Computer Networks(CS30006)

Spring Semester (2021-2022)

Data Link Control

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Data Link layer

Data link control functions include framing, flow and error control, and software implemented protocols that provide smooth and reliable transmission of frames between nodes.

Framing

- Framing in the data link layer separates a message from one source to a destination, or from other messages to other destinations, by adding a sender address and a destination address.

- The destination address defines where the packet is to go; the sender address helps the recipient acknowledge the receipt.

- Whole message could not be packed in one frame because:
  frame will become very large, making flow and error control very inefficient.

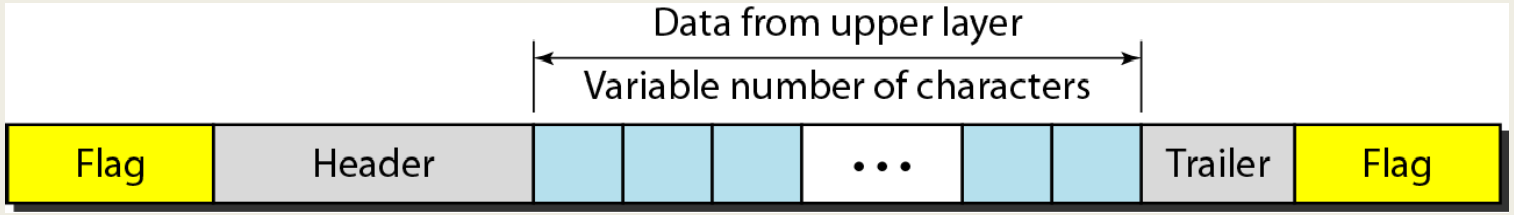

Fig: A frame in a character-oriented protocol

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Byte Stuffing

- In byte stuffing (or character stuffing), a special byte is added to the data section of the frame when there is a character with the same pattern as the flag.
- The data section is stuffed with an extra byte.
- This byte is usually called the escape character (ESC), which has a predefined bit pattern.
- Whenever the receiver encounters the ESC character, it removes it from the data section and treats the next character as data, not a delimiting flag.

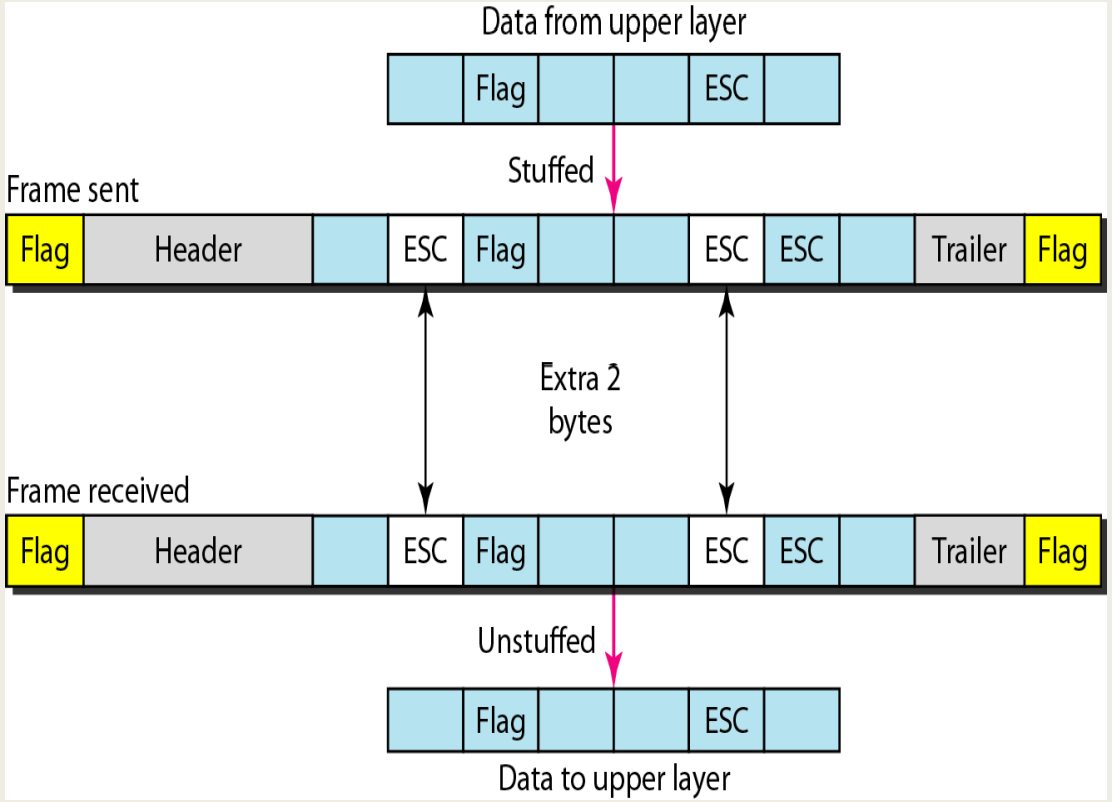

Fig: Byte Stuffing and Unstuffing

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Bit Oriented Protocol

- The data section of a frame is a sequence of bits to be interpreted by the upper layer as text, graphic, audio, video, and so on.
- However, in addition to headers, we still need a delimiter to separate one frame from the other.
- Most protocols use a special 8-bit pattern flag 01111110 as the delimiter to define the beginning and the end of the frame.

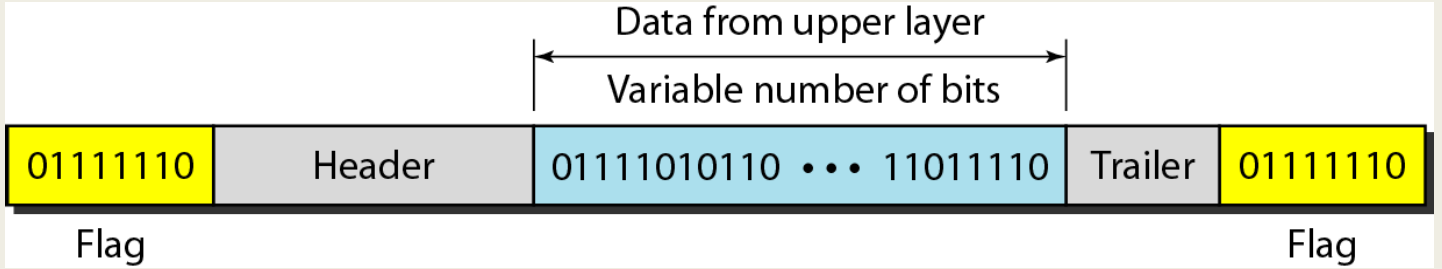

Fig: A frame in a bit-oriented protocol

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

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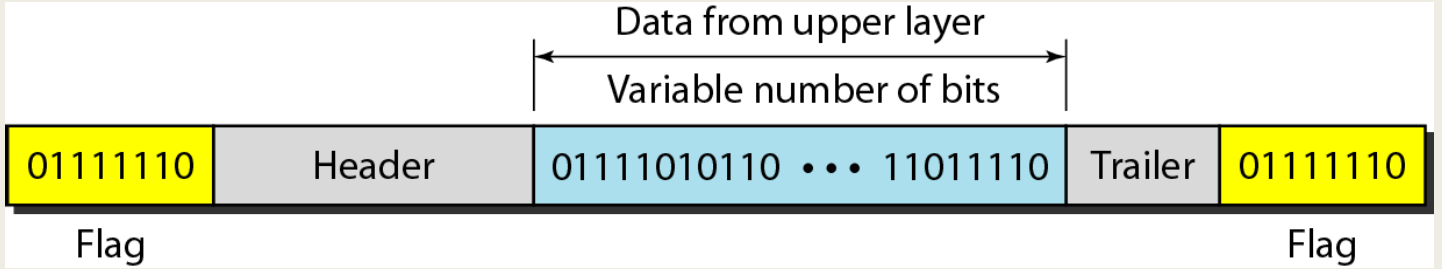


Fig: A frame in a bit-oriented protocol

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Bit Stuffing

- Bit stuffing is the process of adding one extra 0 whenever five consecutive 1 follow a 0 in the data, so that the receiver does not mistake the pattern 0111110 for a flag.

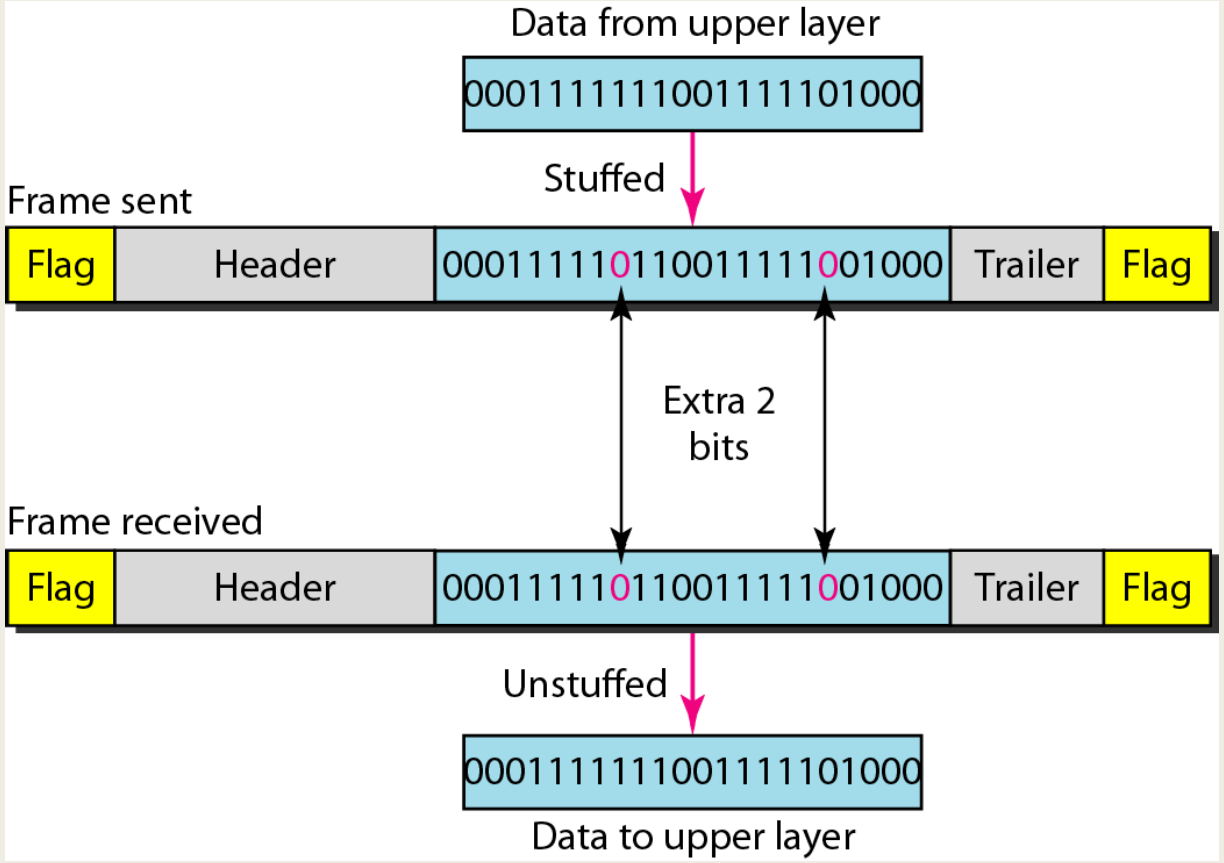


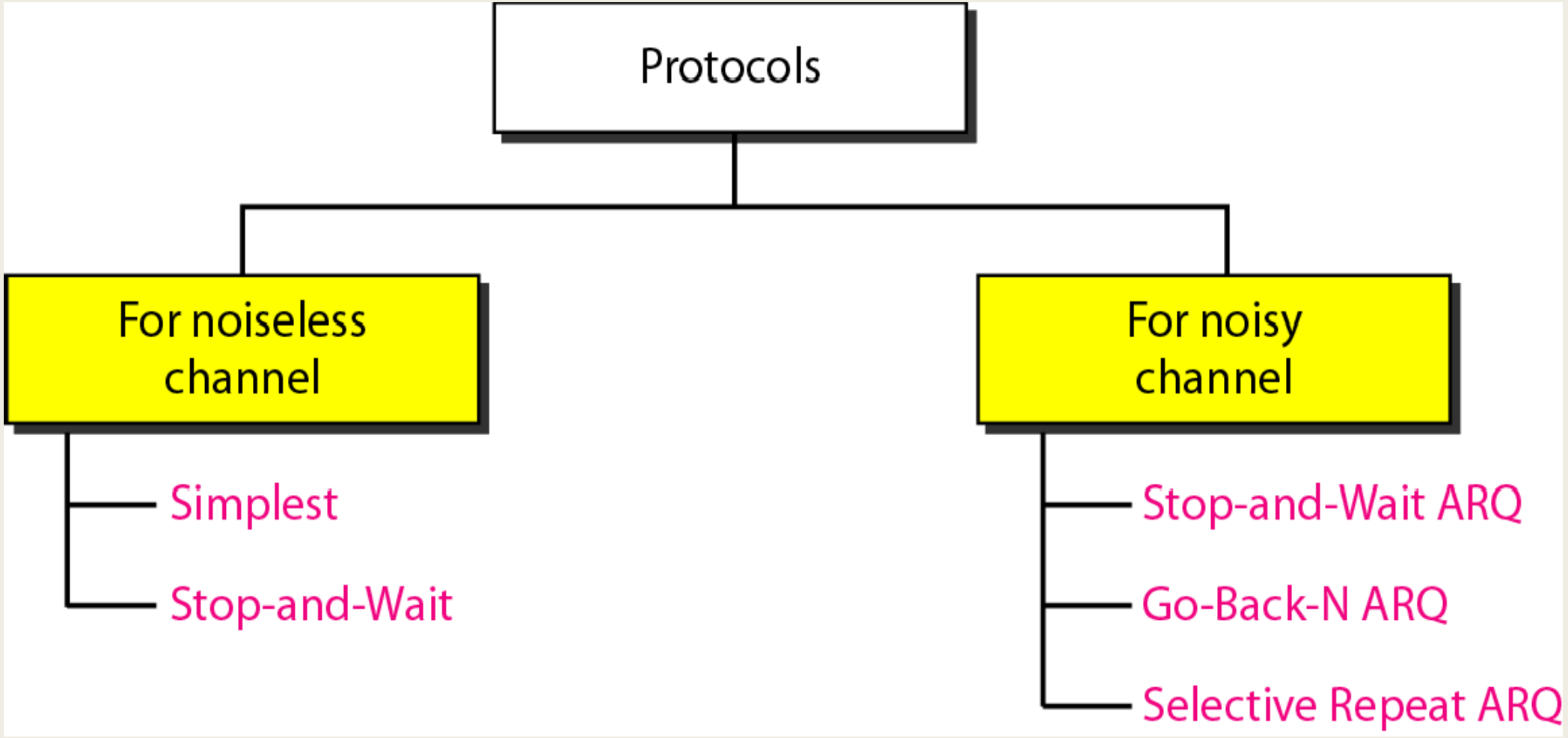
Fig: Byte Stuffing and Unstuffing

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Flow and Error Control

- **Flow control** coordinates the amount of data that can be sent before receiving an acknowledgment and is one of the most important duties of the data link layer.
- In most protocols, **flow control** is a set of procedures that tells the sender how much data it can transmit before it must wait for an acknowledgment from the receiver.
- **Error control** in the data link layer is based on automatic repeat request, which is the retransmission of data.

Protocols



Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Simplest Protocol

- It is a unidirectional protocol in which data frames are traveling in only one direction-from the sender to receiver.
- The receiver can immediately handle any frame it receives with a processing time that is small enough to be negligible.
- The data link layer of the receiver immediately removes the header from the frame and hands the data packet to its network layer, which can also accept the packet immediately.

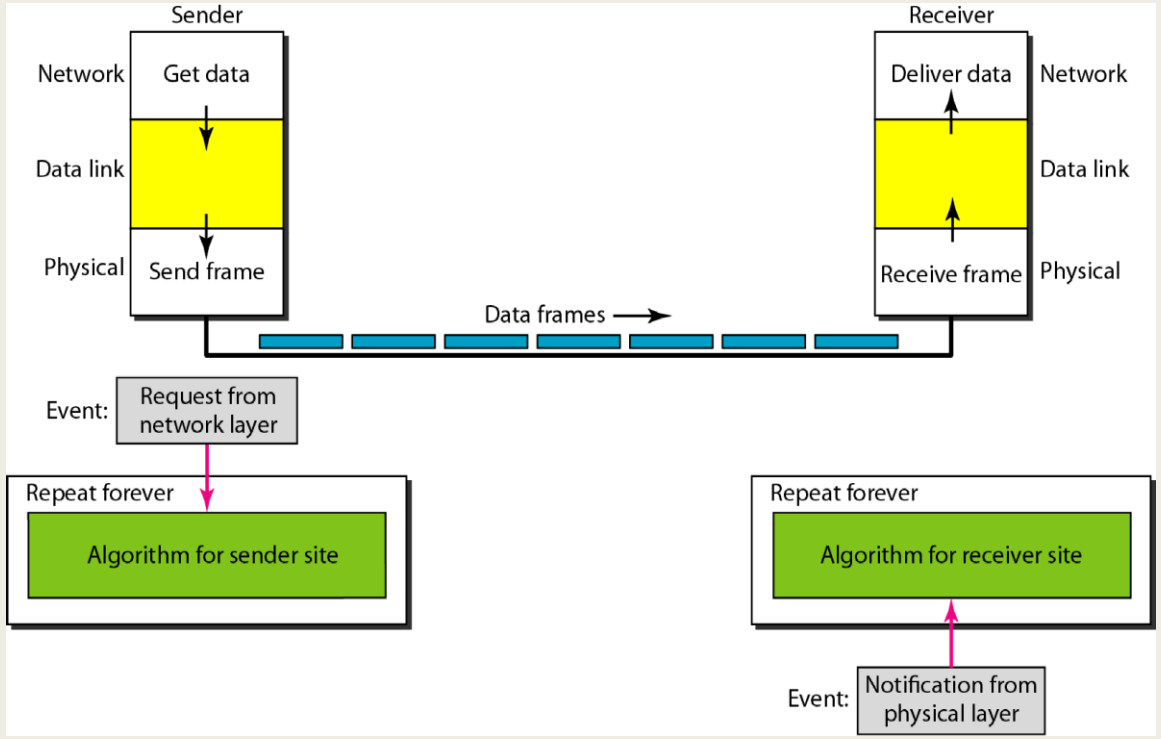


Fig.: The design of the simplest protocol with no flow or error control

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Stop and Wait Protocol

- The sender sends one frame, stops until it receives confirmation from the receiver, and then sends the next frame.
- Unidirectional communication for data frames, but auxiliary ACK frames (simple tokens of acknowledgment) travel from the other direction.

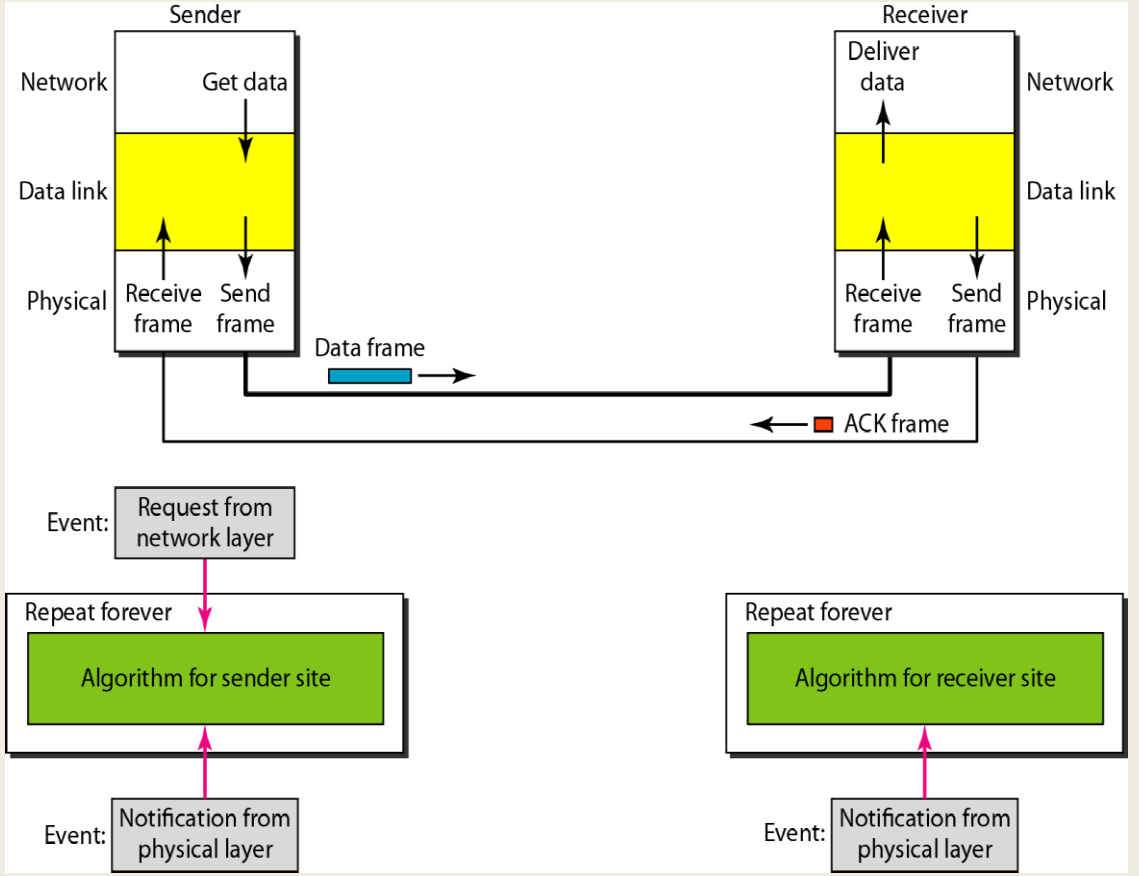
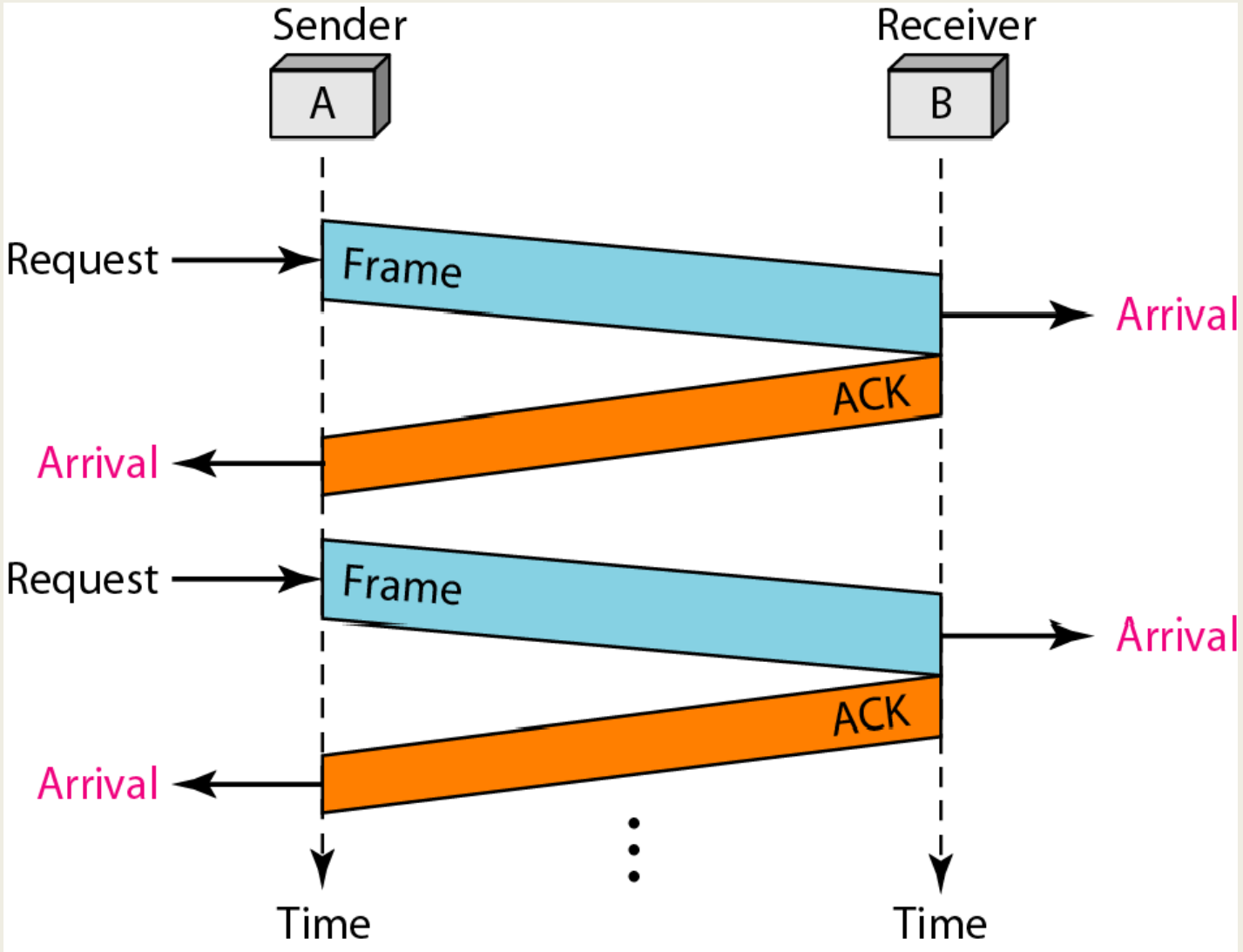


Fig.: The design of the Stop and wait protocol

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Stop and Wait Protocol: Example



Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Stop and Wait Automatic Repeat Request

- The sender keeps a copy of the sent frame. At the same time, it starts a timer.
- If the timer expires and there is no ACK for the sent frame, the frame is resent, the copy is held, and the timer is restarted.
- The protocol uses the stop-and-wait mechanism, there is only one specific frame that needs an ACK even though several copies of the same frame can be in the network.

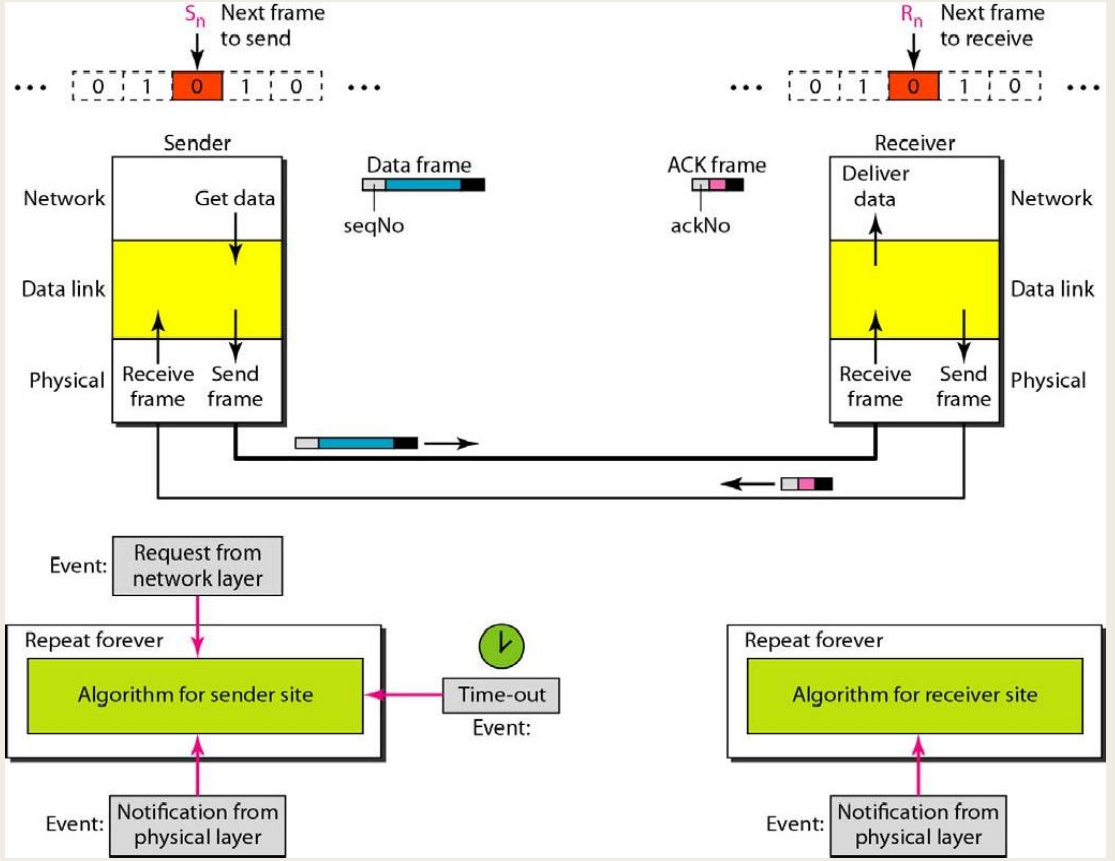
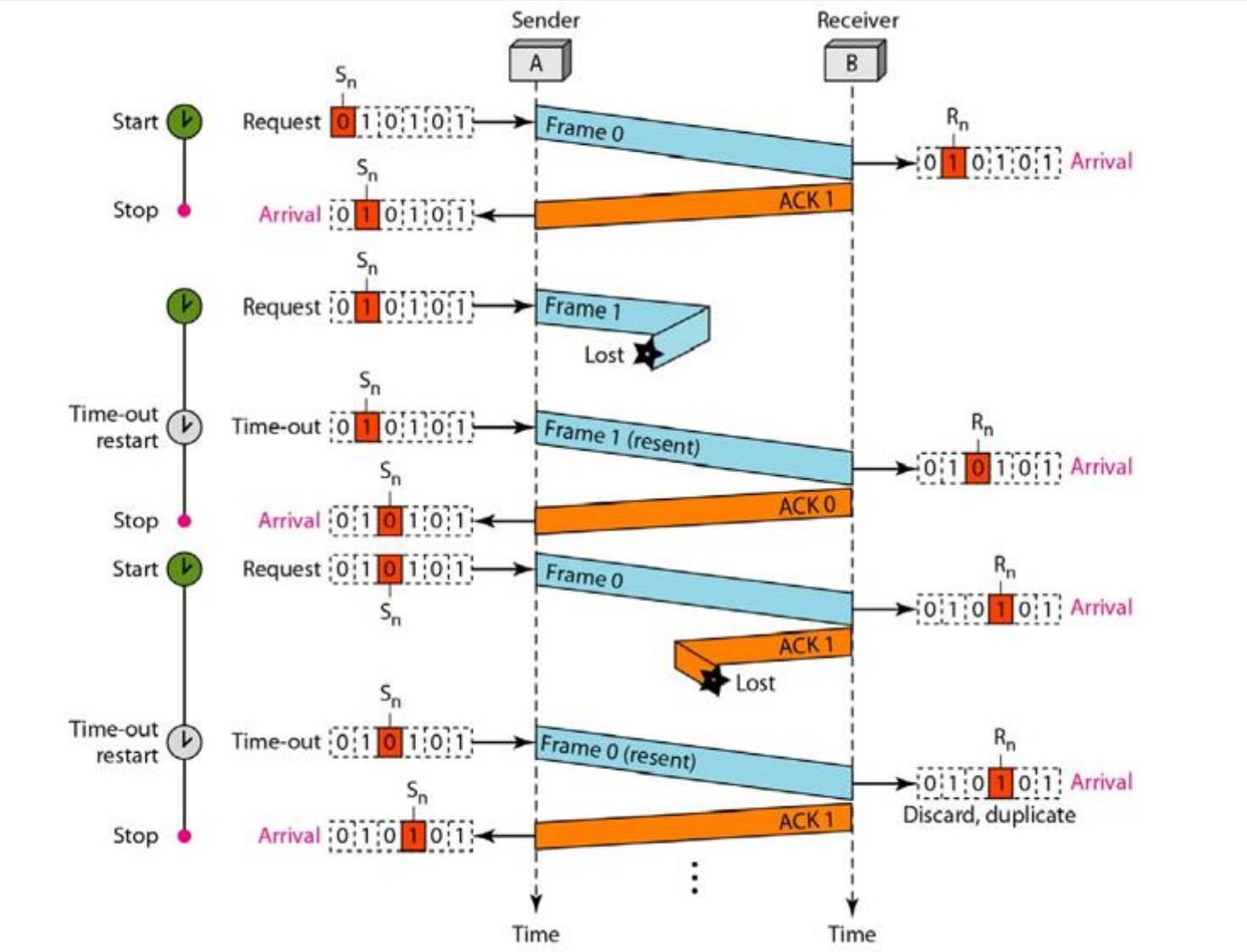


Fig.: The design of the Stop and Wait ARQ protocol

https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxlZWJhaHJpYTV8Z3g6MjE2MzY2MjcxMGU3MmQ4Nw

Example



Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Sequence Number

- A field is added to the data frame to hold the sequence number of that frame.
- The sequence numbers are wrap around. For example, if the field is *m* bits long, the sequence numbers start from 0, go to 2^m - 1, and then are repeated.

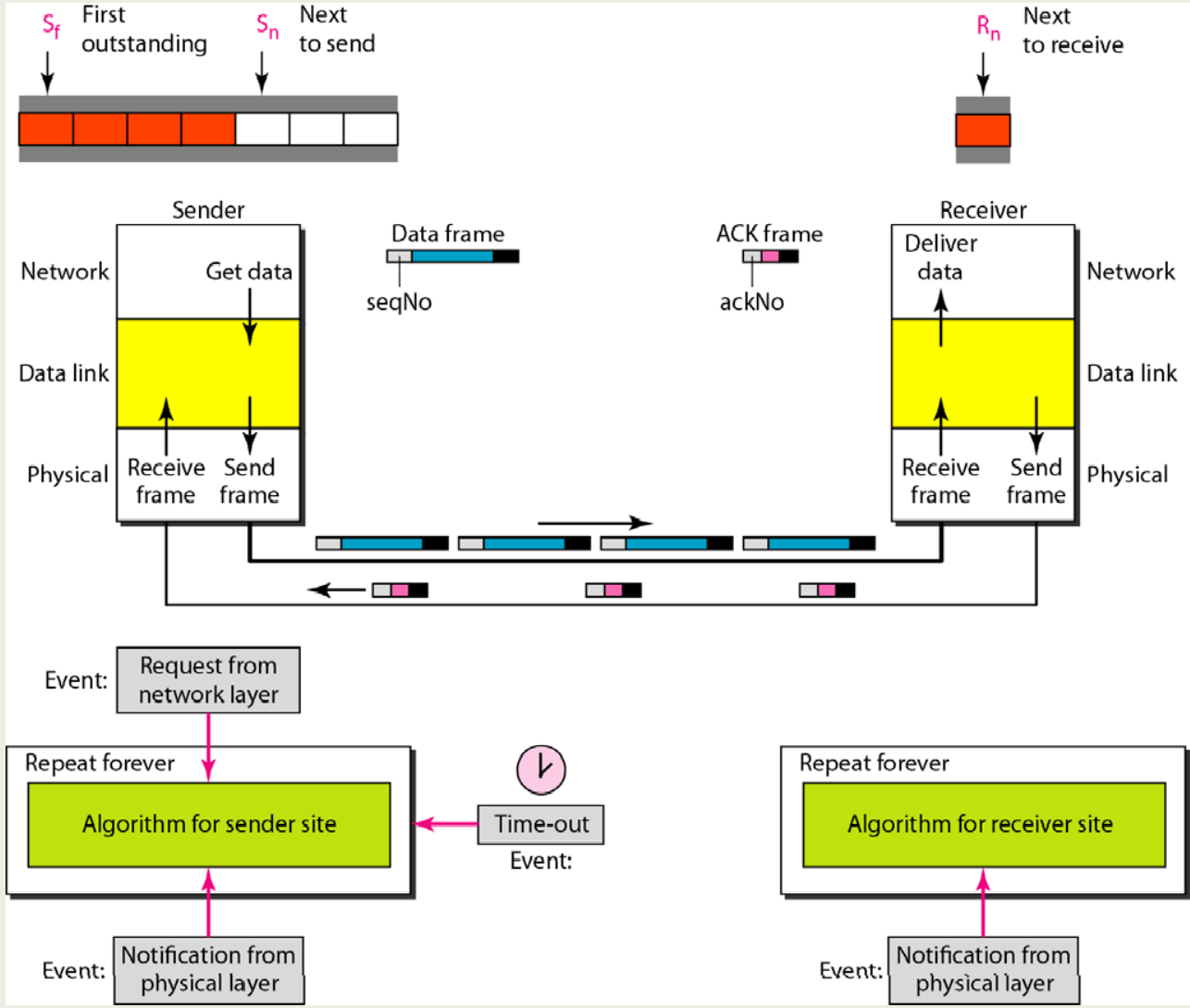
Acknowledgement Number

The acknowledgment numbers always announce the sequence number of the next frame expected by the receiver.

For example, if frame 0 has arrived safe and sound, the receiver sends an ACK frame with acknowledgment 1.
If frame 1 has arrived safe and sound, the receiver sends an ACK frame with acknowledgment 0 (meaning frame 0 is expected).

Go-Back-N Protocol

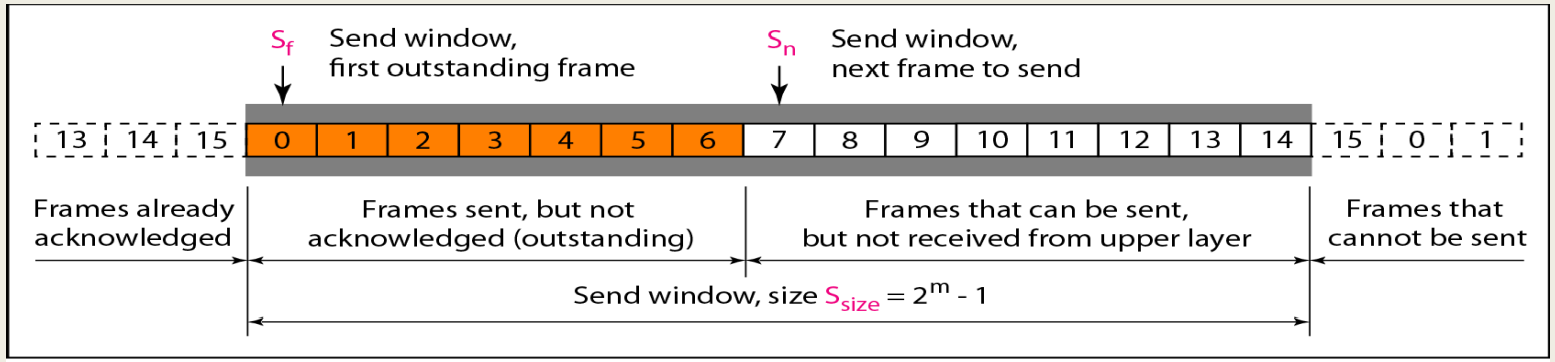
- In this protocol we can send several frames before receiving acknowledgments
- Keep a copy of these frames until the acknowledgments arrive.
- Improve the efficiency of transmission
- In the Go-Back-N Protocol, the sequence numbers are modulo 2^m, where m is the size of the sequence number field in bits.



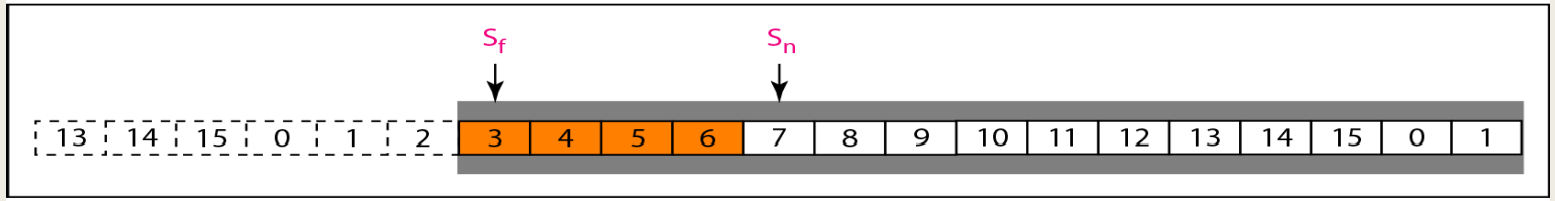
Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Sender Window

- The send window is an imaginary box covering the sequence numbers of the data frames which can be in transit.
- In each window position, some of these sequence numbers define the frames that have been sent; others define those that can be sent.
- The maximum size of the window is $2^m - 1$.
- The send window can slide one or more slots when a valid acknowledgment arrives.



a. Send window before sliding

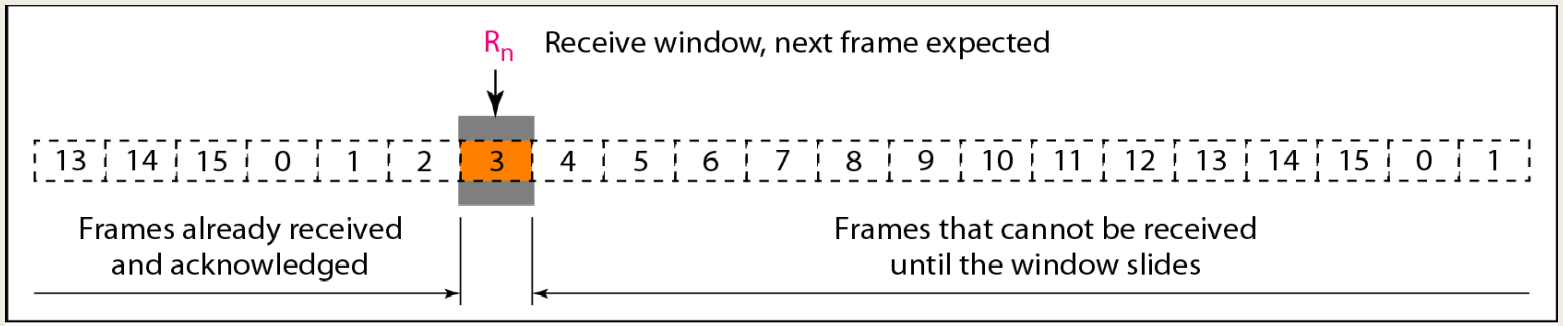


b. Send window after sliding

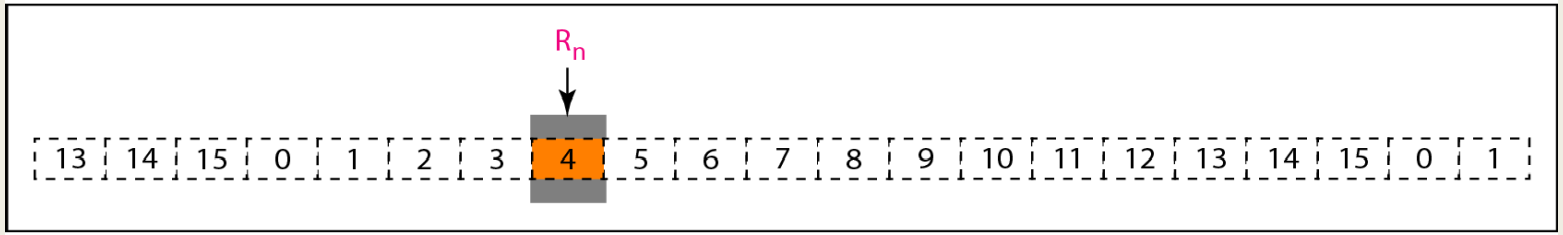
Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Receiver Window

- 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 frame has arrived; sliding occurs one slot at a time.
- In Go-Back-N ARQ, the size of the send window must be less than 2^m; the size of the receiver window is always 1.



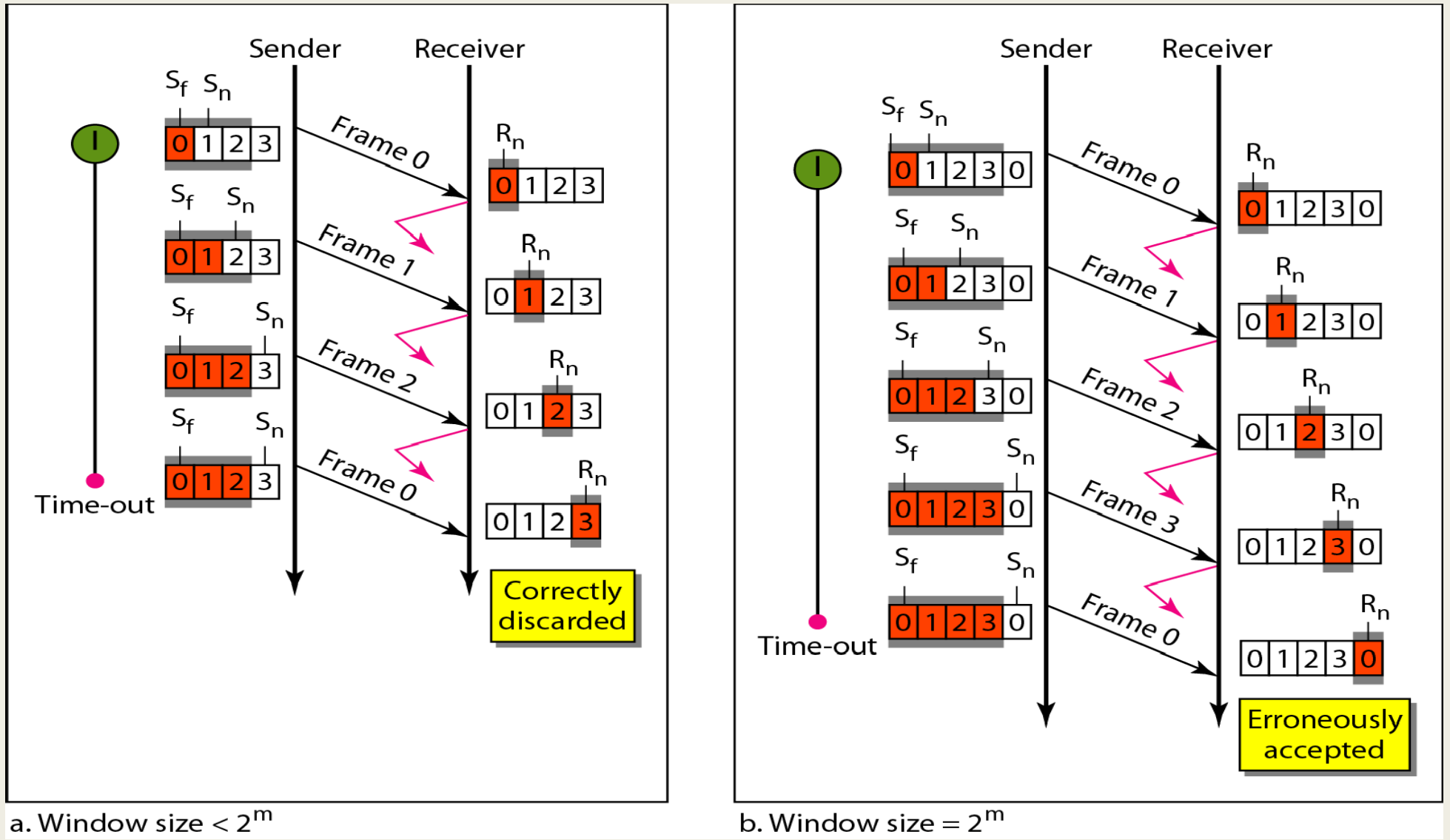
a. Receive window



b. Window after sliding

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Example



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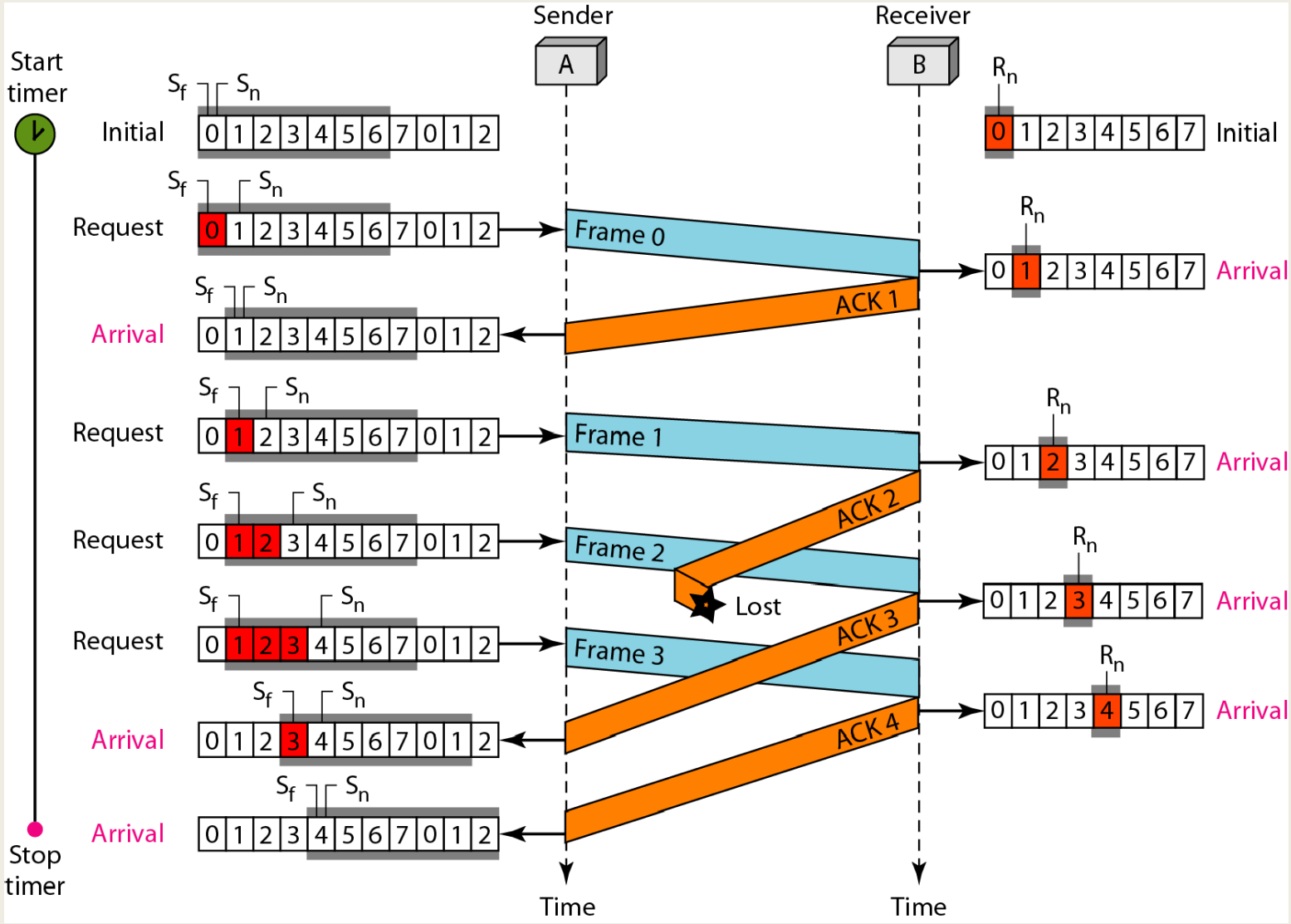
Example



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Selective Repeat ARQ

Does not resend *N* frames when just one frame is damaged; only the damaged frame is resent

In Selective Repeat ARQ, the size of the sender and receiver window must be at most one-half of 2^m.

More efficient for noisy links, but the processing at the receiver is more complex.

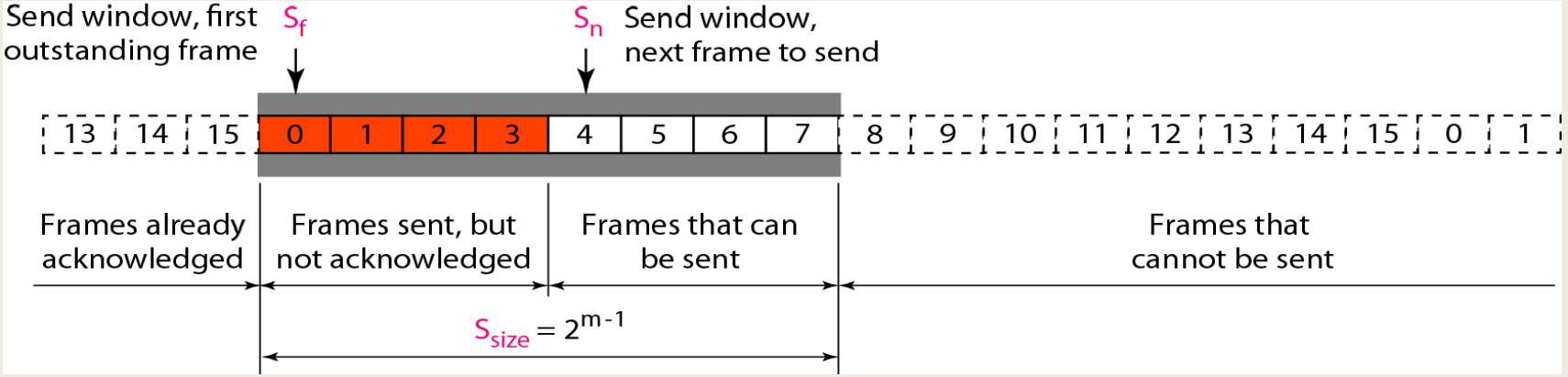


Fig.: Send window for Selective Repeat ARQ

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Selective Repeat ARQ: Receive Window

- The size of the receive window is the same as the size of the send window (2^m- I).
- The Selective Repeat Protocol allows as many frames as the size of the receive window to arrive out of order and be kept until there is a set of in-order frames to be delivered to the network layer.
- The sizes of the send window and receive window are the same, all the frames in the send frame can arrive out of order and be stored until they can be delivered.

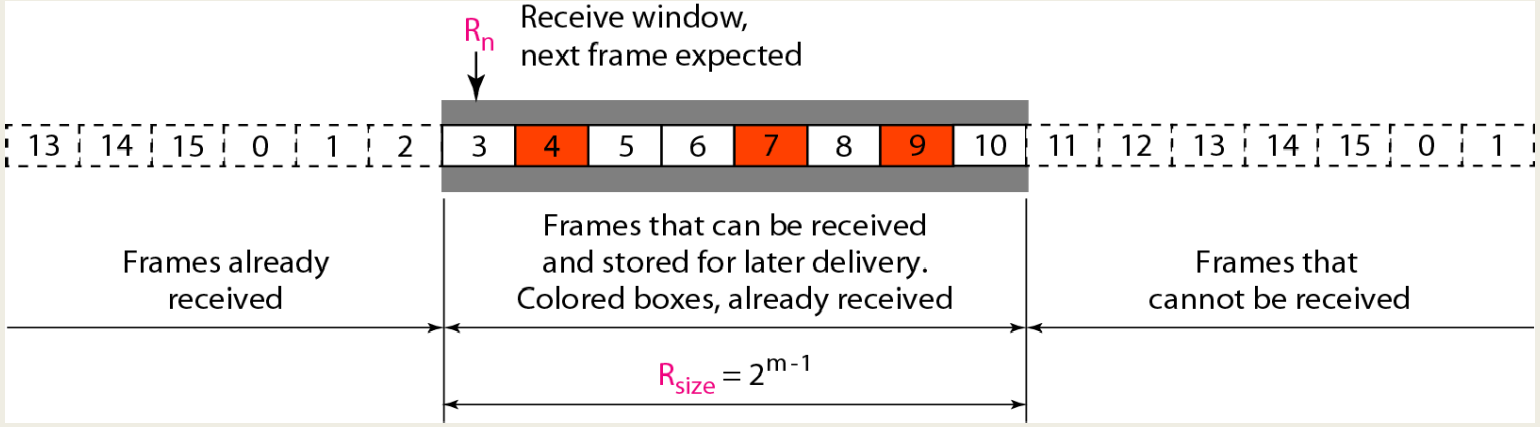
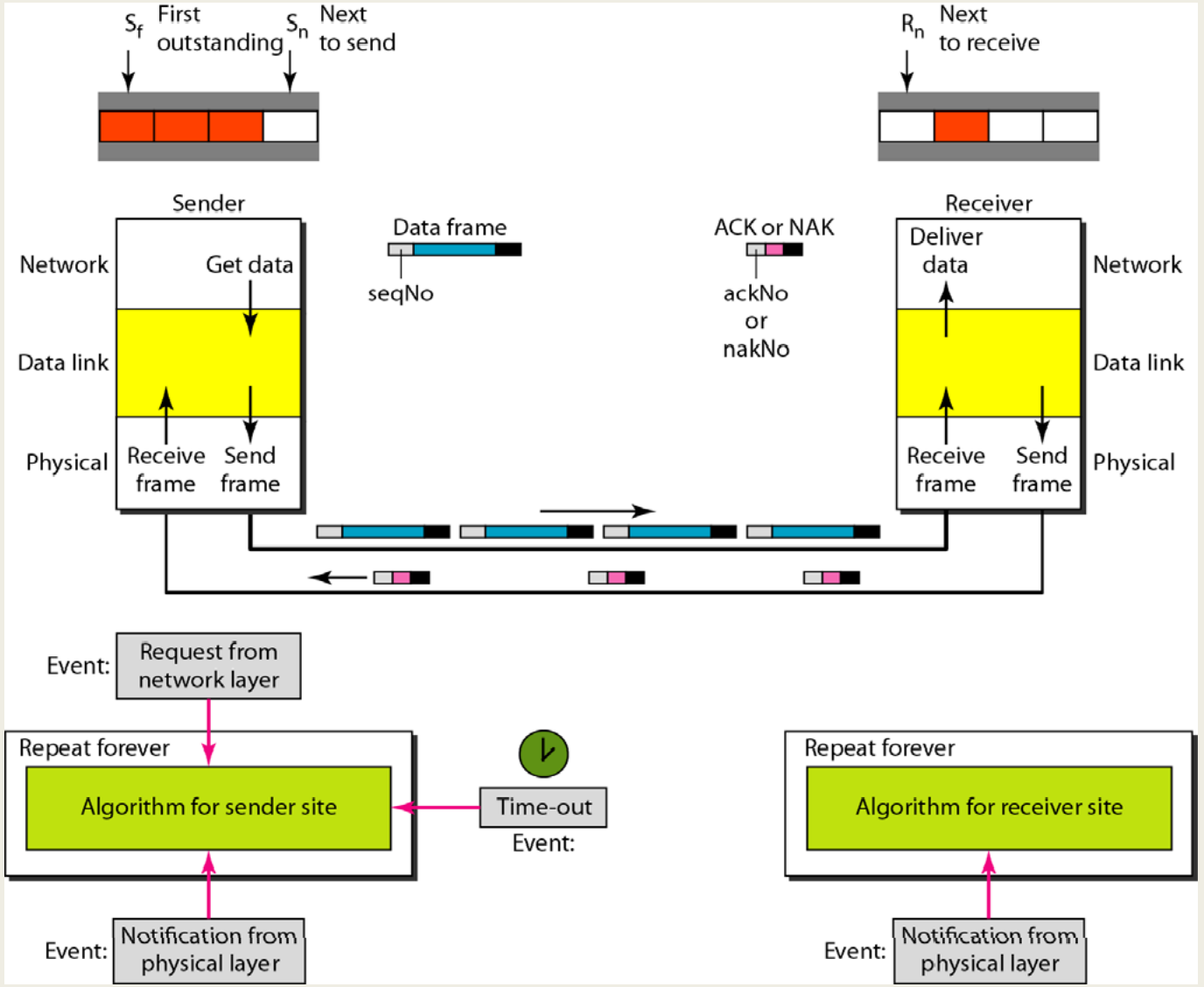


Fig.: Receive window for Selective Repeat ARQ

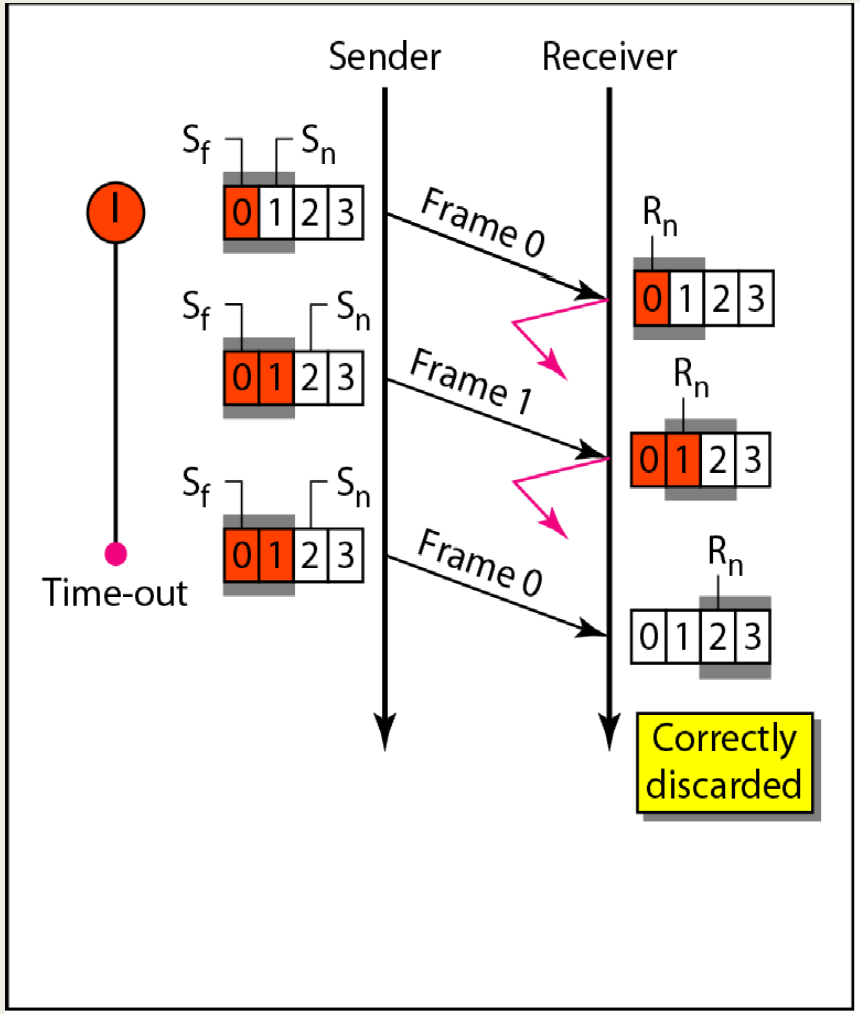
Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Selective Repeat ARQ: Design

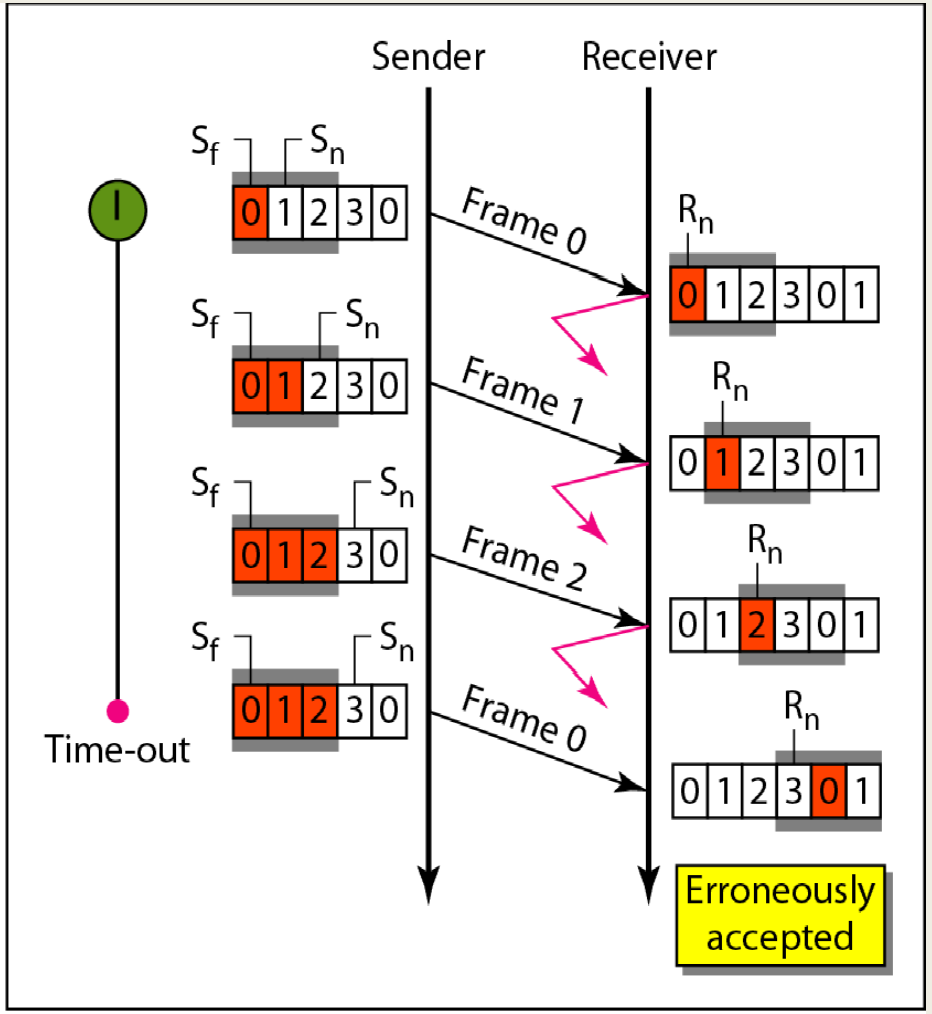


Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Selective Repeat ARQ: Window



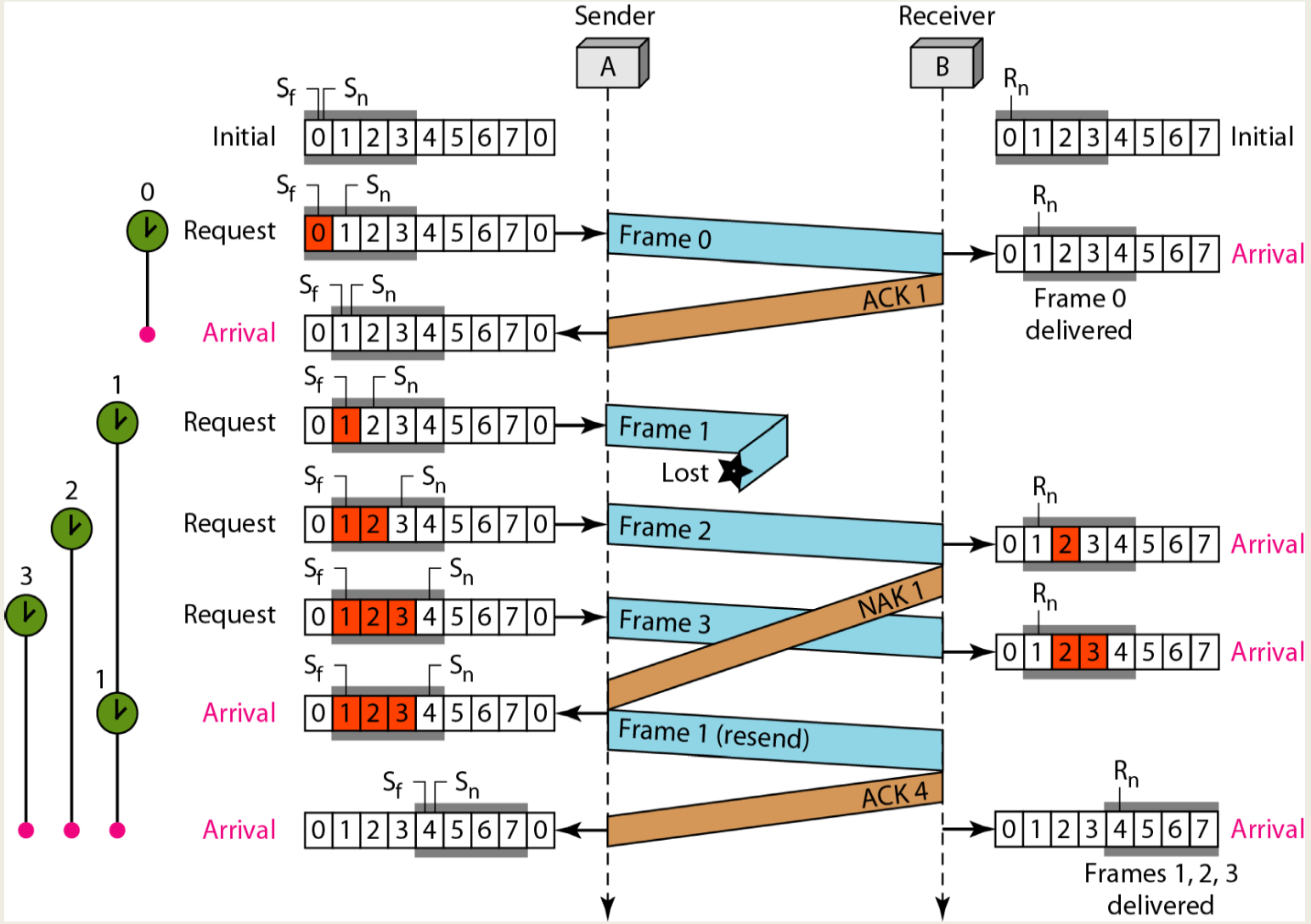
a. Window size = 2^{m-1}



b. Window size > 2^{m-1}

https://docs.google.com/viewer?a=v&pid=sites&srcid=ZGVmYXVsdGRvbWFpbnxlZWJhaHJpYTV8Z3g6MjE2MzY2MjcxMGU3MmQ4Nw

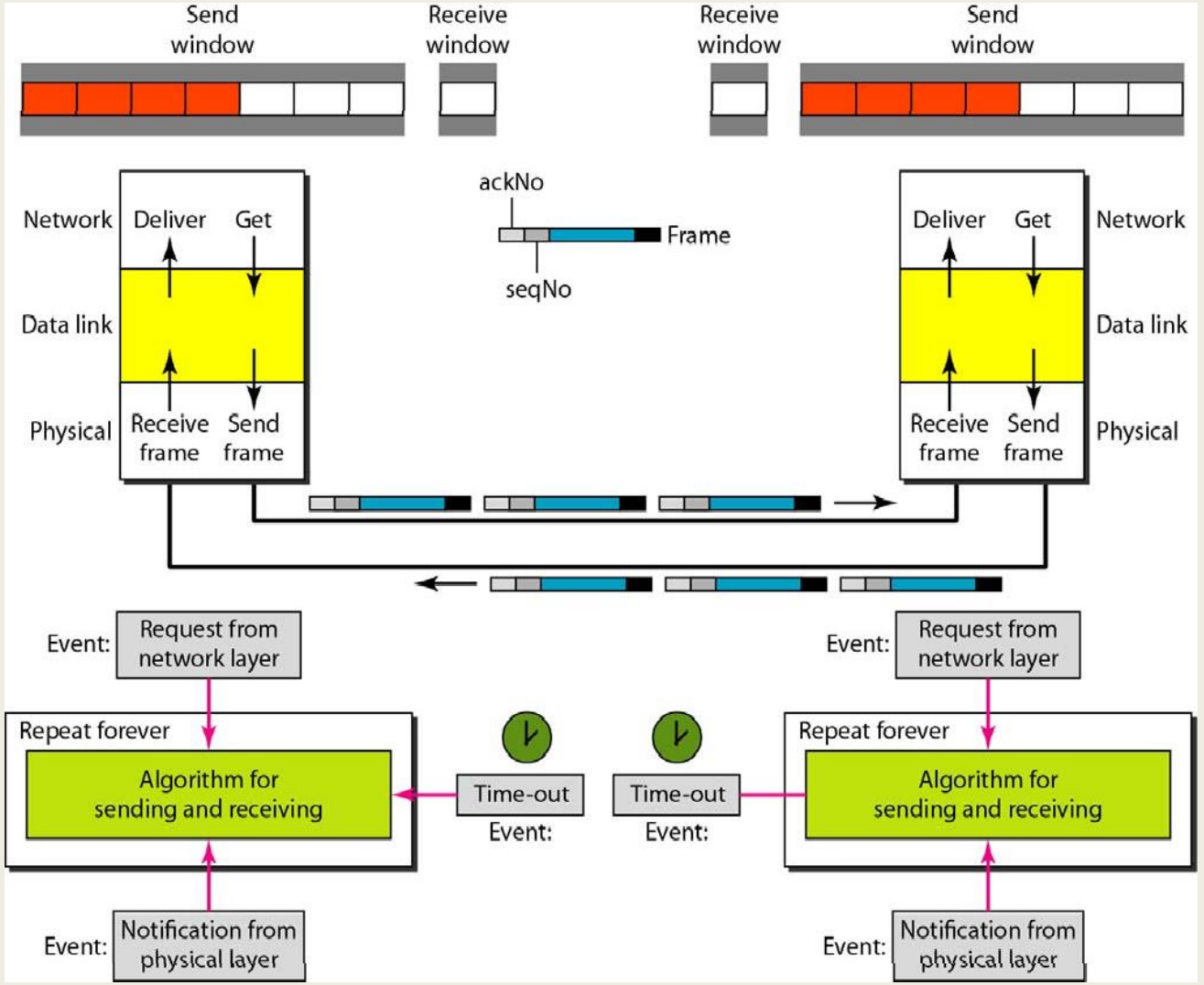
Selective Repeat ARQ: Example



Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Piggybacking

- Improve the efficiency of the bidirectional protocols.
- When a frame is carrying data from A to B, it can also carry control information about arrived (or lost) frames from B; when a frame is carrying data from B to A, it can also carry control information about the arrived (or lost) frames from A.



Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Thank You!!!

Appendix

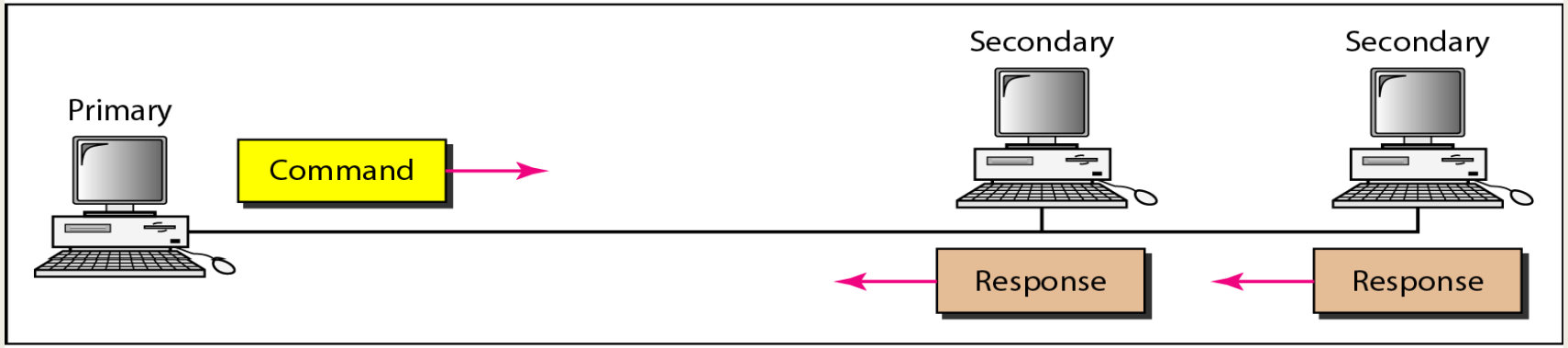
HDLC

- High-level Data Link Control (HDLC) is a bit-oriented protocol for communication over point-to-point and multipoint links.
- It implements the ARQ mechanisms.
- HDLC provides two common transfer modes that can be used in different configurations: **normal response mode (NRM) and asynchronous balanced mode (ABM).**

Normal Response Mode

- The station configuration is unbalanced.
- One primary station and multiple secondary stations.
- A primary station can send commands; a secondary station can only respond.
- The NRM is used for both **point-to-point and multiple-point links**.

a. Point-to-point

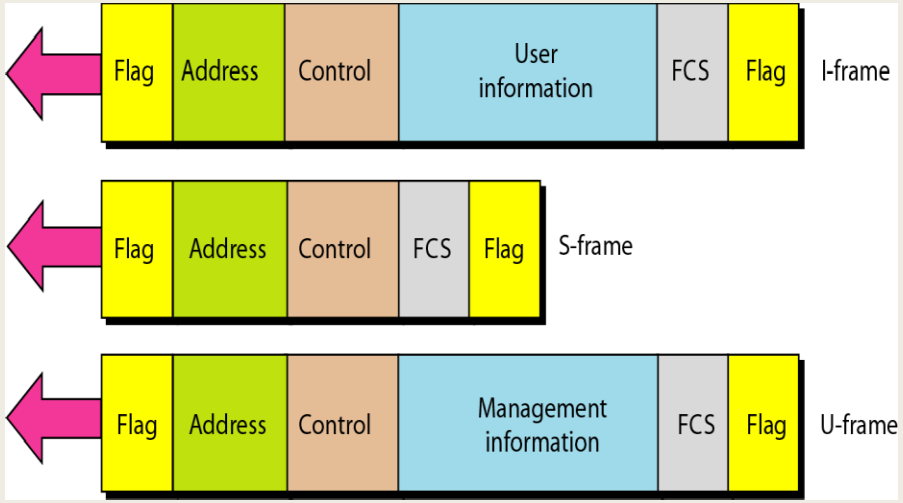


b. Multipoint

Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Frames

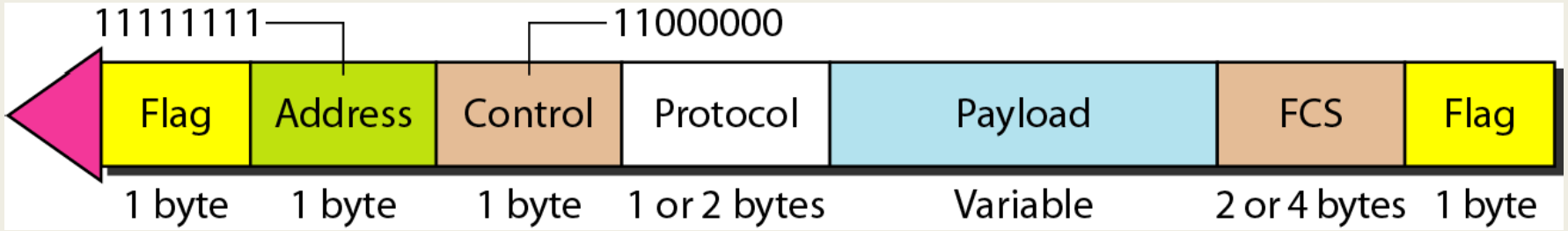
- HDLC defines three types of frames: information frames (I-frames), supervisory frames (S-frames), and unnumbered frames (V-frames).
- Each type of frame serves as an envelope for the transmission of a different type of message.
- I-frames are used to transport user data and control information relating to user data (piggybacking).
- S-frames are used only to transport control information.
- V-frames are reserved for system management. Information carried by V-frames is intended for managing the link itself.



Source: B. A. Forouzan, " Data Communications and Networking ," *McGraw-Hill Forouzan Networking Series*,5E.

Point to Point protocol

- PPP defines the format of the frame to be exchanged between devices.
- PPP defines how two devices can negotiate the establishment of the link and the exchange of data.
- PPP defines how network layer data are encapsulated in the data link frame.
- PPP defines how two devices can authenticate each other.
- PPP provides multiple network layer services supporting a variety of network layer protocols.
- PPP provides connections over multiple links.
- PPP provides network address configuration. This is particularly useful when a home user needs a temporary network address to connect to the Internet.



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