Data Link Control

Data Link Control:

- Requirements for Effective Data Communication:
  - **Frame Synchronization**
  - **Flow control**

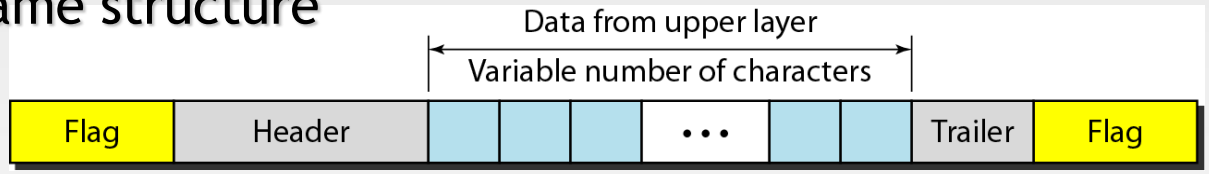
    Enables a receiver to regulate the flow of data from a sender so that the receivers buffers do not overflow
  - **Error control**
    - **Detection**: Detects the errors in received data the receiver
    - **Error Control:** If error, retransmission of damaged frames
  - **Control Information and data on same link**
  - **Link Management**

Framing

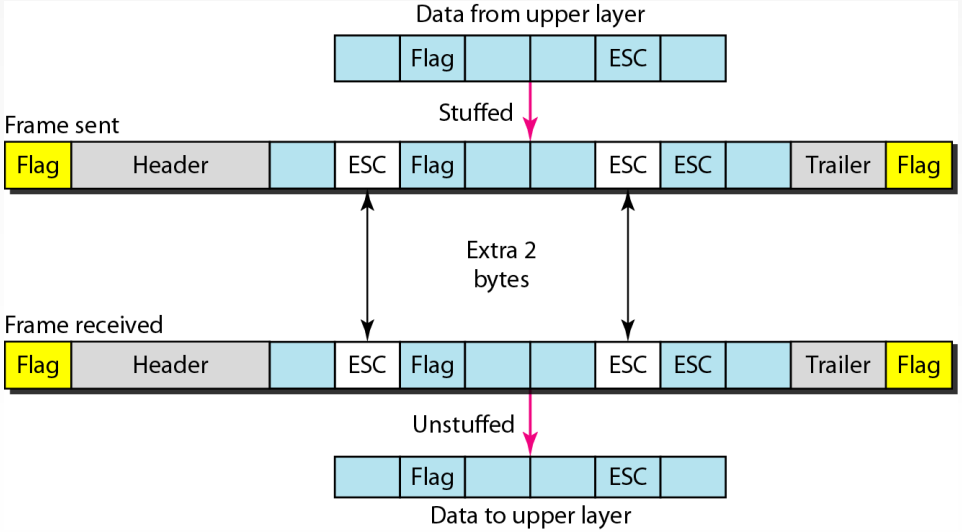
- Data link layer needs to pack bits into frames, so that each frame is distinguishable from another
- Separate a message from one source to a destination, or from other messages to other destinations, by adding a sender address and a destination address
- Fixed-size framing: ATM
- Variable-size framing
  - Need a way to define the end of the frame and the beginning of the next
  - Character-oriented approach and bit-oriented approach

Character-Oriented Protocols

- Frame structure

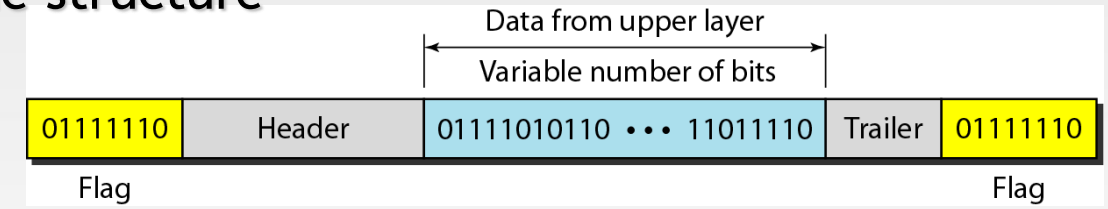


- Byte stuffing: process of adding 1 extra byte whenever there is a flag or escape character in the text

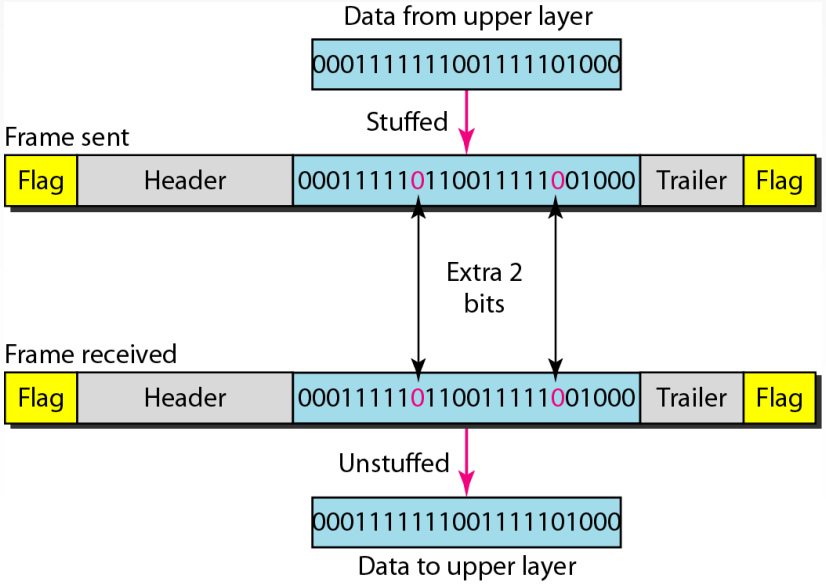


Bit-Oriented Protocols

- Frame structure



- Bit stuffing: process of adding one extra 0 whenever five consecutive 1s follow a 0 in the data



Flow Control:

- Ensuring the sending entity does not overload the receiving entity with data
  - Preventing buffer overflow
- Transmission time
  - Time taken to transmit all bits into medium
- Propagation time
  - Time for a bit to traverse the link

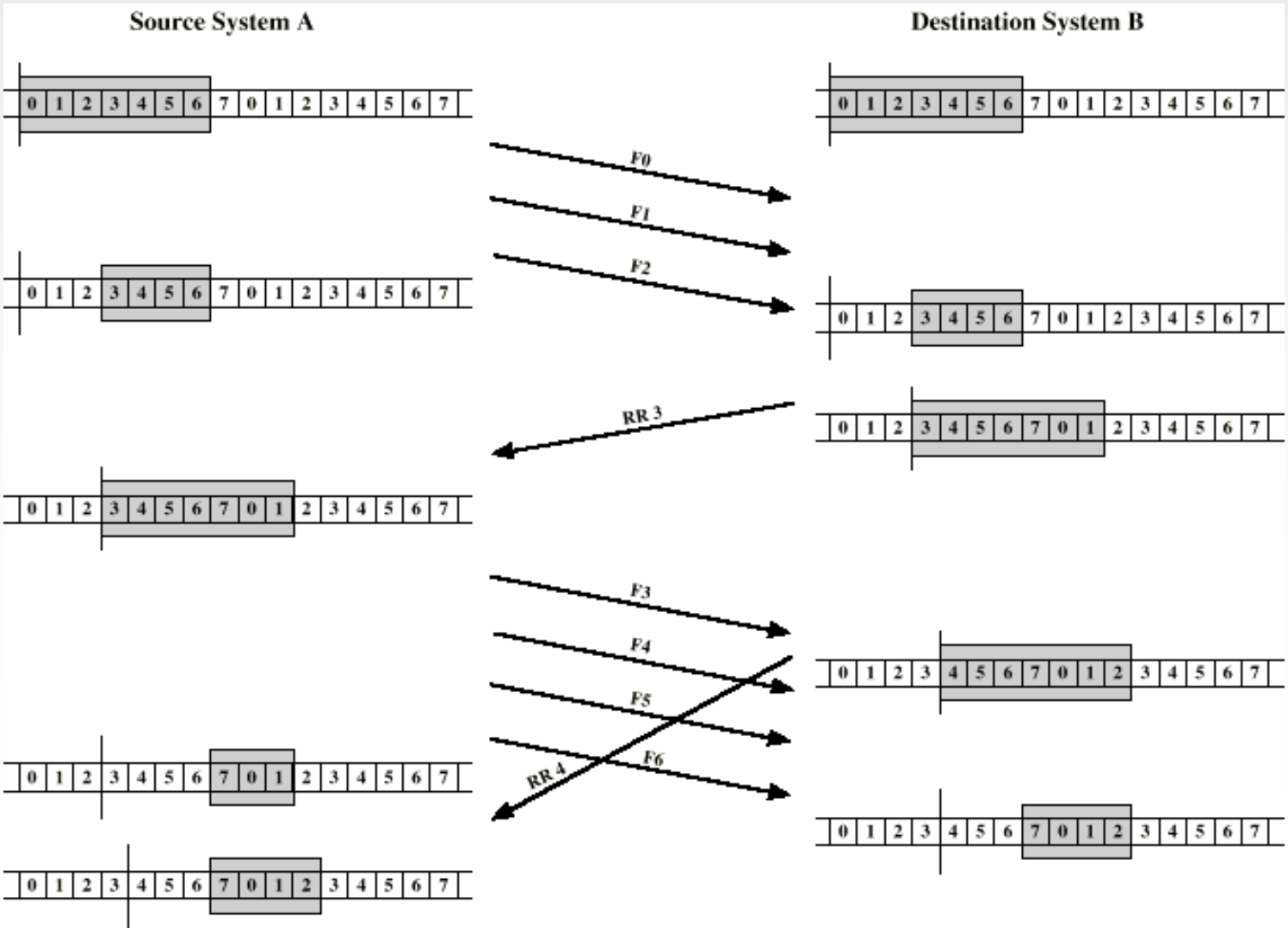
Stop and Wait:

- Source transmits frame
- Destination receives frame and replies with acknowledgement
- Source waits for ACK before sending next frame
- Destination can stop flow by not sending ACK
- Works well when message is sent in a few large frames

Sliding Windows Flow Control:

- Allow multiple frames to be in transit
- Receiver has buffer *W* long
- Transmitter can send up to *W* frames without ACK
- Each frame is numbered
- ACK includes number of next frame expected
- Sequence number bounded by size of field (k bits)
  - Frames are numbered as 2^k
  - Actual window size: $2^k - 1$

Example Sliding Window:



Sliding Window Enhancements:

- Receiver can acknowledge frames without permitting further transmission (Receive Not Ready)
- Must send a normal acknowledge to resume
- If duplex, use piggybacking
  - If no data to send, use acknowledgement frame
  - If data but no acknowledgement to send, send last acknowledgement number again.

Error Detection:

- Additional bits added by transmitter for error detection code
- Parity
  - **Value of parity bit is such that character has even (even parity) or odd (odd parity) number of ones**
  - **Even number of bit errors goes undetected**

Cyclic Redundancy Check (CRC):

- For a block of *k* bits transmitter generates *n* bit sequence
- Transmit *n* bits which is exactly divisible by some number
- Receiver divides frame by that number
  - If no remainder, assume no error

Error Control:

- Automatic Repeat Request
  - Error detection
  - Positive acknowledgment
  - Retransmission after timeout
  - Negative acknowledgement and retransmission

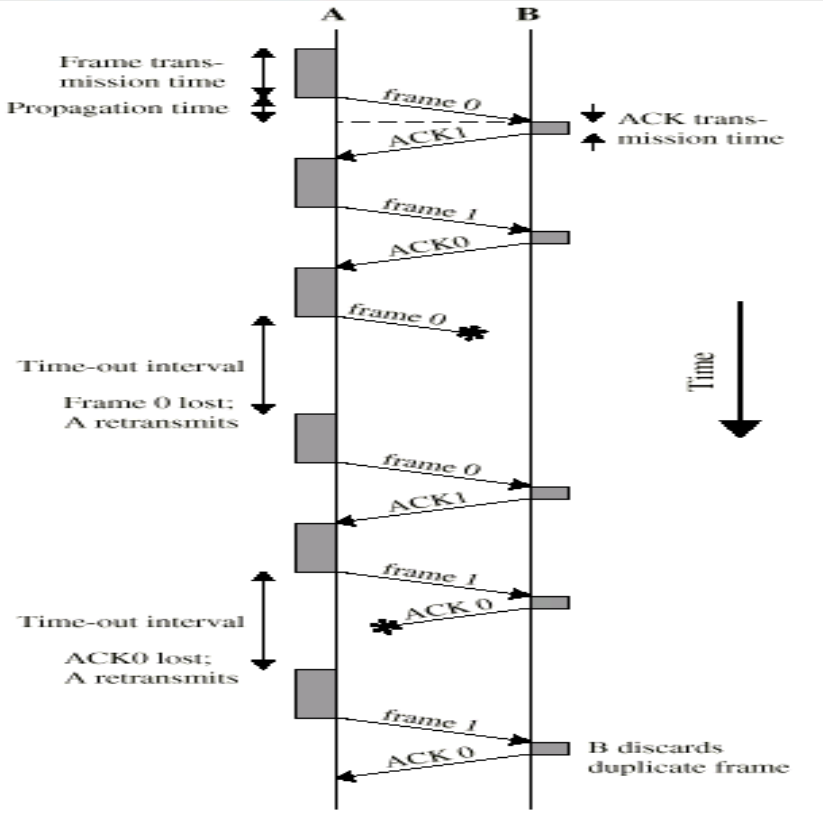
Automatic Repeat Request (ARQ):

- Stop and wait
- Go back N
- Selective reject (selective retransmission)

Stop and Wait:

- Source transmits single frame
- Wait for ACK
- If received frame damaged, discard it
  - Transmitter has timeout
  - If no ACK within timeout, retransmit
- If ACK damaged, transmitter will not recognize it
  - Transmitter will retransmit
  - Receive gets two copies of frame
  - Use ACK0 and ACK1

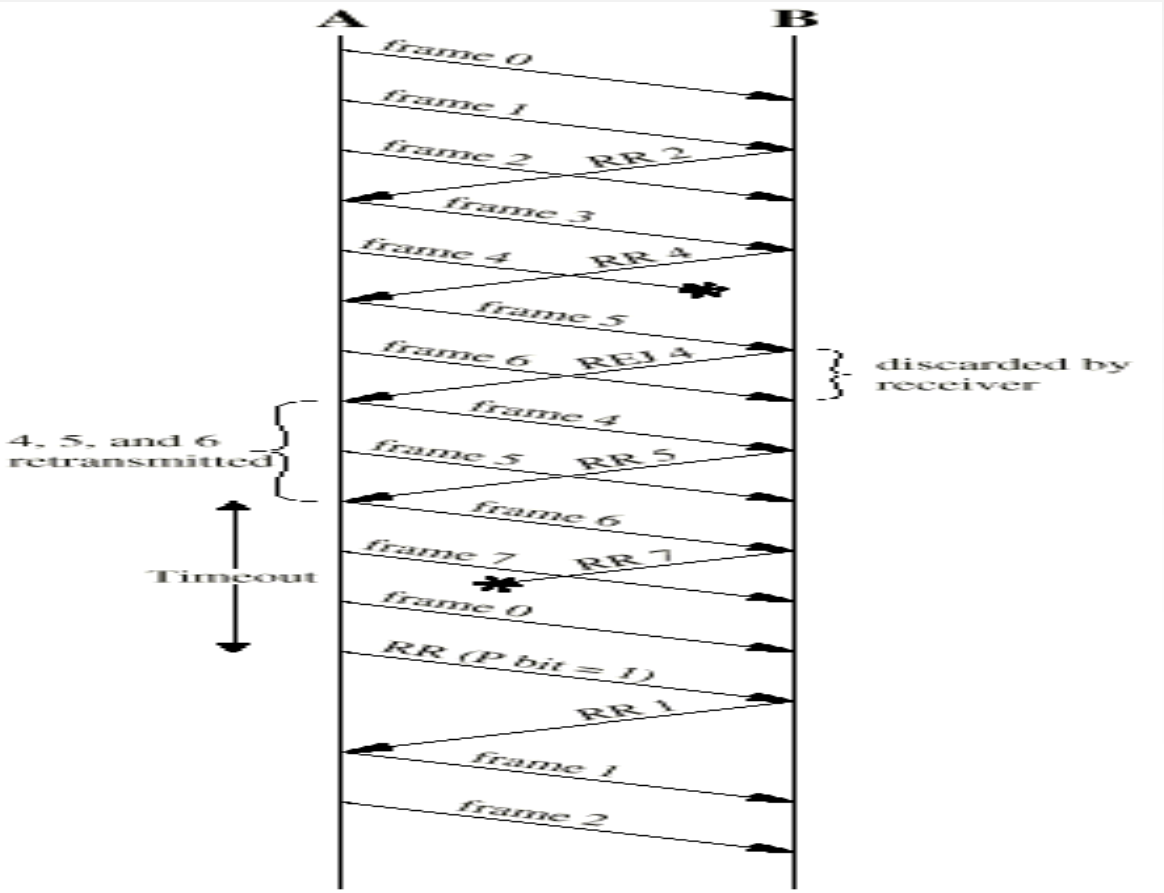
Stop and Wait:



- Simple but Inefficient

Go Back N:

- Based on sliding window
- Retransmit all the frames from the frame with error



Selective Reject:

- Also called selective retransmission
- Only rejected frames are retransmitted
- Subsequent frames are accepted by the receiver and buffered
- Minimizes retransmission
- Receiver must maintain large enough buffer
- More complex

Selective Reject: