Computer Networks: Transport Layer

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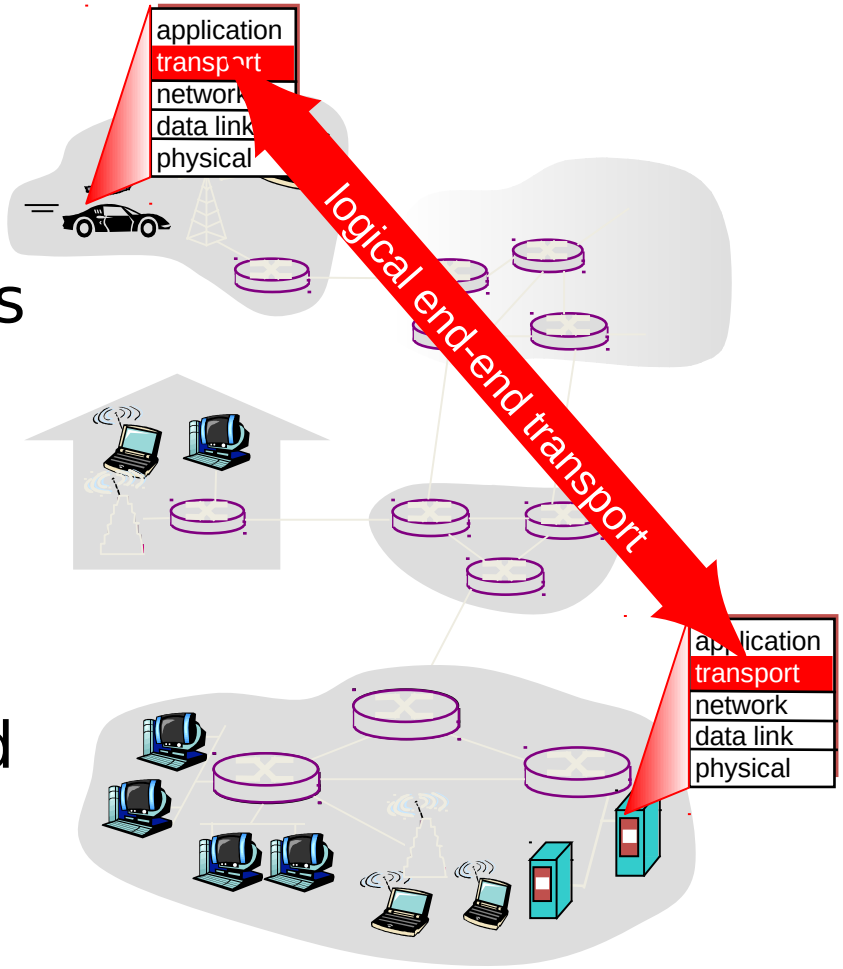
Transport Layer Services

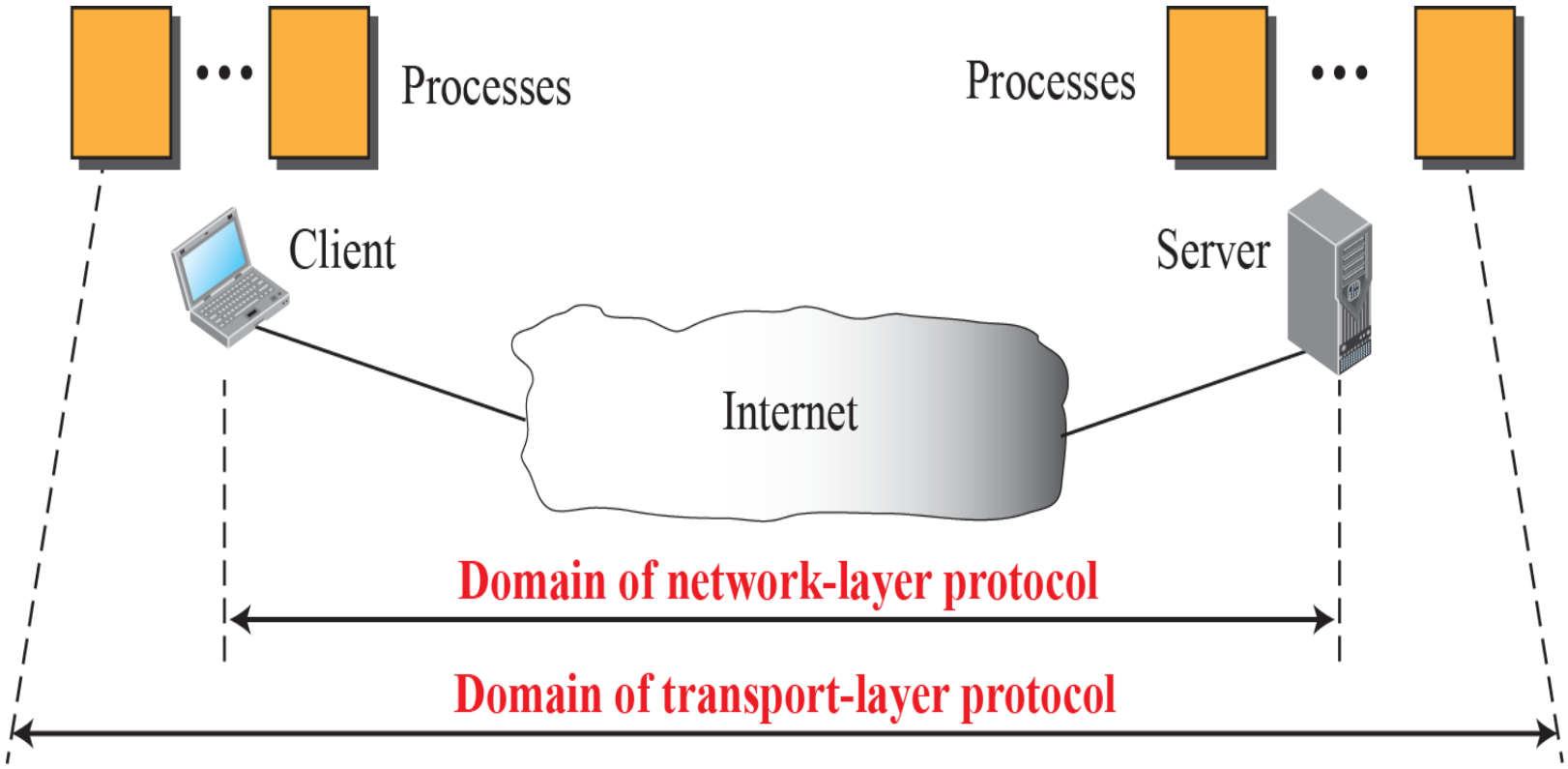
Household analogy:

5 kids sending letters to 5 kids

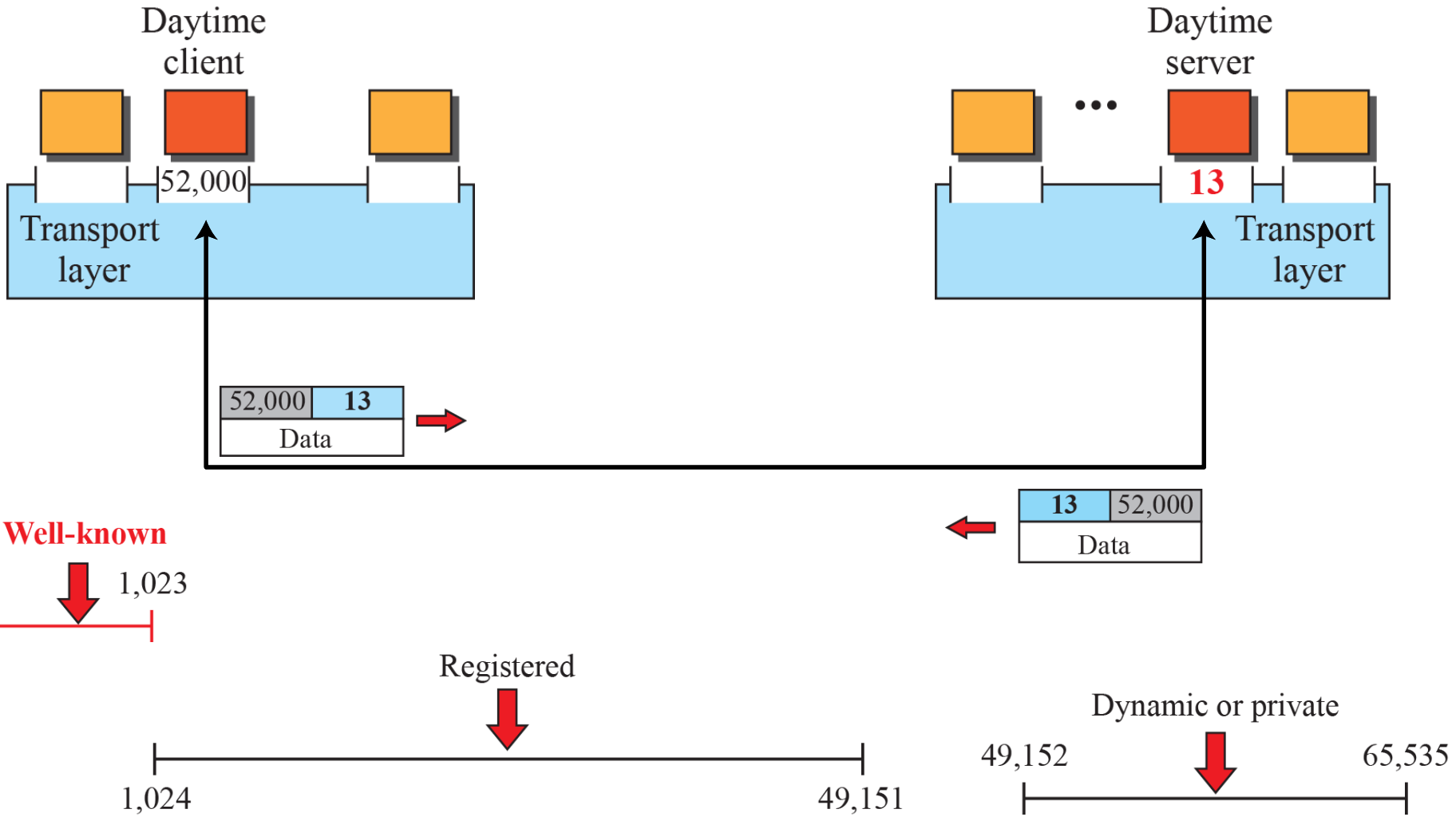
- processes = kids
- app messages = letters in envelopes
- hosts = houses
- transport protocol = Raj and Amit
- network-layer protocol = postal service



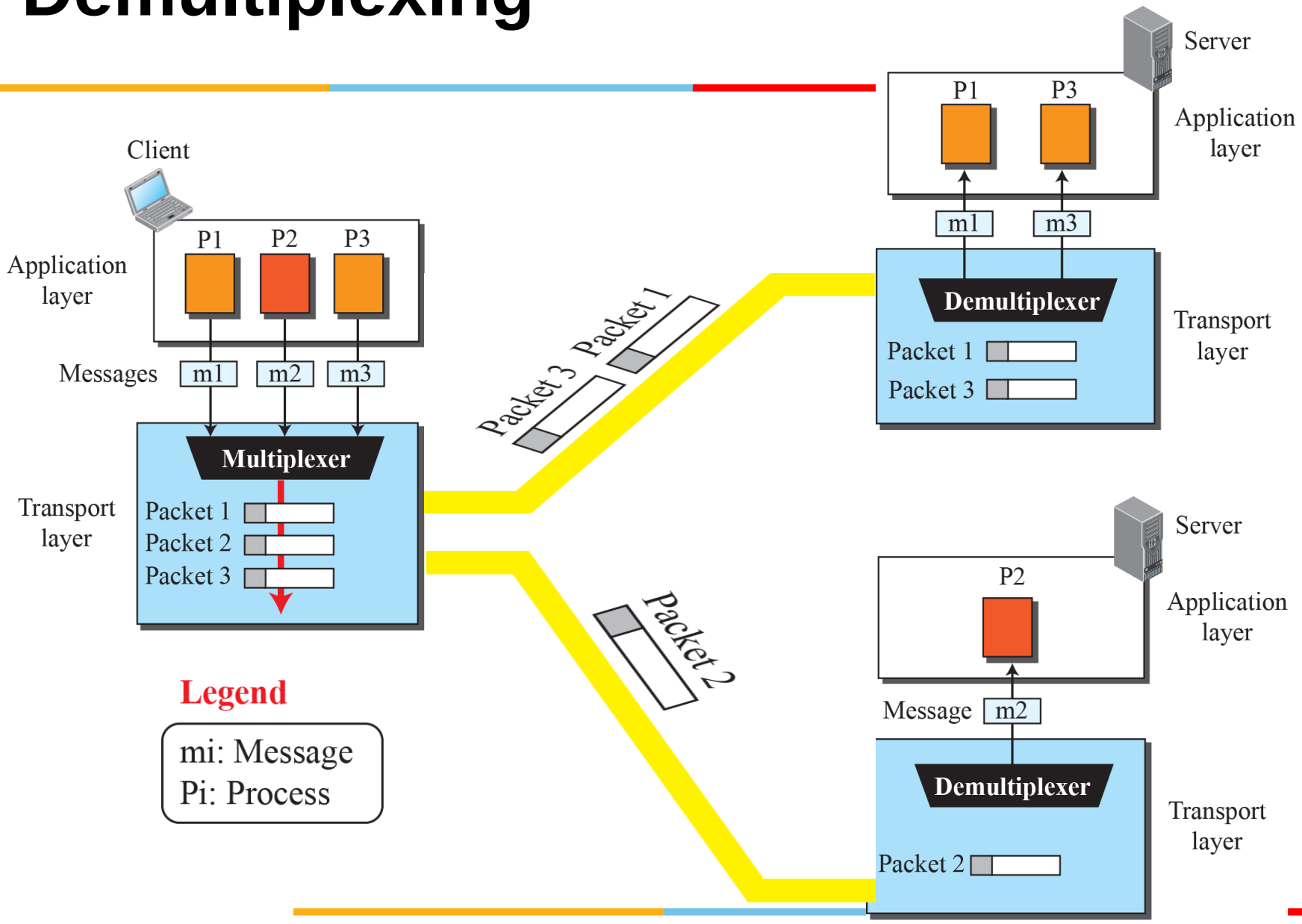
Network Vs Transport Layer



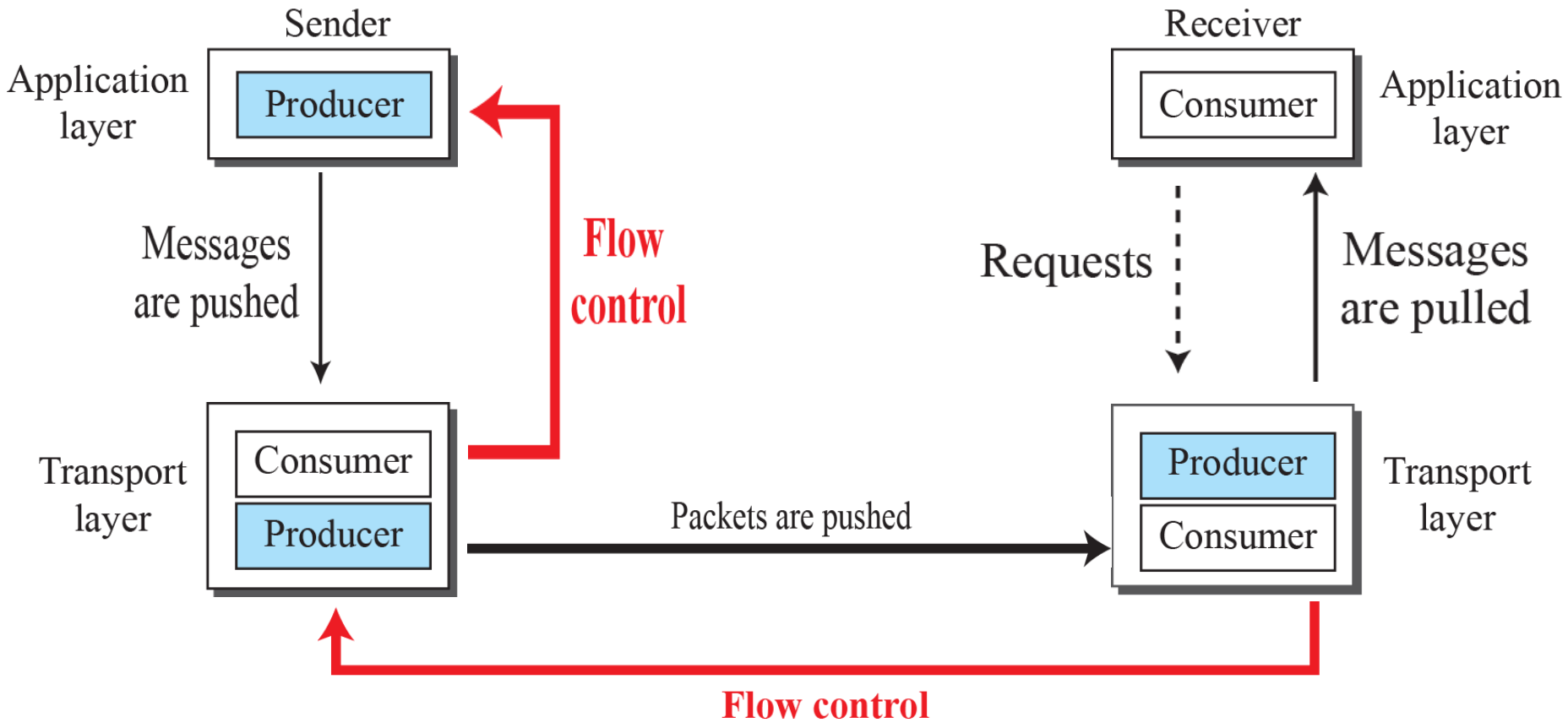
Port Numbers



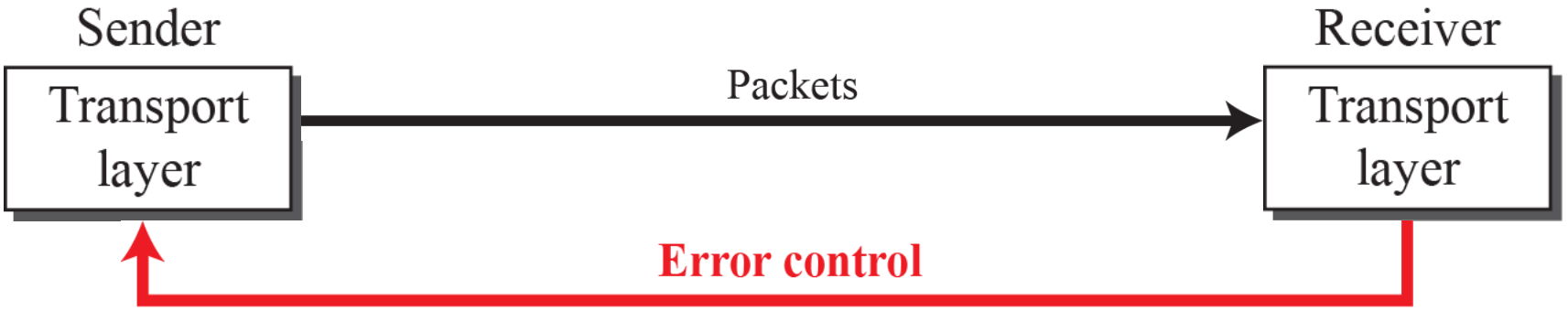
Multiplexing and Demultiplexing



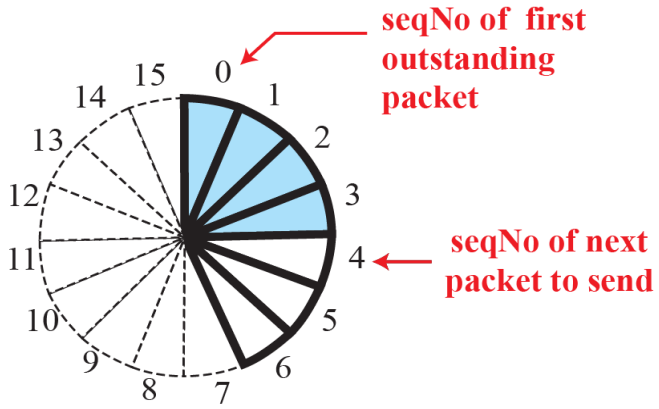
Flow Control at Transport Layer



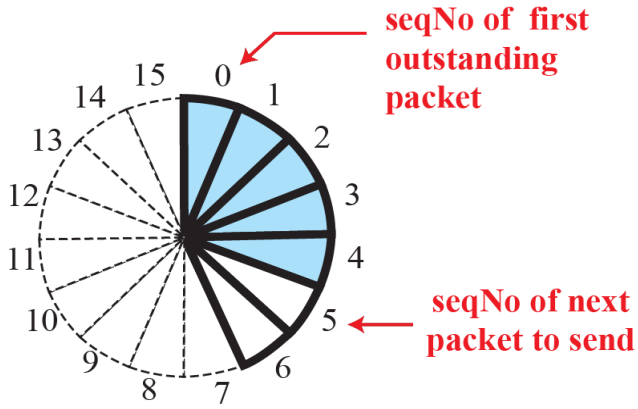
Error Control at Transport Layer



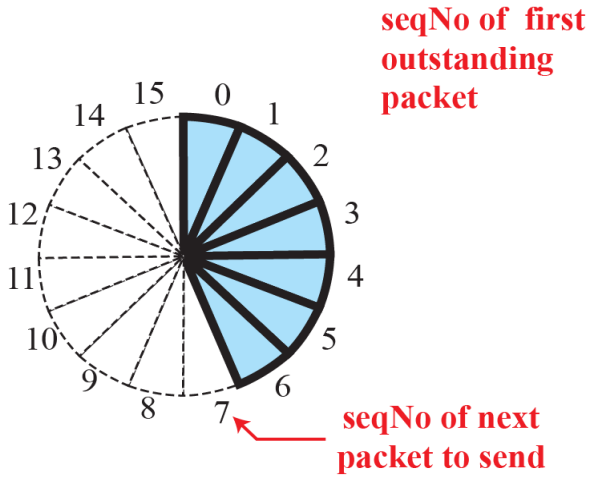
Sliding Window



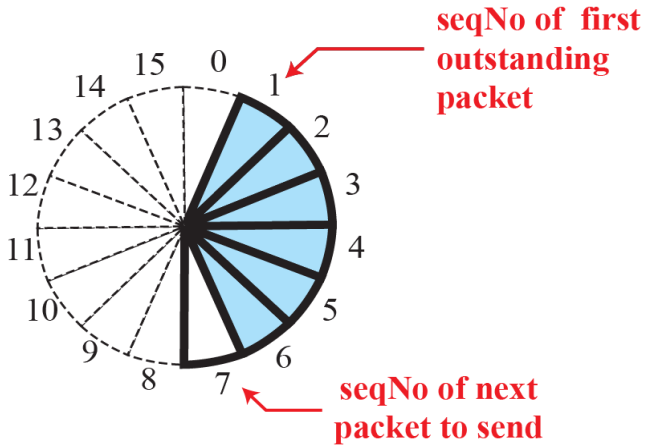
a. Four packets have been sent.



b. Five packets have been sent.

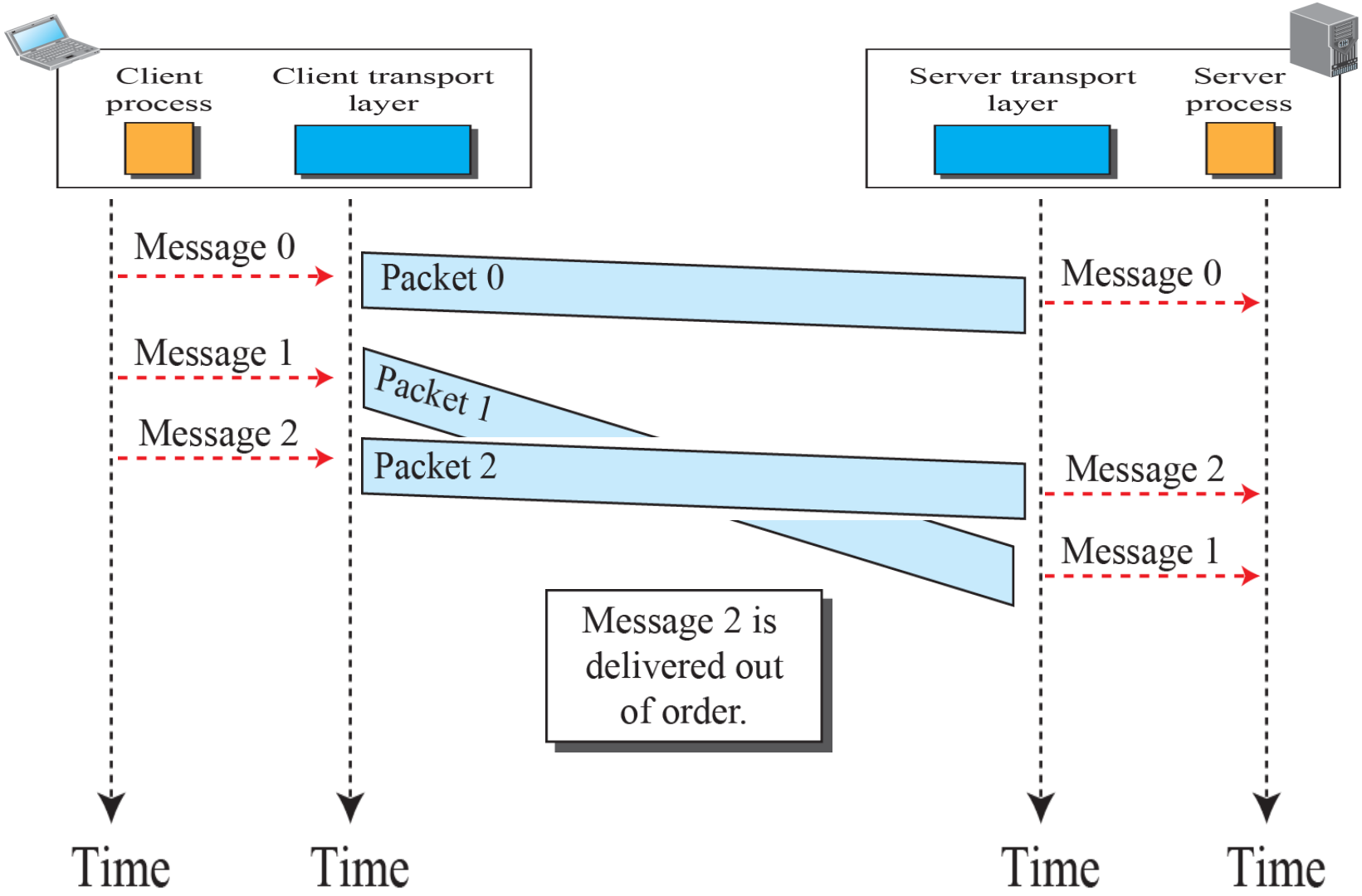


c. Seven packets have been sent; window is full.

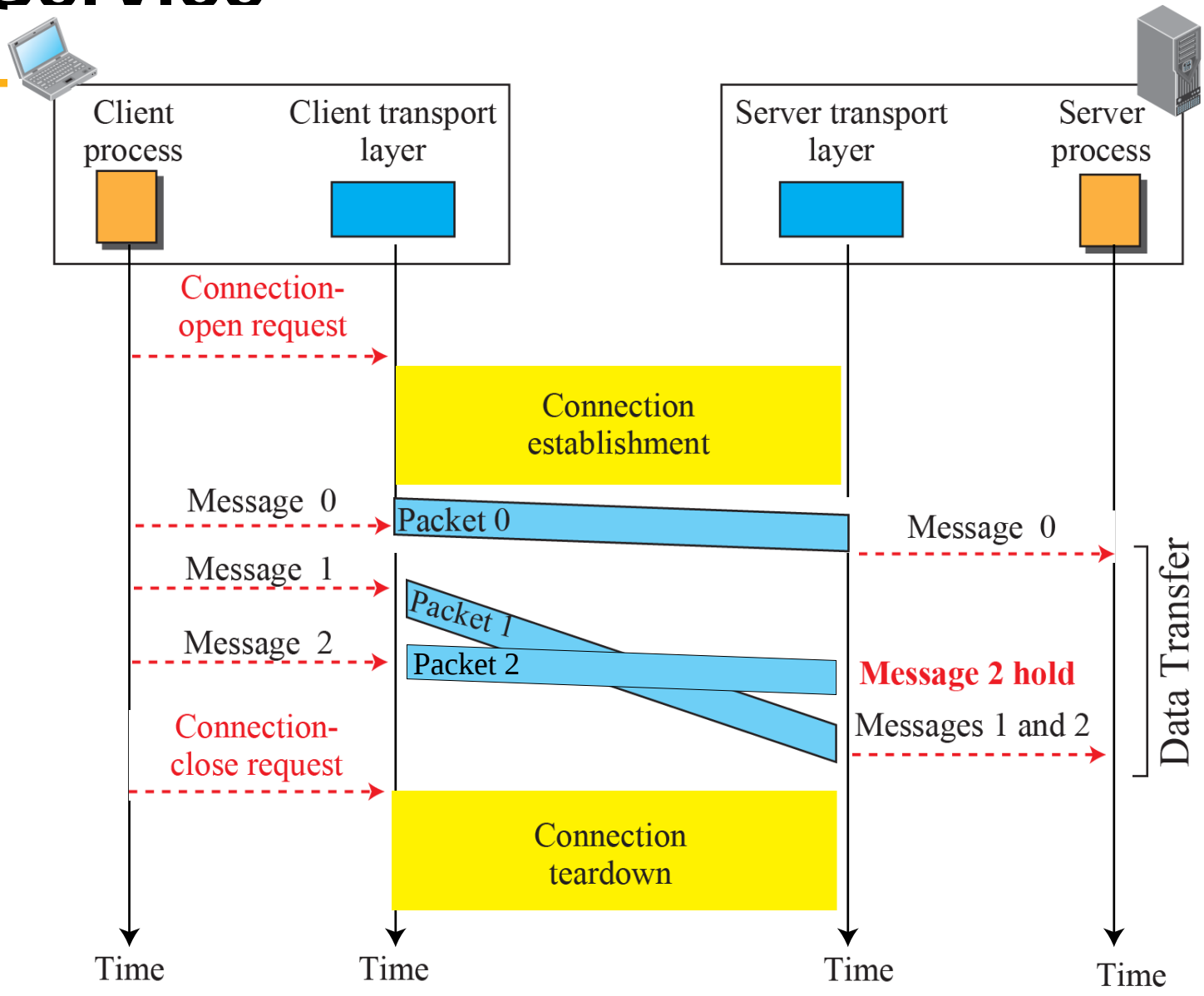


d. Packet 0 has been acknowledged; window slides.

Connectionless Service

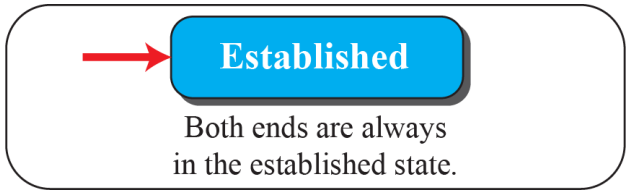


Connection Oriented Service



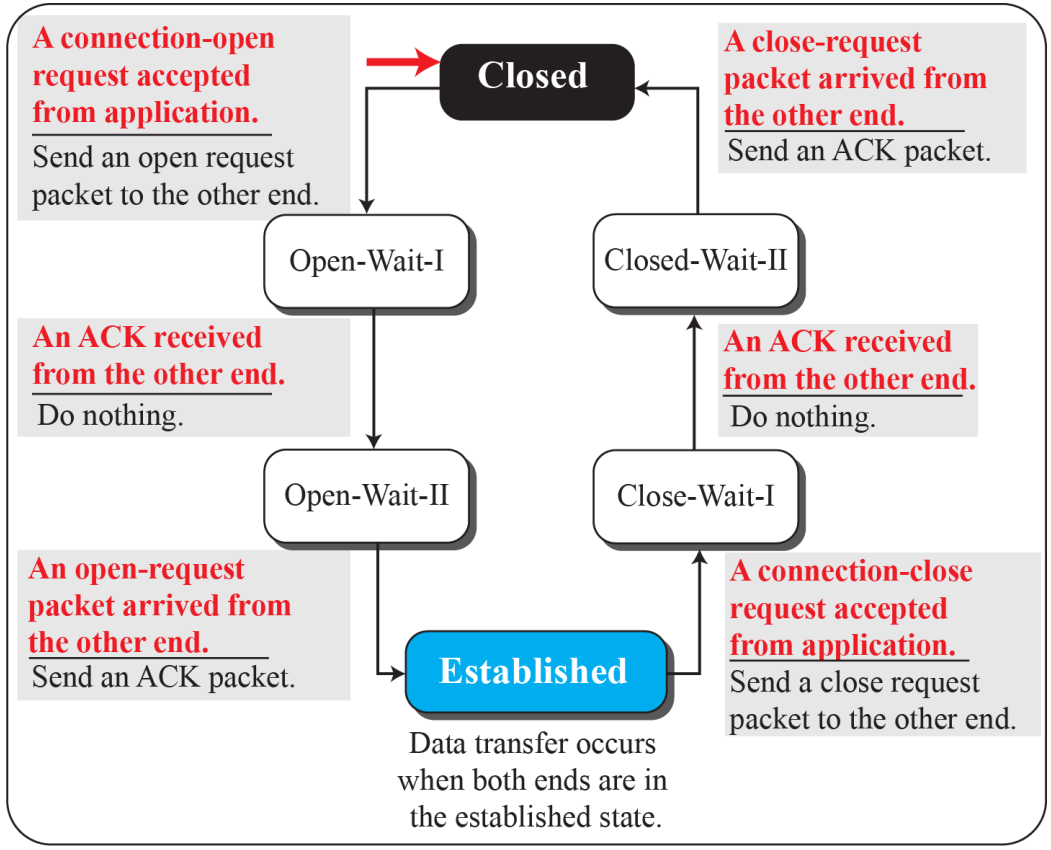
Finite State Machines

FSM for connectionless transport layer



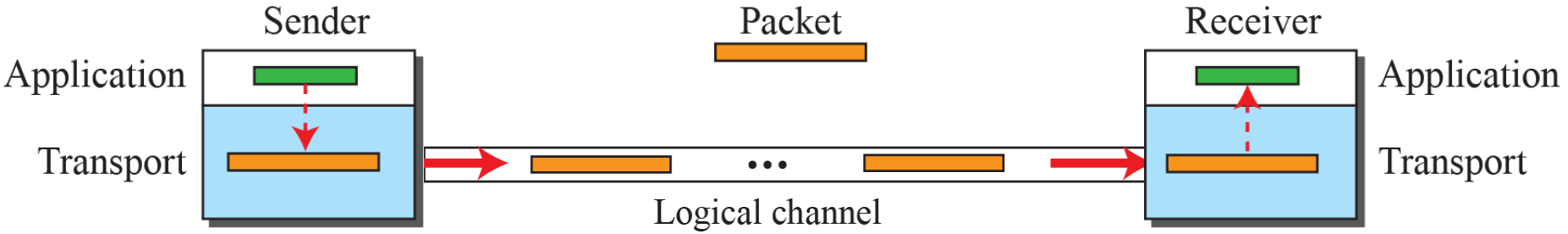
Note:
The colored arrow shows the starting state.

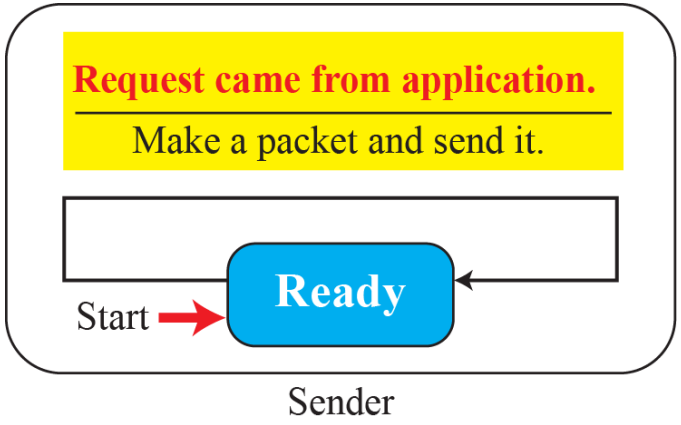
FSM for connection-oriented transport layer

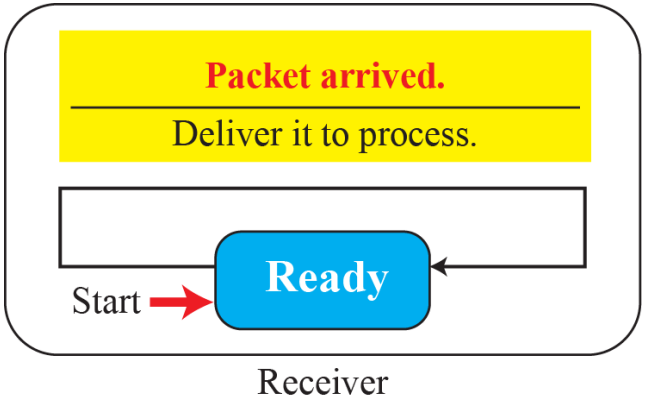


Transport layer protocols

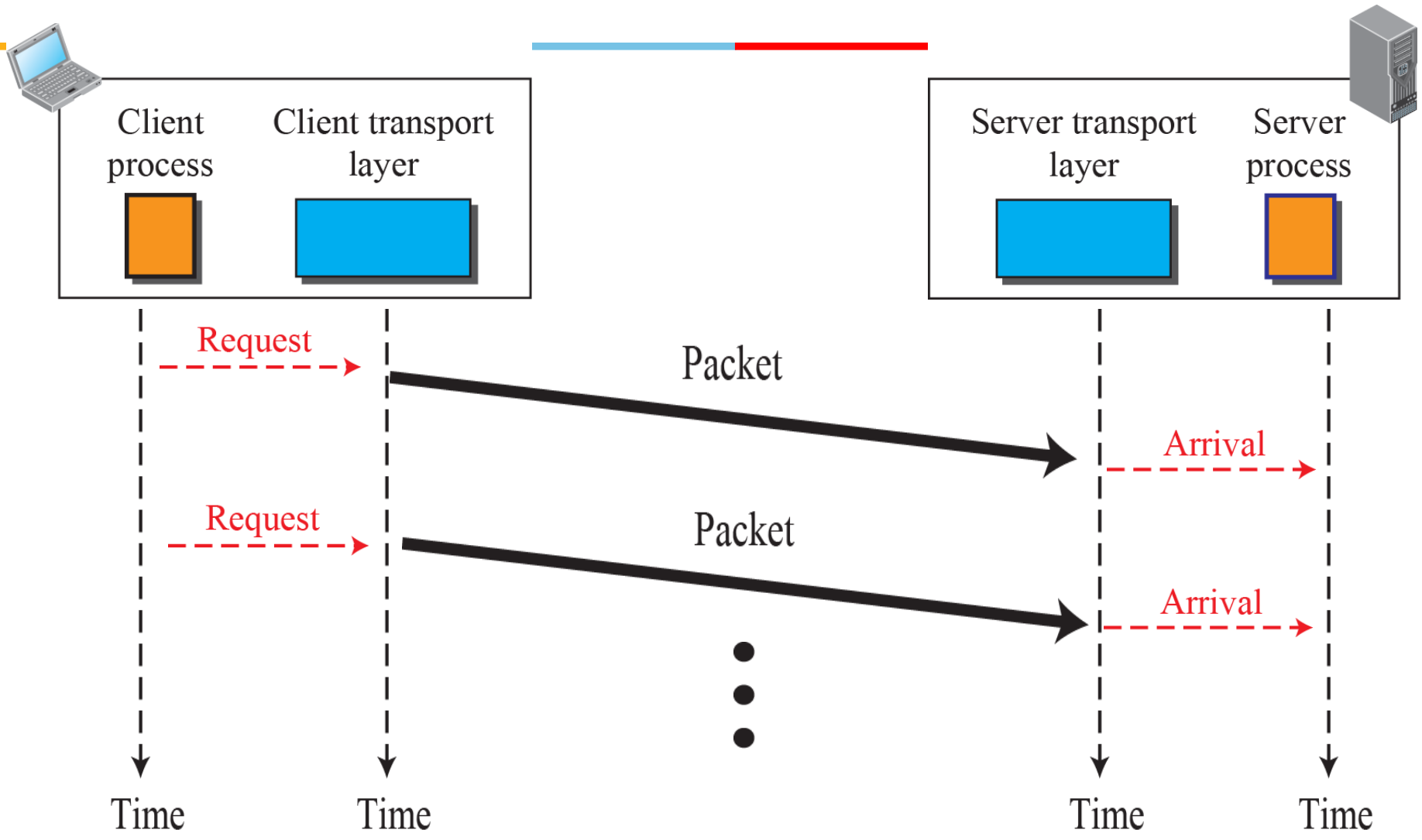
Simple Connectionless



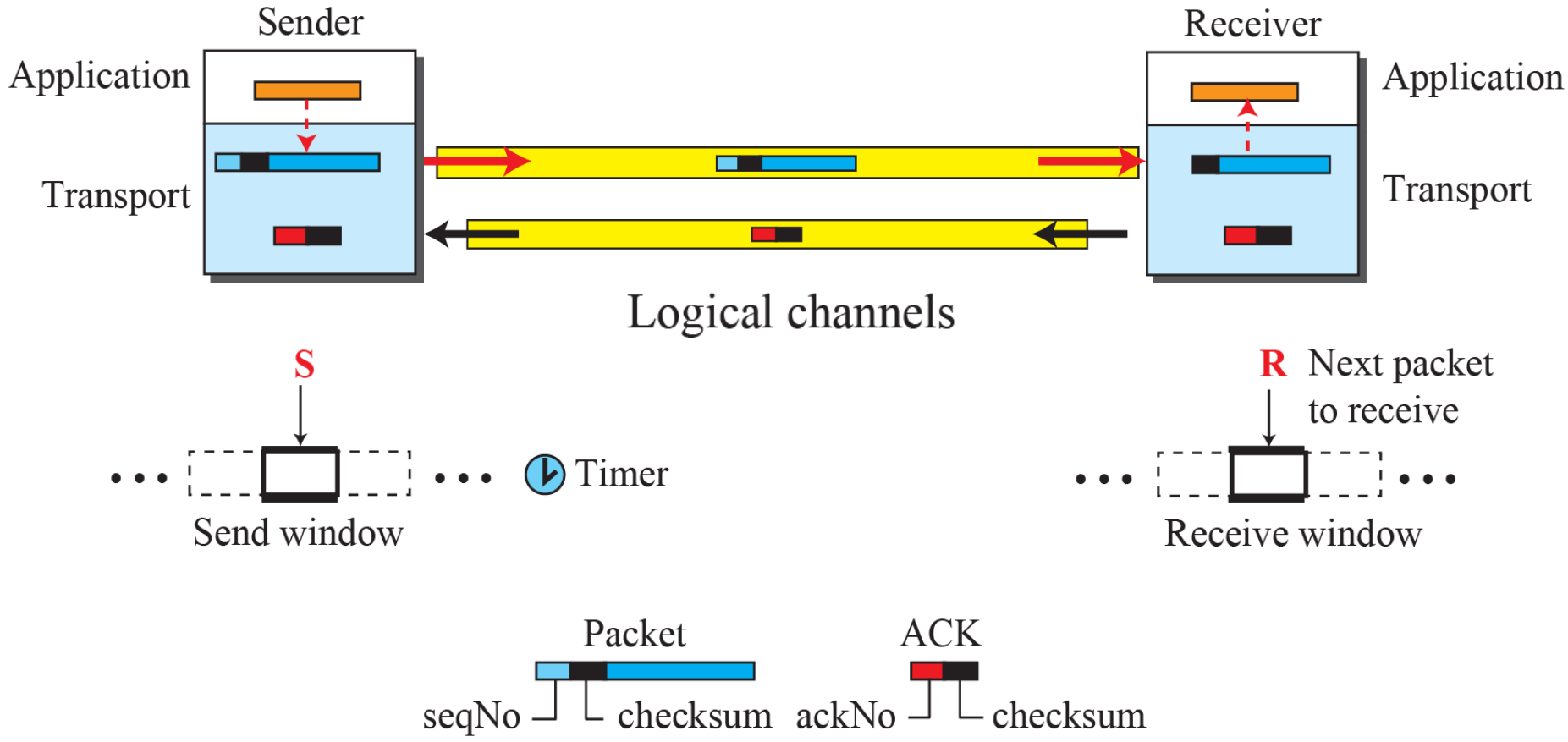




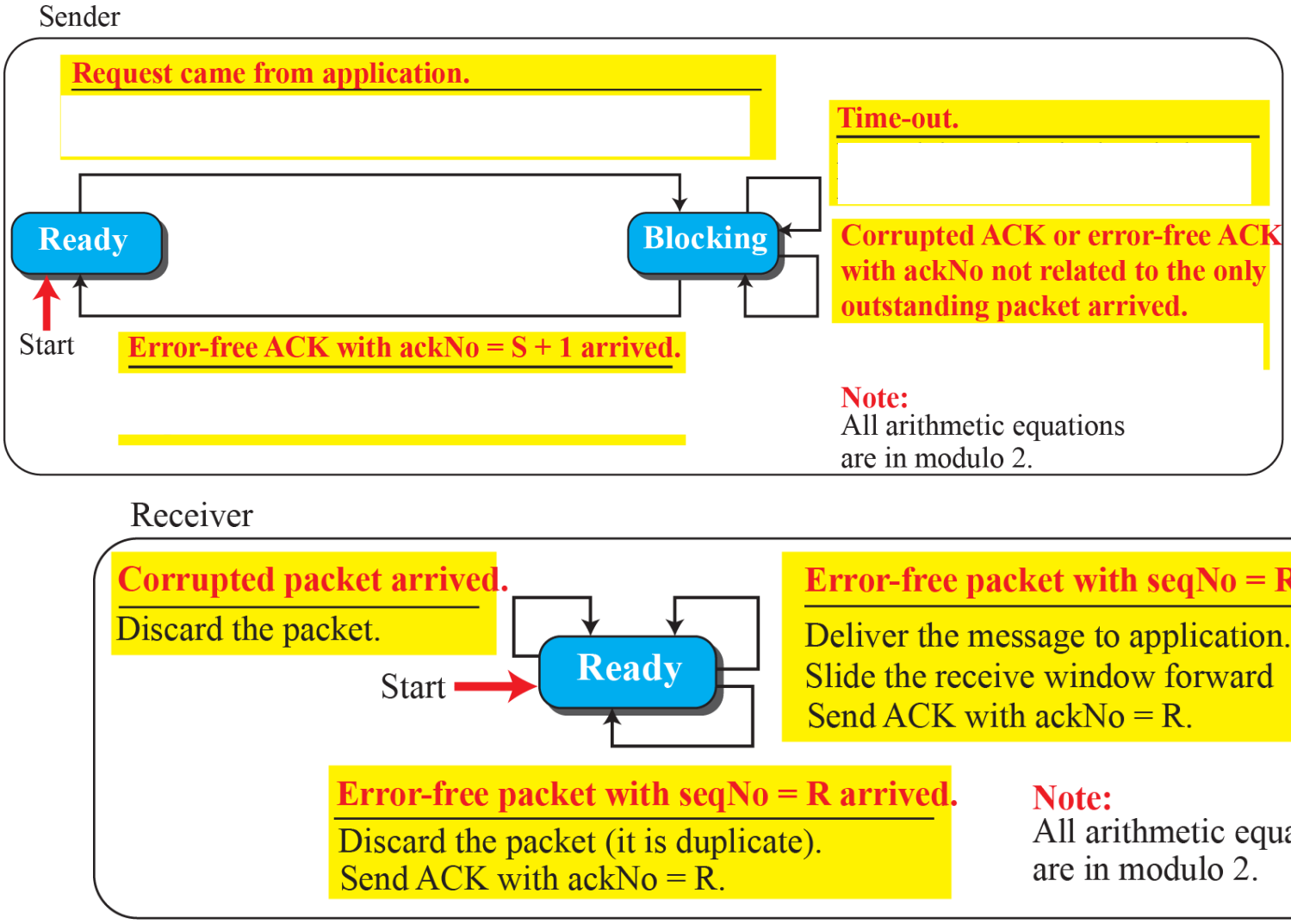
Example


Client process
Client transport layer
Server transport layer
Server process
Request
Packet
Arrival
Request
Packet
Arrival
Time
Time
Time
Time

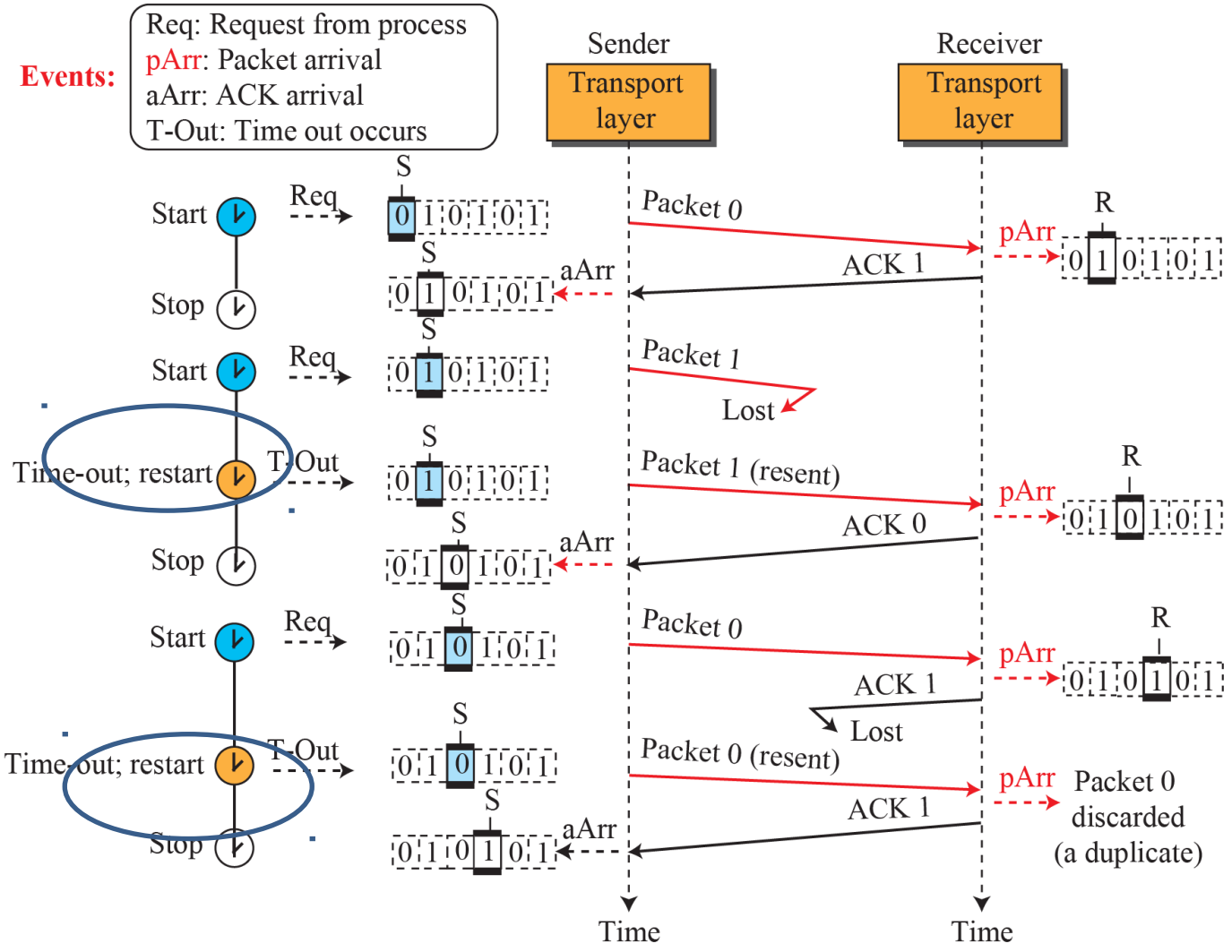
Transport layer protocols:
Connection oriented stop and wait



FSM for Stop and Wait



Example Stop and Wait



Efficiency of Stop & Wait: bandwidthXdelay

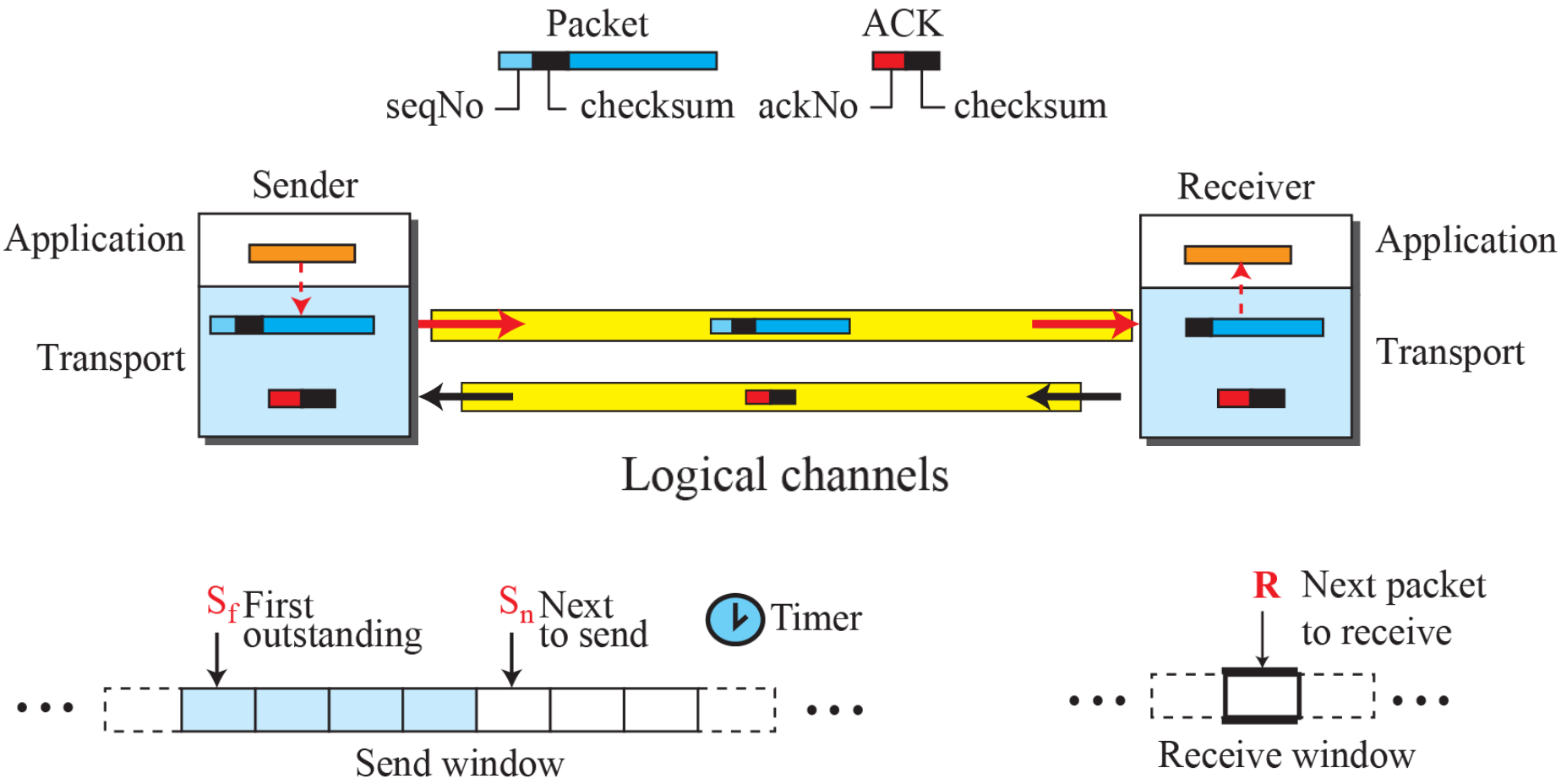
It is a measure of the number of bits a sender can transmit through the system while waiting for an acknowledgement.

Assume that, in a Stop-and-Wait system, the bandwidth of the line is 1 Mbps, and 1 bit takes 20 milliseconds to make a round trip. What is the bandwidth-delay product? If the system data packets are 1,000 bits in length, what is the utilization percentage of the link?

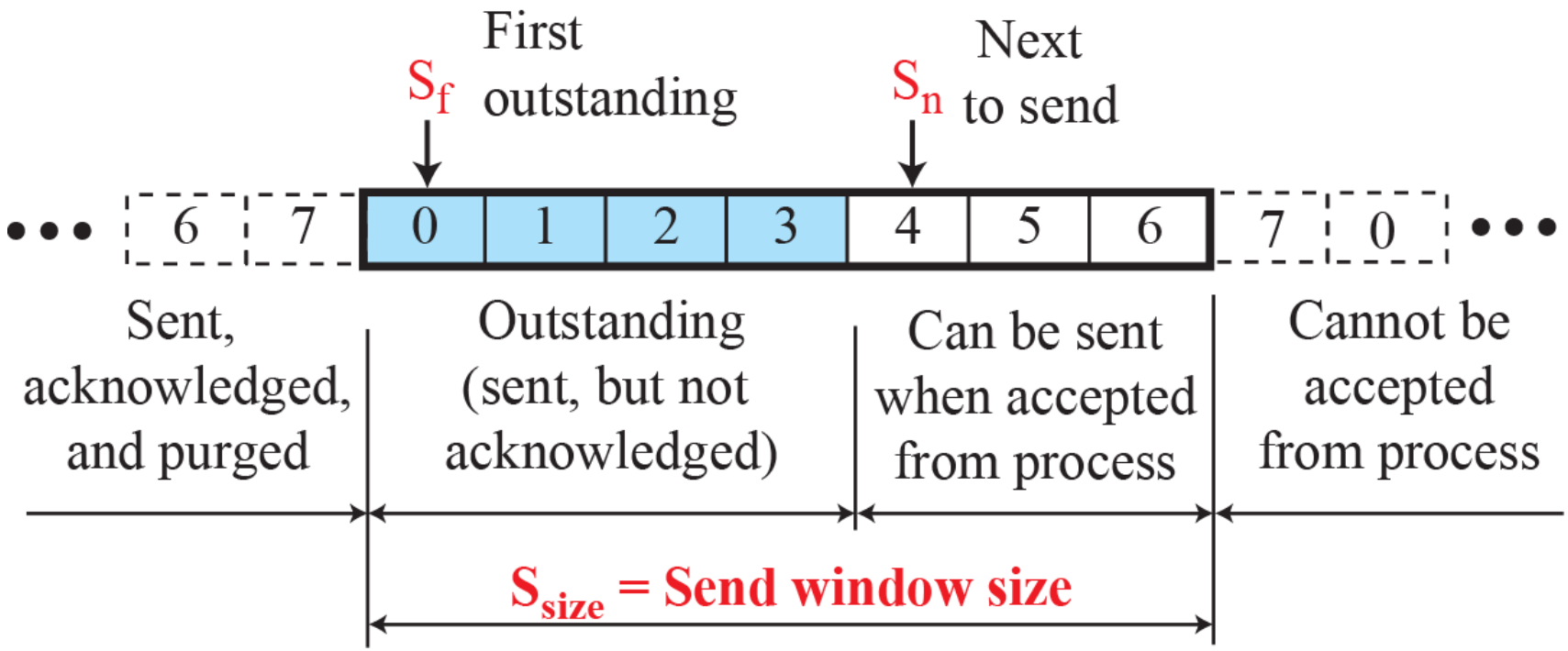
What is the utilization percentage of the link in above example if we have a protocol that can send up to 15 packets before stopping and worrying about the acknowledgments?

Pipelining

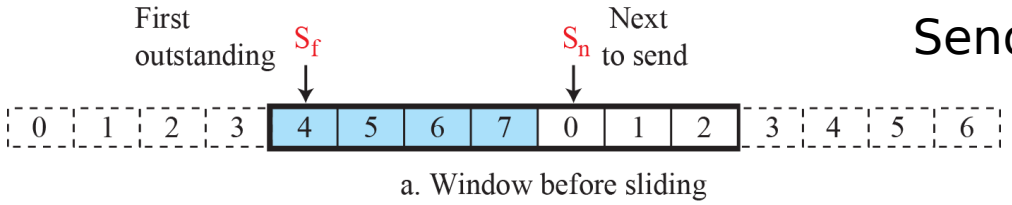
Go-Back-N protocol



Send window for Go-Back-N



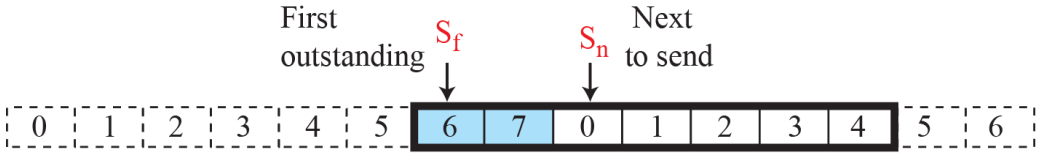
Sliding the send window



a. Window before sliding

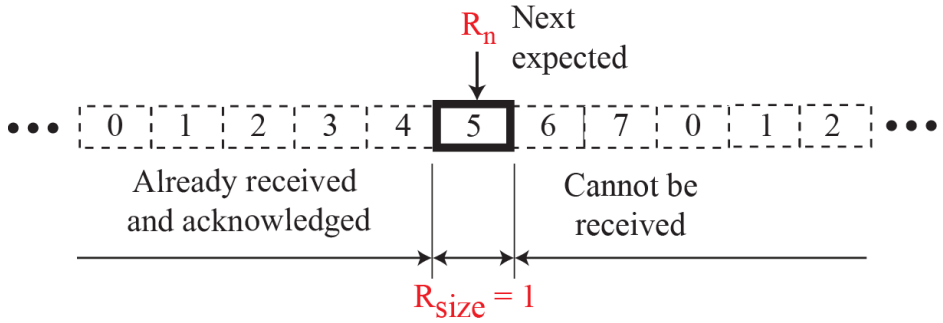
Send window

Sliding direction

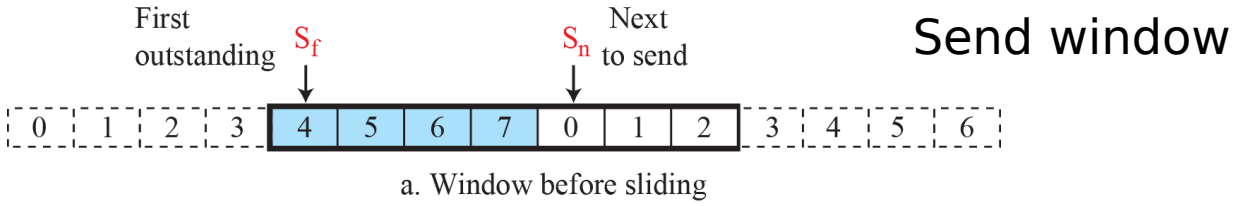


b. Window after sliding (an ACK with ackNo = 6 has arrived)

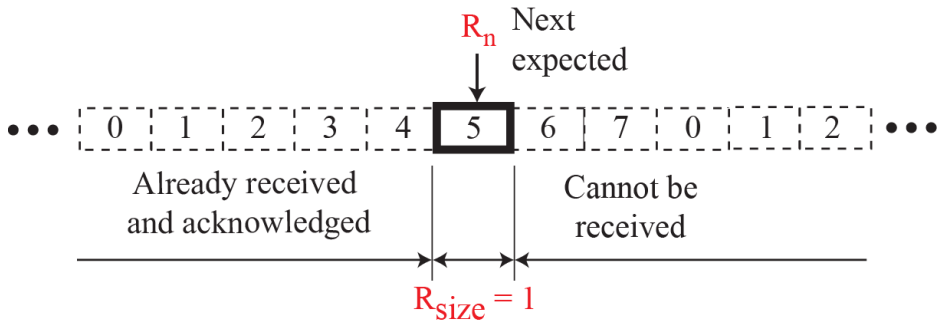
Receive window



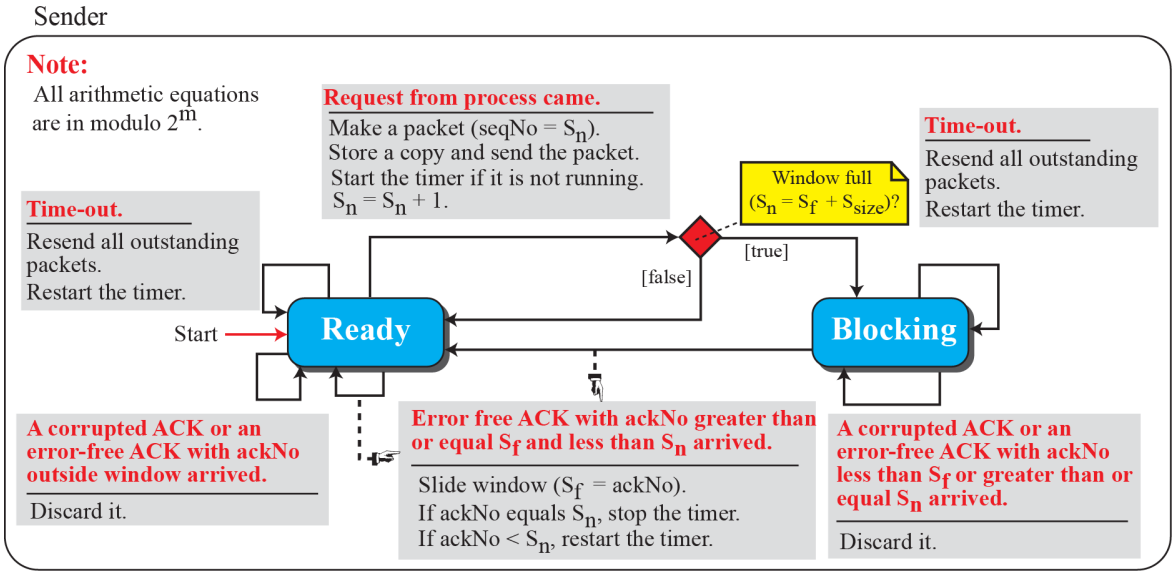
Go-Back-N: Sliding the send window recap



Receive window

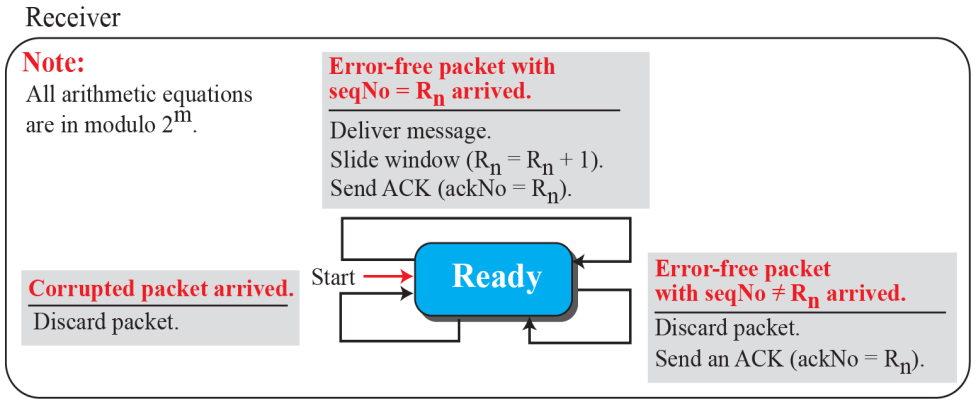


FSMs for the Go-Back-N protocol

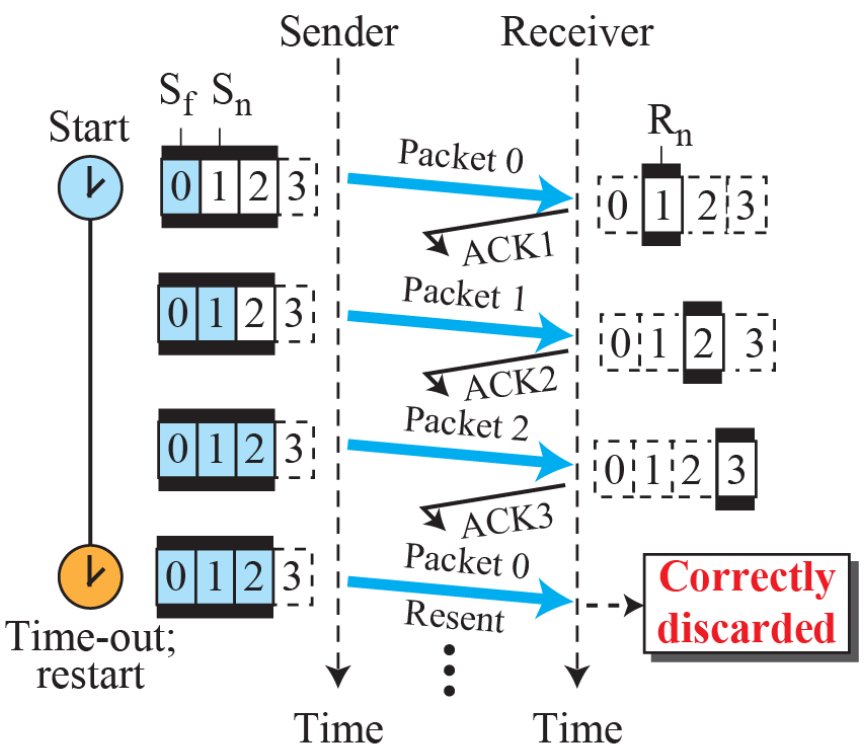


Go-back-N: Pipelining

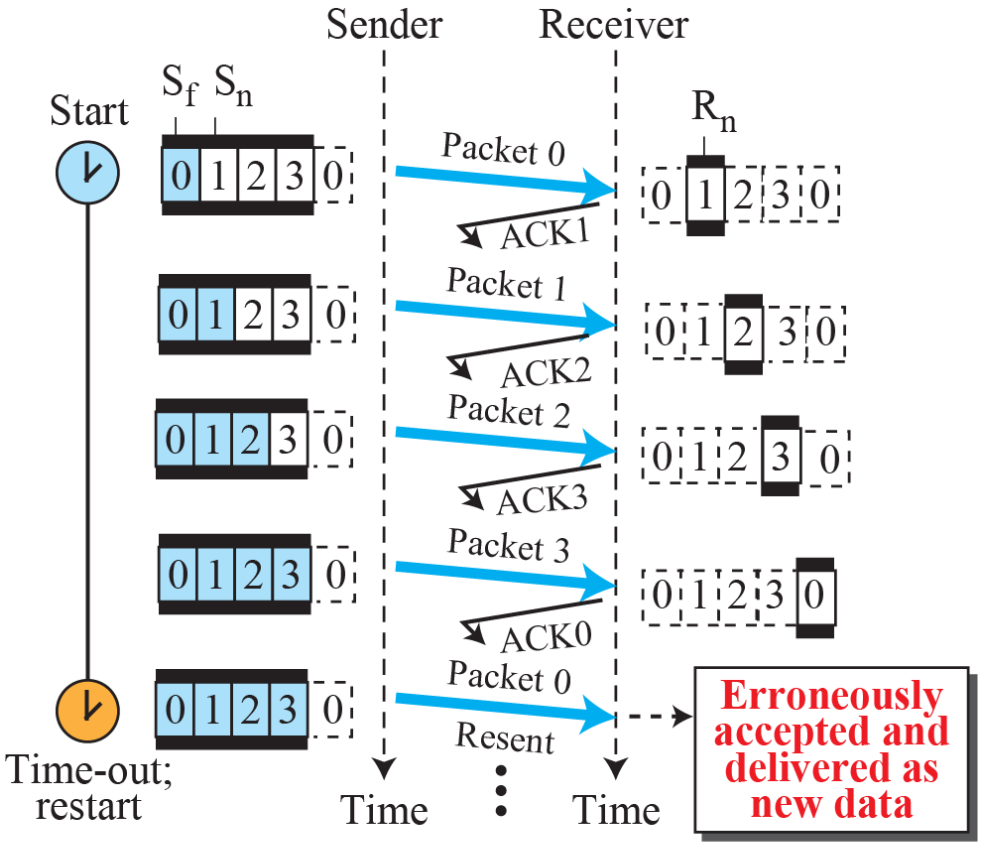
- Sender can have up to N unacked packets in pipeline
- Rcvr only sends cumulative acks
  - Doesn't ack packet if there's a gap
- Sender has timer for oldest unacked packet
  - If timer expires, retransmit all unacked packets



Send window size for Go-Back-N

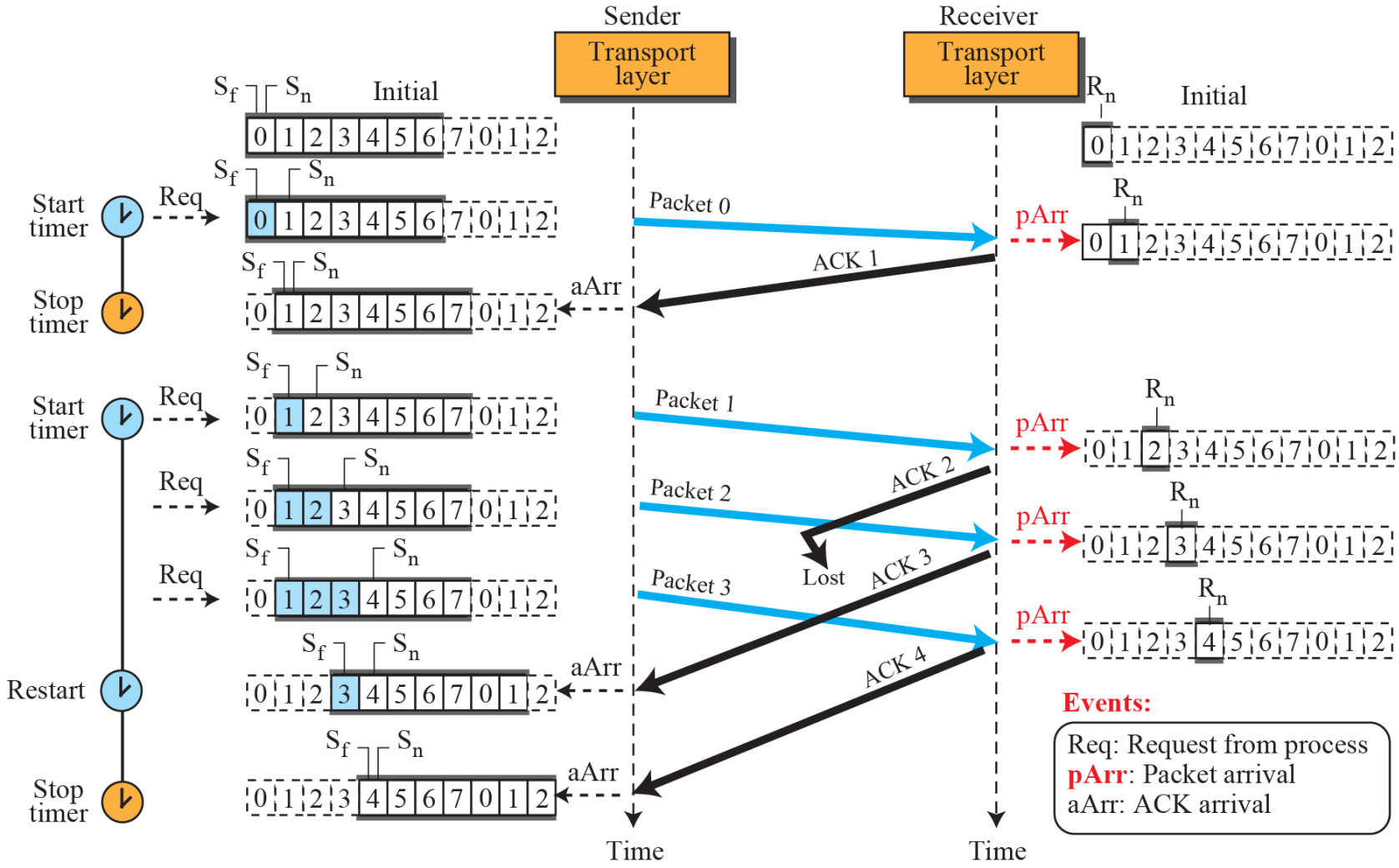


a. Send window of size $< 2^m$

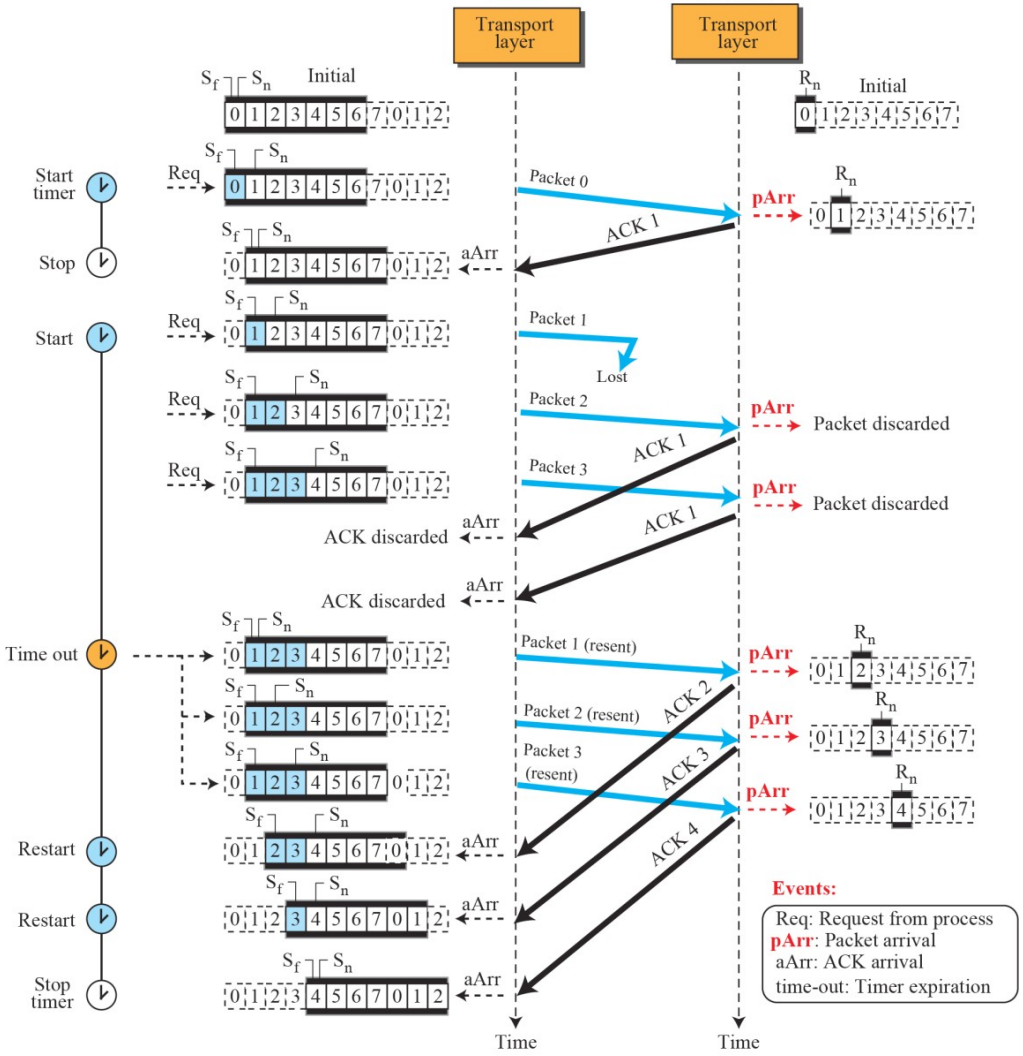


b. Send window of size $= 2^m$

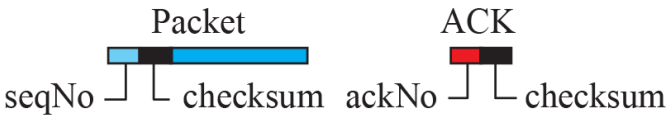
Example Go-Back-N with cumulative Ack

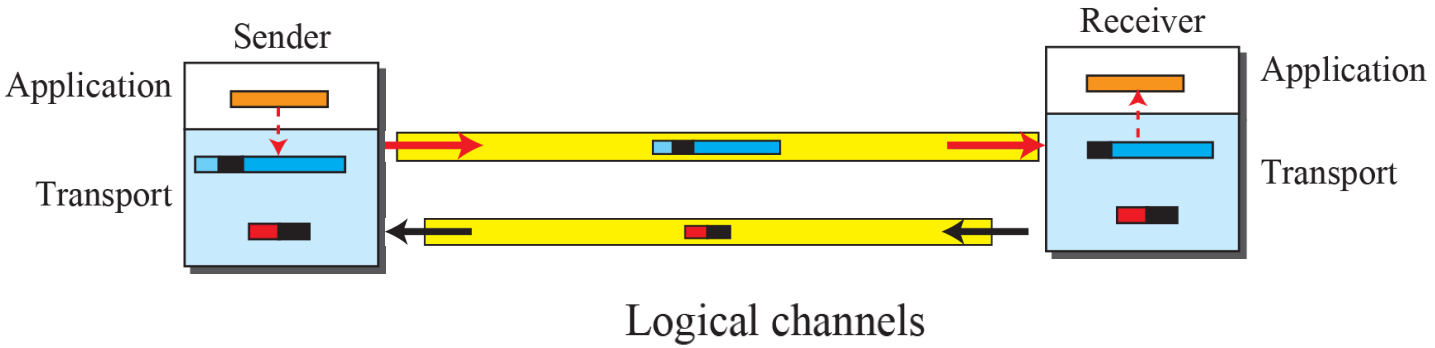


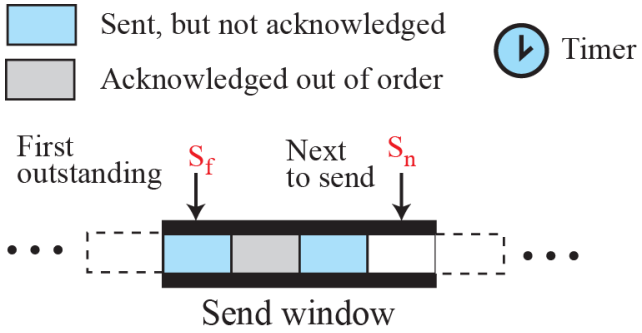
Example Go-Back-N when a packet is lost

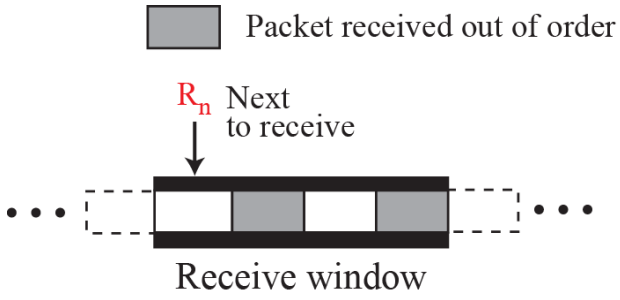


Selective Repeat protocol

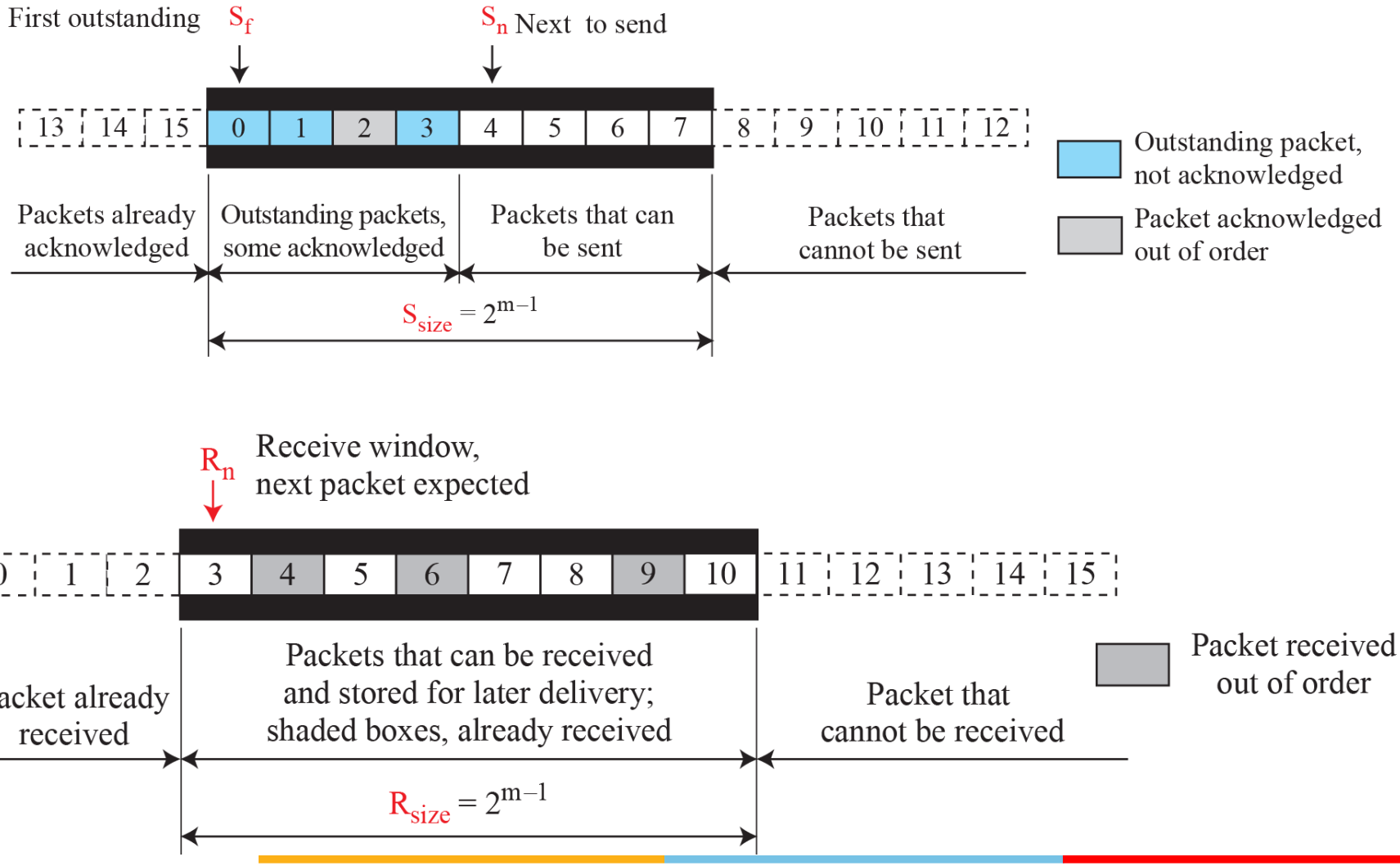








Send and Receive Windows for SR



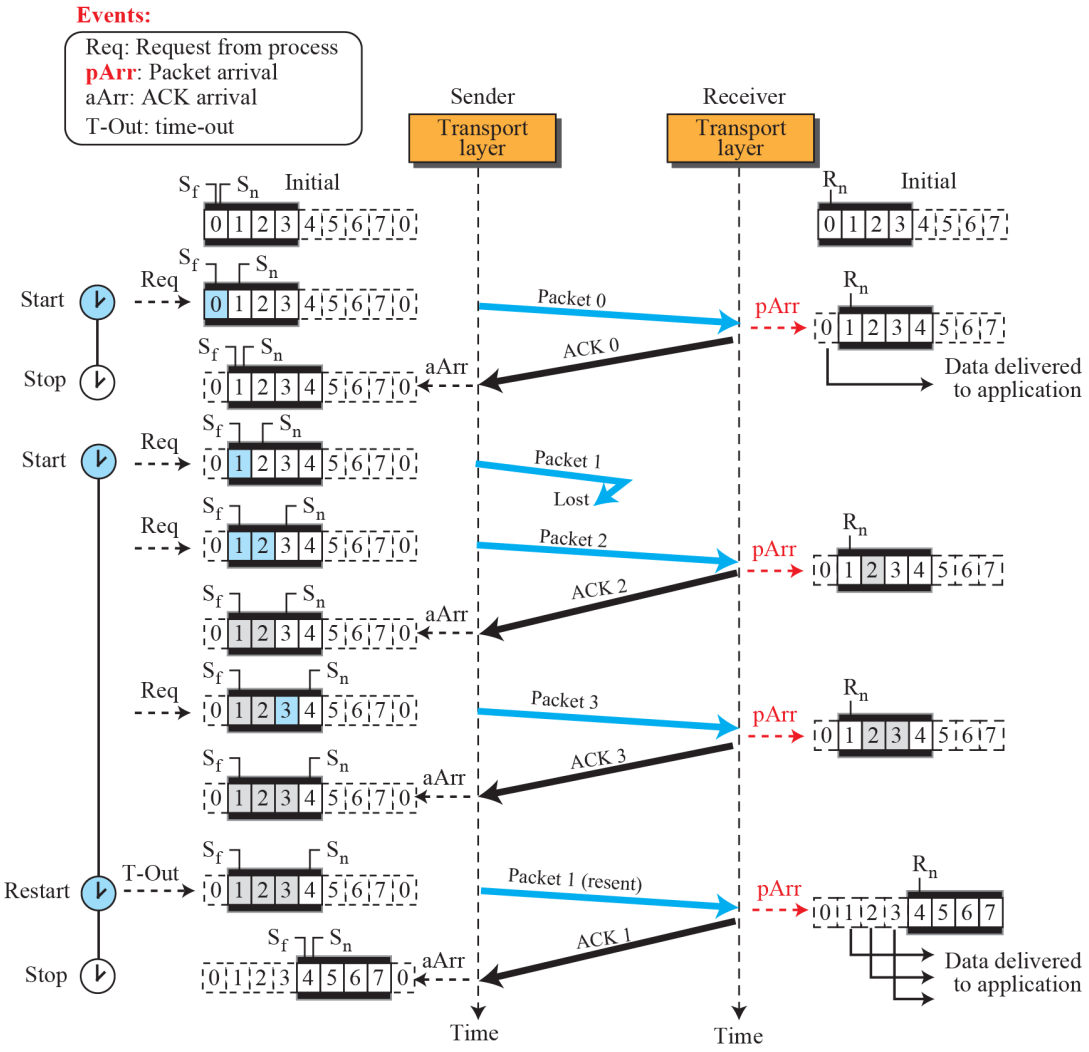
Selective Repeat interpretation

Assume a sender sends 6 packets: packets 0, 1, 2, 3, 4, and 5. The sender receives an ACK with ackNo = 3. What is the interpretation if the system is using GBN or SR?

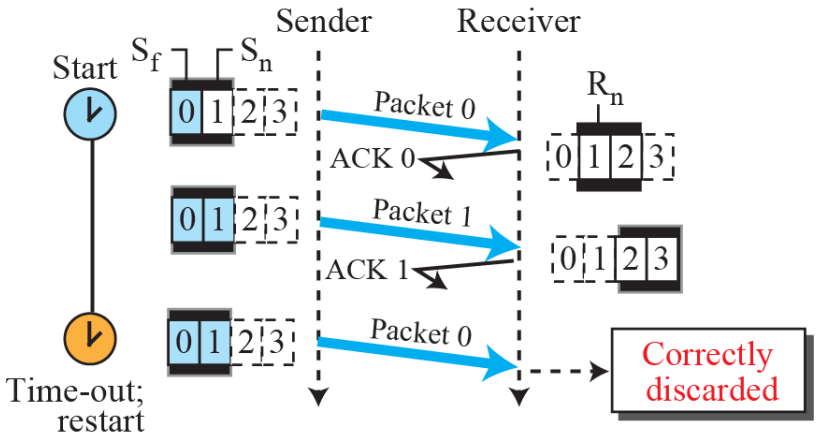
Solution

If the system is using GBN, it means that packets 0, 1, and 2 have been received uncorrupted and the receiver is expecting packet 3. If the system is using SR, it means that packet 3 has been received uncorrupted; the ACK does not say anything about other packets.

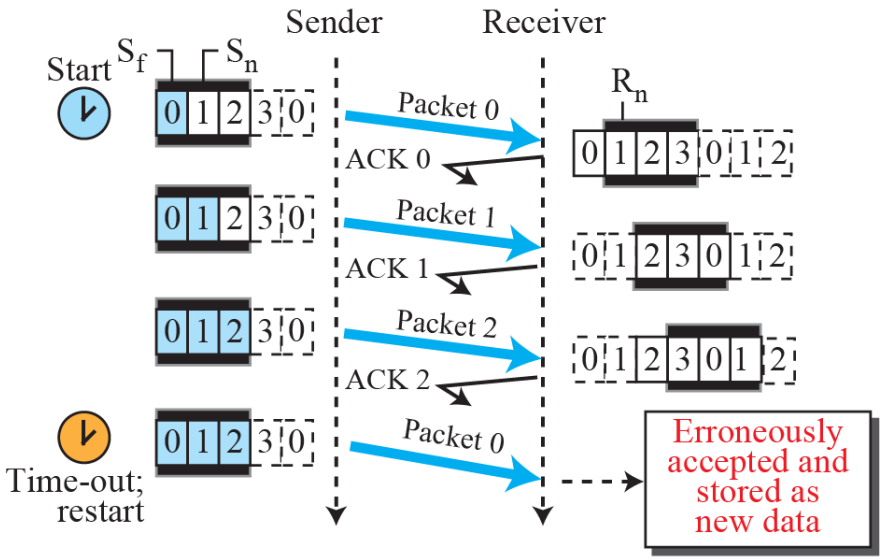
Selective Repeat Example



Selective Repeat Window size



a. Send and receive windows of size = 2^{m-1}



b. Send and receive windows of size > 2^{m-1}