COMPUTER COMMUNICATION NETWORKS

Department of Electronics and Communication Engineering

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Principles of reliable data transfer: Pipelining, GBN and SR

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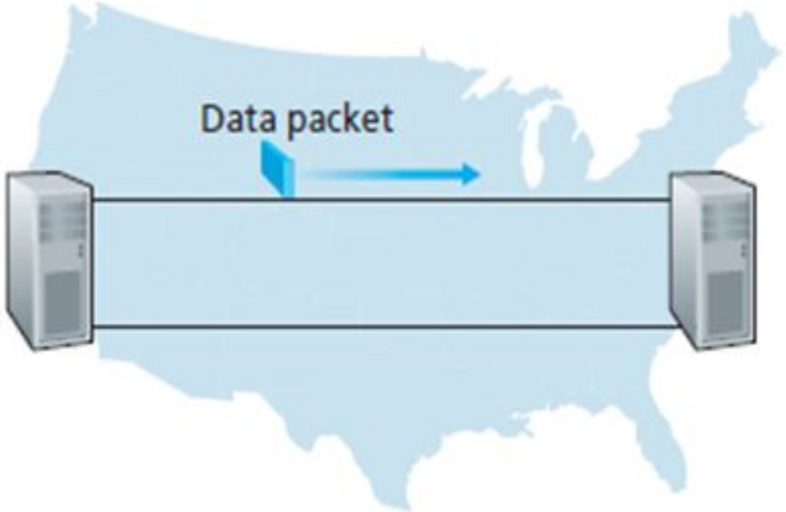
Pipelining

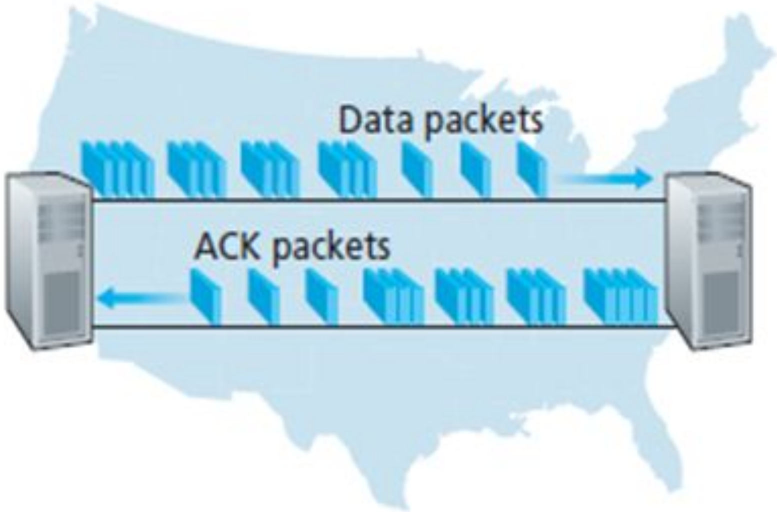
Rather than operate in a stop-and-wait manner, the sender is allowed to send multiple packets without waiting for acknowledgments.

If the sender is allowed to transmit three packets before having to wait for acknowledgments, the utilization of the sender is essentially tripled. Since the many in-transit sender-to-receiver packets can be visualized as filling a pipeline, this technique is known as **pipelining.**

Pipelining



What is the utilization with respect to the sender?

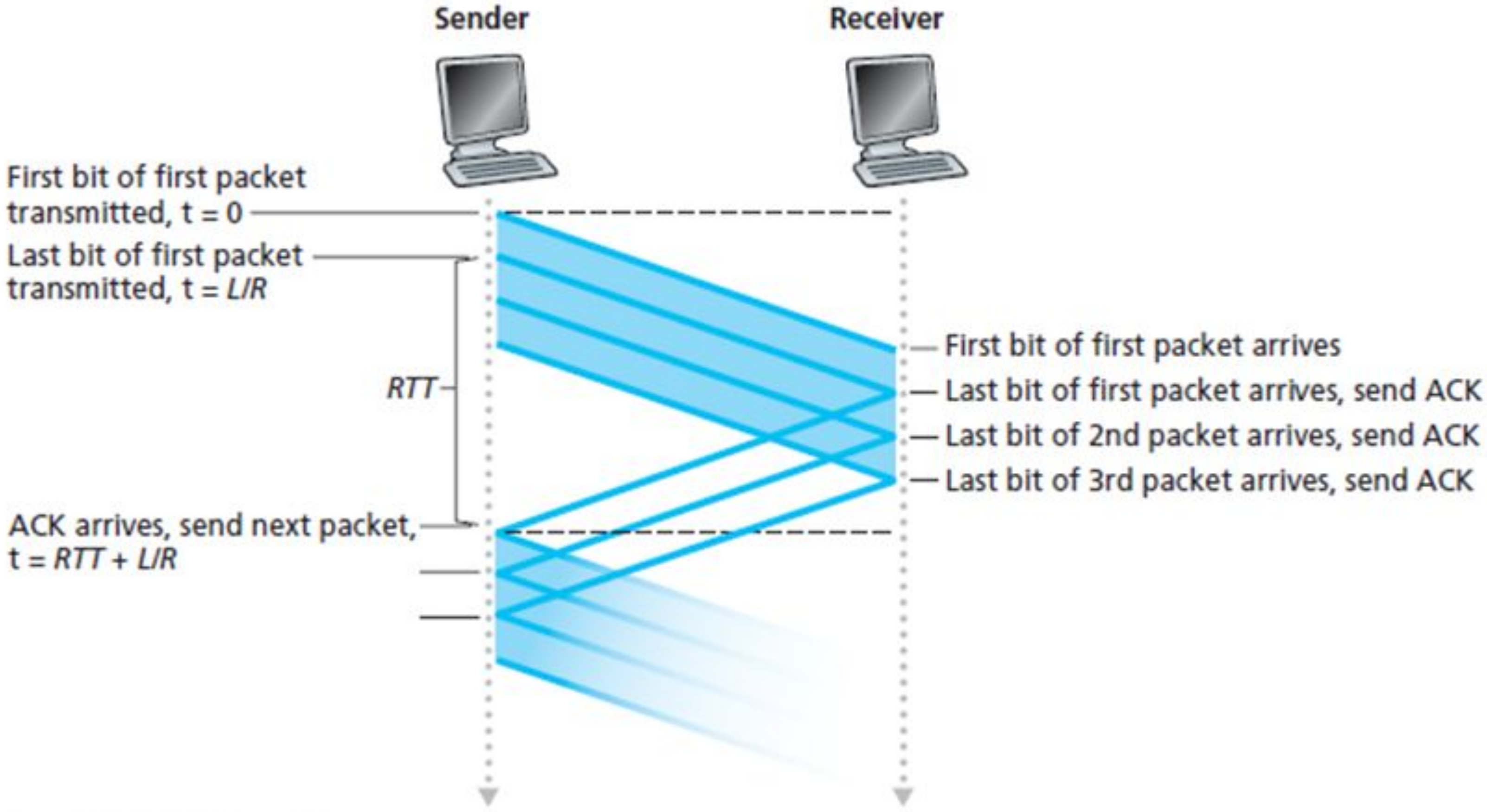


b. A pipelined protocol in operation

RTT = 30 ms
Packet length = 1000 bytes
Transmission rate = 1 Gbps
Assume processing delay at sender is negligible

Pipelining

Concept of pipelining



b. Pipelined operation

Pipelining

Changes due to pipelining.

- Range of sequence numbers is increased.
- The number of packets in the pipeline is fixed.
- Use transmit and receive buffers.
- Timers are used for ascertaining packet loss

Types of pipelining

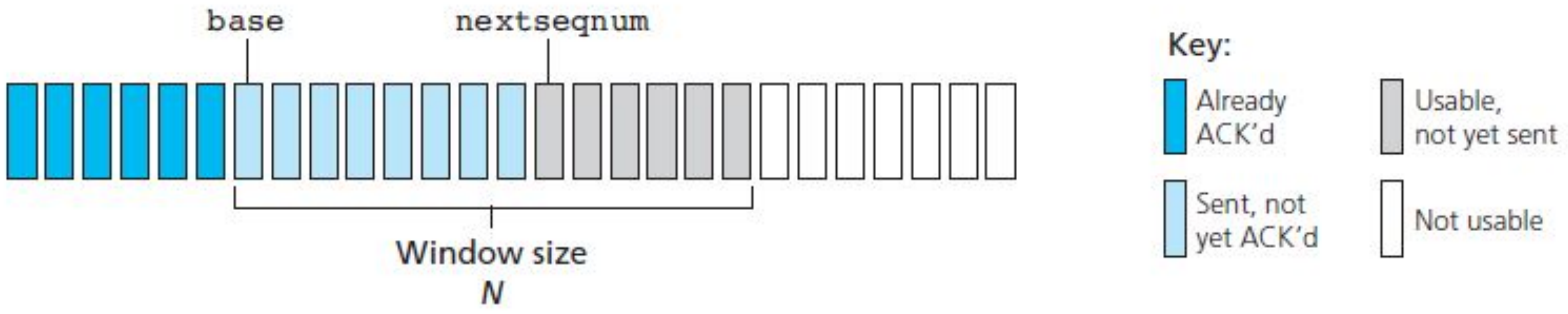
1. Go-back N protocol.
2. Selective repeat protocol

GBN

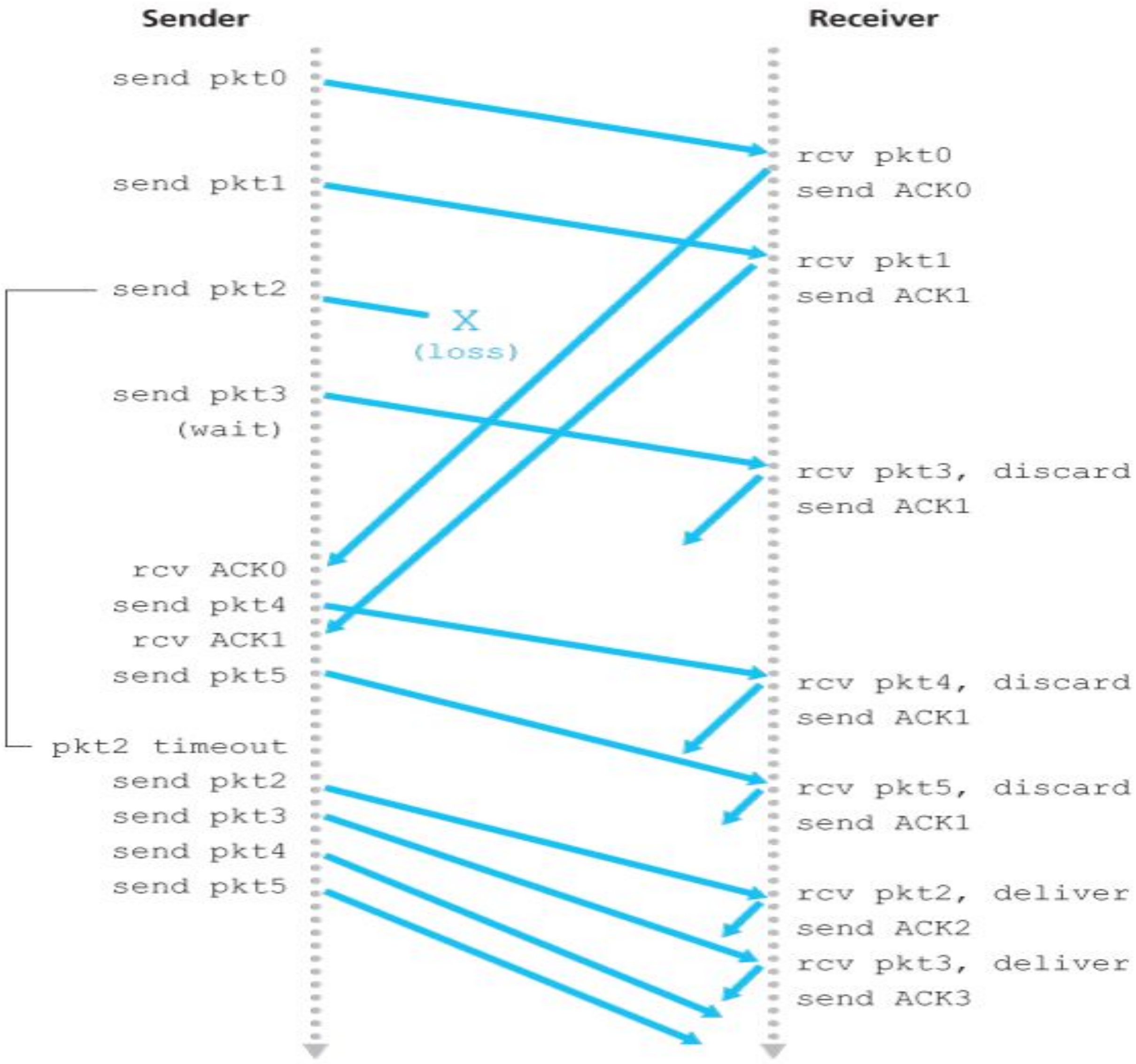
In a Go-Back-N (GBN) protocol, the sender is allowed to transmit multiple packets (when available) without waiting for an acknowledgment, but is constrained to have no more than some maximum allowable number, N, of unacknowledged packets in the pipeline.

N is referred to as the window size and the GBN protocol itself as a sliding-window protocol.

Concept of GBN



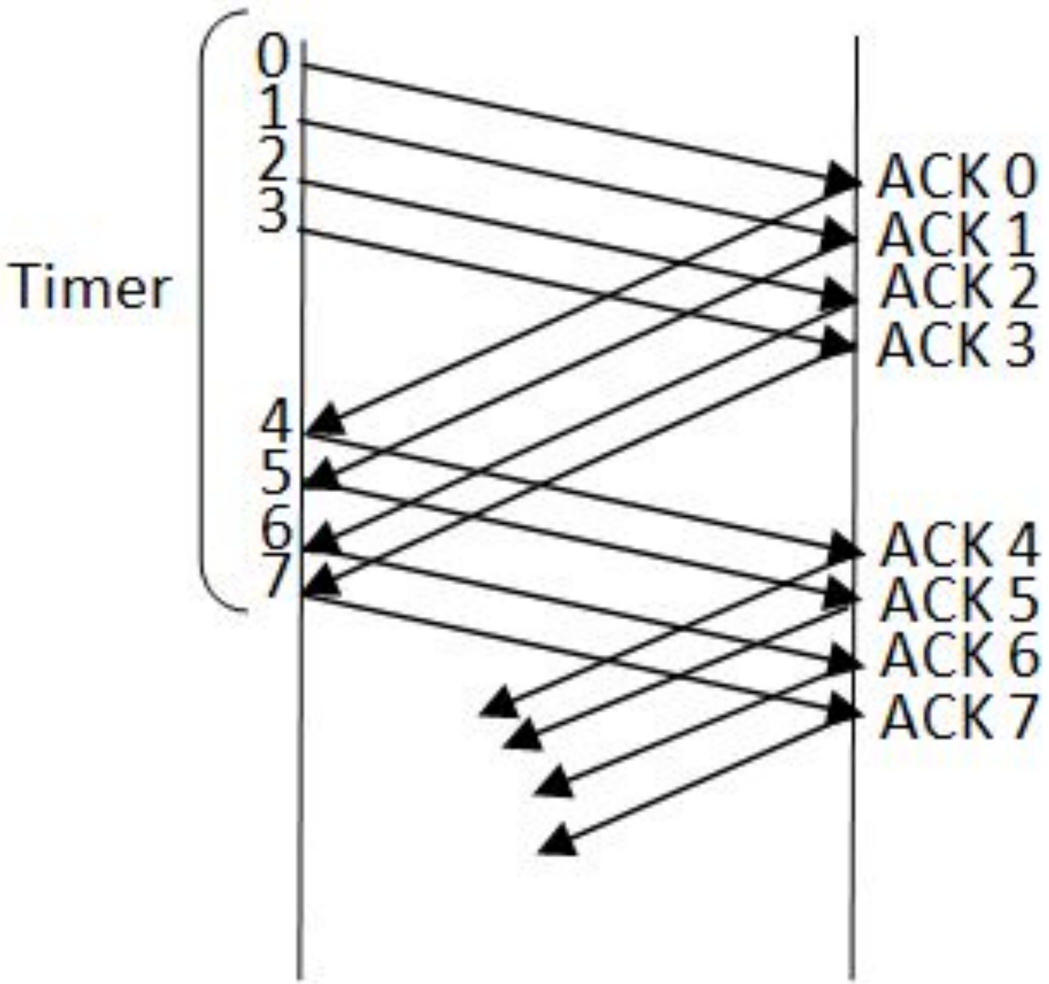
Sender's view of sequence numbers in Go-Back-N



Go-Back-N in operation

Pipelining

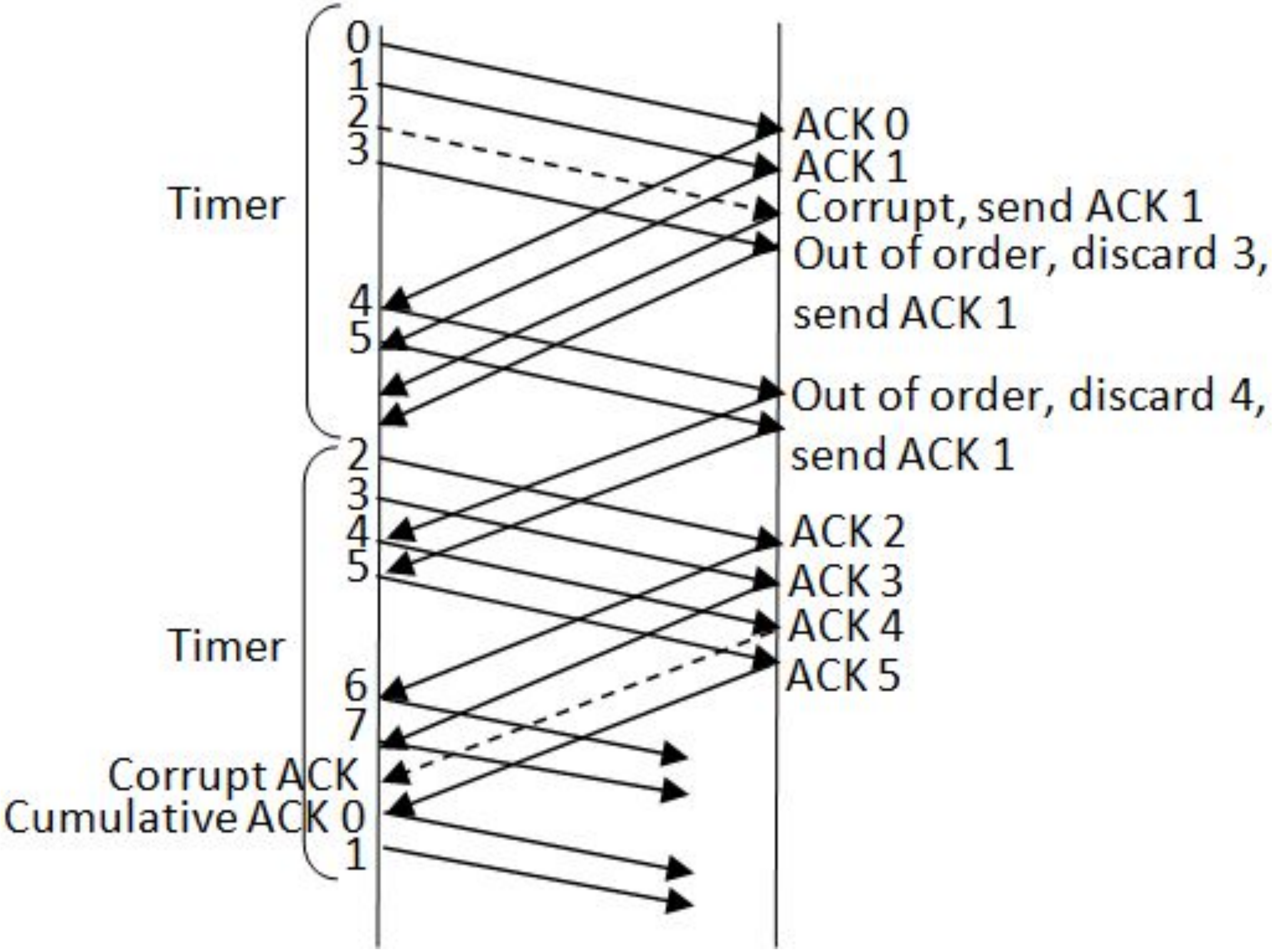
Timing diagram of Go Back N and SR (seq. nos. 0-7 and transit at most 4 packets)



Scenario 1: No packet loss
GBN: Given figure
For SR: Same figure with individual timers for each packet

Pipelining

Timing diagram of Go Back N (seq. nos. 0-7 and transit at most 4 packets)



<u>Corrupt packets:</u>

<u>Case 1:</u> In-order ACK repeated

<u>Case 2:</u> Corrupt ACK followed by correct ACK is taken as cumulative acknowledgement

Concept of SR

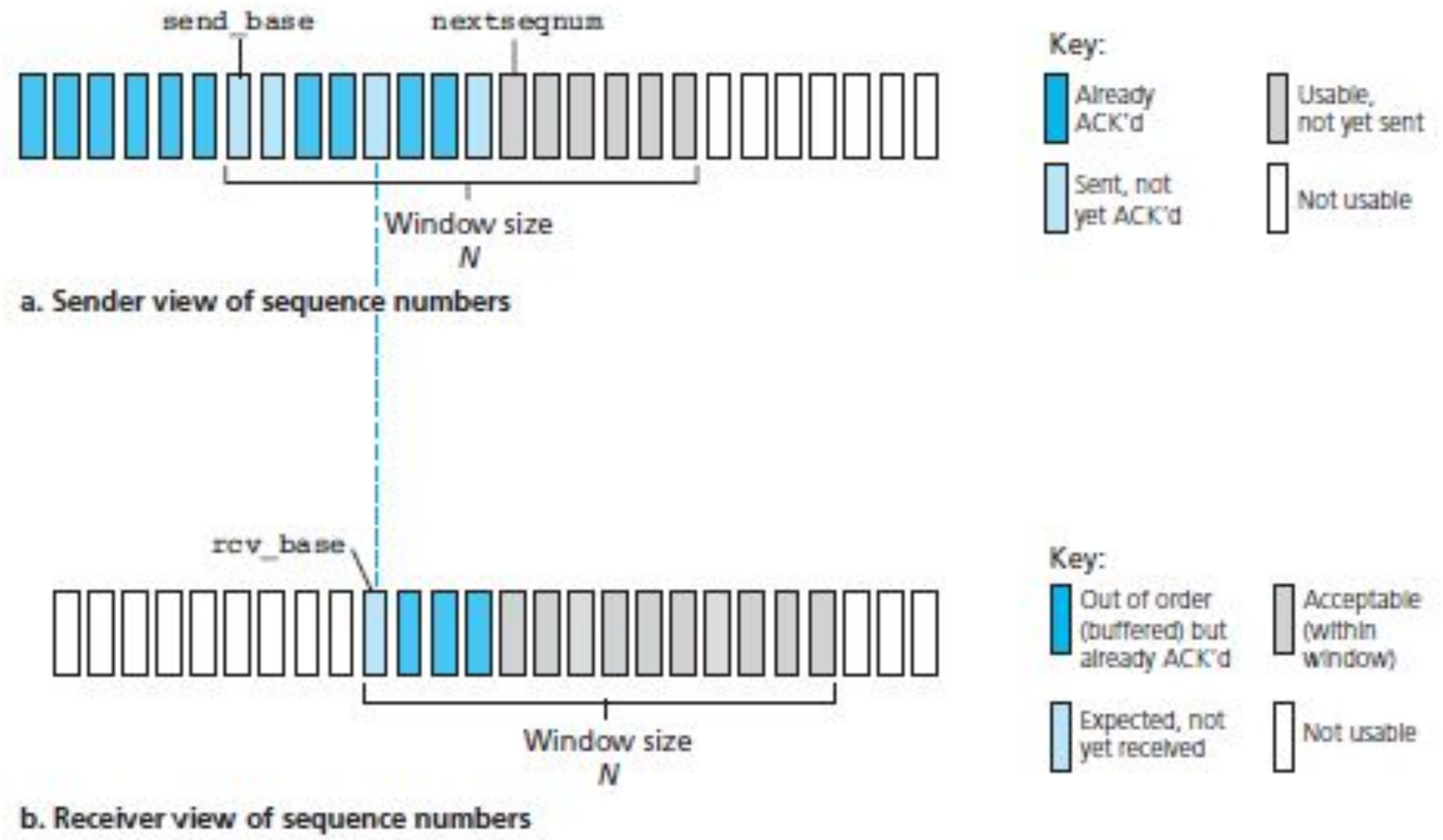
GBN fills the pipeline

When the window size and bandwidth-delay product are both large, many packets can be in the pipeline.

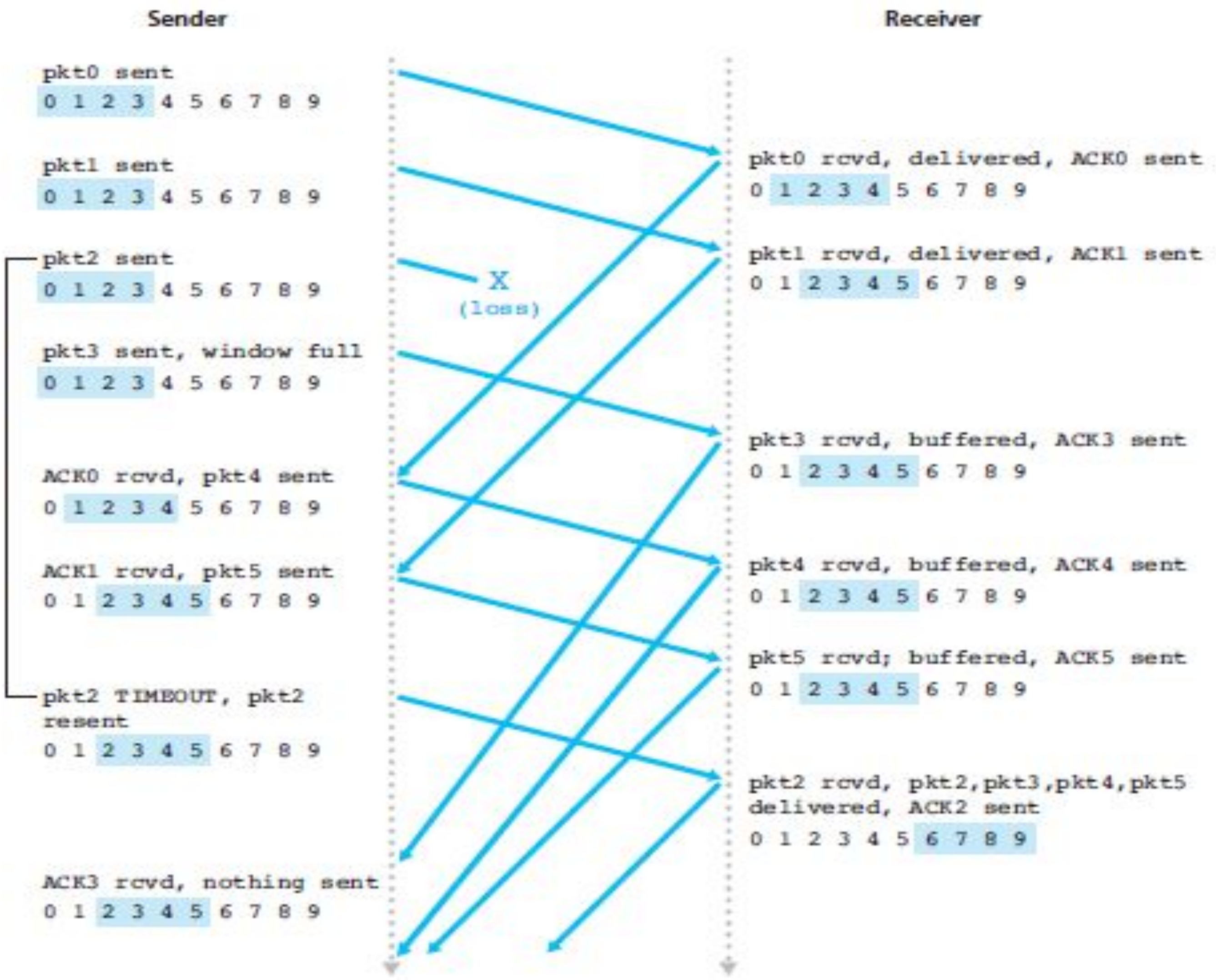
A single packet error can thus cause GBN to retransmit a large number of packets, many unnecessarily.

As the probability of channel errors increases, the pipeline can become filled with retransmissions.

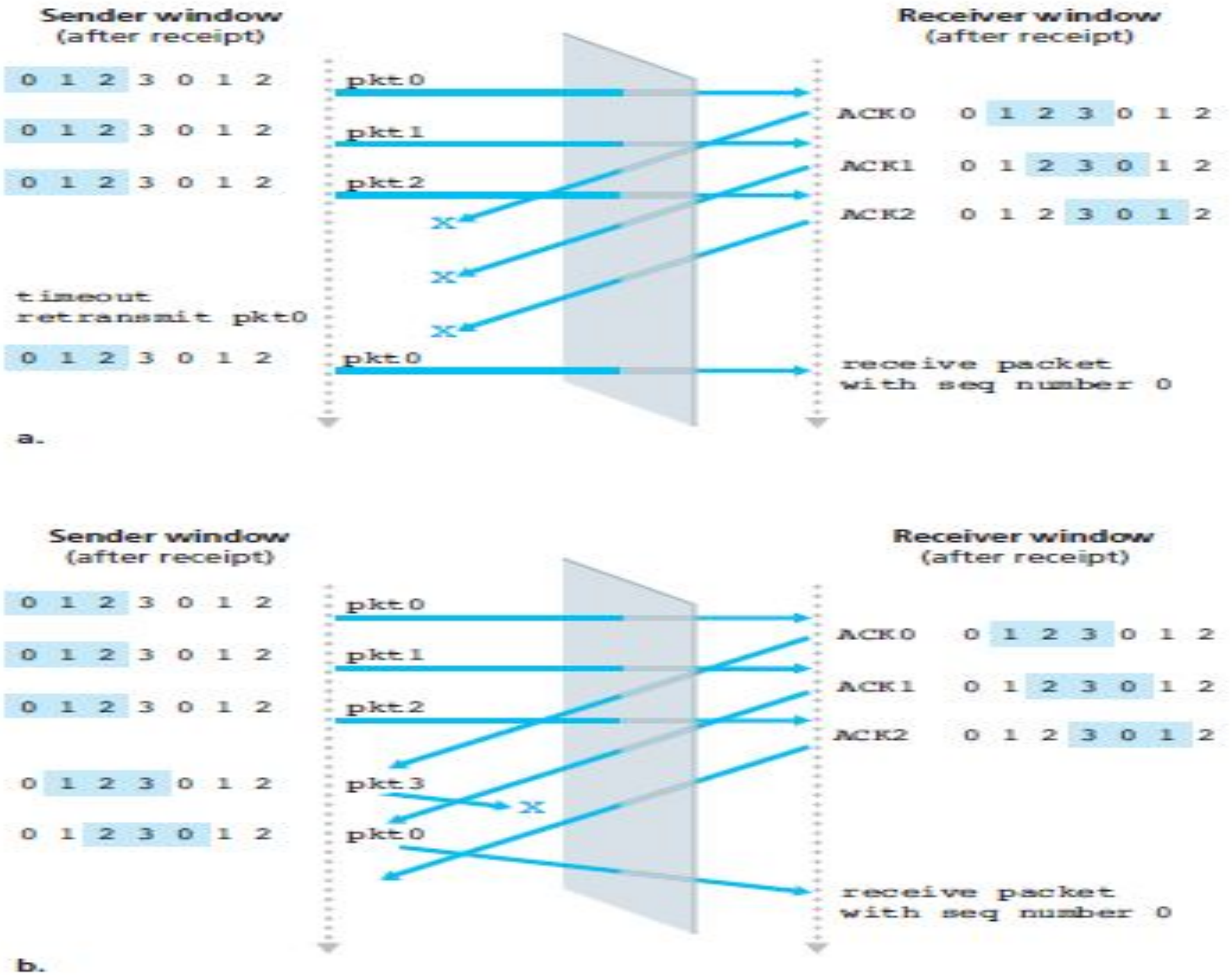
Selective-Repeat protocols avoid unnecessary retransmissions by having the sender retransmit only those packets that it suspects were received in error (that is, were lost or corrupted) at the receiver.



Selective-repeat (SR) sender and receiver views of sequence-number space

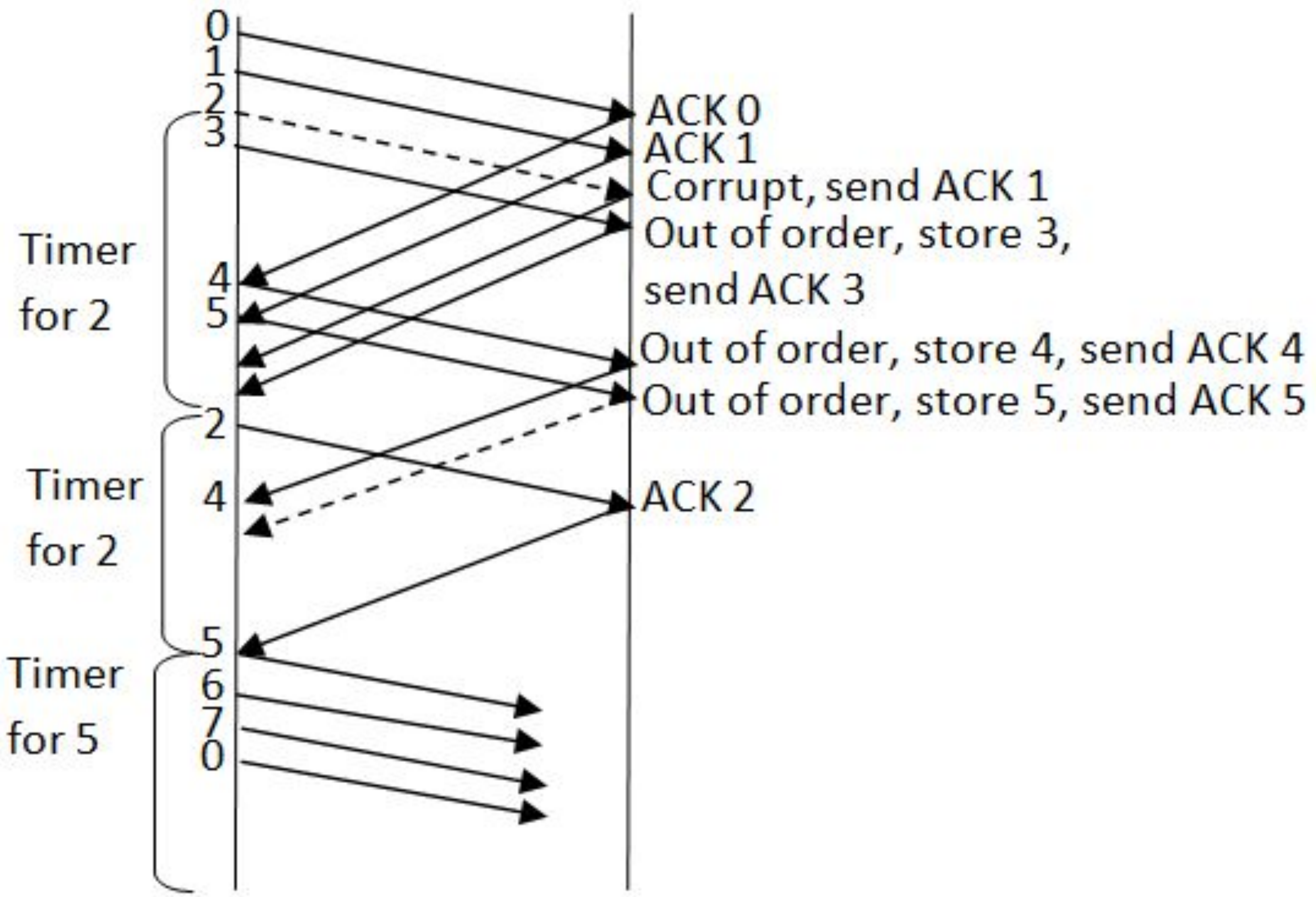


SR operation



SR receiver dilemma with too-large windows: A new packet or a retransmission?

Timing diagram of SR (seq. nos. 0-7 and transit at most 4 packets)



Only some timers depicted

<u>Corrupt packets:</u>

<u>Case 1:</u> In-order ACK repeated

<u>Case 2:</u> Corrupt ACK followed by correct ACK but no cumulative acknowledgement

Pipelining

Event	Go back N	Selective repeat
Range of seq. nos.	0 to 2N – 1 and cyclic for sliding window size of N	Same as Go back N
Batch of packets ready for transmission	Assign seq. no. to each packet and transmit at most N packets	Assign seq. no. to each packet and transmit at most N packets
Starting timer	Start timer after transmitting all packets	Start a new timer for each packet

Sliding window represents the max number of packets that can be in transit between sender and receiver

Cyclic assignment: Suppose a last packet in the transmit buffer was assigned seq. no. N-1, the next arriving packet into the transmit buffer is given seq. no. 0

Pipelining

Event	Go back N	Selective repeat
Receiver decodes a new in–order packet	Store the packet and send ACK with the seq. no. of received packet	Store the packet and send ACK with the seq. no. of received packet
Receiver decodes an old in–order packet	Discard the packet and send ACK of last in-order packet that was stored	Discard the packet and send ACK of last in-order packet that was stored
Receiver decodes a new out–of–order packet	Discard the packet and send ACK of last in-order packet that was stored	Store the packet and send ACK with the sequence number of received packet
Receiver is unable to decode received packet	Discard the packet and send ACK of last in-order packet that was stored	Discard the packet and send ACK of last in-order packet that was stored

Pipelining

Event	Go back N	Selective repeat
Sender decodes in-order ACK before timeout	All packets up to the in-order packet are presumed to be delivered. Next packet is transmitted	Corresponding packet is presumed to be delivered. Next packet is transmitted
Sender decodes out-of-order ACK before timeout	Sender waits for missing ACKs and timer expiry	Terminate corresponding timer and wait for missing ACKs
Sender is unable to decode the received packet before timeout	Sender waits for missing ACKs and timer expiry	Sender waits for missing ACKs and timer expiry
Timer expires	Retransmit all packets following the last in-order ACKed packet	Retransmit the packet for which timer expired

Summary: Features of pipelining protocol

- Sequence numbers are used to distinguish between old packets and new packets.
- Checksum is used for error detection.
- Sliding windows and buffers are maintained by sender and receiver to keep track of packets in transit.
- Sequence number of last correctly received (in-order) packet is maintained.
- Timers are used by sender to limit the occurrence of packet retransmissions.
- Choosing small value for the timer causes more retransmissions while a large value causes less throughput

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Summary: Comparison of Go-back N and Selective Repeat

- GBN takes cumulative acknowledgements whereas SR doesn’t.
- Suppose some ACKs were missing, GBN retransmits all packets under the sliding window whereas SR retransmits selectively.
- A receiver using GBN does not store out-of-order packets whereas it does store out-of-order when using SR.
- Sender and receiver sliding windows are in sync under GBN whereas under SR they can be out-of-sync.
- Both of them retransmit unacknowledged packets upon timeout

Summary: Limitations of Go-back N and Selective Repeat

- Timer values are fixed arbitrarily.
- Transmission rate (i.e., sliding window length) is fixed.
- Due to the above two limitations these protocols can neither exploit low network congestion nor can prevent causing network congestion.
- Message segmentation is performed arbitrarily.
- Buffer overflow may occur at the receiver.
- Two-way data transmission cannot be implemented.
- Only one pair of processes between sender-receiver can communicate at any time.
- Hence, we need an adaptive protocol which overcomes the above limitations..
- The answer is *Transmission Control Protocol* (TCP)

Pipelining

1 A. Consider using a stop and wait protocol between two hosts who are connected by a direct link of rate 1 Mbps. Let the one way propagation delay be 99.5 ms. For a packet of size 1000 bits, determine the link utilization (%) and the throughput of the sender (bits/s). Explain your result with appropriate formulae.

Pipelining

Link utilization is expressed as

$$\frac{\text{transmission delay}}{\text{transmission delay} + \text{RTT}}$$

$$= \frac{(1000/10^6)}{(1000/10^6) + 2 \times 99.5 \times 10^{-3}} = 0.5\ \%$$

Throughput of the sender is

$$\frac{\text{packet size}}{\text{transmission delay} + \text{RTT}} = 5000\ \text{bps}$$

Pipelining

1B. Suppose a pipelining protocol is used instead of a stop and wait protocol in the question 1A. Calculate the number of packets to achieve 100% link utilization. What will be the number of bits required to represent the sequence numbers in this case?

Pipelining

One packet achieves only 0.5% link utilization.

To achieve 100% utilization, the number of packets to be transmitted is given by

$$100\% \times 1/0.5\% = 200$$

The number of bits required to represent the sequence numbers is

$$\log_2(200) = 7.6439 \implies 8 \text{ bits}$$

THANK YOU

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