Data Link Control Protocols

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  - Sliding Window
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Concept

Concept

Technology

Data Link Control Protocols

- Need layer of logic above Physical Layer
  - Physical layer concentrates on sending signals over transmission link
  - More control and management is needed to send data over data communications link
    - Frame synchronization: start and end of each frame
    - Flow control: ensure sender does not send too fast for receiver
    - Error control: correct bit errors introduced by transmission system
    - Addressing: must specify identity of two stations communicating
    - Control and data: receiver must distinguish between control and data information
    - Link management: setup and maintain the link
  - Hence, data link layer (and data link control protocols)

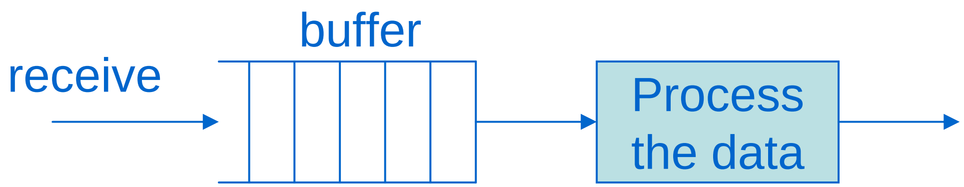
Flow Control

Stop-and-Wait

Sliding Window

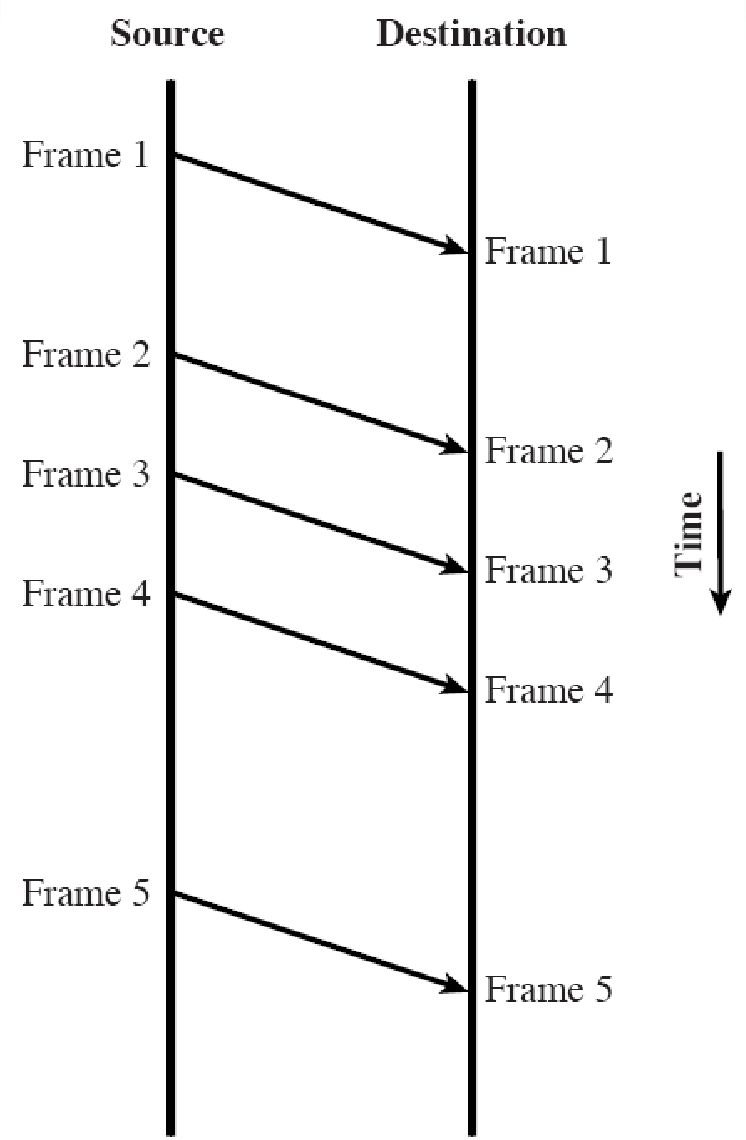
Flow Control

- Receivers typically have a finite amount of memory (buffer space) to store received data before processing



- Flow control aims to ensure sending entity does not overwhelm receiving entity
  - by preventing buffer overflow
- Influenced by:
  - transmission time
    - time taken to emit all bits into medium
  - propagation time
    - time for a bit to traverse the link
- Assume there are no errors but varying delays

Error-Free Frame Transmission



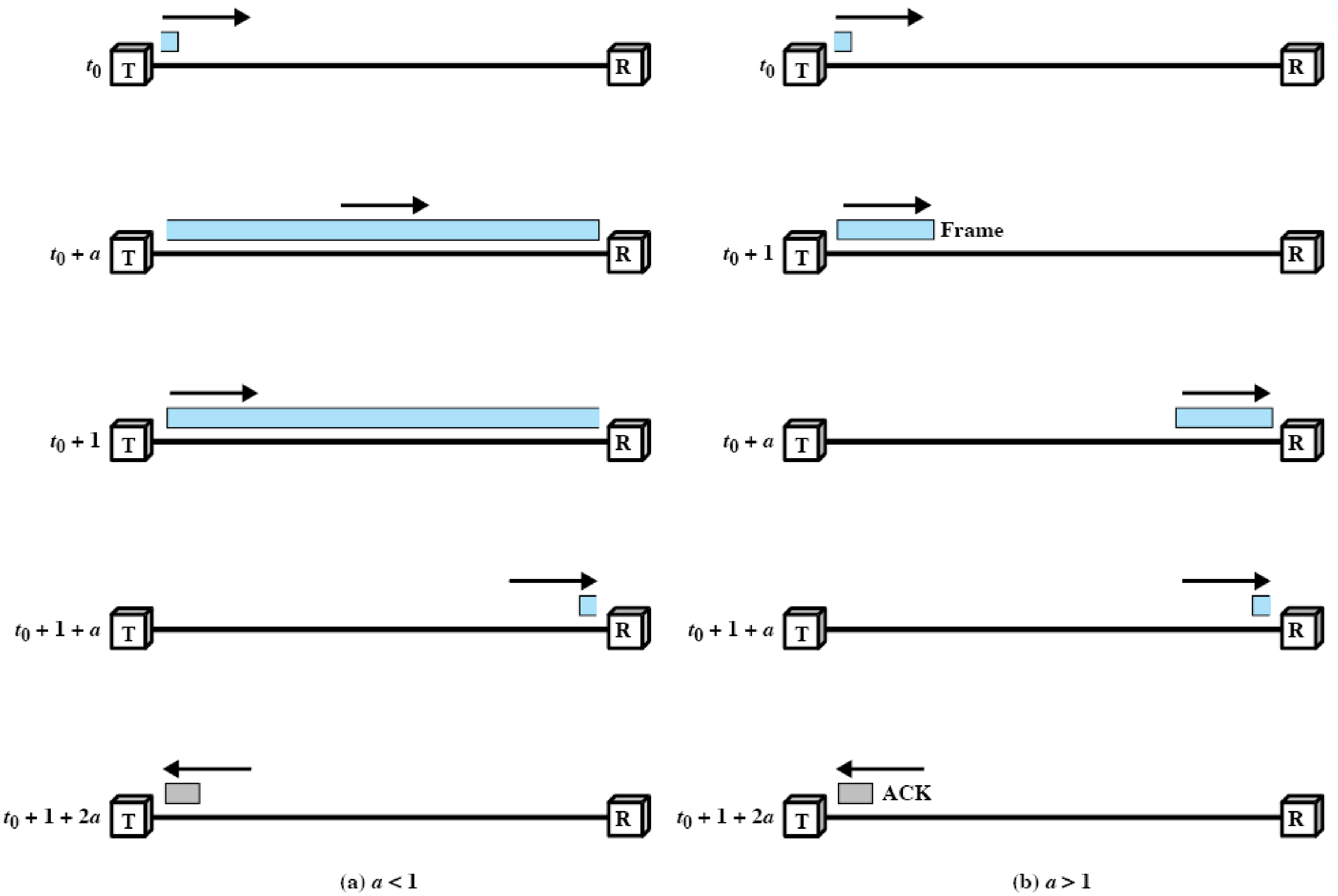
Stop and Wait Flow Control

- Rules:
  - Source transmits a frame
  - Destination receives frame and replies with an acknowledgement (ACK)
  - Source waits for ACK before sending next frame
  - Destination can stop the flow of data by not sending ACK
- Works well for a few large frames
- Stop and wait becomes inadequate if large block of data is split into small frames
  - Large blocks of data are split into small frames for several reasons:
    - Buffer size of the receiver may be limited
    - Larger frames lead to longer transmission times and higher chance of frame error and large amount of data to be retransmitted
    - On shared mediums (e.g. LAN), usually only want one station to occupy the medium for short period of time

Stop and Wait Link Utilization

- The number of bits on a link at an instance of time if the link is fully occupied is (bit length of link)
  - B = Rate x (distance / Velocity)
- If B is greater than the frame length, then Stop and Wait is inefficient
  - Assume transmission time is normalised to 1, and propagation delay is a = B / L where L is length of frame in bits
  - If a > 1 (that is, B is greater than frame length) the link is underutilized (inefficient)
    - Corresponds to links with high data rates and/or large distance between transmitter and receiver

Stop and Wait Link Utilization

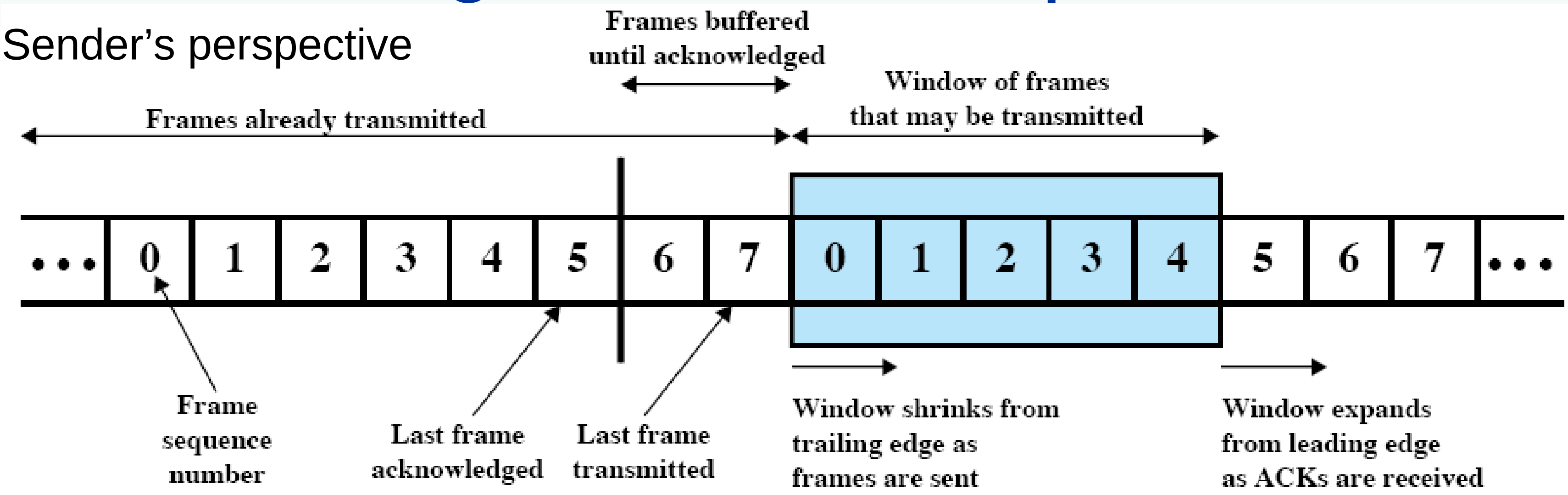


Sliding Window Flow Control

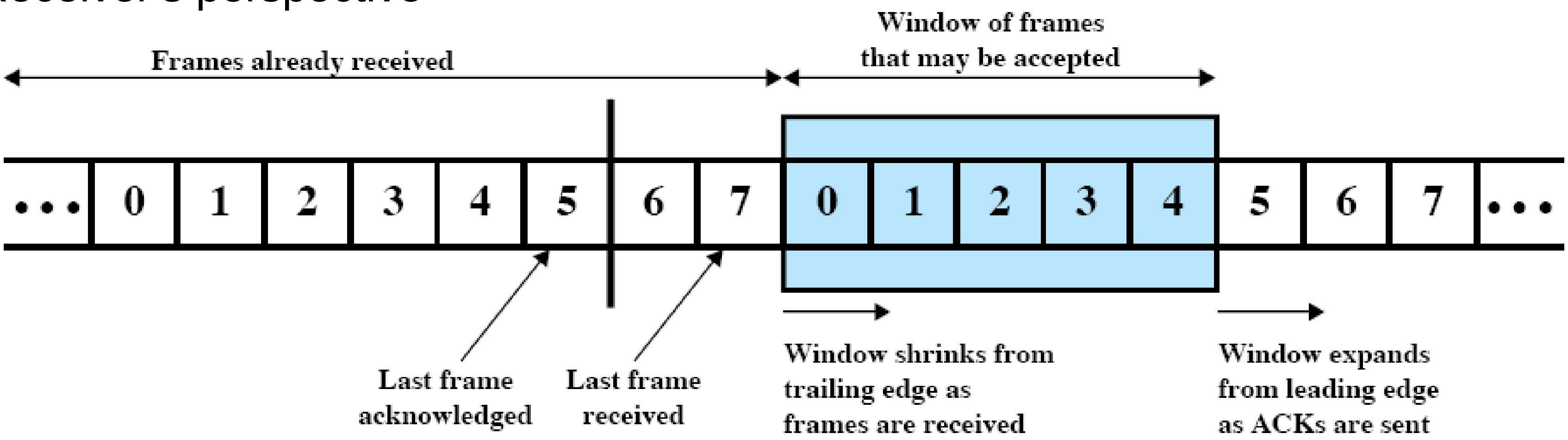
- Stop and Wait only allows 1 frame to be in transit
- Sliding Window allows multiple numbered frames to be in transit
  - Receiver has buffer for W frames
  - Transmitter sends up to W frames without receiving ACK
    - Each frame has a sequence number, bounded by size of field (k) and numbered modulo 2^k
    - Maximum window size is 2^k -1
  - ACK from receiver includes sequence number of the next frame expected
  - Receiver can ACK frames without permitting further transmission (Receive Not Ready)
    - Must send a normal acknowledge to resume
  - If have full-duplex link, can piggyback ACKs on data

Sliding Window Components

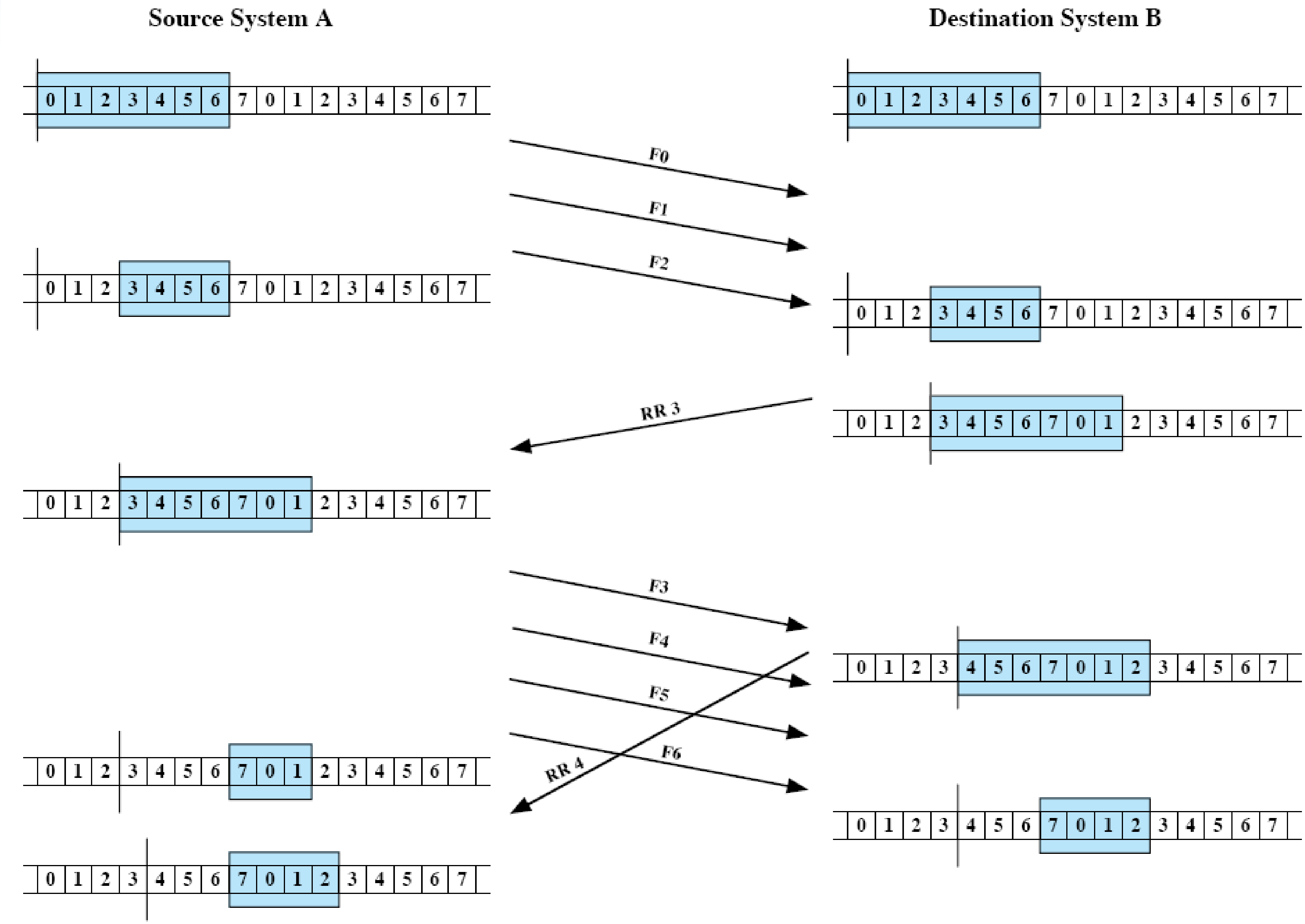
Sender's perspective



Receiver's perspective



Sliding Window Example



Error Control

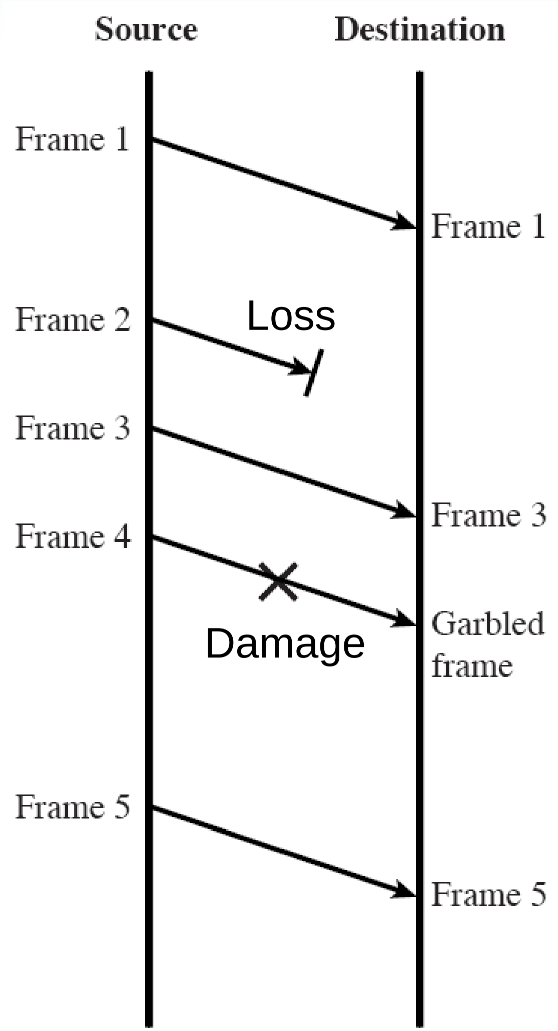
Stop-and-Wait

Go-Back-N

Selective-Reject

Error Control

- Detection and correction of errors such as:
  - lost frames
  - damaged frames
- Common techniques use:
  - Error detection (discussed in previous topic)
  - Positive acknowledgment: destination returns a positive ACK after successfully receiving error-free frames
  - Retransmission after timeout: source retransmits a frame that has not been ACKed after predetermined time
  - Negative acknowledgement and retransmission: destination returns negative ACK for frames in which an error is detected
- Together, these techniques are called *automatic repeat request* (ARQ). Three versions:
  - Stop-and-wait ARQ
  - Go-back-N ARQ
  - Selective-reject ARQ



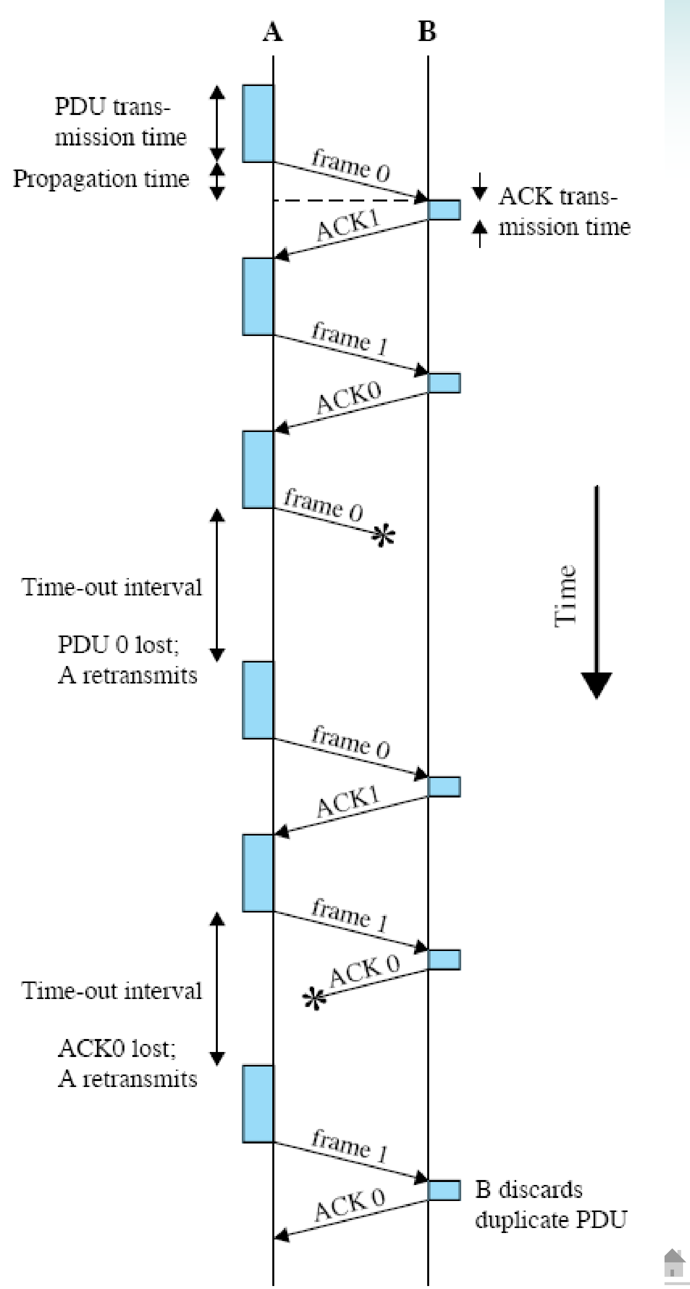
Stop-and-Wait ARQ

- Based on stop-and-wait flow control:
  - Source transmits a single frame, and starts timer for that frame
  - Source waits for ACK
  - Destination:
    - If received frame damaged, discard it
  - Source has timeout:
    - If timer reaches maximum value before ACK is received, then retransmit the frame
  - If damaged ACK is received, source will not recognize it
    - Source will retransmit
    - Destination will receive two copies of the frame
    - Hence, source labels frames with 0 or 1, and destination uses alternate numbering in ACKs: ACK0 acknowledges receipt of frame 1 and ACK1 acknowledges receipt of frame 0

S&W ARQ Example

Stop-and-Wait ARQ

- Example shows lost Data packet (PDU) and lost ACK
- Advantage: simple
- Disadvantage: inefficient



Go-Back-N ARQ

- Based on sliding window flow control
  - If no error, ACK as in sliding window (ACK is called Receive Ready, RR, and contains sequence number of next expected frame)
  - Use window to control number of outstanding frames
  - If error, reply with negative ACK (rejection, REJ)
    - Destination will discard that frame and all future frames until error frame received correctly
    - Transmitter must go back and retransmit that frame and all subsequent frames
  - Destination receives damaged frame *i*
    - If destination also receives frame *i+1*, will send REJ *i*, and source must retransmit *i* and all subsequent frames
    - If destination does not respond, source will not receive REJ – after timeout, source will send RR with P bit set to 1. This means destination must send a RR.
      - When sending RR, source also sets a timer – if no response received, then source will try again, up until a maximum number of times (after which it returns an error)
  - Maximum window size: 2^k -1

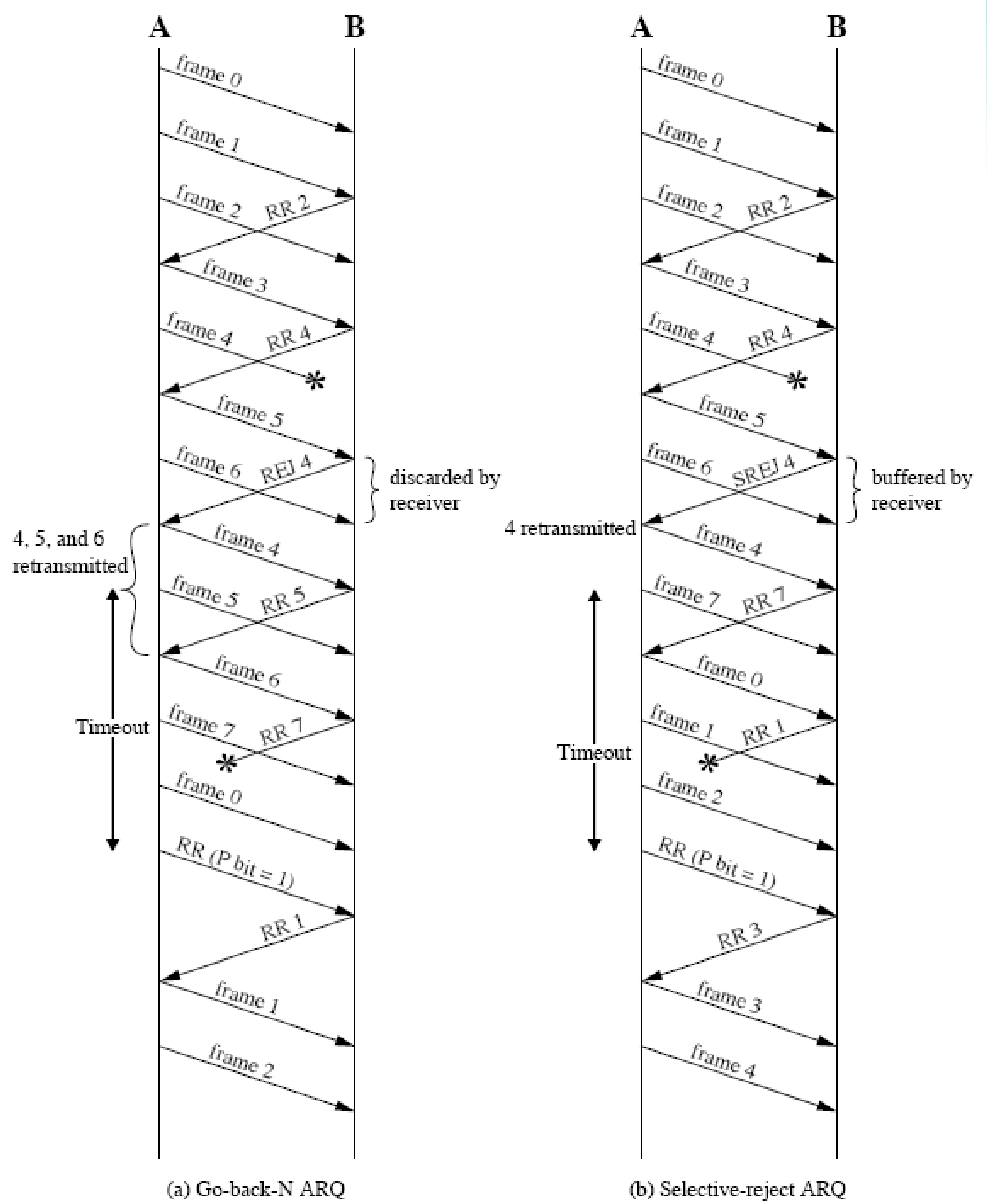
Go-Back-N Example

Selective Reject ARQ

- Also called selective retransmission
  - Only frames that are rejected or timeout are retransmitted
  - Subsequent frames are accepted by the destination and buffered
  - Maximum window size: $2^{(k-1)}$
- Minimizes retransmission
  - Destination must maintain large enough buffer
  - More complex logic in transmitter, hence less widely used
- Useful for satellite links with long propagation delays

Selective Rep Example

Go-Back-N vs Selective-Reject



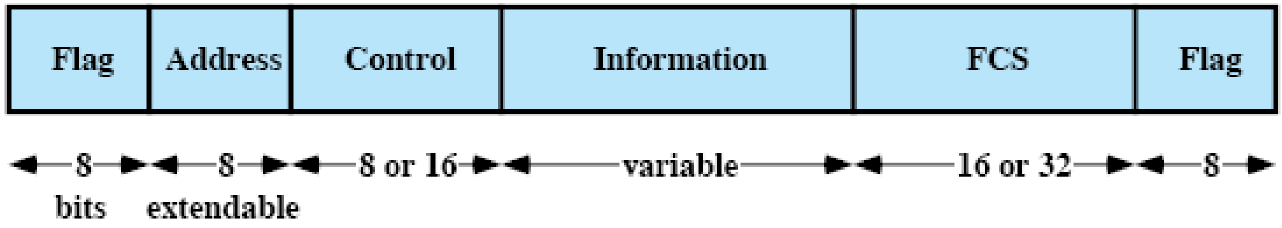
High Level Data Link Control

High Level Data Link Control (HDLC)

- An important data link control protocol
  - Many other data link protocols are based on HDLC
  - Specified as ISO 33009, ISO 4335
- Three station types:
  - Primary – controls operation of link
  - Secondary – under control of primary station
  - Combined – issues commands and responses
- Two link configurations
  - Unbalanced – 1 primary, multiple secondary
  - Balanced – 2 combined stations
- Three transfer modes:
  - Normal Response Mode (NRM)
    - unbalanced configuration, primary initiates transfer
    - used on multi-drop lines, e.g. host + terminals
  - Asynchronous Balanced Mode (ABM)
    - balanced configuration, either station initiates transmission, has no polling overhead, widely used
  - Asynchronous Response Mode (ARM)
    - unbalanced configuration, secondary may initiate transmit without permission from primary, rarely used

HDLC Frame Structure

- Synchronous transmission of frames
- Single frame format used
  - Header fields: Flag, Address, Control
  - Payload: Information
  - Trailer fields: FCS, Flag
- Some fields are extendable: allow larger sizes for different address and sequence number schemes



Flag Fields and Bit Stuffing

- Delimit frame at both ends with 01111110 seq
- Receiver hunts for flag sequence to synchronize
- Bit stuffing used to avoid confusion with data containing flag seq 01111110
  - 0 inserted after every sequence of five 1s
  - if receiver detects five 1s it checks next bit
  - if next bit is 0, it is deleted (was stuffed bit)
  - if next bit is 1 and seventh bit is 0, accept as flag
  - if sixth and seventh bits 1, sender is indicating abort

Original Pattern:

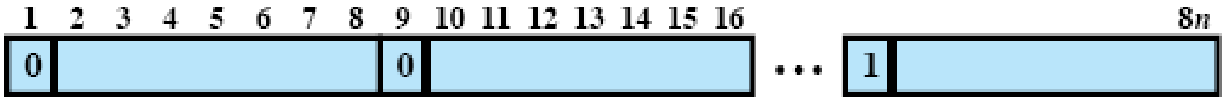
111111111111011111101111110

After bit-stuffing

1111101111101101111101011111010

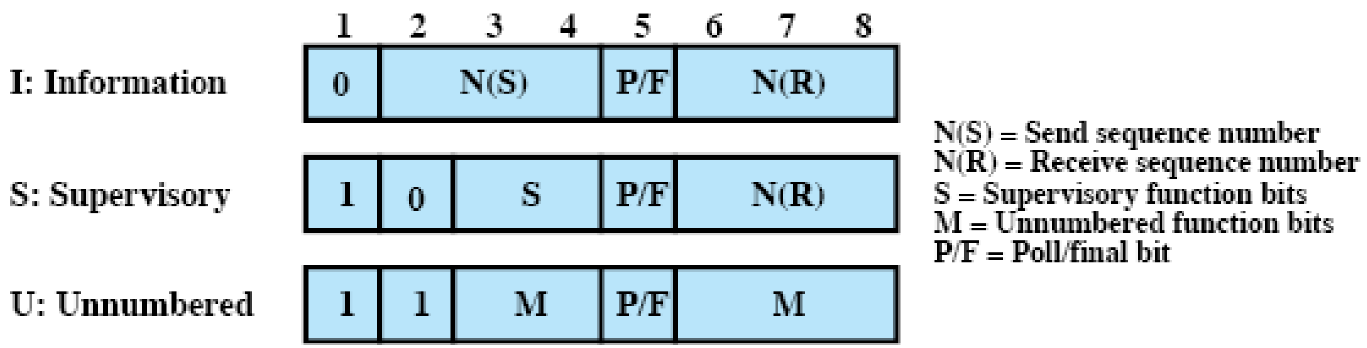
Address Field

- Identifies secondary station that sent or will receive frame
- Usually 8 bits long
- May be extended to multiples of 7 bits
  - LSB indicates if is the last octet (1) or not (0)
- All ones address 11111111 is broadcast



Control Field

- Different for different frame type
  - Information - data transmitted to user (next layer up)
    - Flow and error control piggybacked on information frames
  - Supervisory - ARQ when piggyback not used
  - Unnumbered - supplementary link control
- First 1-2 bits of control field identify frame type



Control Field

- Use of Poll/Final bit depends on context
  - In command frame is P bit set to1 to solicit (poll) response from peer
  - In response frame is F bit set to 1 to indicate response to soliciting command
- Sequence number usually 3 bits
  - can be extended to 8 bits as shown below

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Information	0	N(S)							P/F	N(R)						
Supervisory	1	0	S		0	0	0	0	P/F	N(R)						

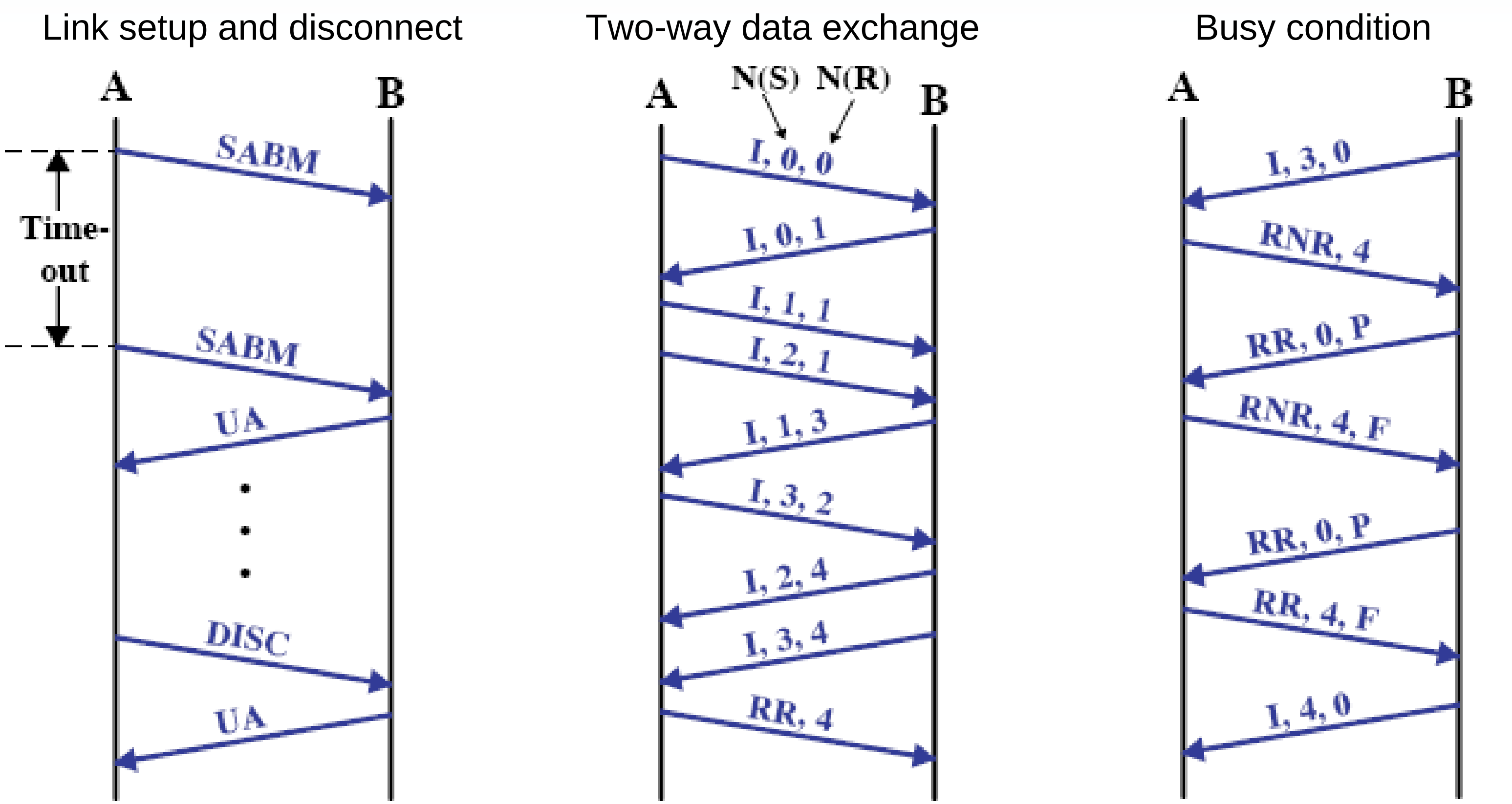
Information and FCS Fields

- Information Field
  - in Information and some Unnumbered frames
  - must contain integral number of octets
  - variable length
- Frame Check Sequence Field (FCS)
  - used for error detection
  - either 16 bit CRC or 32 bit CRC

HDLC Operation

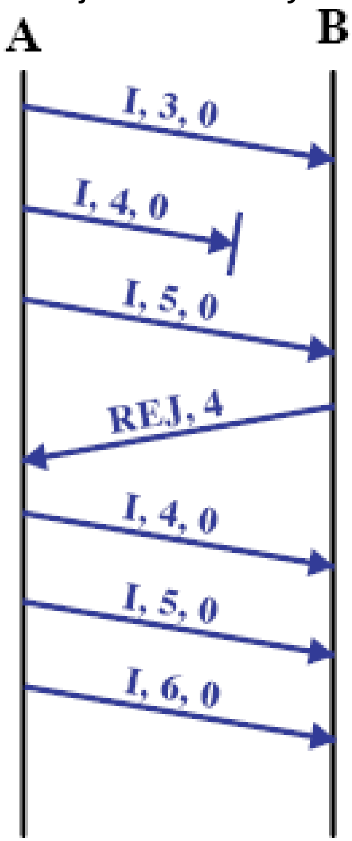
- Consists of exchange of information, supervisory and unnumbered frames
- Have three phases
  - Initialization
    - by either side, set mode & seq
  - Data transfer
    - with flow and error control
    - using both I & S-frames (RR, RNR, REJ, SREJ)
  - Disconnect
    - when ready or fault noted

HDLC Operation Example



HDLC Operation Example

Reject Recovery



Timeout Recovery