Transport Layer

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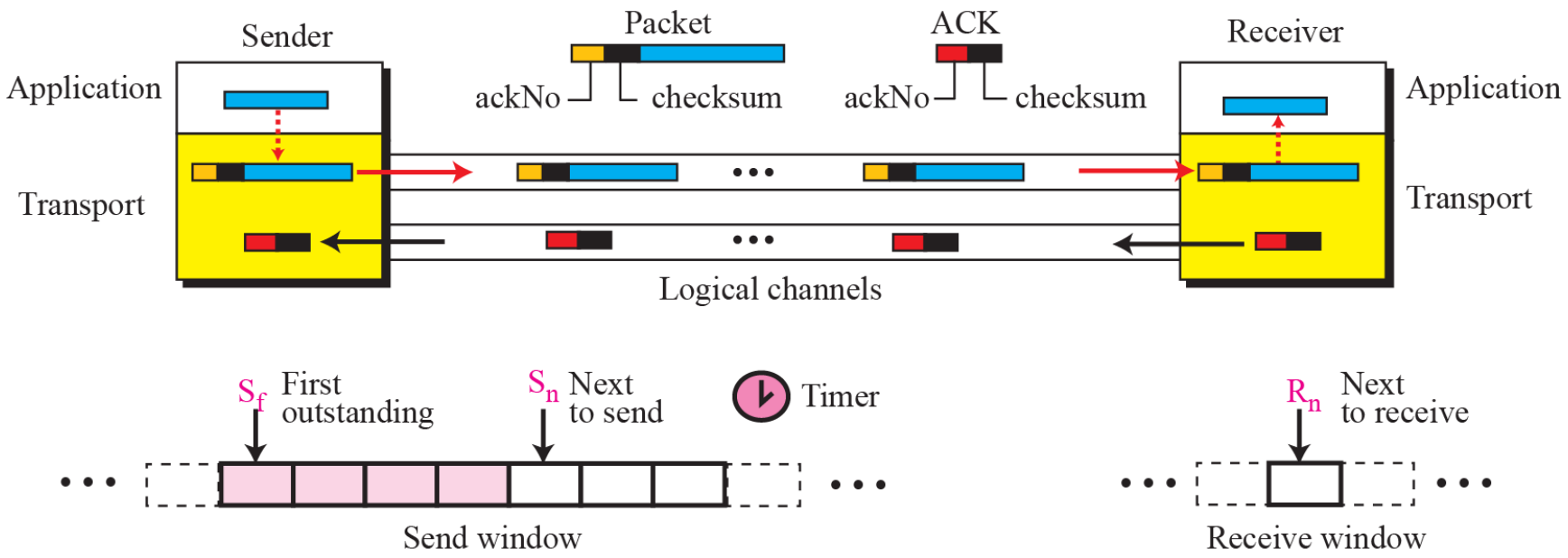
Go-Back-N protocol



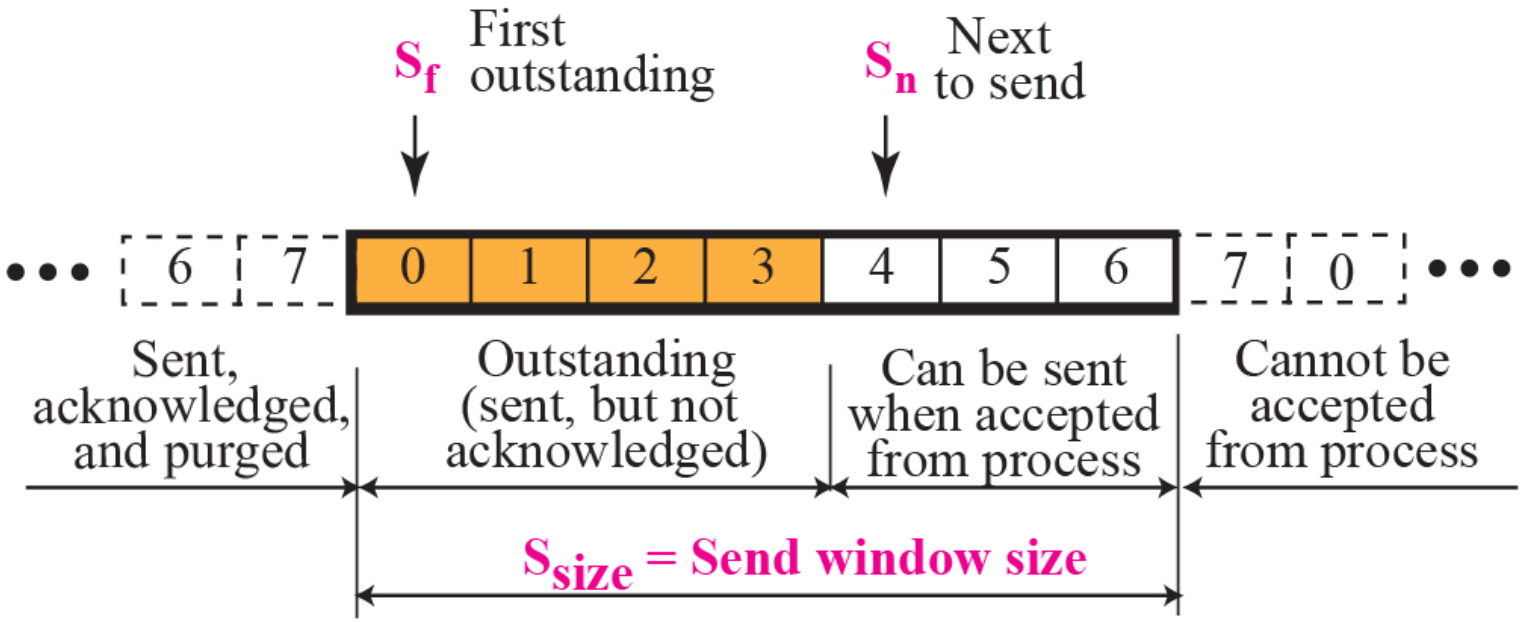
When the sender doesn't receive ACK, it retransmits the packet in error plus all the succeeding packets. Hence, the name of the protocol is go-back-N ARQ.

Go-Back-N protocol Cont..

- In the Go-Back-N Protocol, the sequence numbers are modulo 2^m, where m is the size of the sequence number field in bits.

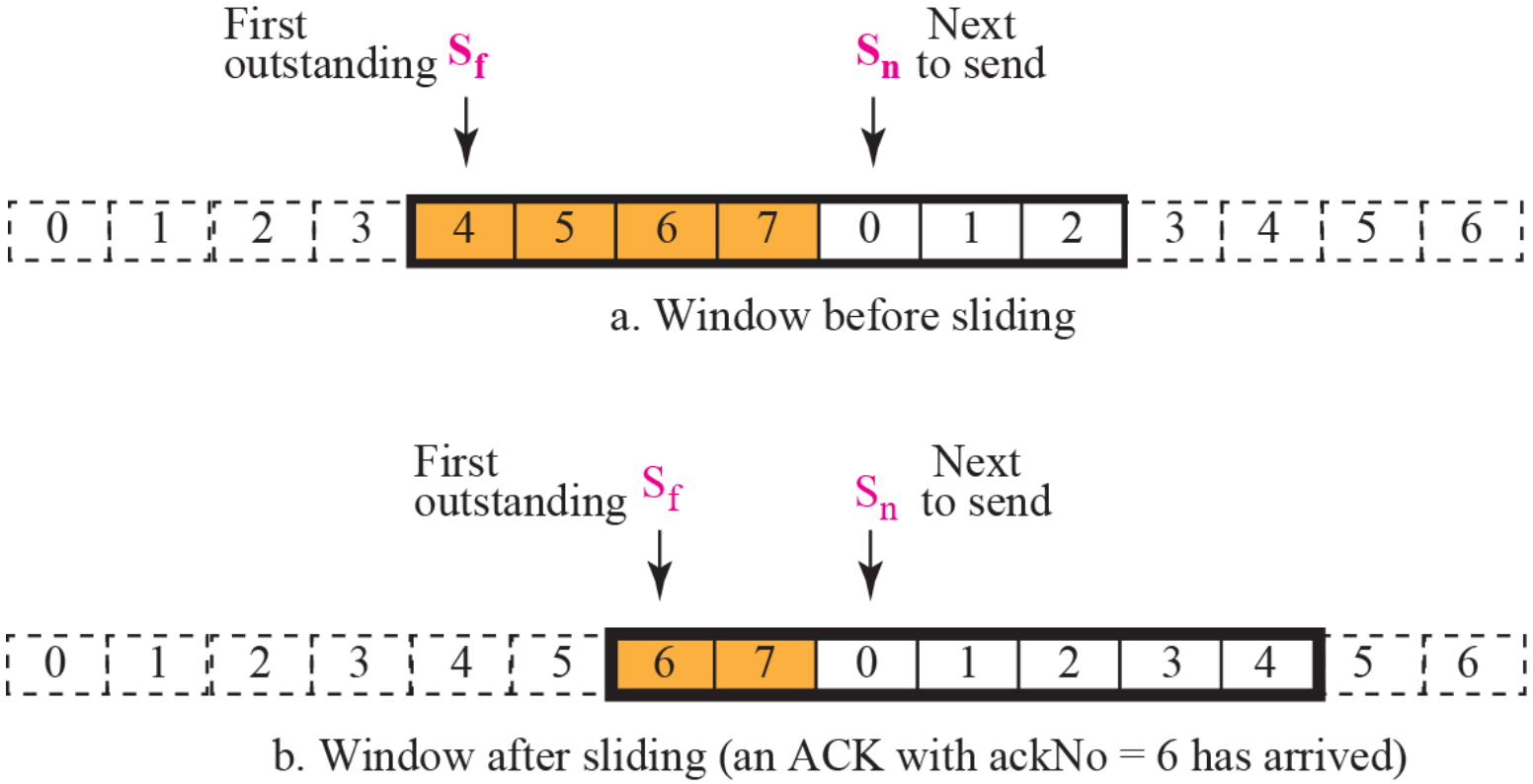
- In the Go-Back-N protocol, the acknowledgment number is cumulative and defines the sequence number of the next packet expected to arrive.

Send window for Go-Back-N

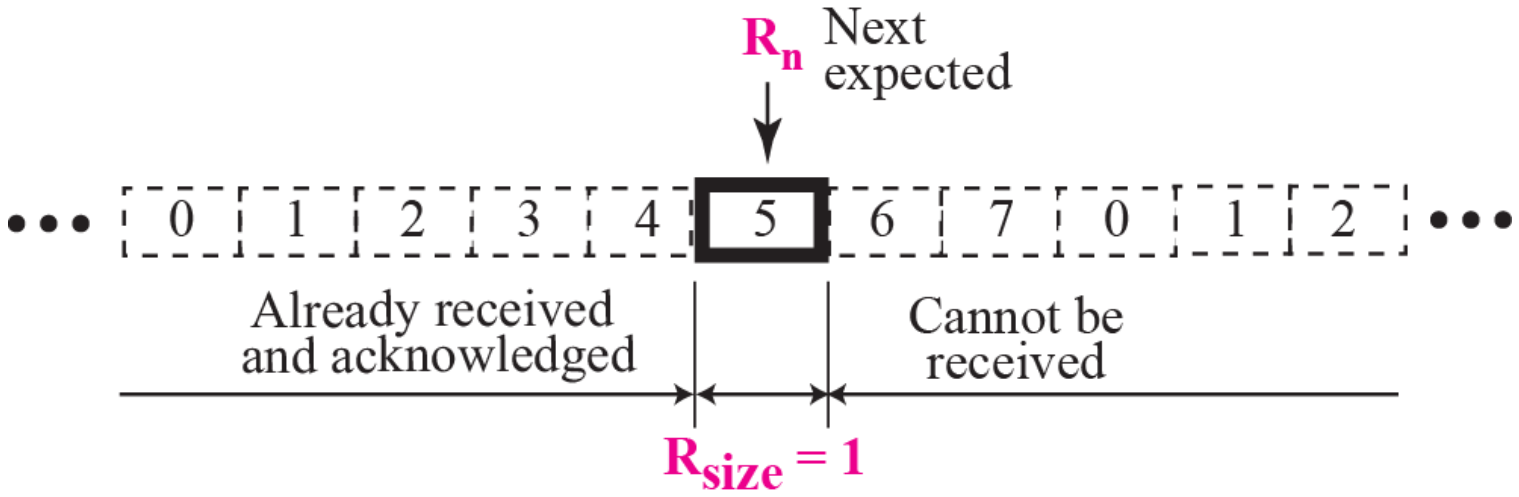


- *The send window is an abstract concept defining an imaginary box of maximum size = $2^m - 1$ with three variables: S_f, S_n, and S_{size}.*
- *The send window can slide one or more slots when an error-free ACK with ack No. between S_f and S_n (in modular arithmetic) arrives.*

Sliding the send window

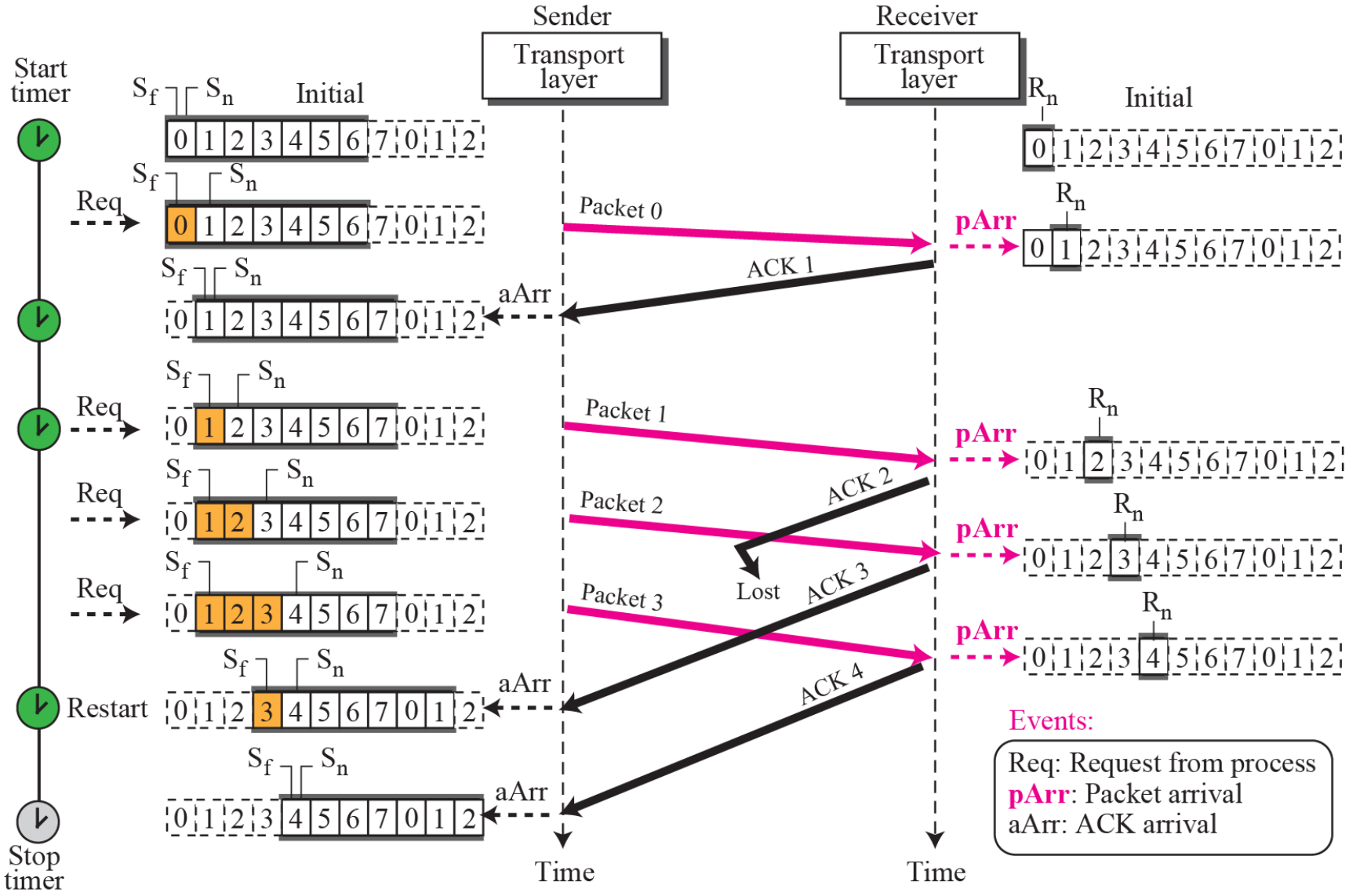


Receive window for Go-Back-N



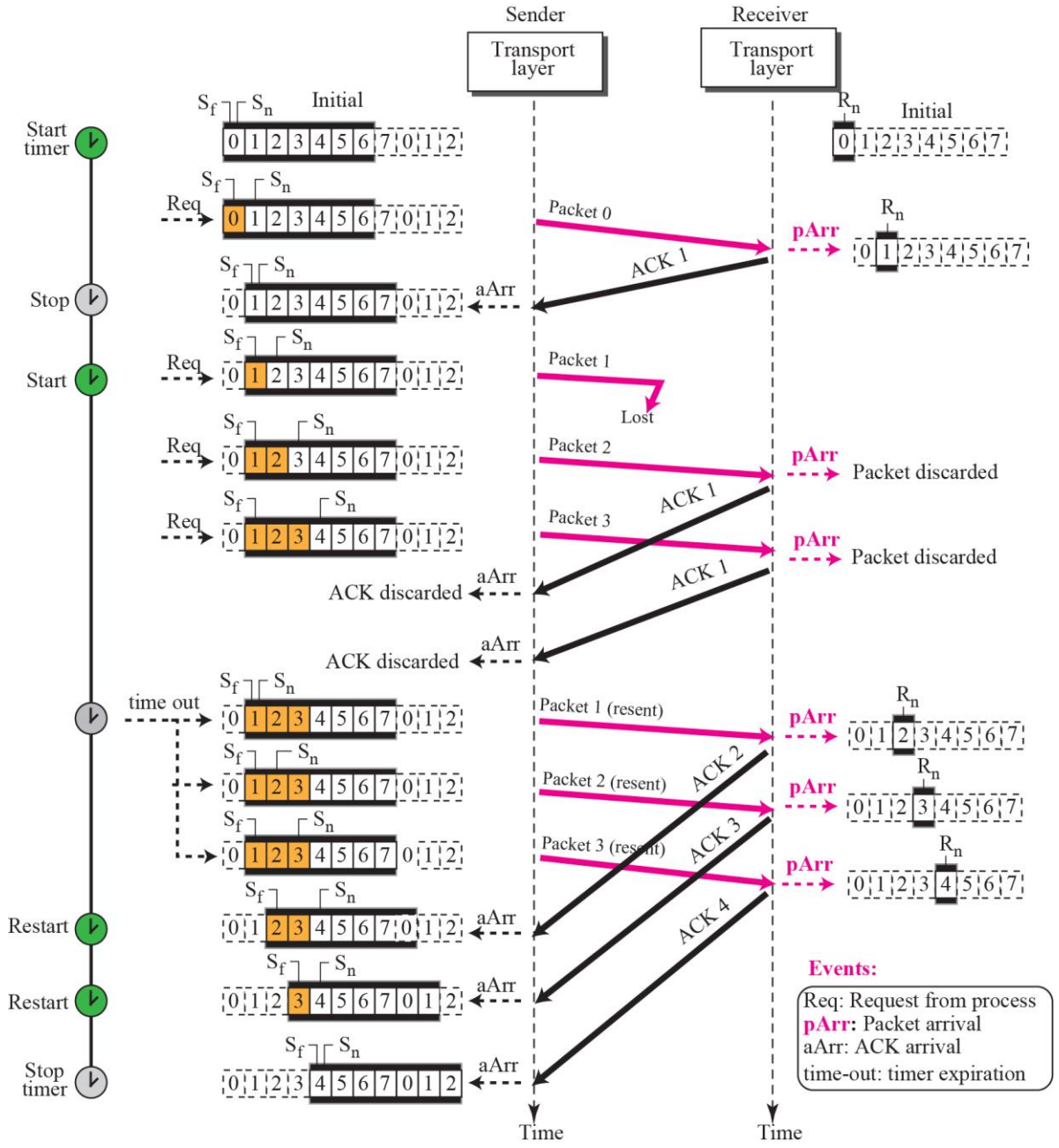
- The receive window is an abstract concept defining an imaginary box of size 1 with one single variable R_n.
- The window slides when a correct packet has arrived; sliding occurs one slot at a time.
- *In the Go-Back-N protocol, the size of the send window must be less than 2^m; the size of the receive window is always 1.*

Example

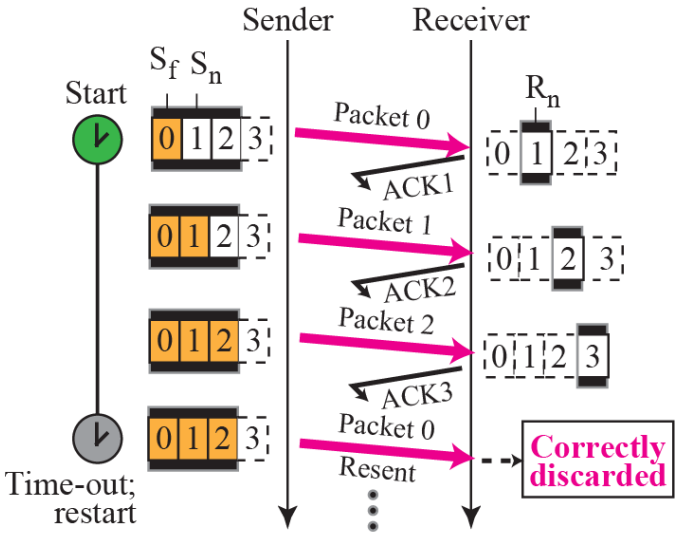


Cumulative acknowledgments can help

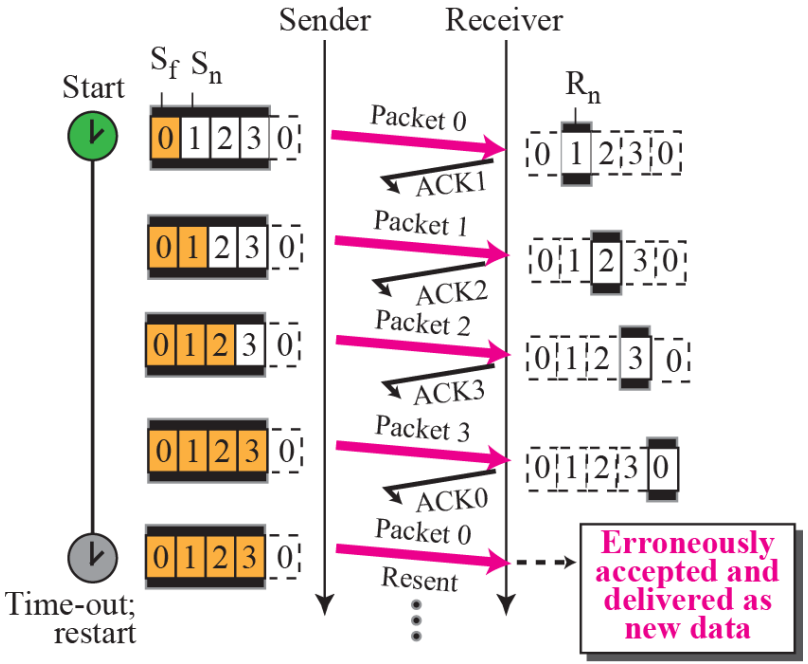
Example 2


Sender
Transport layer
Receiver
Transport layer
Initial
Start timer
Stop
Start
Restart
Restart
Stop timer
Req
Packet 0
ACK 1
aArr
pArr
Packet 1
Lost
Packet 2
Packet discarded
Packet 3
ACK discarded
time out
Packet 1 (resent)
Packet 2 (resent)
Packet 3 (resent)
ACK 2
ACK 3
ACK 4
Events:
Req: Request from process
pArr: Packet arrival
aArr: ACK arrival
time-out: timer expiration
Time
Time

Send window size for Go-Back-N



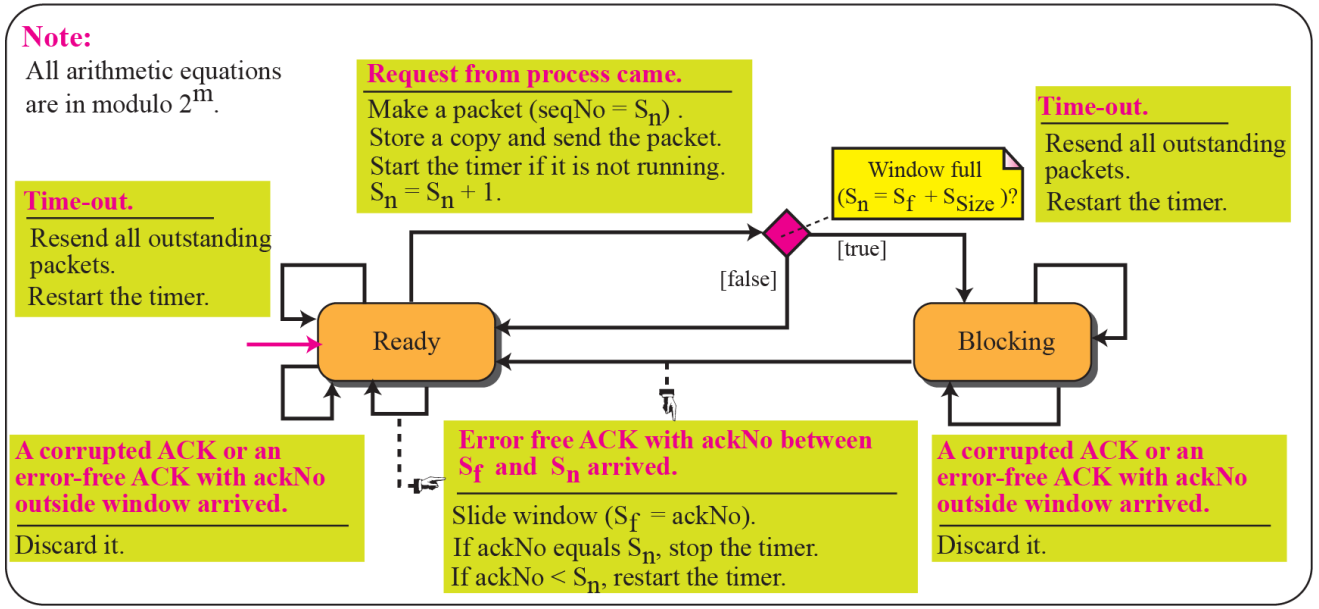
a. Send window of size $< 2^m$



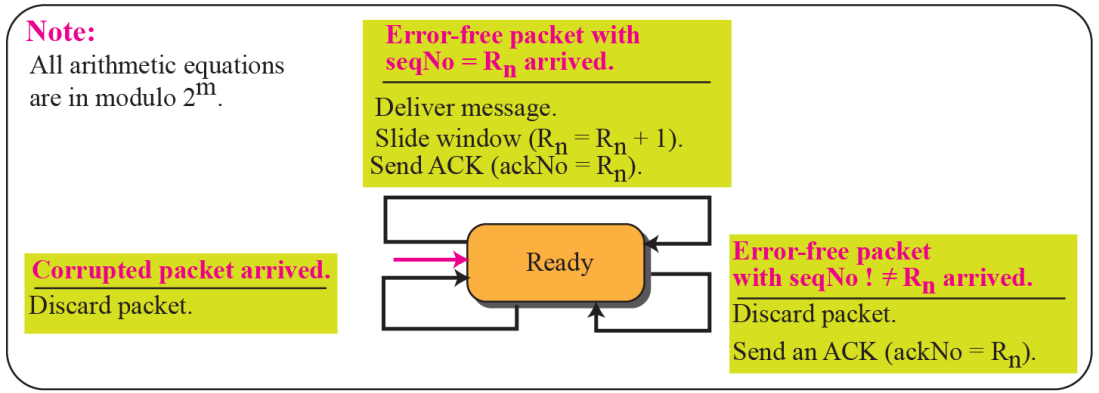
b. Send window of size $= 2^m$

FSMs for Go-Back-N

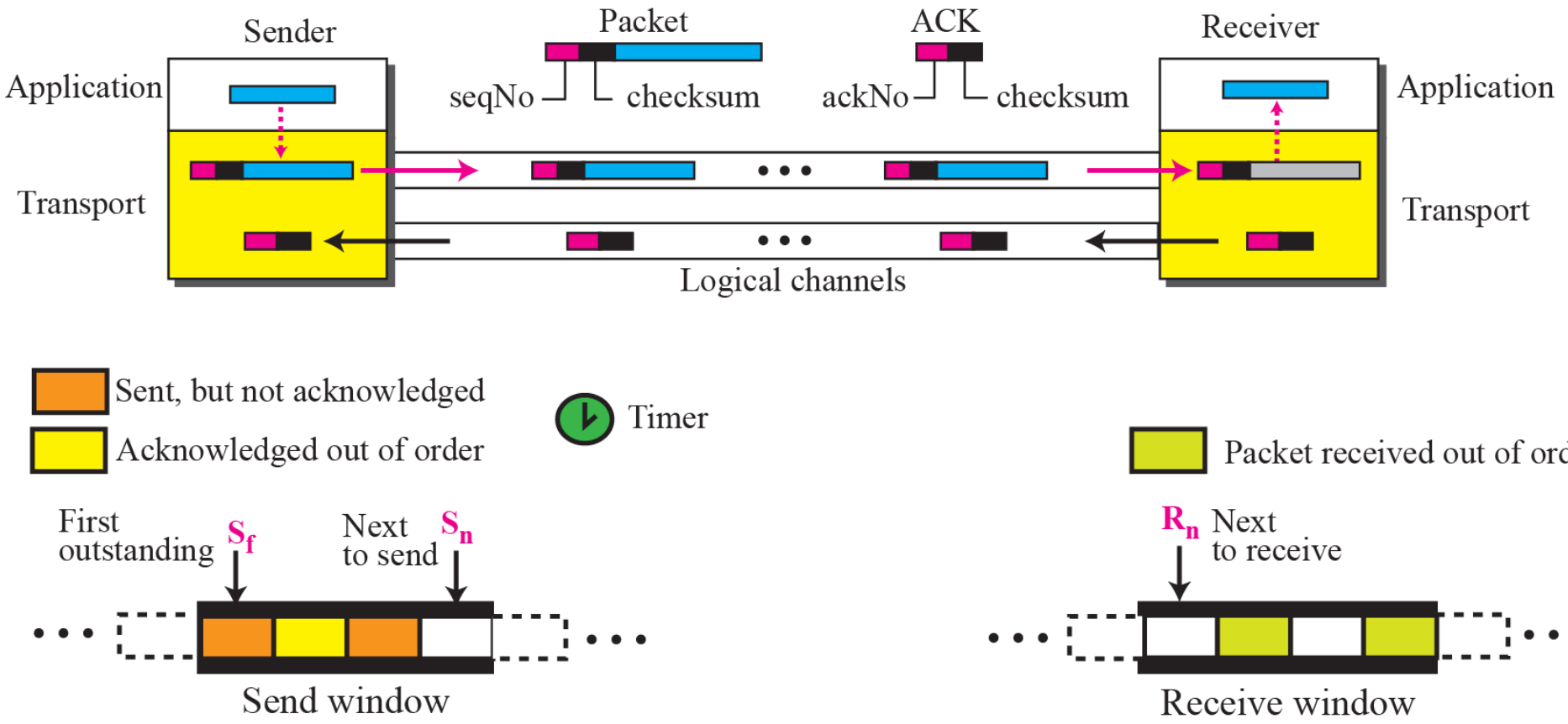
Sender



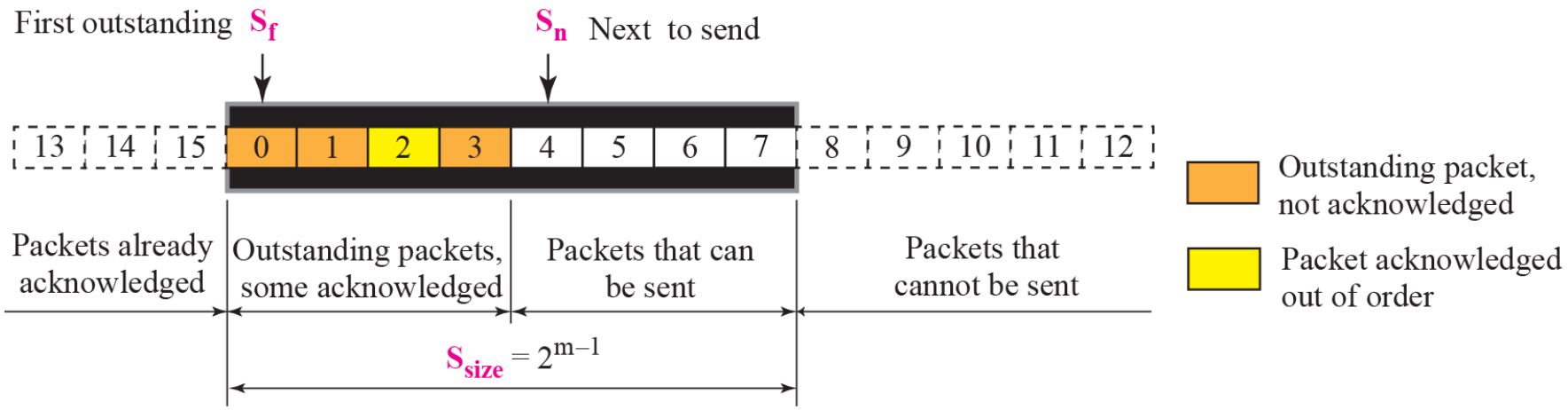
Receiver



Outline of Selective-Repeat

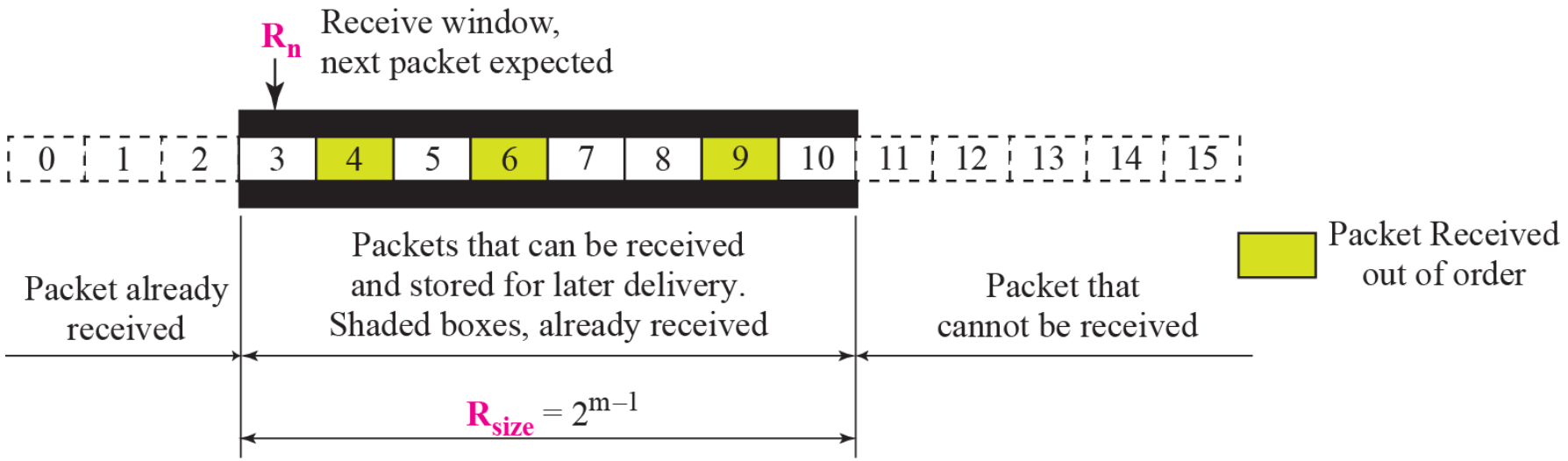


Send window for Selective-Repeat protocol



- *In the Selective-Repeat protocol, an acknowledgment number defines the sequence number of the error-free packet received.*

Receive window for Selective-Repeat protocol



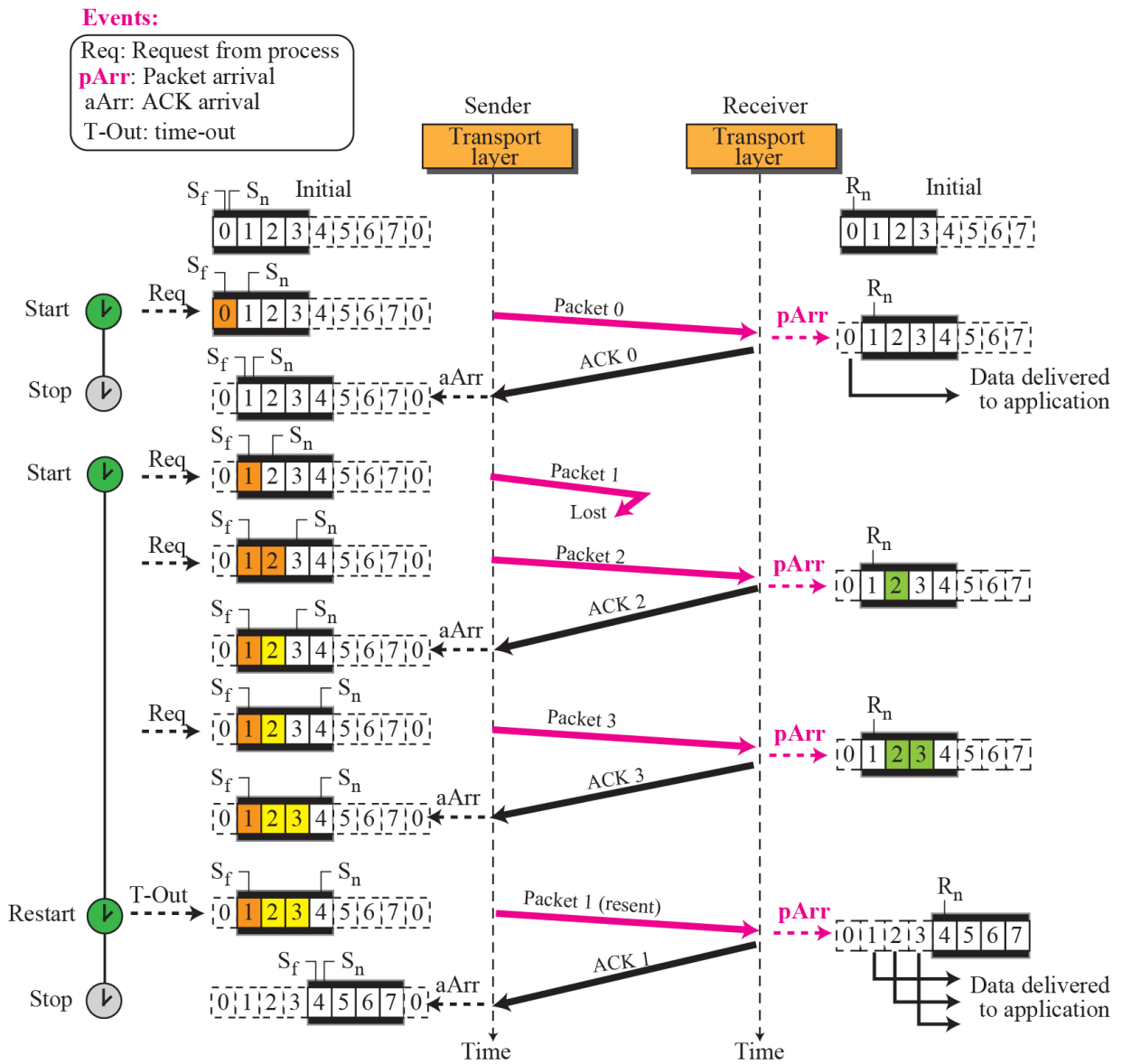
Example

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?

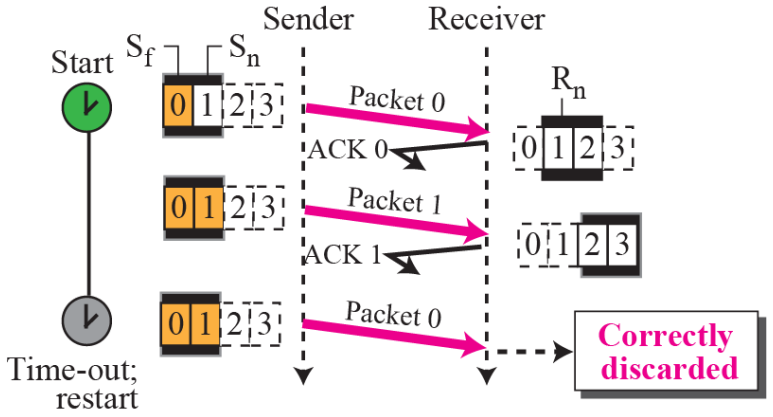
Solution

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.

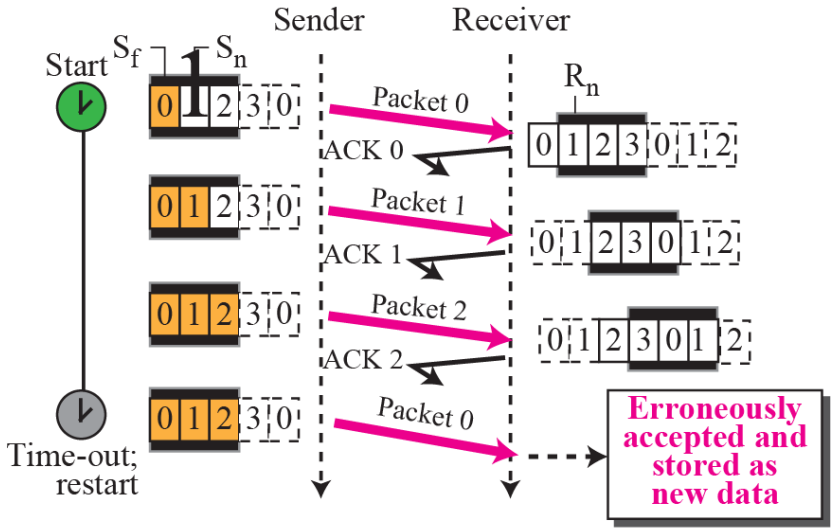
Example


Events:
Req: Request from process
pArr: Packet arrival
aArr: ACK arrival
T-Out: time-out
Sender
Transport layer
Receiver
Transport layer
Initial
Start
Stop
Req
Packet 0
ACK 0
pArr
Data delivered to application
Packet 1
Lost
Packet 2
ACK 2
Packet 3
ACK 3
T-Out
Restart
Packet 1 (resent)
ACK 1
Time
Time

Selective-Repeat window size



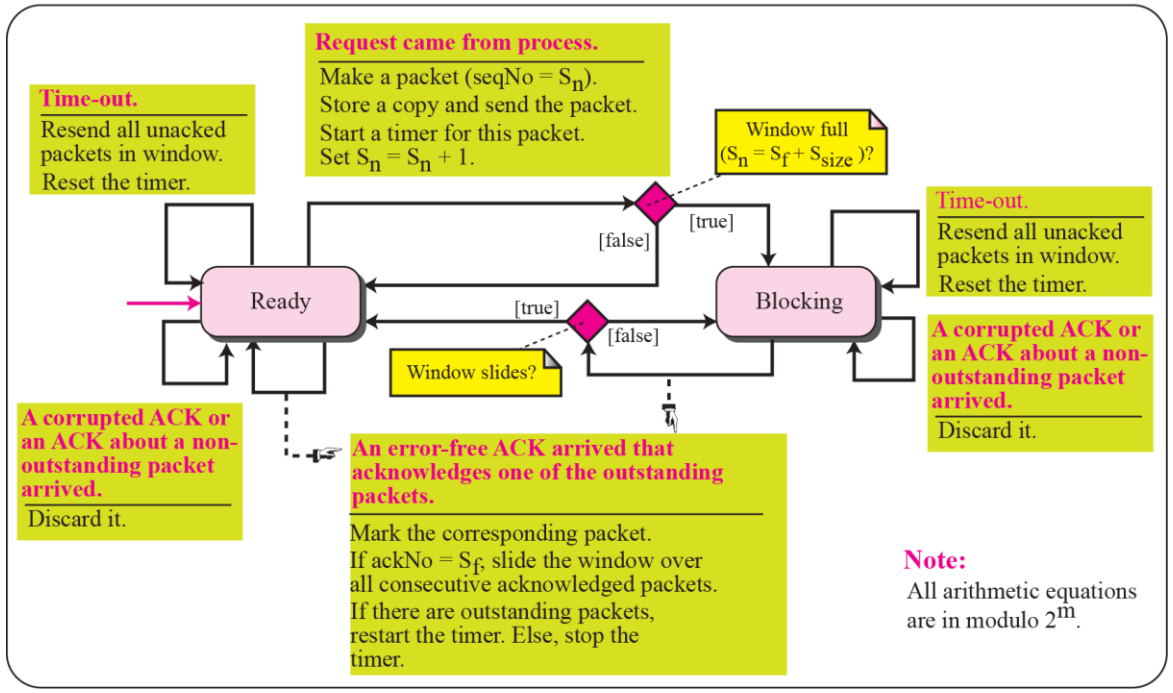
a. Send and receive windows of size = 2^{m-1}



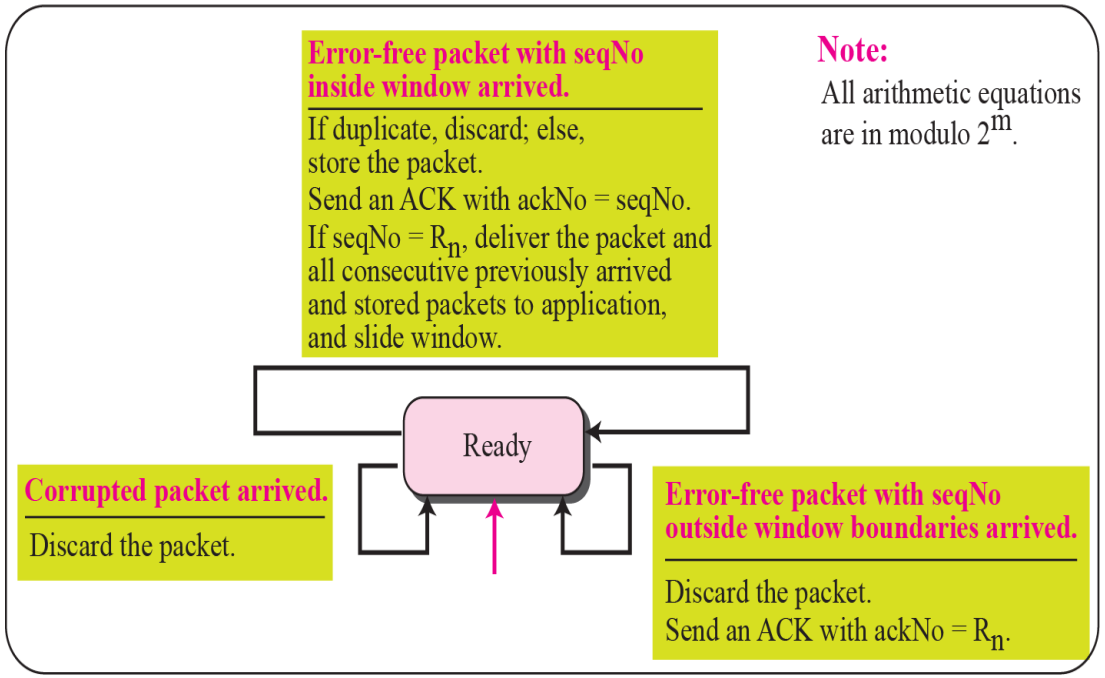
b. Send and receive windows of size > 2^{m-1}

FSMs for SR protocol

Sender



Receiver



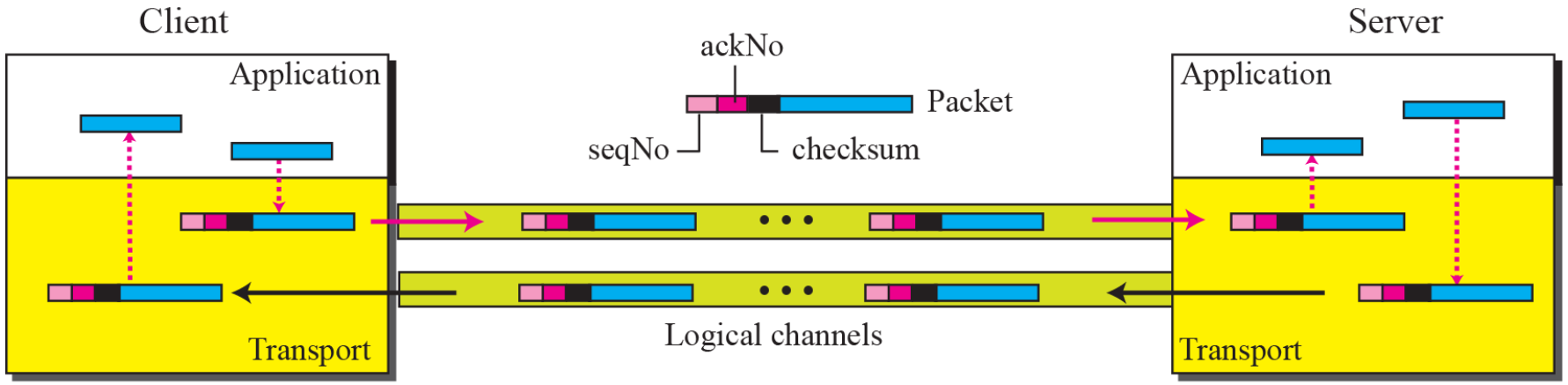
Selective-Repeat

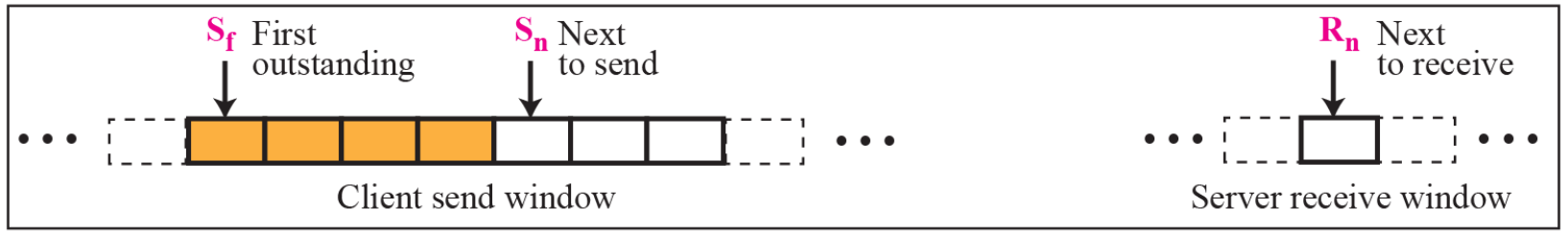
This is the most efficient among the ARQ schemes, but the sender must be more complex so that it can send out-of-order frames. The receiver also must have storage space to store the post-NAK frames and processing power to reinsert frames in proper sequence.

Bidirectional Protocol: Piggybacking

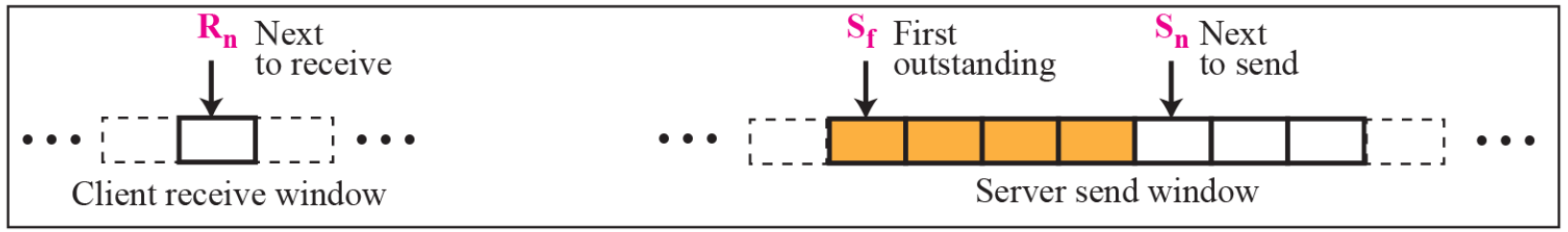
- The flow we discussed are unidirectional. Data packets flow in one direction and ACKs travel in other direction.
- In real life data packets flow in both the directions: Client to server and server to client. Thus, ACK also need to flow in both the directions.
- A technique called piggybacking is used to improve the efficiency of bidirectional protocols.
- When a packet carrying data from A to B, it can also carry ACK feedback about arrived packets from B.

Design of piggybacking for Go-Back-N



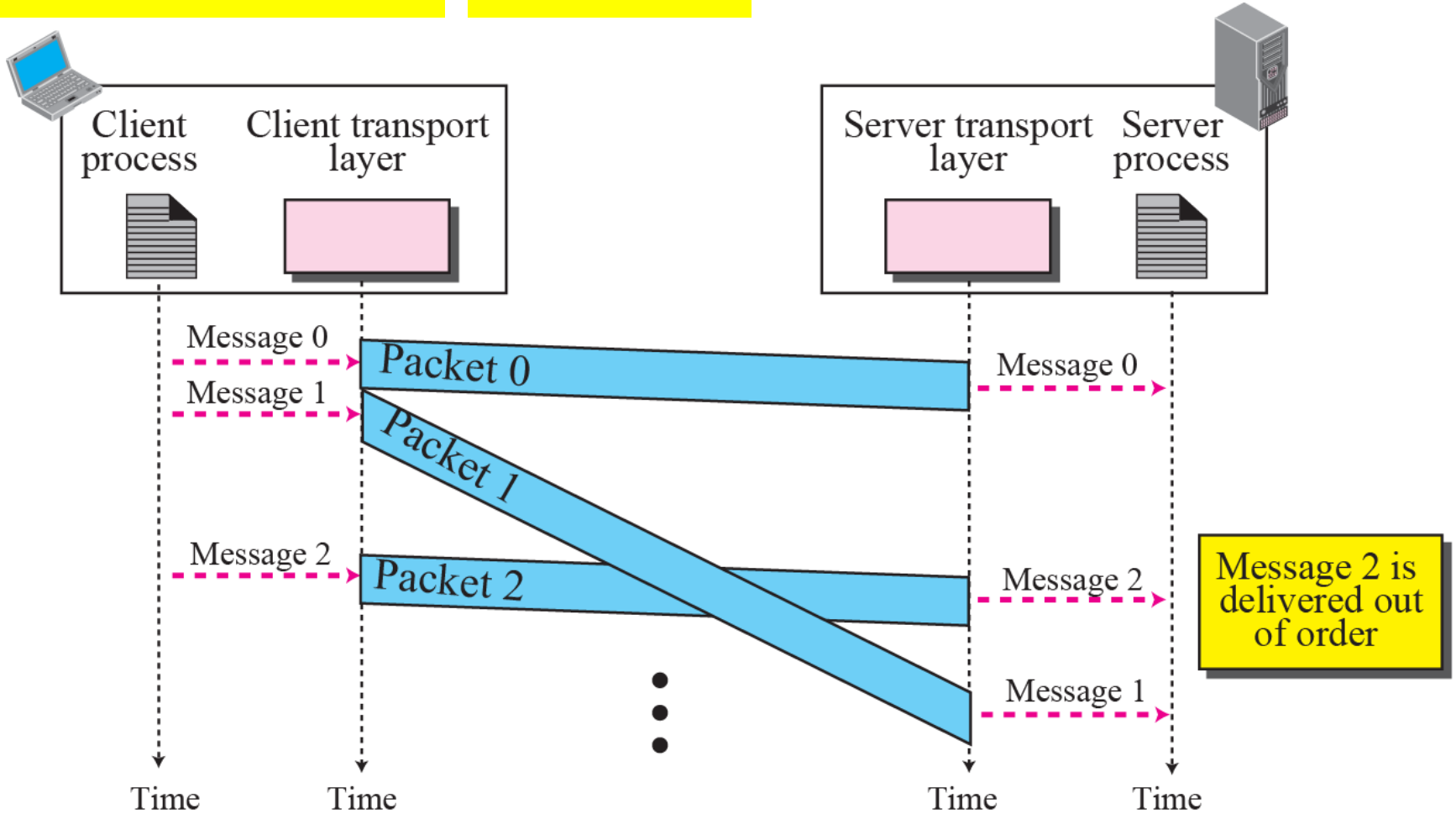


Windows for communication from client to server

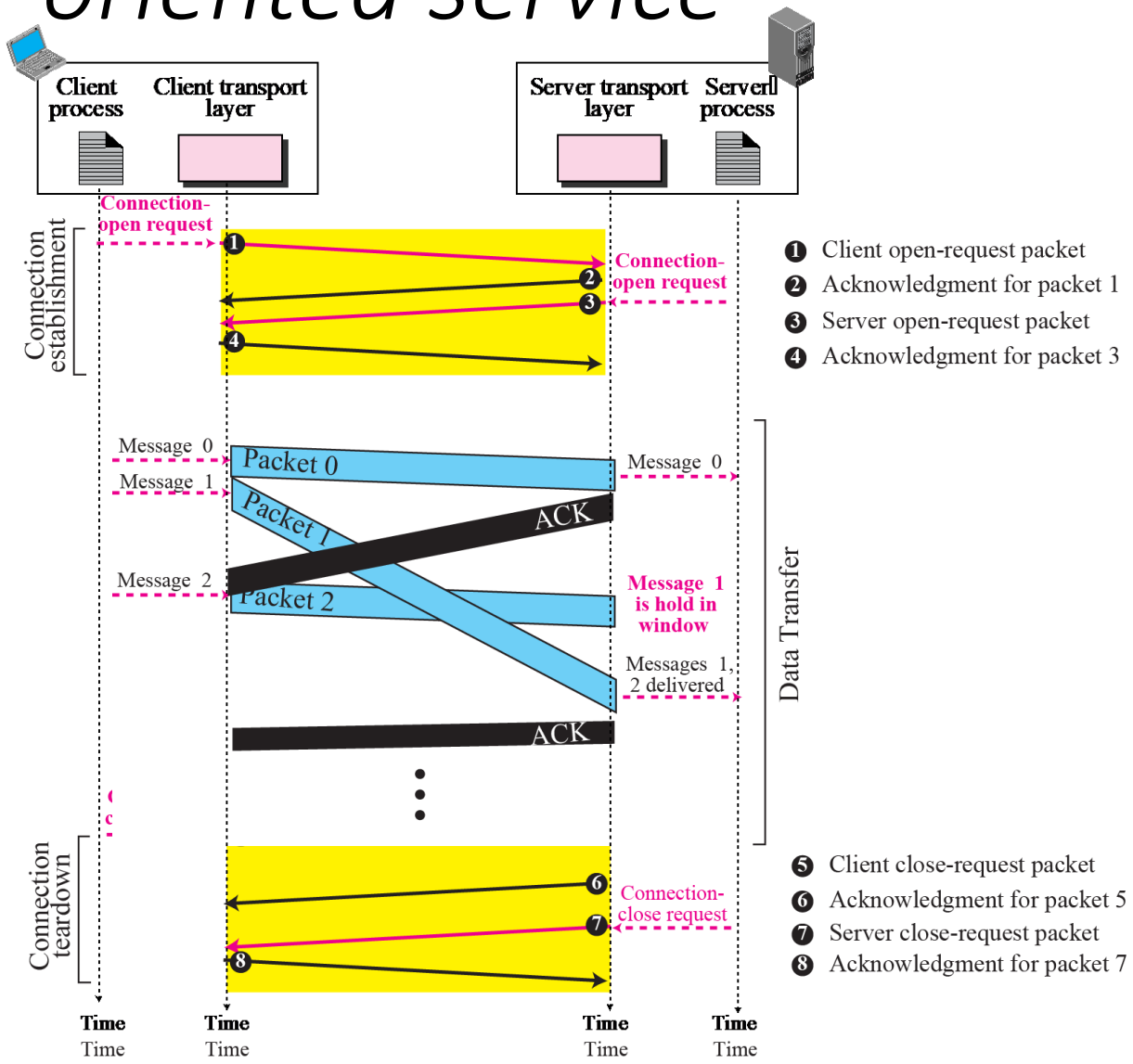


Windows for communication from server to client

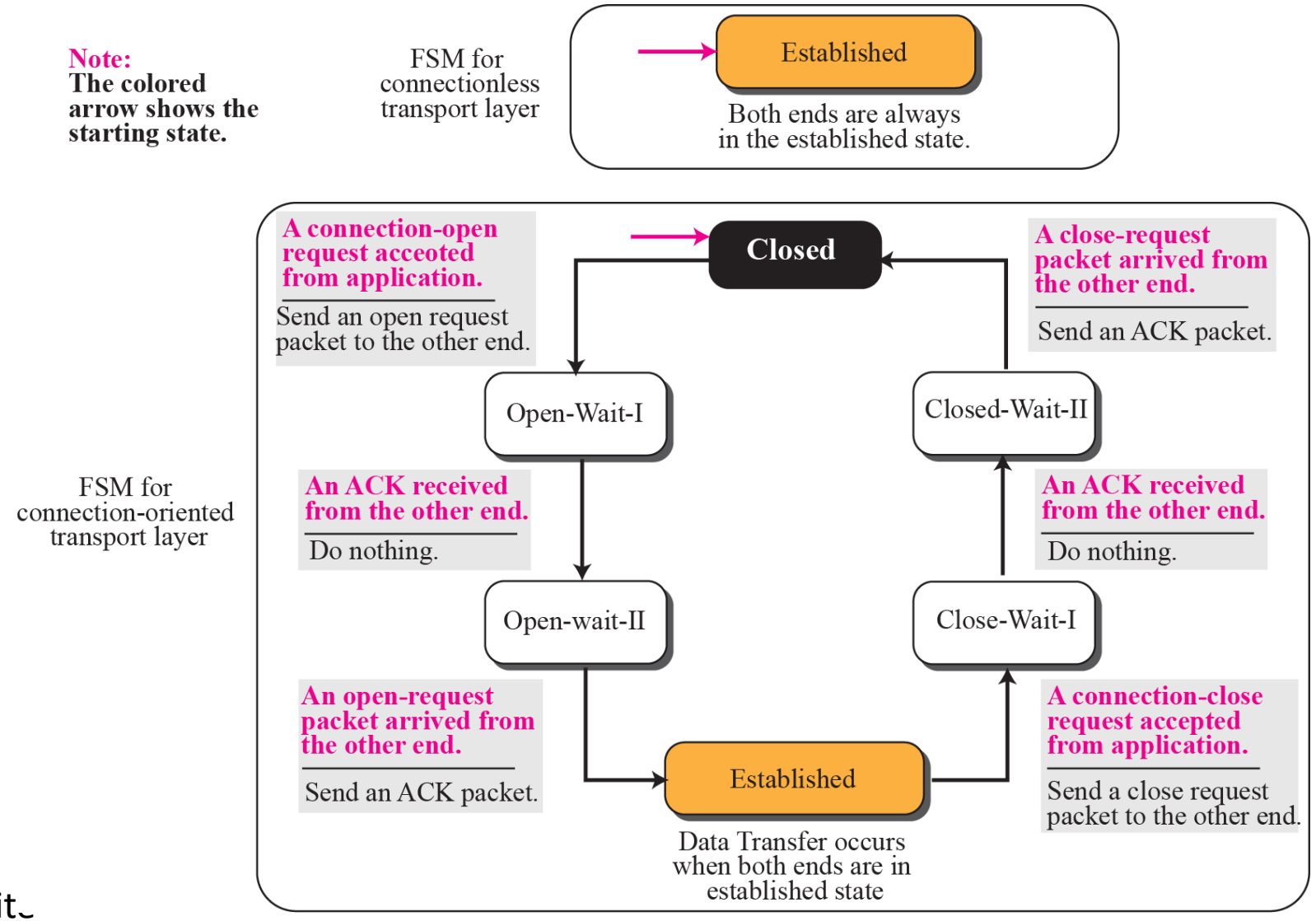
Connectionless Service



Connection-oriented service



Connectionless and connection-oriented services as FSMs



Transport Layer Protocols

- We can create a transport-layer protocol by combining a set of services described in the previous sections.
- The TCP/IP protocol uses a transport layer protocol that is either a modification or a combination of some of these protocols.