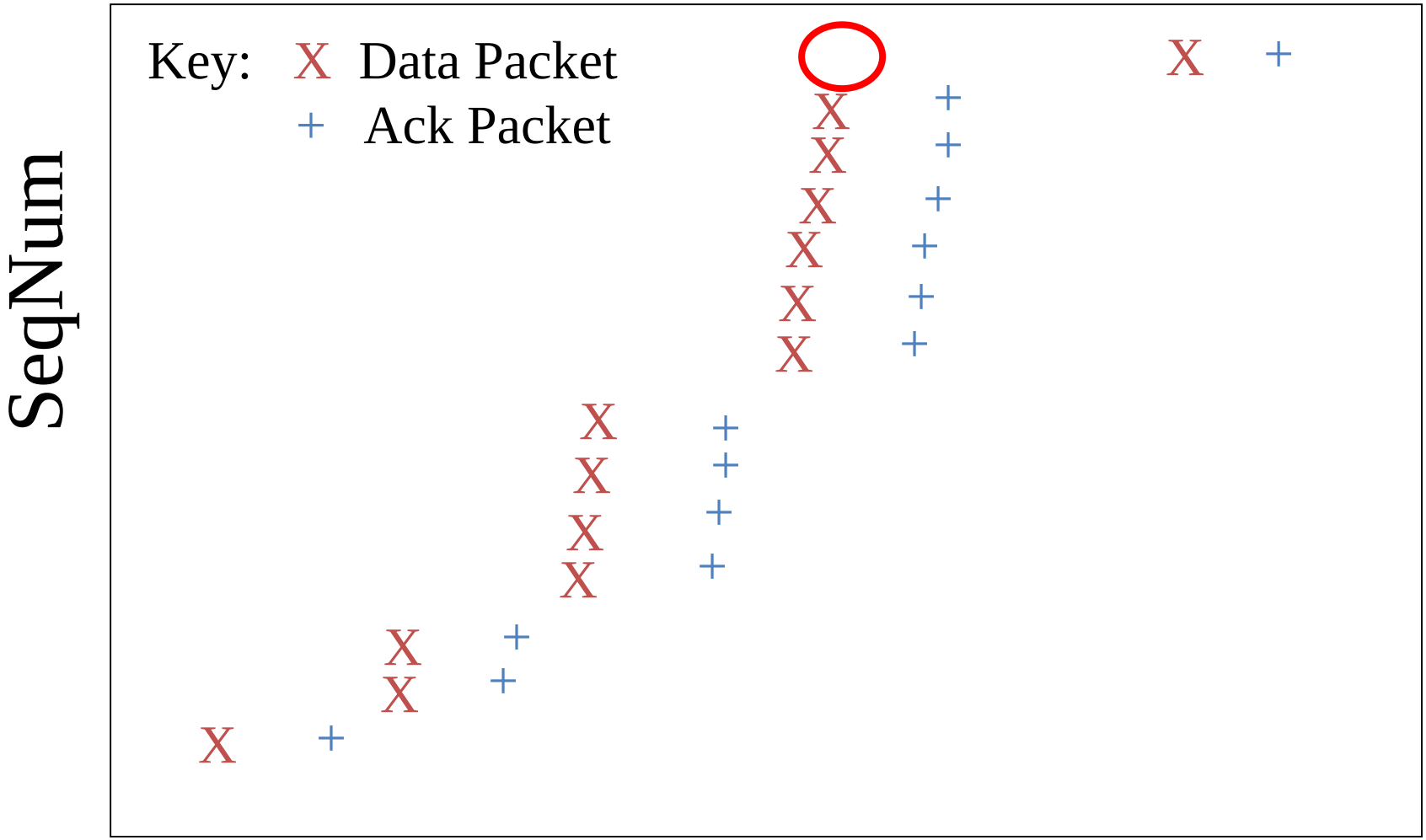
TCP 201 (Cont'd)

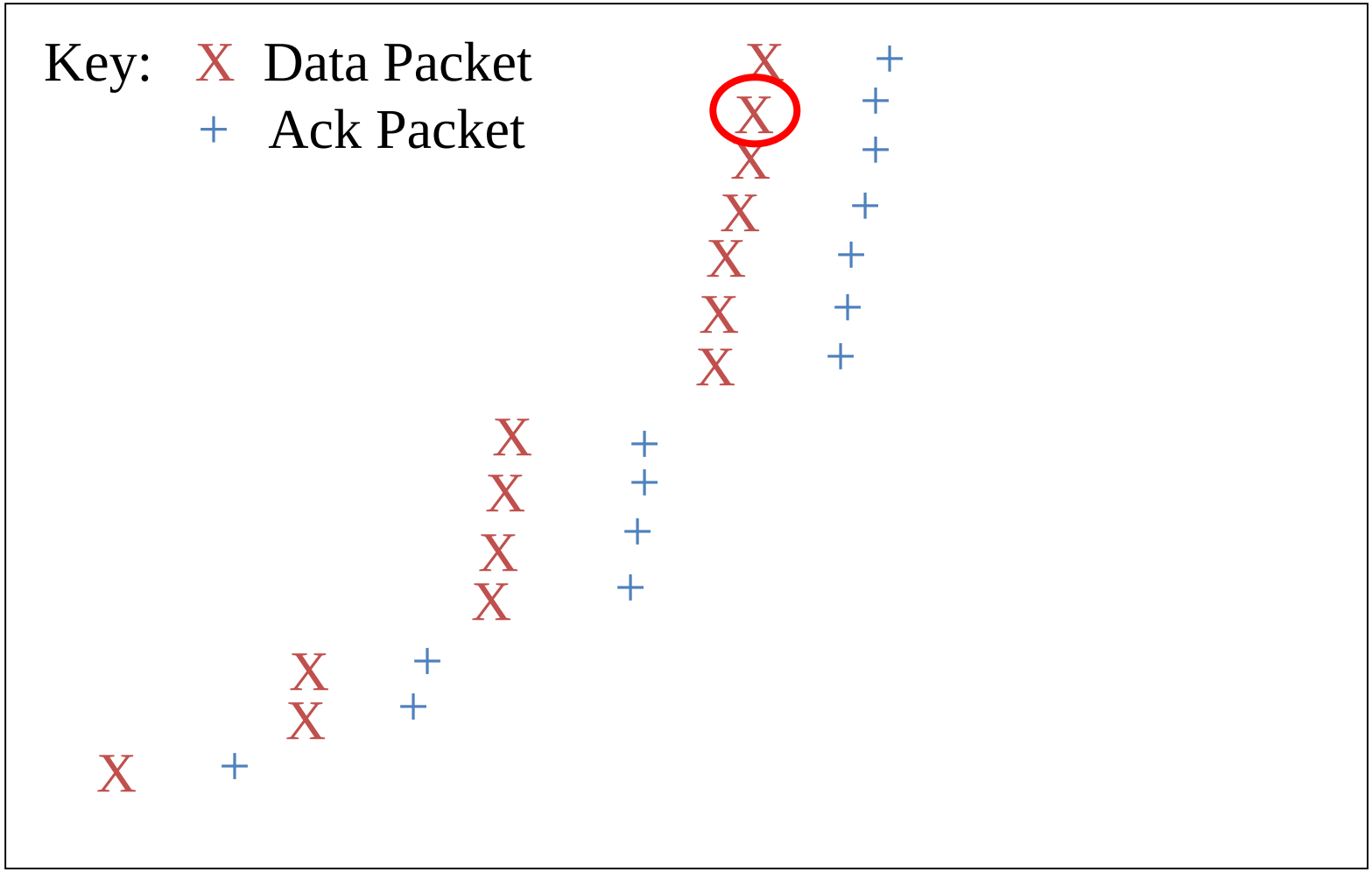
- What happens when a packet loss occurs?

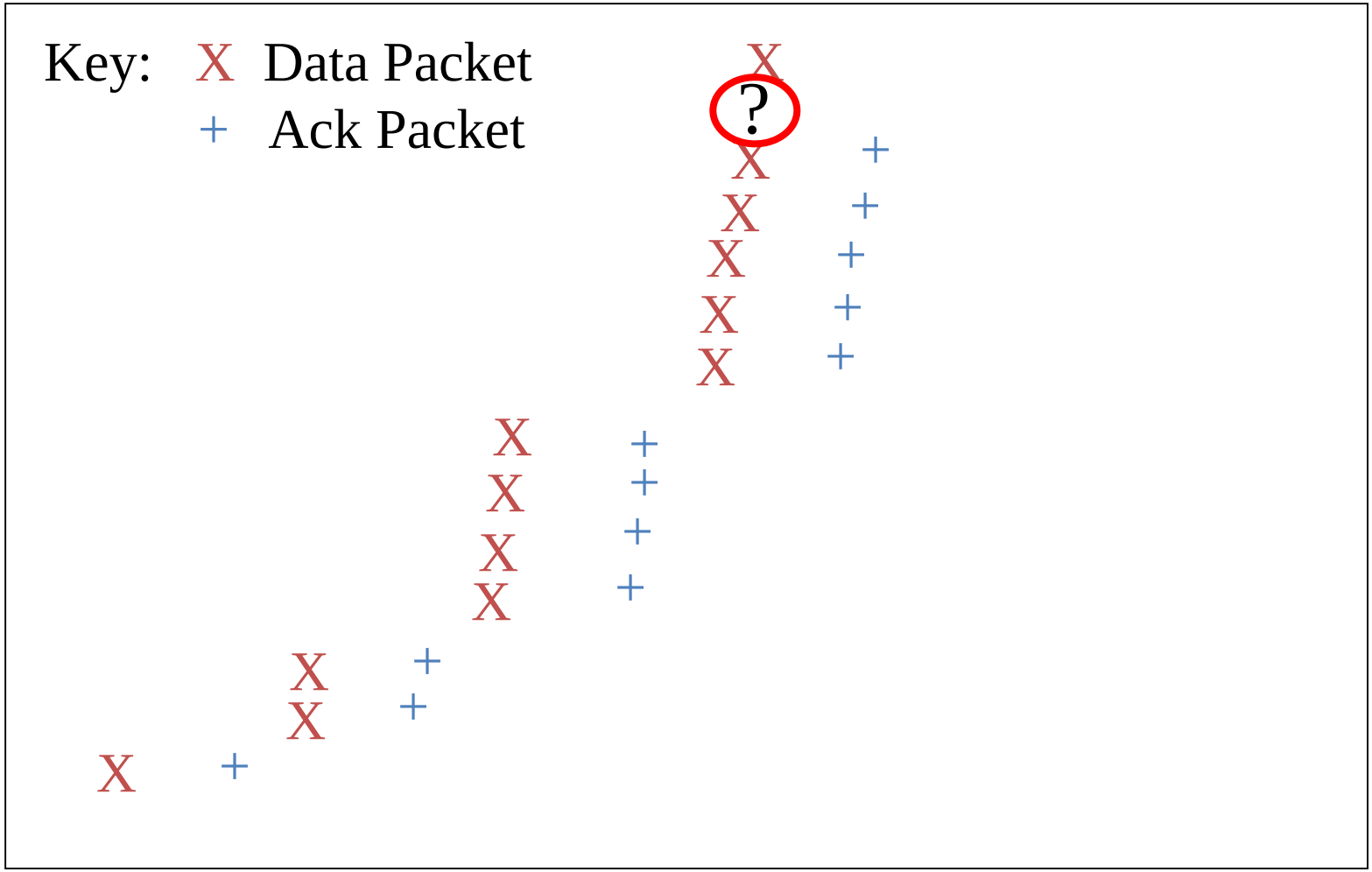
- Quiz Time...
  - Consider a 14-packet Web document
  - For simplicity, consider only a single packet loss

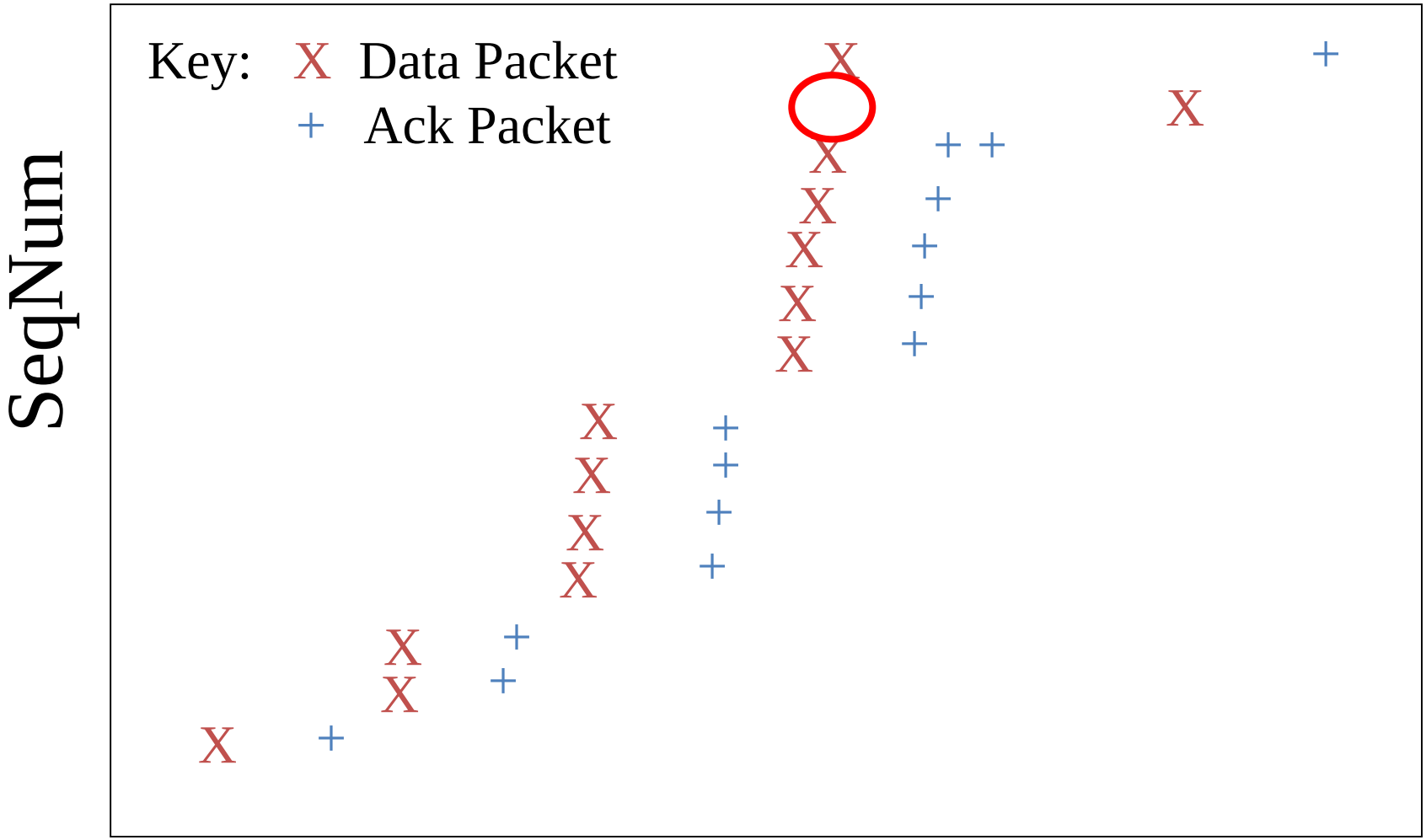

SeqNum
Key:
X Data Packet
+ Ack Packet

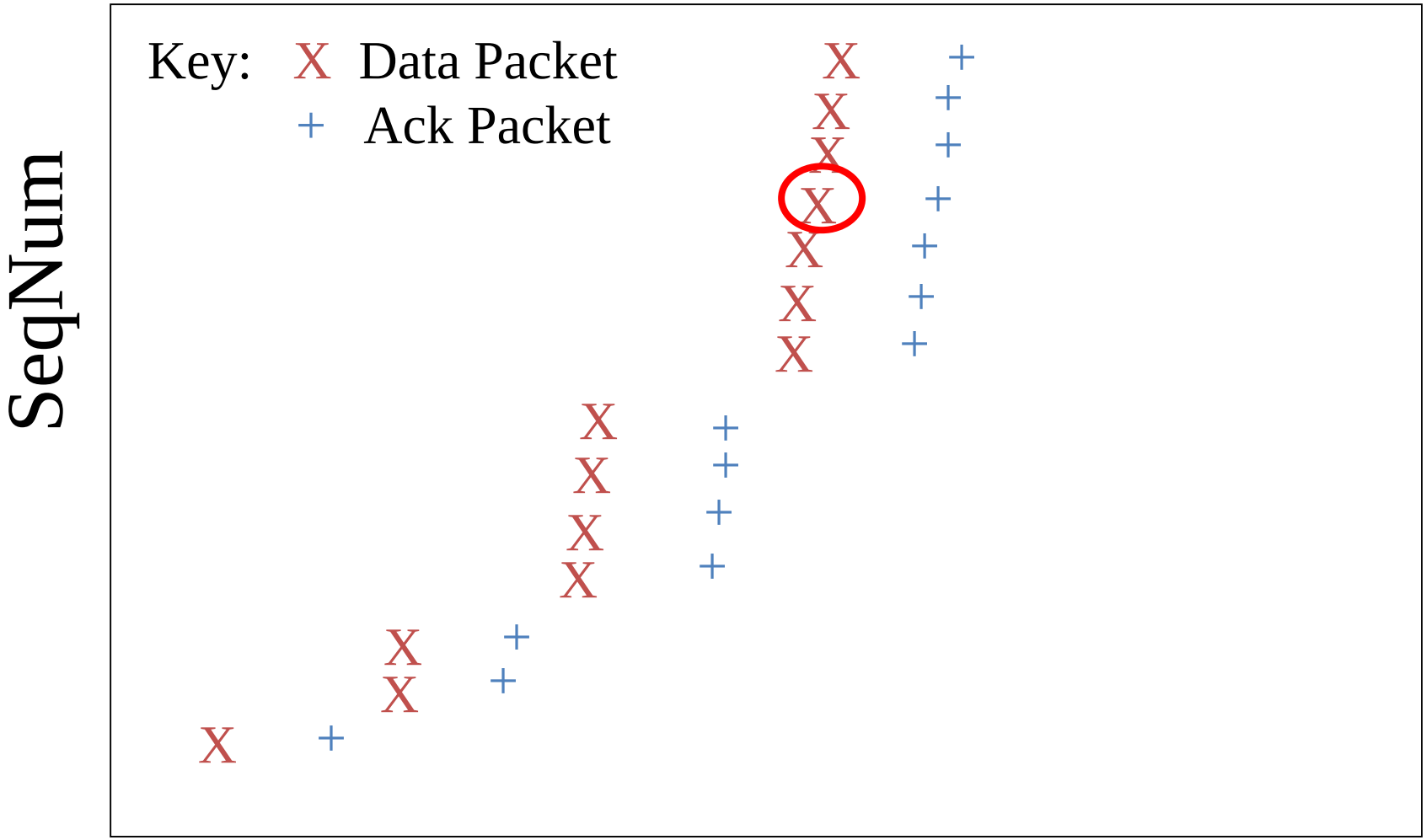

SeqNum
Key:
X Data Packet
+ Ack Packet
?

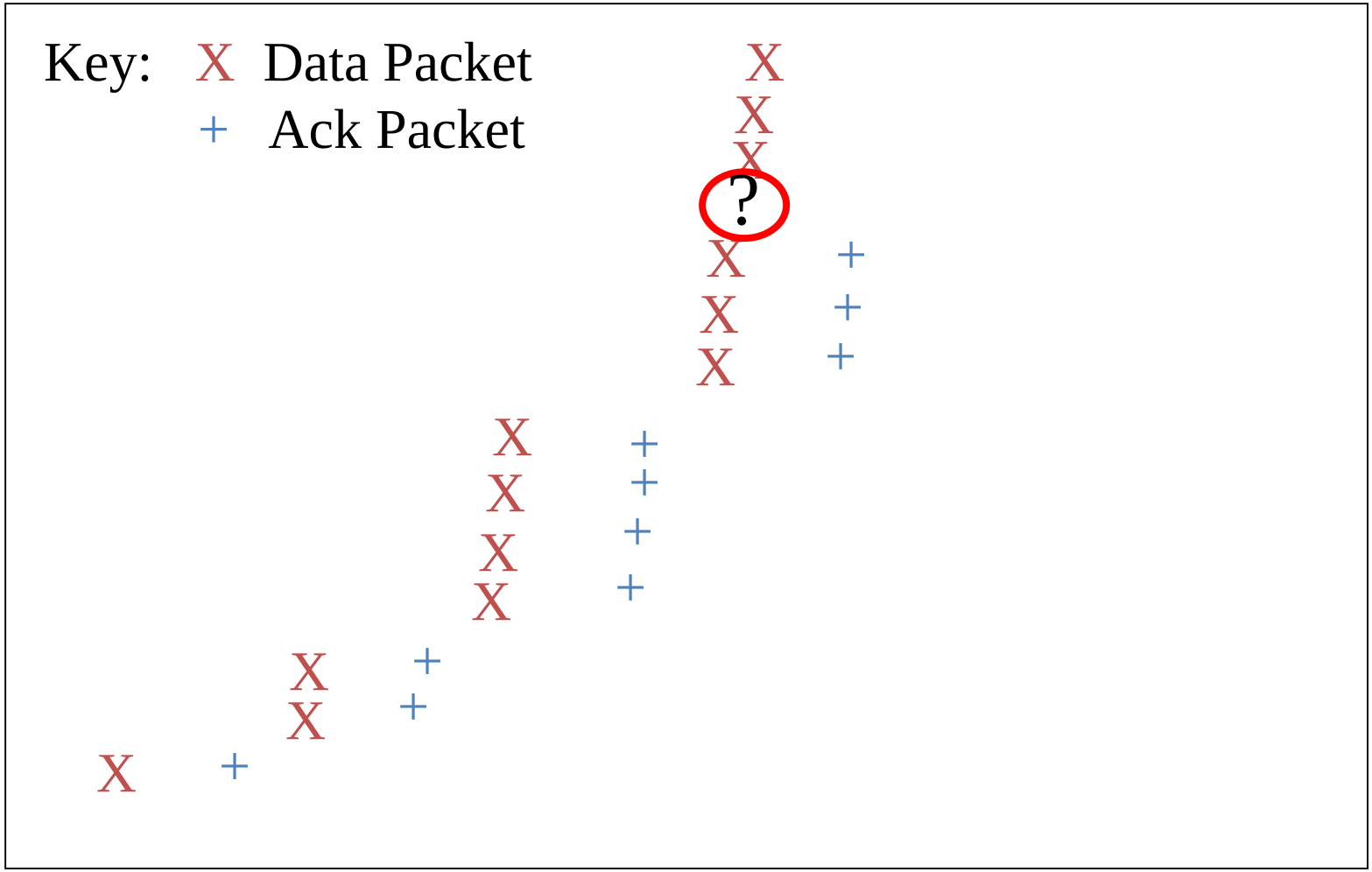

SeqNum
Key:
X Data Packet
+ Ack Packet

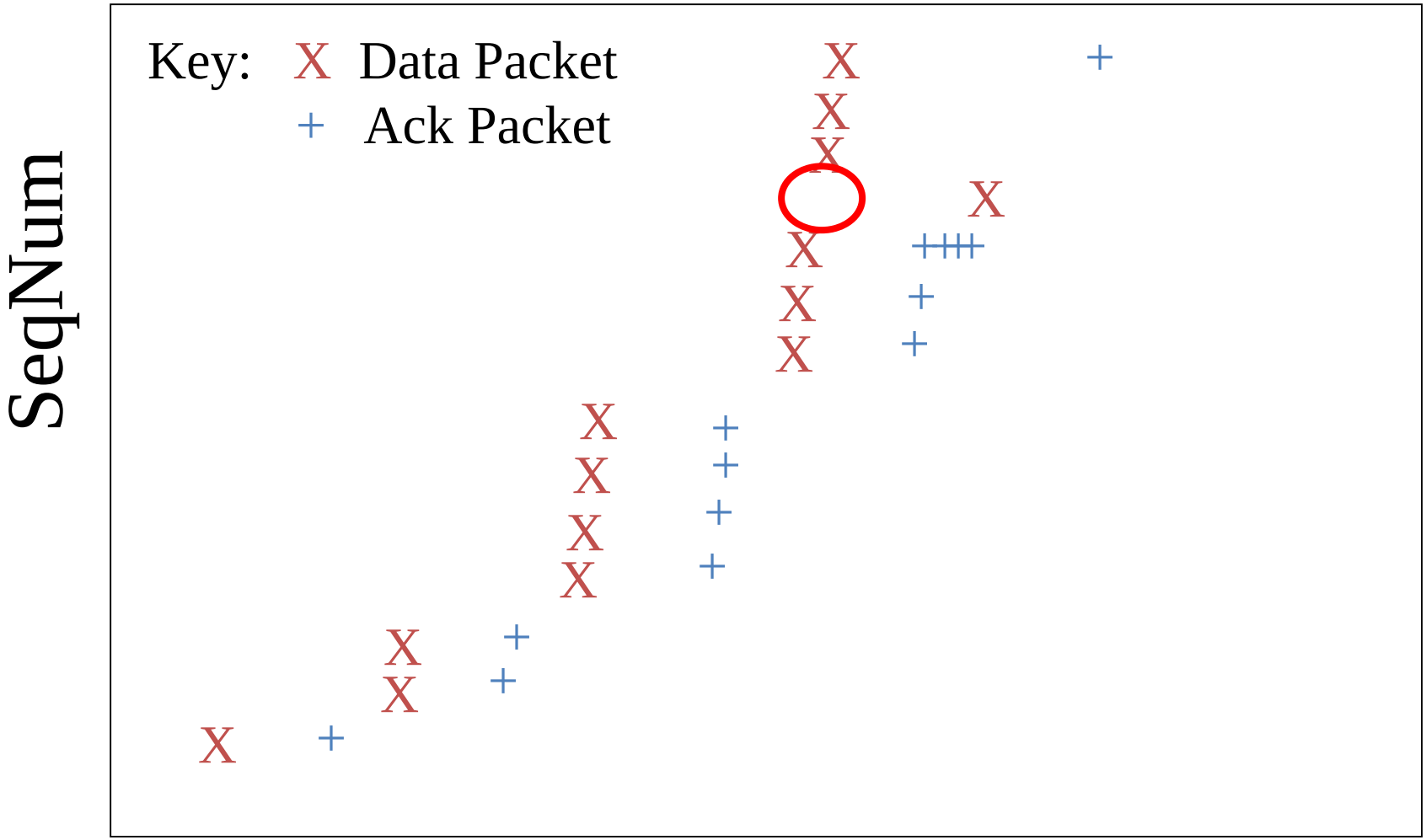

SeqNum
Key:
X Data Packet
+ Ack Packet

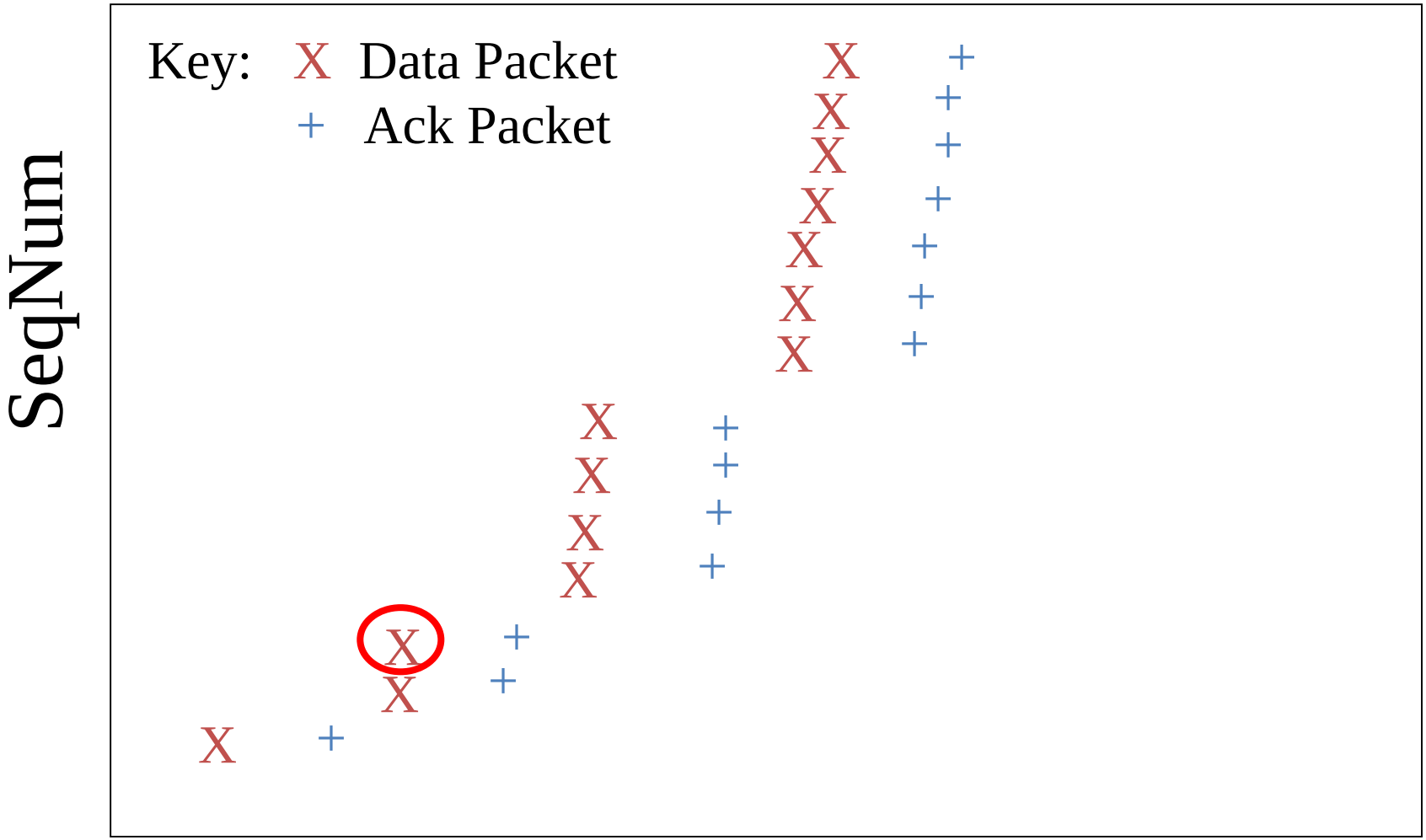

SeqNum
Key:
X Data Packet
+ Ack Packet
?


SeqNum
Key:
X Data Packet
+ Ack Packet

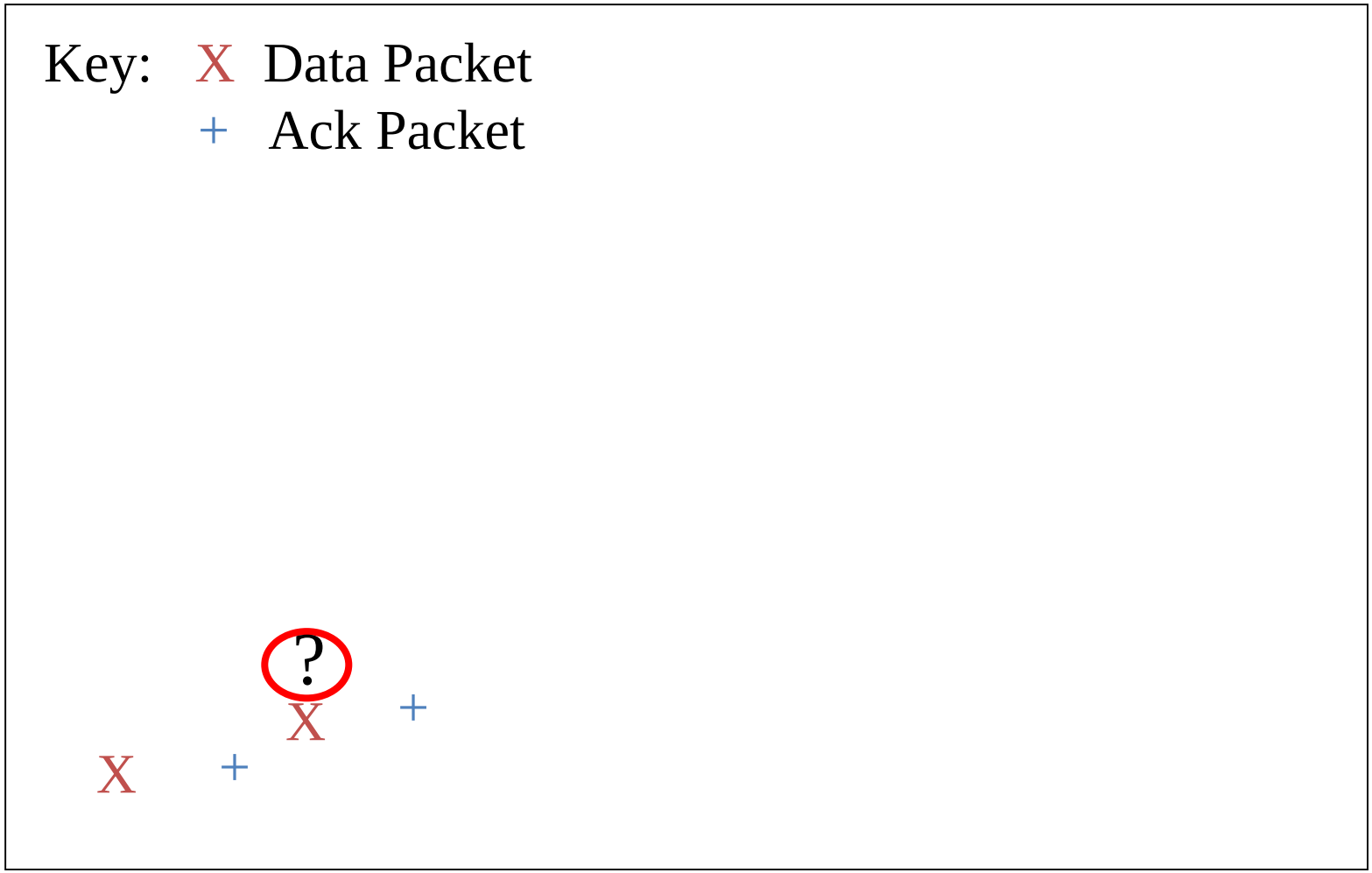

SeqNum
Key:
X Data Packet
+ Ack Packet

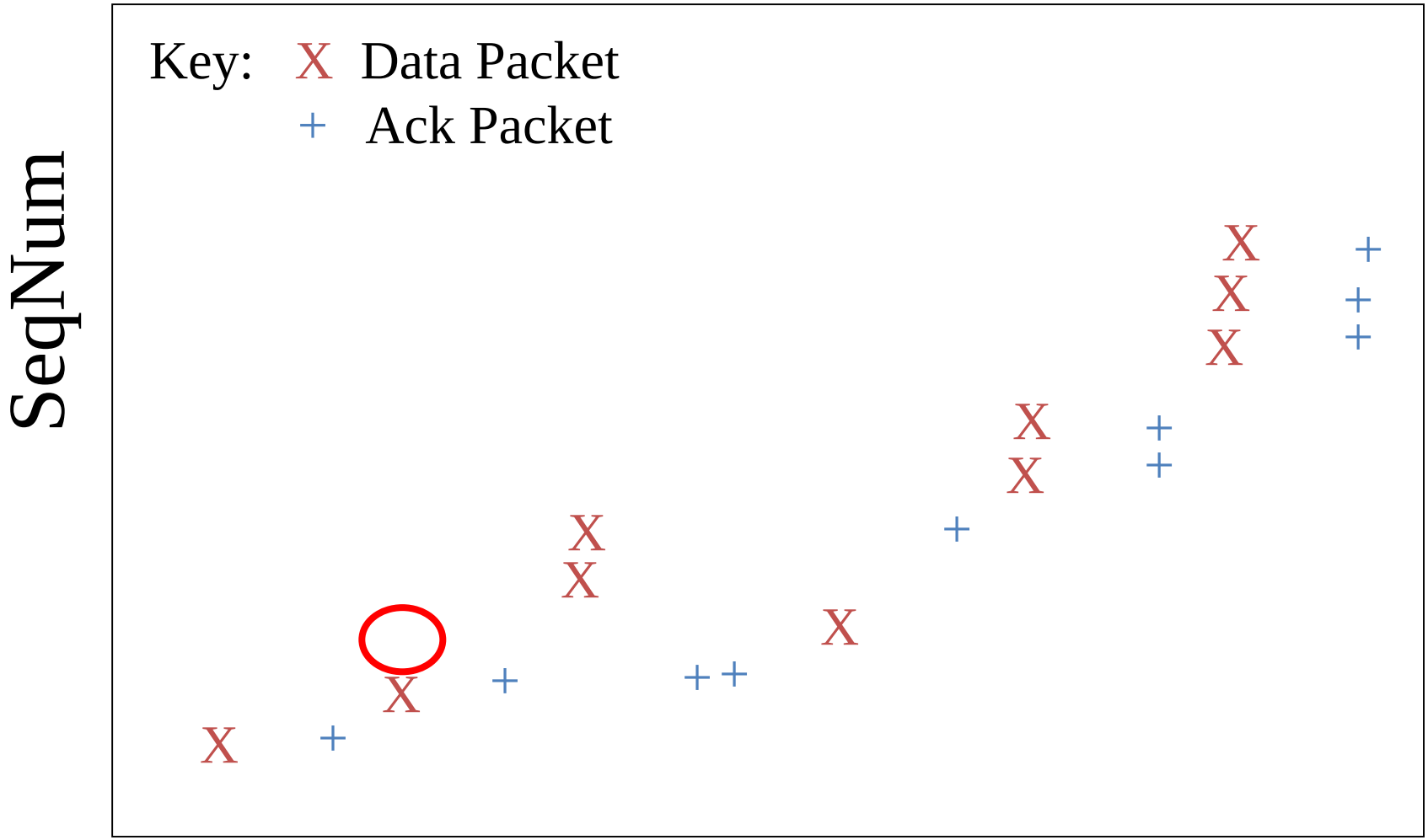

SeqNum
Key:
X Data Packet
+ Ack Packet
?


SeqNum
Key:
X Data Packet
+ Ack Packet


SeqNum
Key:
X Data Packet
+ Ack Packet

SeqNum




SeqNum
Key: X Data Packet
+ Ack Packet

TCP 201 (Cont'd)

- 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

UNIVERSITY OF CALGARY

Congratulations!

- You are now a TCP expert!