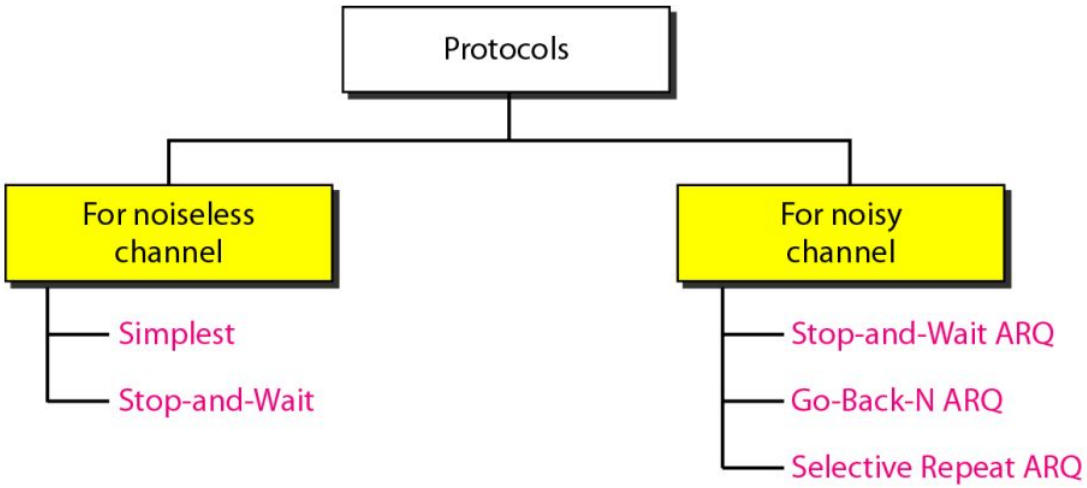
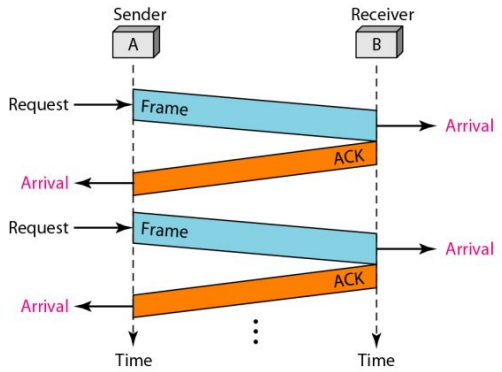
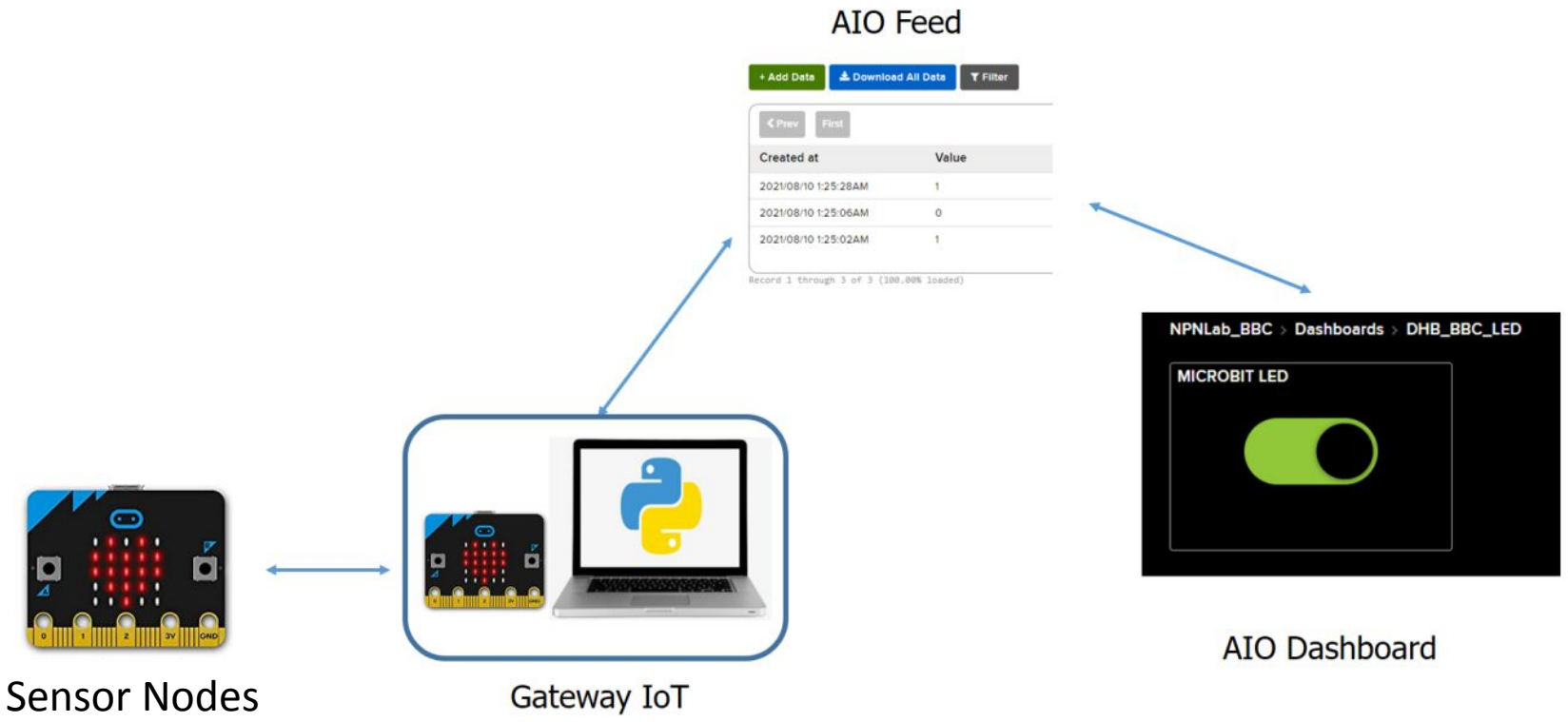
Error Control in Communication





System Architecture

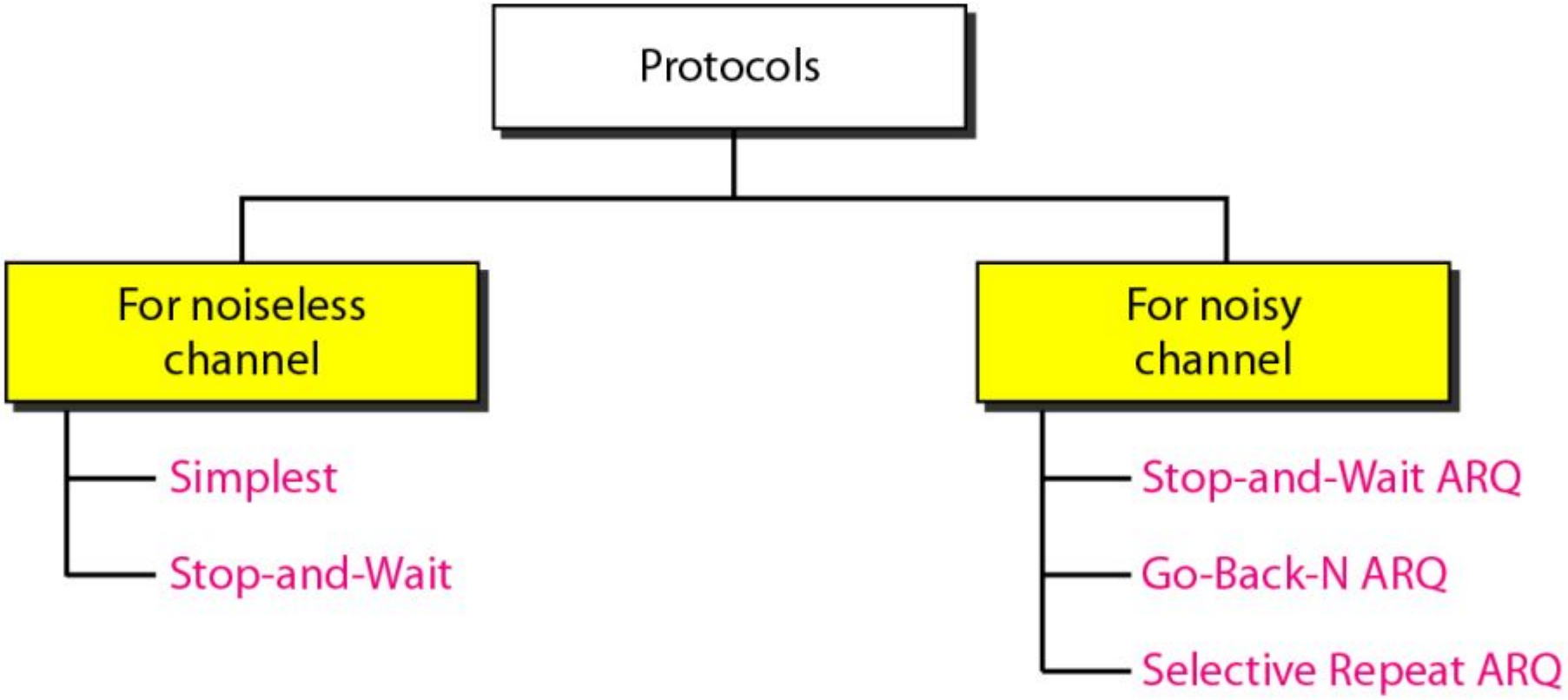


Communication Protocol

- The combination of **framing**, **flow control**, and **error control** to achieve the delivery of data from one node to another.

- The protocols are normally **implemented in software** by using one of the common programming languages.

Classification of Protocols



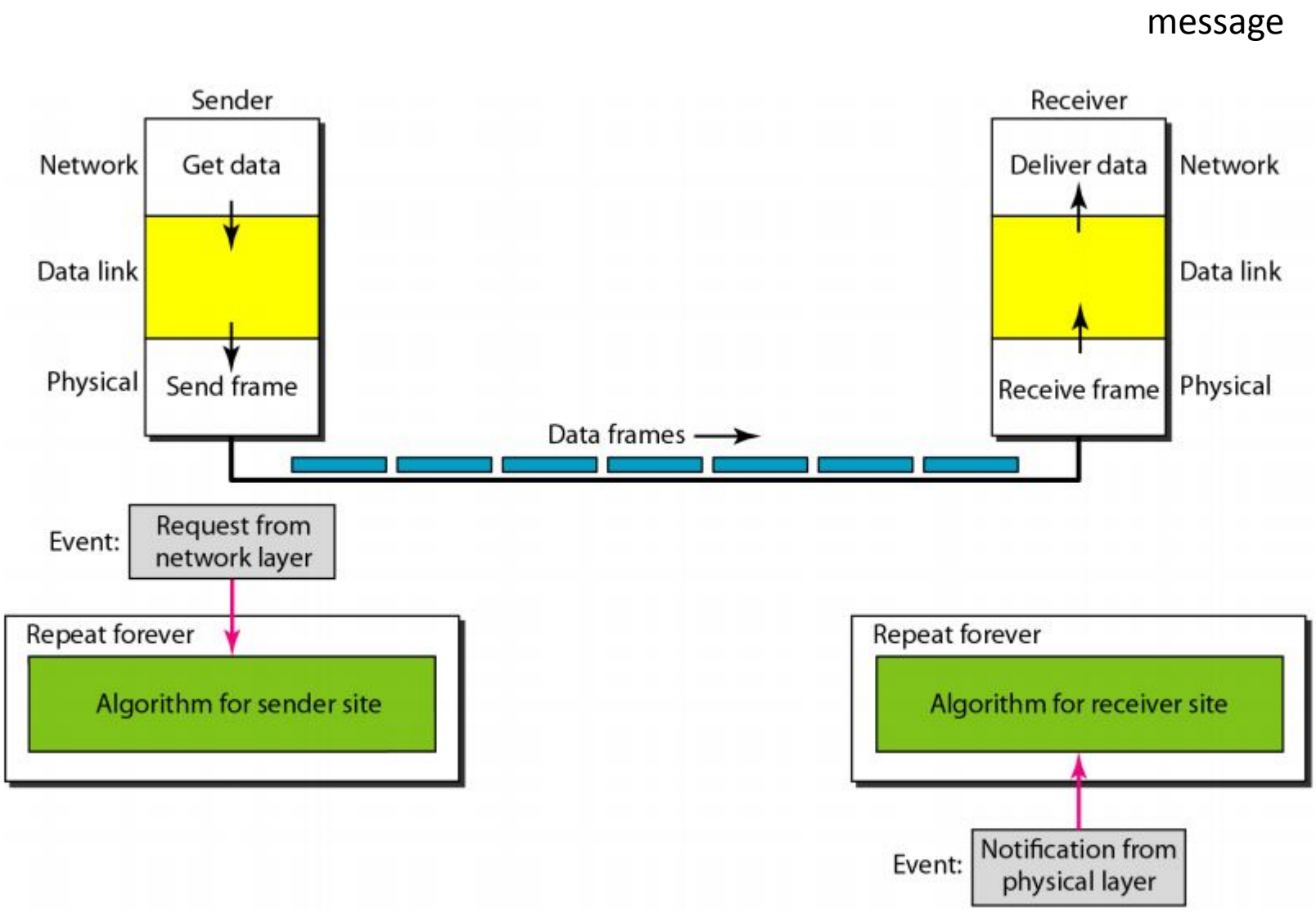
NOISELESS CHANNELS

- No frames are lost, duplicated, or corrupted
- **Simplest Protocol** – has no flow or error control
- **Stop-and-Wait Protocol** – sender sends one frame, stops until it receives agree from receiver and then sends the next frame

Simplest Protocol

- **Unidirectional protocol:** 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 network layer, which can also accept the packet immediately.

Simplest Protocol Design

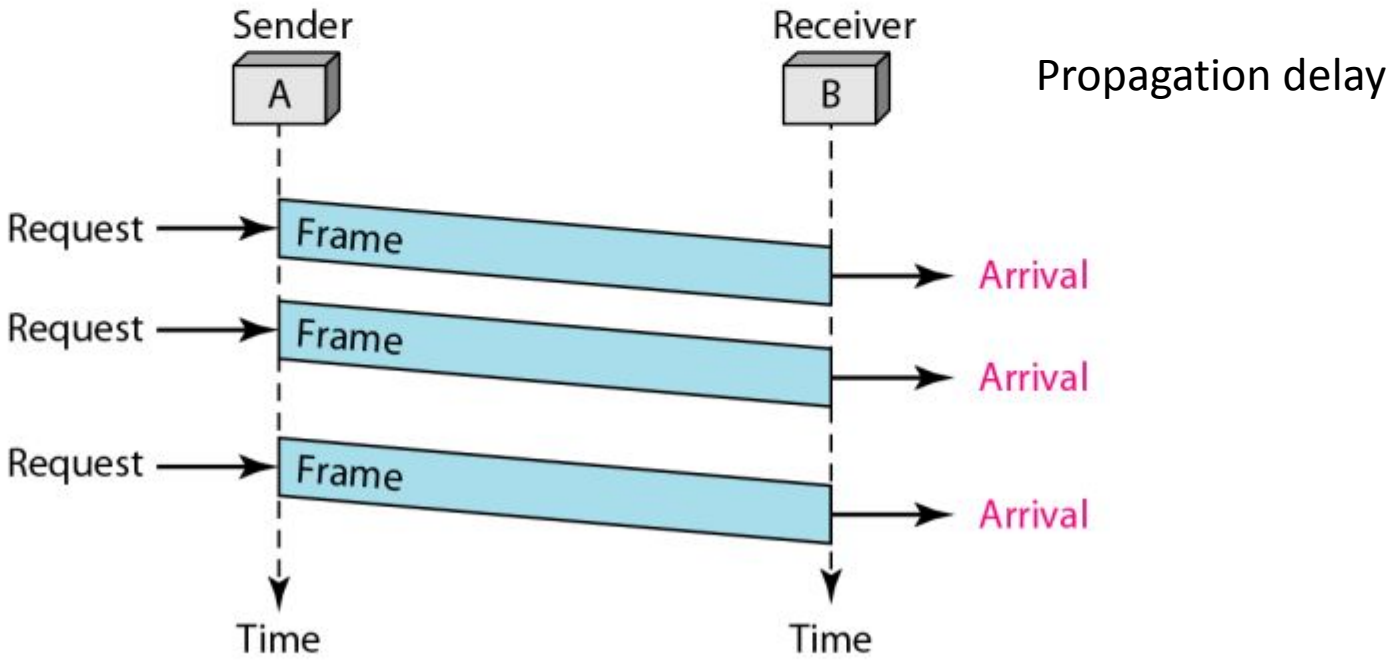


Implementation

```
while(true){
    WaitForEvent();
    if(Event(RequestToSend)){
        GetData();
        MakeFrame();
        SendFrame();
    }
}
```

```
while(true){
    WaitForEvent();
    if(Event(ArrivalNotification)){
        ReceiveFrame();
        ExtractData();
        DeliverData();
    }
}
```

Example

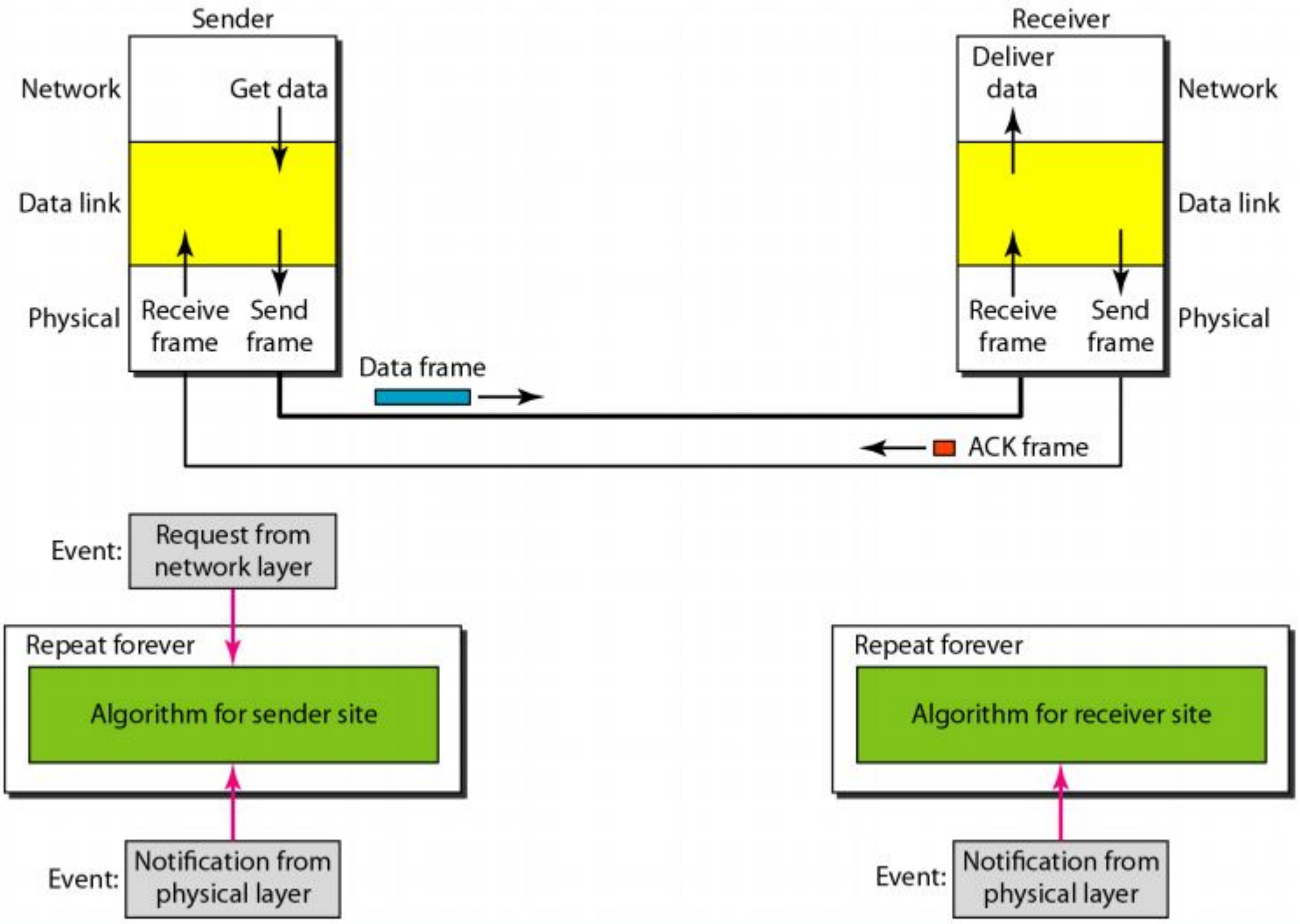


- The sender **sends a sequence of frames** without even thinking about the receiver
- There is no error handler
- There is no synchronization (the receiver processing time is slower than the transmission speed)

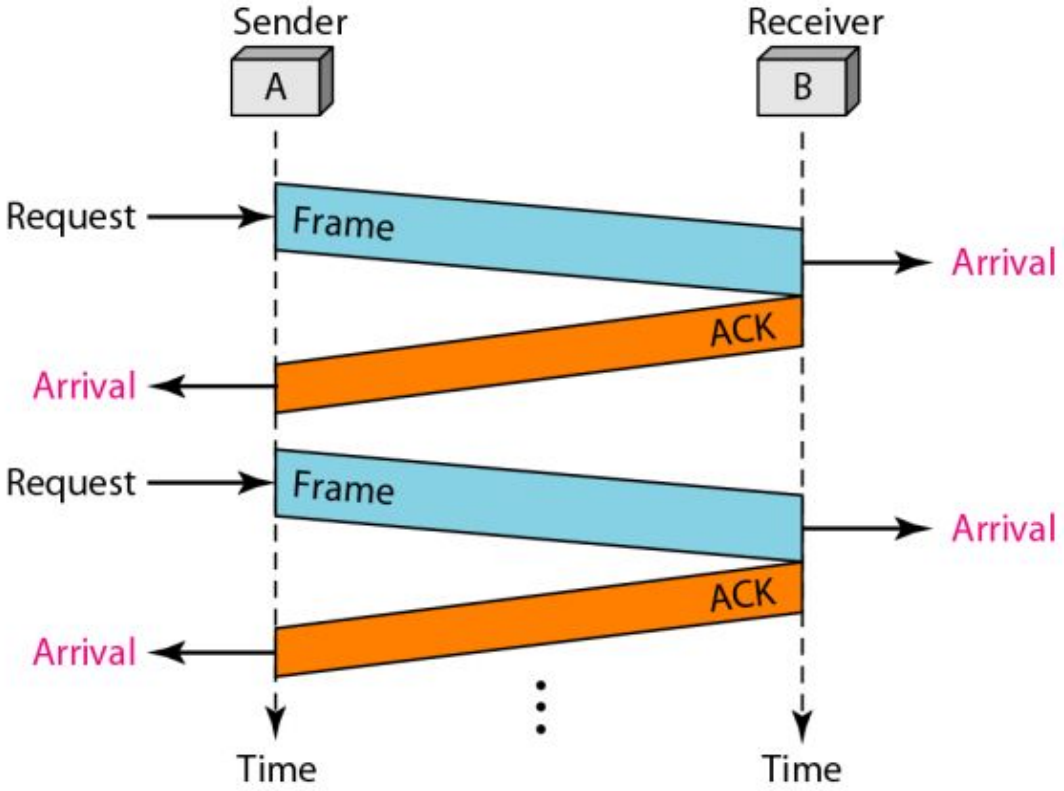
Stop and Wait Protocol

- If data frames arrive at the receiver site faster than they can be processed, **the frames must be stored** until their use
- Normally, the **receiver does not have enough storage space**, especially if it is receiving data from many sources
- The sender sends one frame, stops until it receives agreement the receiver (okay to go ahead), and then sends the next frame
- **ACK frames** (simple tokens of acknowledgment) travel from the other direction

Stop and Wait Protocol Design



Example



- The sender sends one frame and waits for feedback from the receiver before sending the next frame
- Four events at the Sender and two events at the Receiver

NOISY CHANNELS

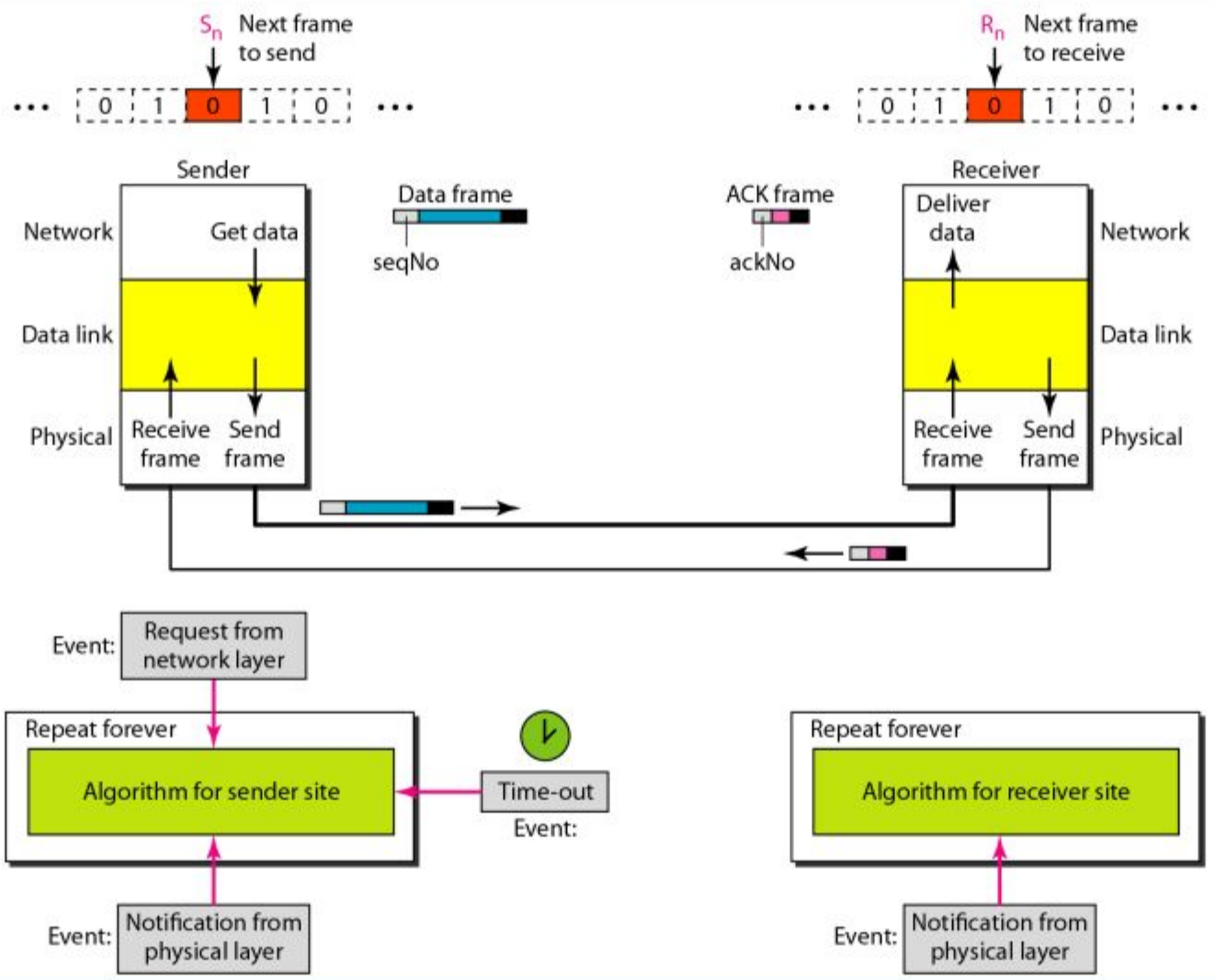
- Although the Stop-and-Wait Protocol gives us an idea of how to add flow control to its predecessor, **noiseless channels are nonexistent.**

- Stop-and-Wait Automatic Repeat Request(ARQ)
- Go-Back-N Automatic Repeat Request
- Selective Repeat Automatic Repeat Request

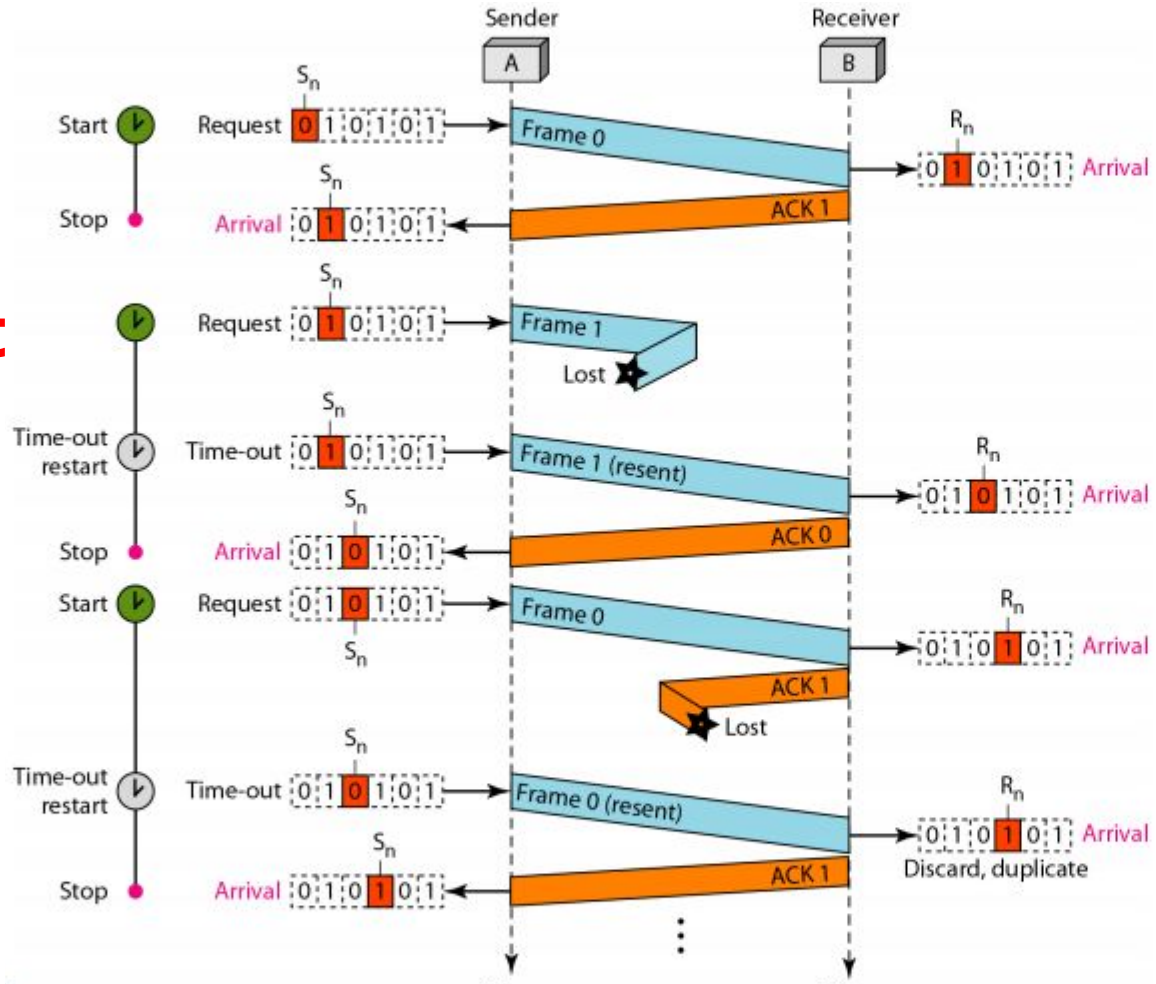
Stop and Wait ARQ Principles

- A copy of a frame (sent to the receiver) is kept in the buffer
- Retransmitting this frame when the timer expires, meaning that ACK is not received
- **Sequence numbers** are used to index the frames.
- The acknowledgment number always announces the sequence number of the **next frame expected**

Stop and Wait ARQ Protocol



Example



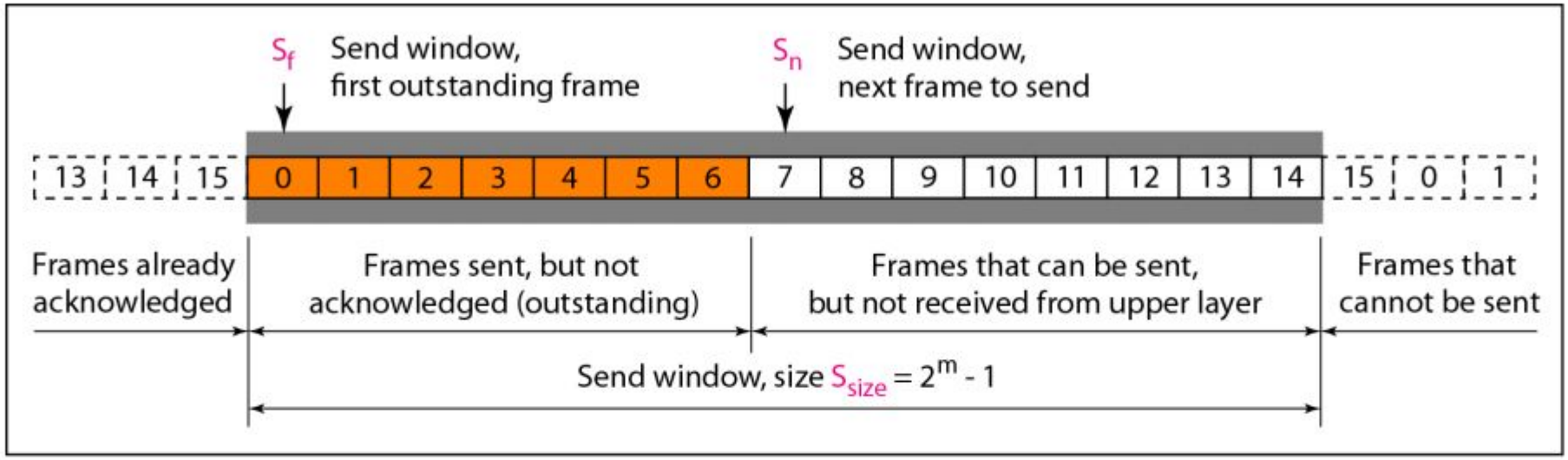
- **Frame is lost**
- **ACK is lost**
  - Duplicate reception at the receiver

Go-Back-N Automatic Repeat Request

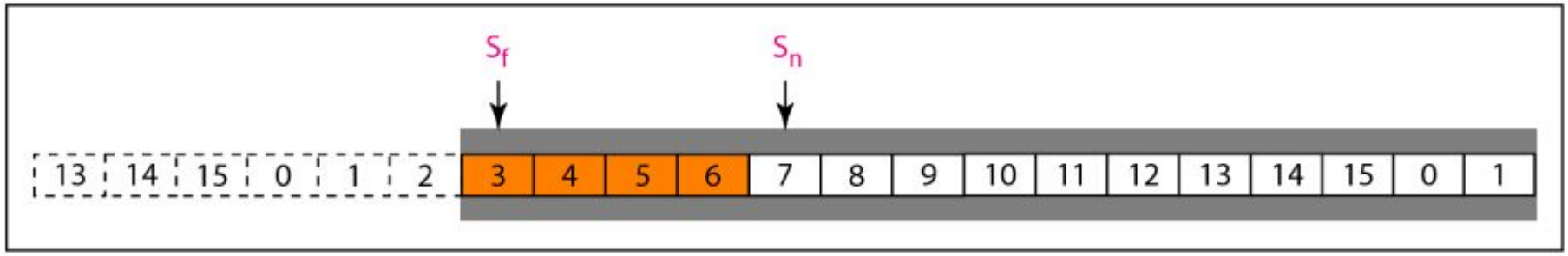
- **Multiple frames must be in transition** while waiting for acknowledgment to maximize the efficiency

- Protocol principles:
  - Several frames are sent before receiving ACKs
  - A copy of these frames are kept until the ACKs arrive

Send Windows for Go Back N (m=4)



a. Send window before sliding



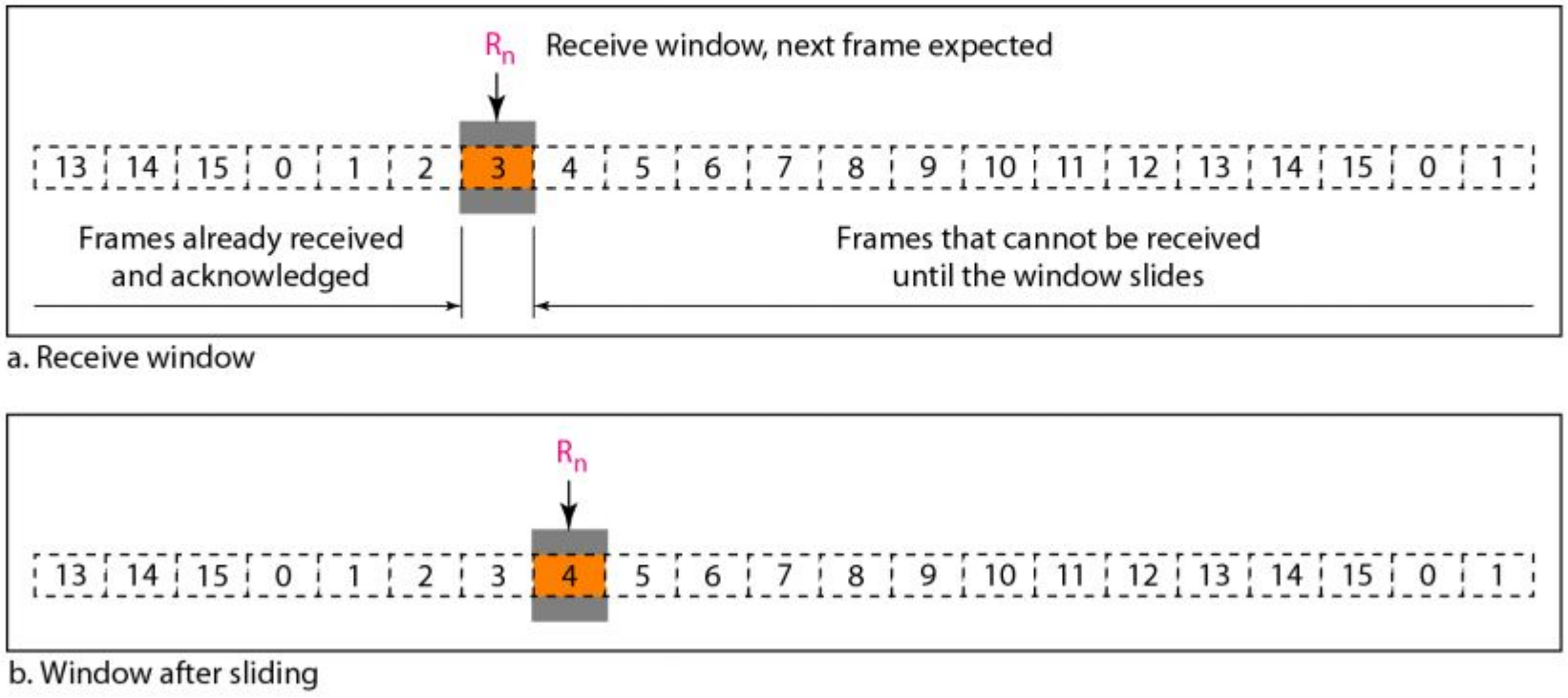
b. Send window after sliding

Definitions

- S_f: the sequence number of the first (oldest) outstanding frame
- S_n: the sequence number that will be assigned to the next frame to be sent.
- S_{size}: the size of the window, which is fixed in our protocol.

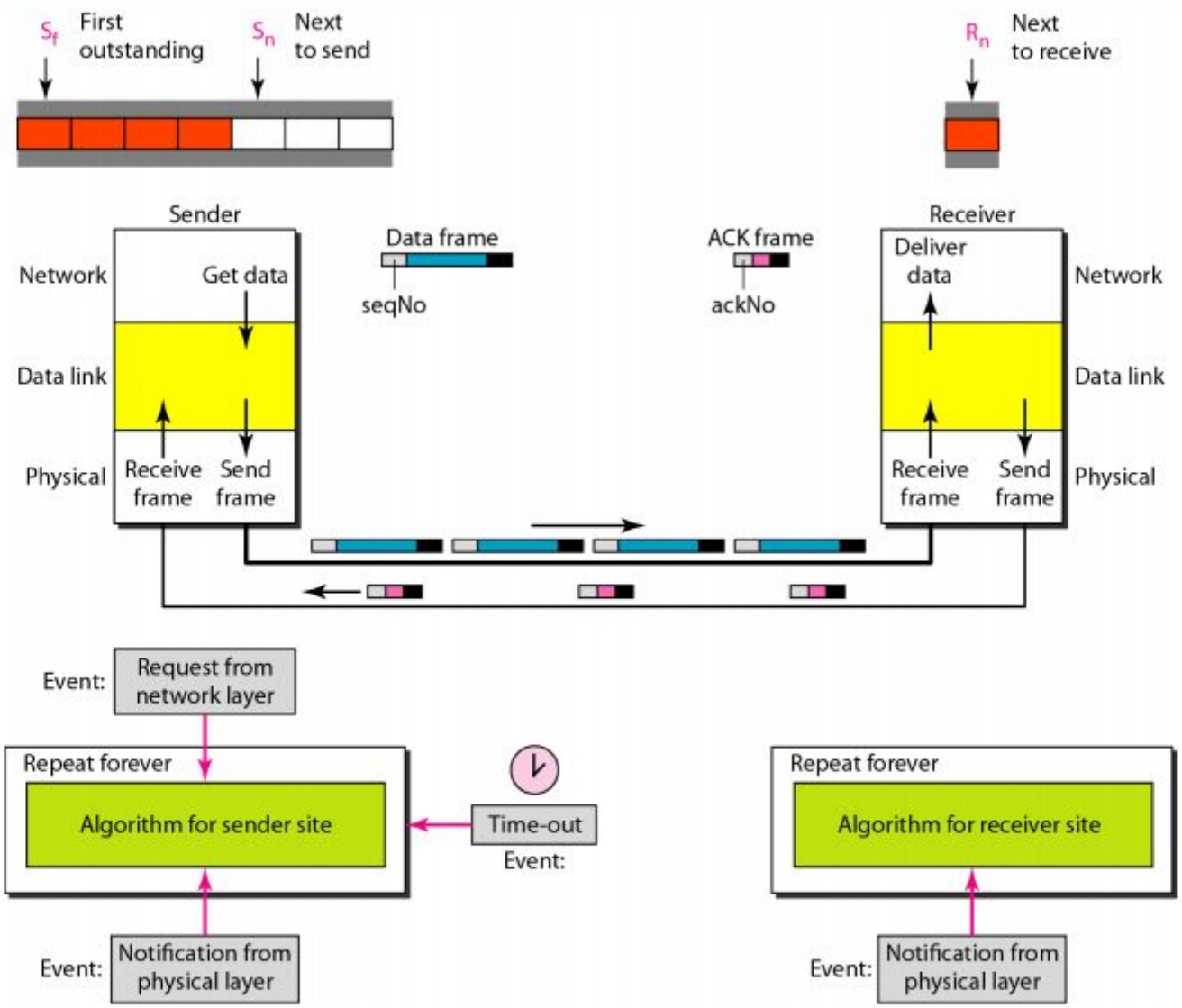
- S_f can **slide one or more slots** when a valid ACK arrives.

Receive Windows for Go Back N



- The window **slides one slot** when a correct frame has arrived;

Go Back N Design



Selective Repeat Automatic Repeat Request

- In a noisy link a frame has a higher probability of damage, which means the **resending of multiple frames.** This resending uses up the bandwidth and slows down the transmission

- Selective Repeat ARQ: **does not resend N frames** when just **one frame is damaged**

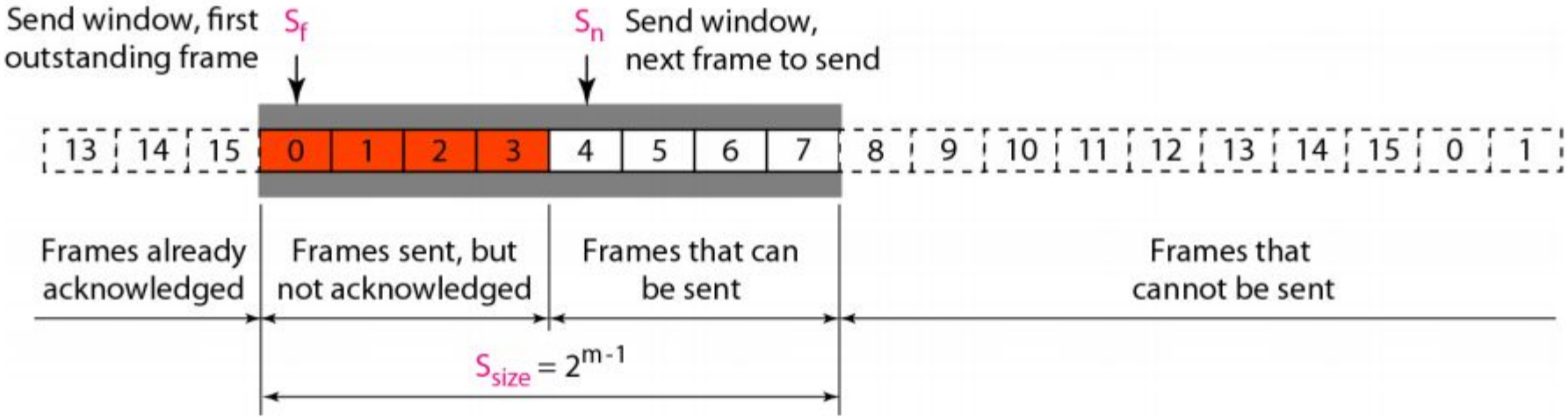
- It is **more efficient** for noisy links, but the processing at the receiver is **more complex** compared to Go Back N

Selective Repeat ARQ

- **Two windows are used**: a send window and a receive window as Go Back N
- The size of the sending window is smaller: 2^{m-1}
- The received window is the same size as the send window (in Go Back N, the size is only **1**).

- For example, if m = 4, the sequence numbers go from 0 to 15, but the size of the window is just 8 (it is 15 in the Go-Back-N Protocol). The smaller window size means **less efficiency in transmission**, but the fact that there are fewer duplicate frames.

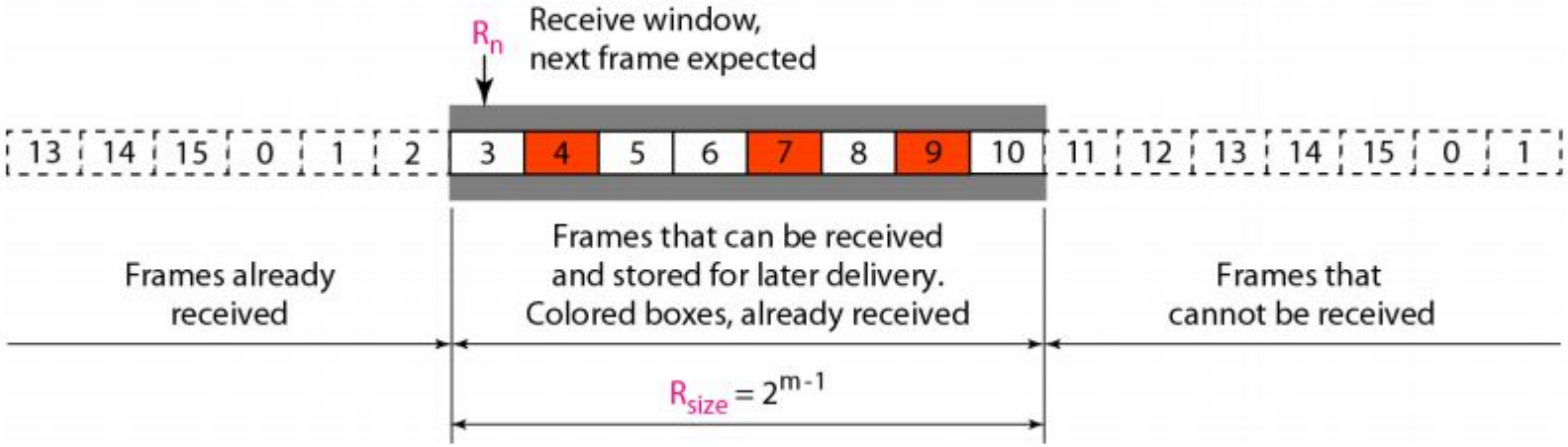
Sending Windows (m=4)



Received Windows (size 2^{m-1})

- Many frames can be arrived **out of order** and be kept until there is **a set of in-order frames** to be delivered to the network layer

- All the frames in the send frame can arrive out of order and be stored until they can be delivered.



Design of Selective Repeat ARQ