Data and Computer Communications

Chapter 7 – Data Link Control Protocols

Eighth Edition

by William Stallings

Lecture slides by Lawrie Brown

Data Link Control Protocols

"Great and enlightened one," said Ten-teh, as soon as his stupor was lifted, "has this person delivered his message competently, for his mind was still a seared vision of snow and sand and perchance his tongue has stumbled?"

"Bend your ears to the wall," replied the Emperor, "and be assured."

—*Kai Lung's Golden Hours*, Earnest Bramah

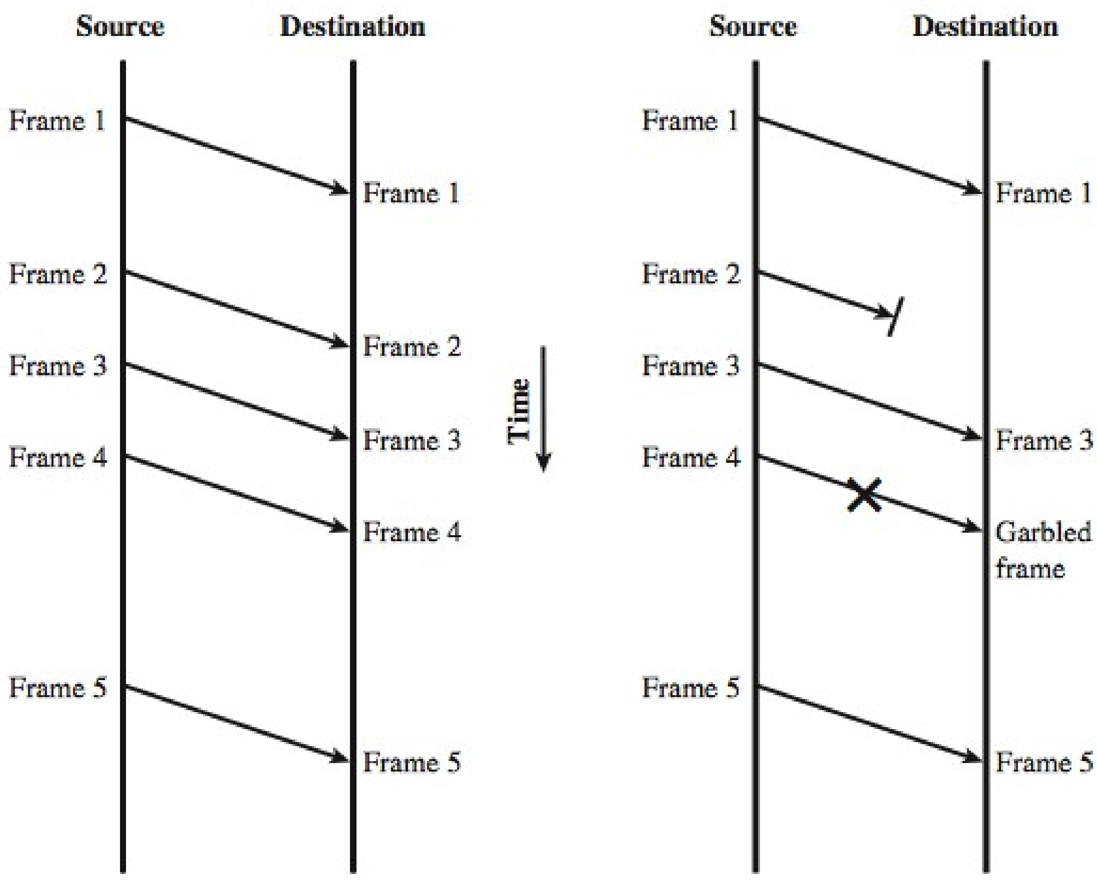
Data Link Control Protocols

- need layer of logic above Physical
- to manage exchange of data over a link
  - frame synchronization
  - flow control
  - error control
  - addressing
  - control and data
  - link management

Flow Control

- 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 here no errors but varying delays

Model of Frame Transmission



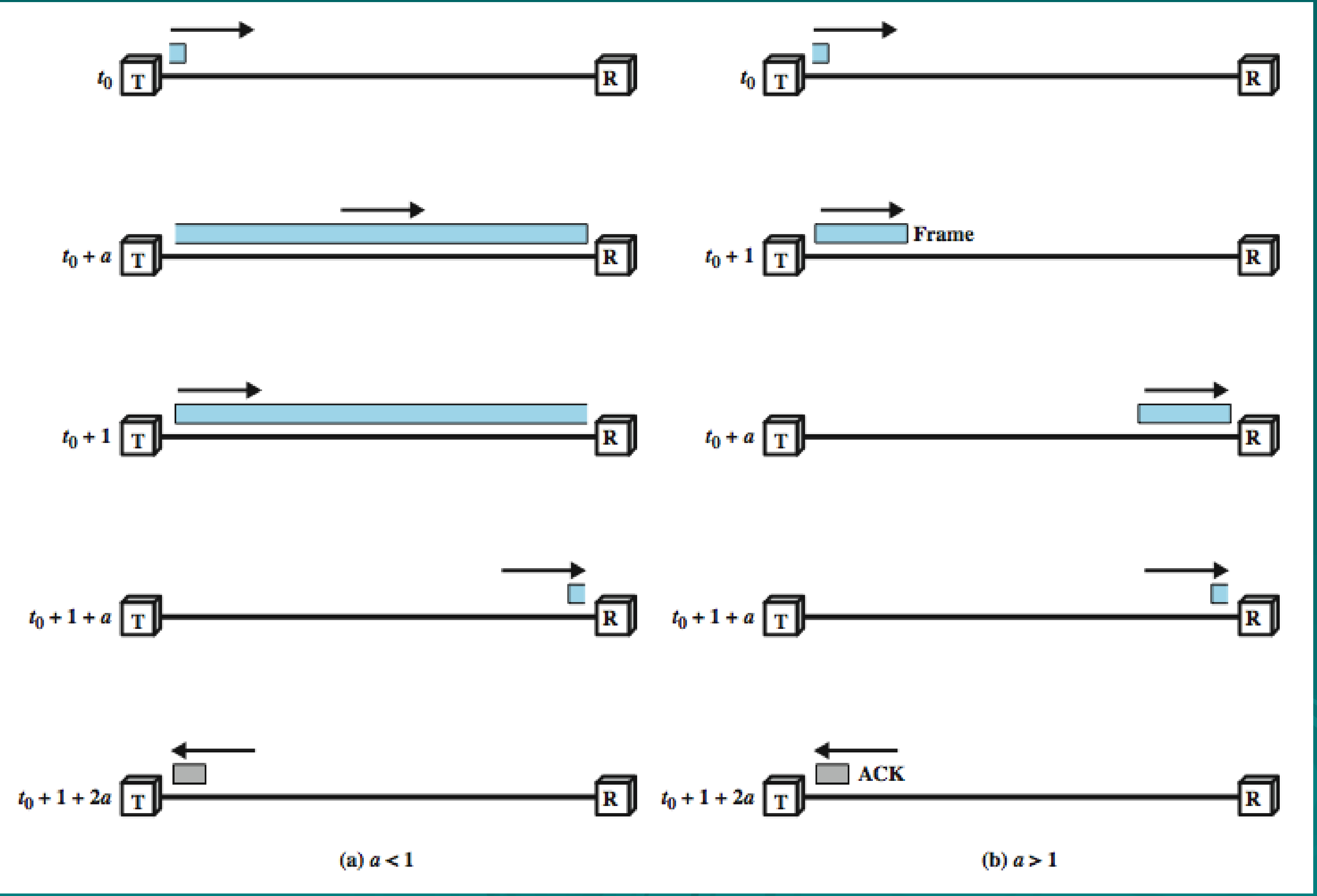
(a) Error-free transmission

(b) Transmission with losses and errors

Stop and Wait

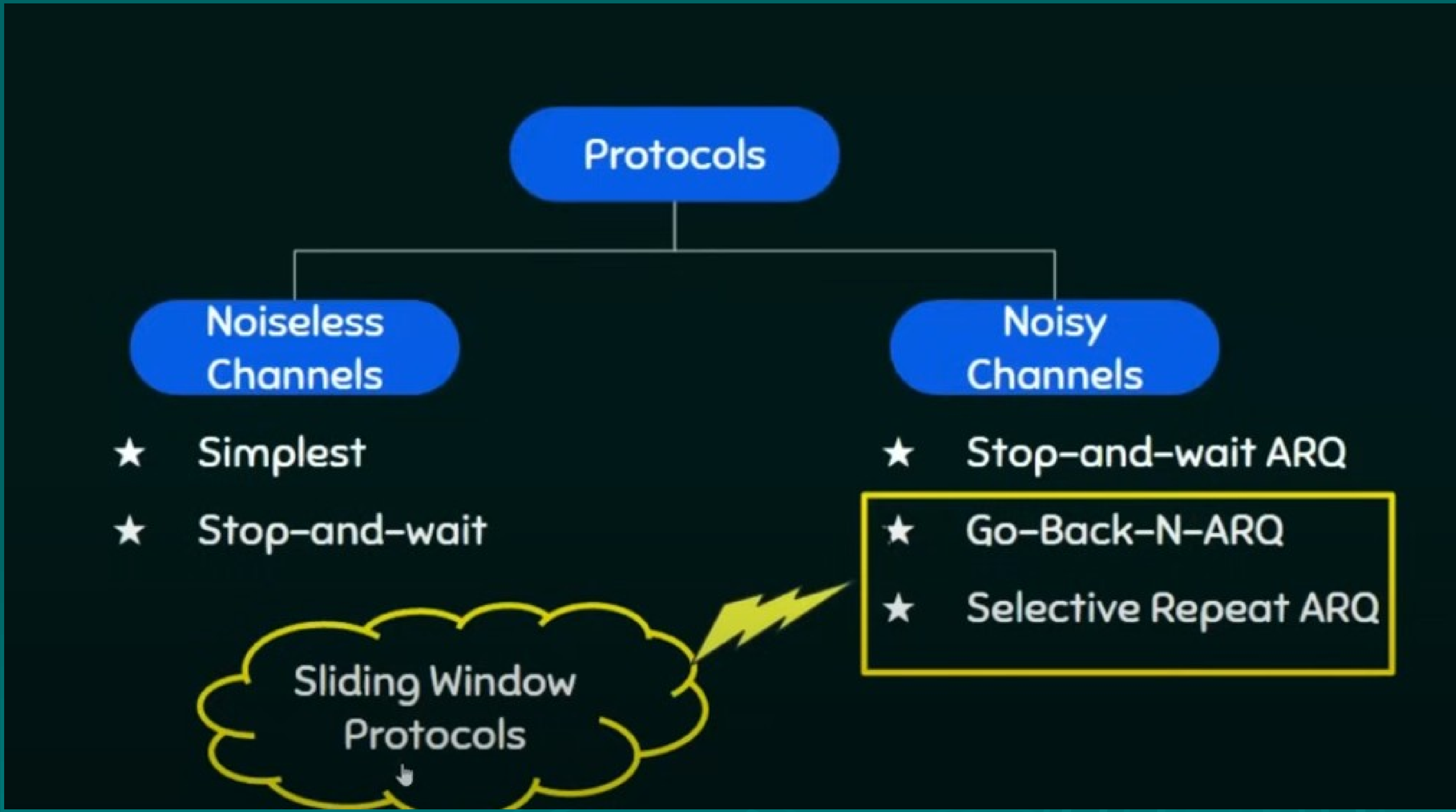
- source transmits frame
- destination receives frame and replies with acknowledgement (ACK)
- source waits for ACK before sending next
- destination can stop flow by not send ACK
- works well for a few large frames
- Stop and wait becomes inadequate if large block of data is split into small frames

Stop and Wait Link Utilization



Disadvantage of Stop-and-Wait

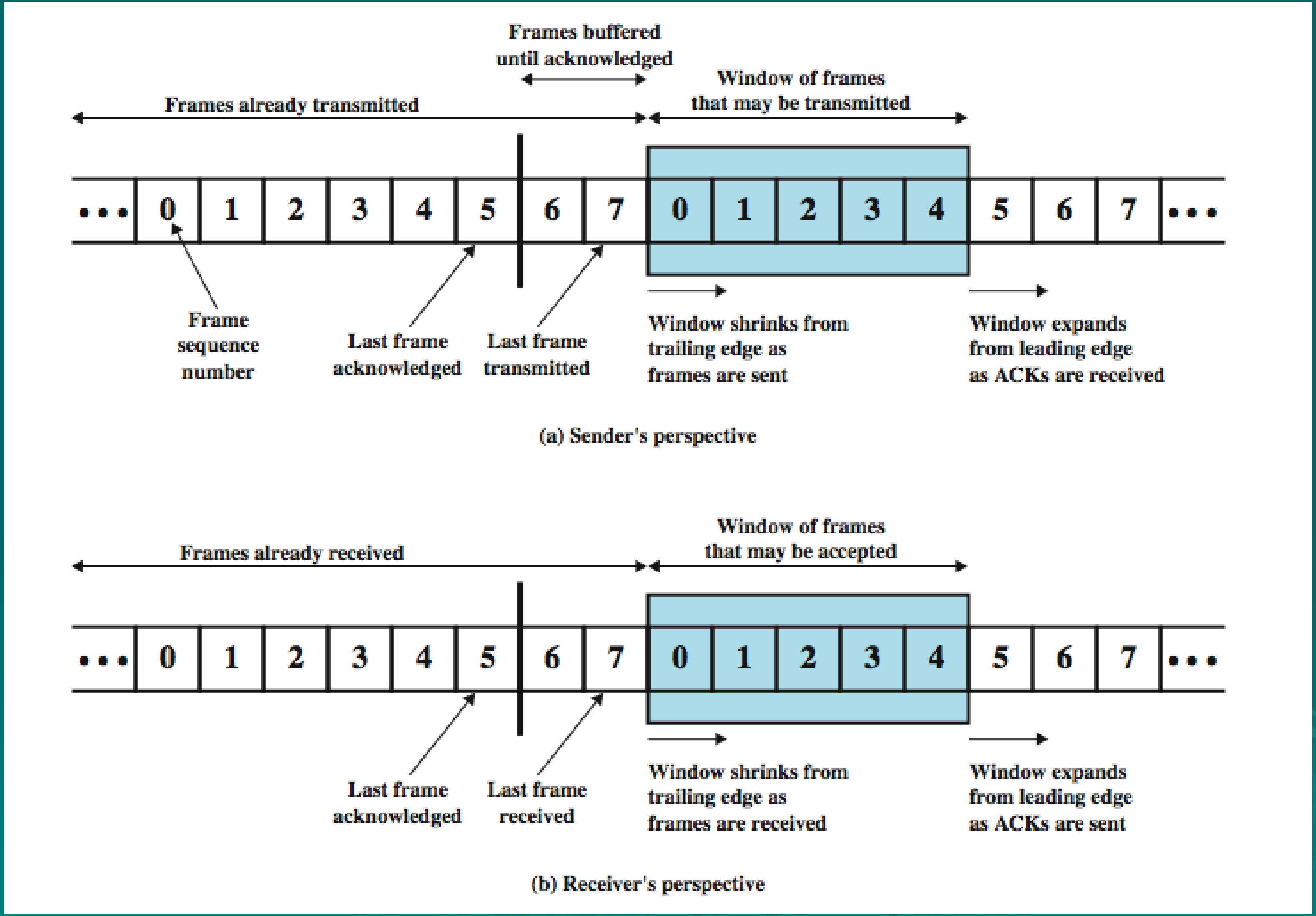
- In stop-and-wait, at any point in time, there is only one frame that is sent and waiting to be acknowledged.
- This is not a good use of transmission medium.
- To improve efficiency, multiple frames should be in transition while waiting for ACK.
- Two protocol use the above concept,
  - **Go-Back-N ARQ**
  - **Selective Repeat ARQ**


Protocols
Noiseless Channels
Noisy Channels
★ Simplest
★ Stop-and-wait
★ Stop-and-wait ARQ
★ Go-Back-N-ARQ
★ Selective Repeat ARQ
Sliding Window Protocols

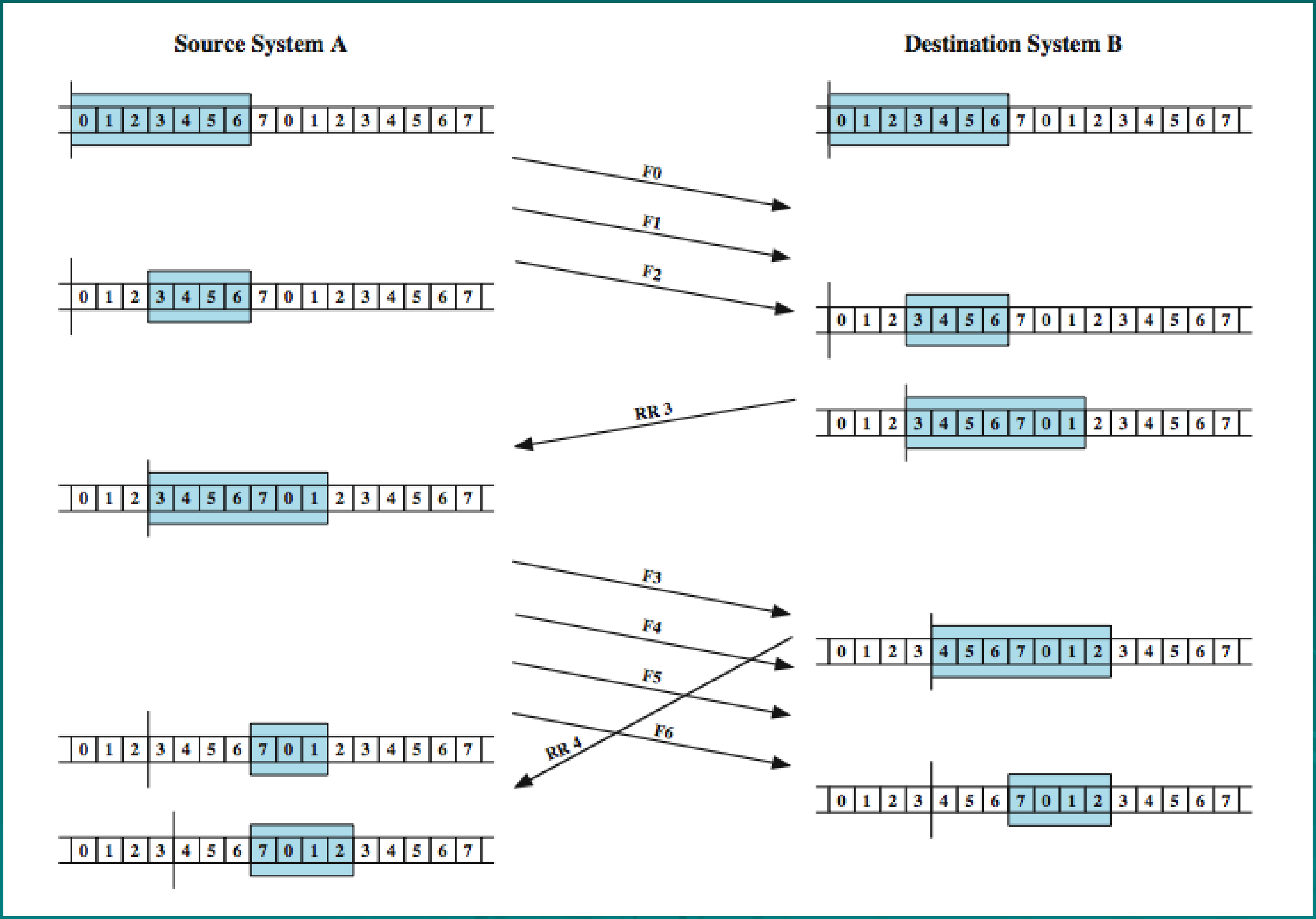
Sliding Windows Flow Control

- allows multiple numbered frames to be in transit
- receiver has buffer W long
- transmitter sends up to W frames without ACK
- ACK includes number of next frame expected
- sequence number is bounded by size of field (k)
  - frames are numbered modulo 2^k
  - giving max window size of up to $2^k - 1$
- 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

Sliding Window Diagram



Sliding Window Example



Error Control

- detection and correction of errors such as:
  - lost frames
  - damaged frames
- common techniques use:
  - error detection
  - positive acknowledgment
  - retransmission after timeout
  - negative acknowledgement & retransmission

Automatic Repeat Request (ARQ)

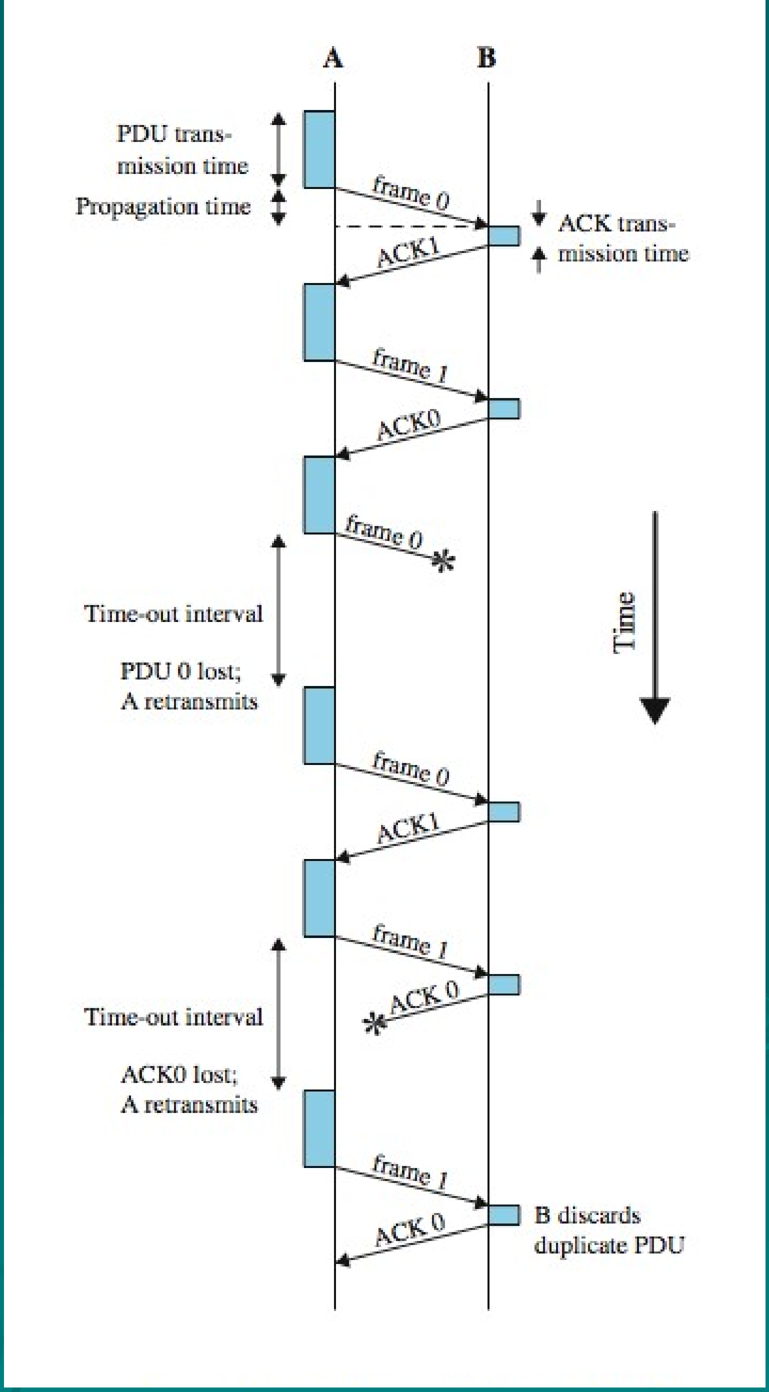
- collective name for such error control mechanisms, including:
- stop and wait
- go back N
- selective reject (selective retransmission)

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 alternate numbering and ACK0 / ACK1

Stop and Wait

- see example with both types of errors
- pros and cons
  - simple
  - inefficient



Go Back N

- based on sliding window
- if no error, ACK as usual
- use window to control number of outstanding frames
- if error, reply with rejection
  - discard that frame and all future frames until error frame received correctly
  - transmitter must go back and retransmit that frame and all subsequent frames

Go Back N - Handling

- Damaged Frame
  - error in frame *i* so receiver rejects frame *i*
  - transmitter retransmits frames from *i*
- Lost Frame
  - frame *i* lost and either
    - transmitter sends *i+1* and receiver gets frame *i+1* out of seq and rejects frame *i*
    - or transmitter times out and send ACK with P bit set which receiver responds to with ACK *i*
  - transmitter then retransmits frames from *i*

Go Back N - Handling

- Damaged Acknowledgement
  - receiver gets frame *i*, sends ack (*i+1*) which is lost
  - acks are cumulative, so next ack (*i+n*) may arrive before transmitter times out on frame *i*
  - if transmitter times out, it sends ack with P bit set
  - can be repeated a number of times before a reset procedure is initiated
- Damaged Rejection
  - reject for damaged frame is lost
  - handled as for lost frame when transmitter times out

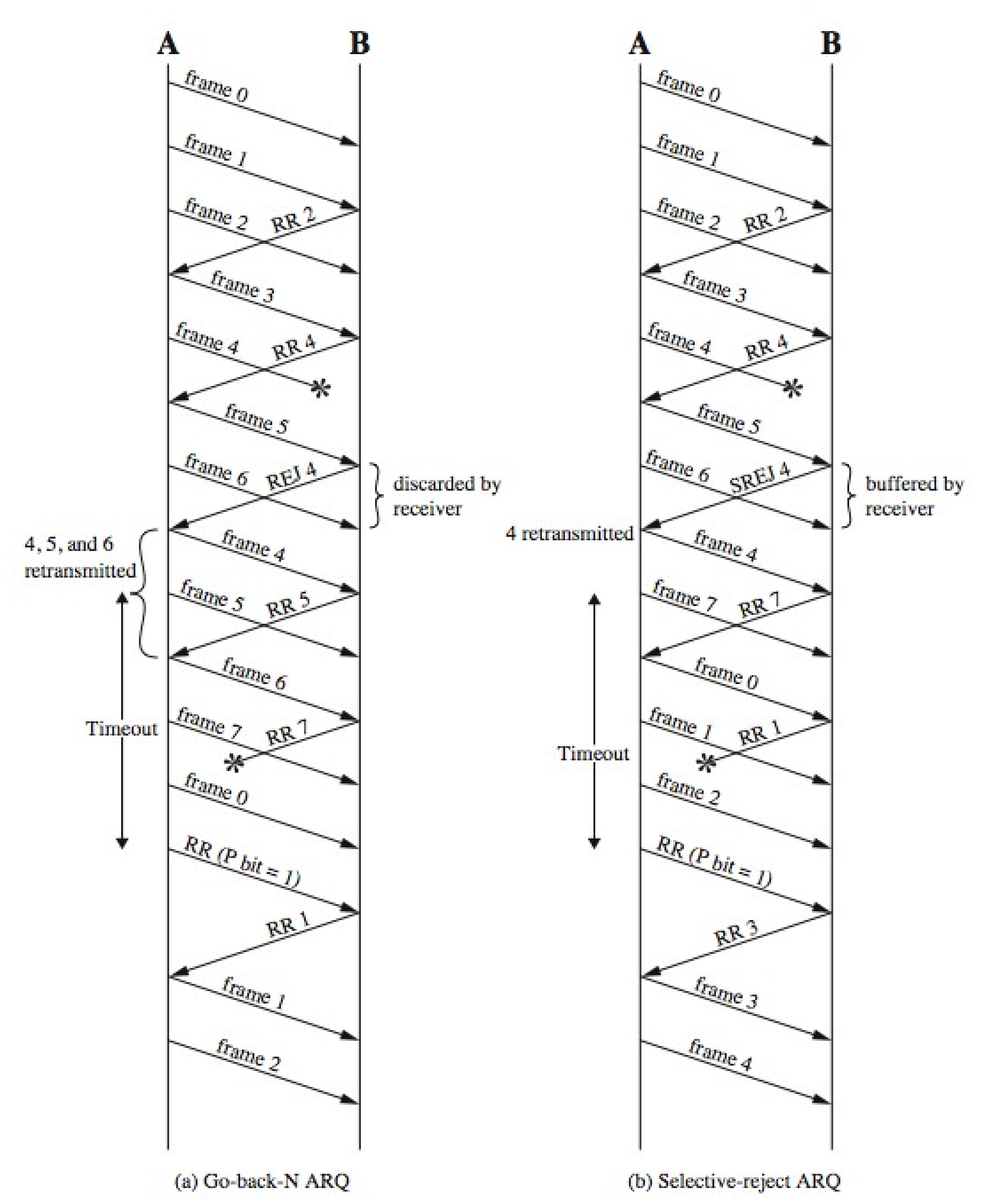
Selective Reject

- 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 logic in transmitter
- hence less widely used
- useful for satellite links with long propagation delays

Go-Back-N ARQ

- N – Sender's Window Size.
- For example, if the sending window size is 4 (2^2), then the sequence numbers will be 0, 1, 2, 3, 0, 1, 2, 3, 0, 1, and so on.
- The number of bits in the sequence number is 2 to generate the binary sequence 00, 01, 10, 11.

Go Back N vs Selective Reject



High Level Data Link Control (HDLC)

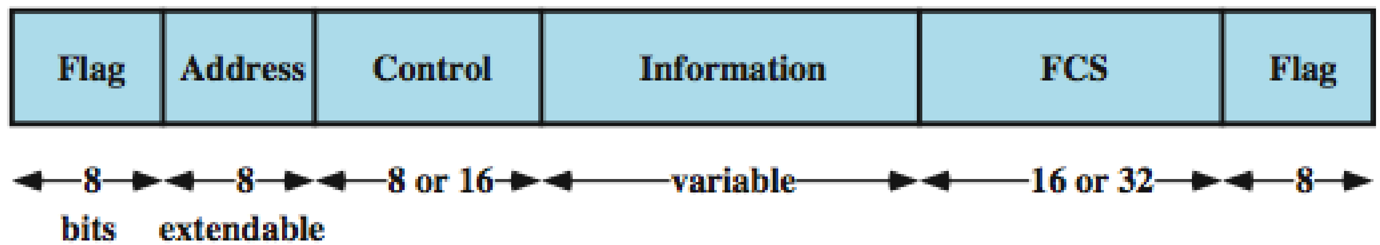
- an important data link control protocol
- specified as ISO 33009, ISO 4335
- station types:
  - Primary - controls operation of link
  - Secondary - under control of primary station
  - Combined - issues commands and responses
- link configurations
  - Unbalanced - 1 primary, multiple secondary
  - Balanced - 2 combined stations

HDLC Transfer Modes

- Normal Response Mode (NRM)
  - unbalanced config, primary initiates transfer
  - used on multi-drop lines, eg host + terminals
- Asynchronous Balanced Mode (ABM)
  - balanced config, either station initiates transmission, has no polling overhead, widely used
- Asynchronous Response Mode (ARM)
  - unbalanced config, secondary may initiate transmit without permission from primary, rarely used

HDLC Frame Structure

- synchronous transmission of frames
- single frame format used



(a) Frame format

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:

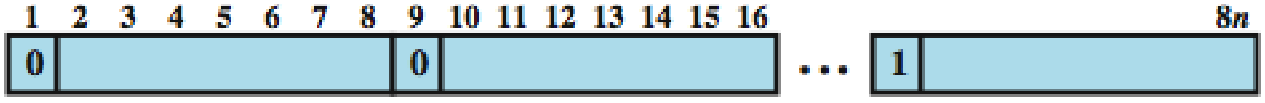
111111111111011111101111110

After bit-stuffing

1111101111101101111101011111010

Address Field

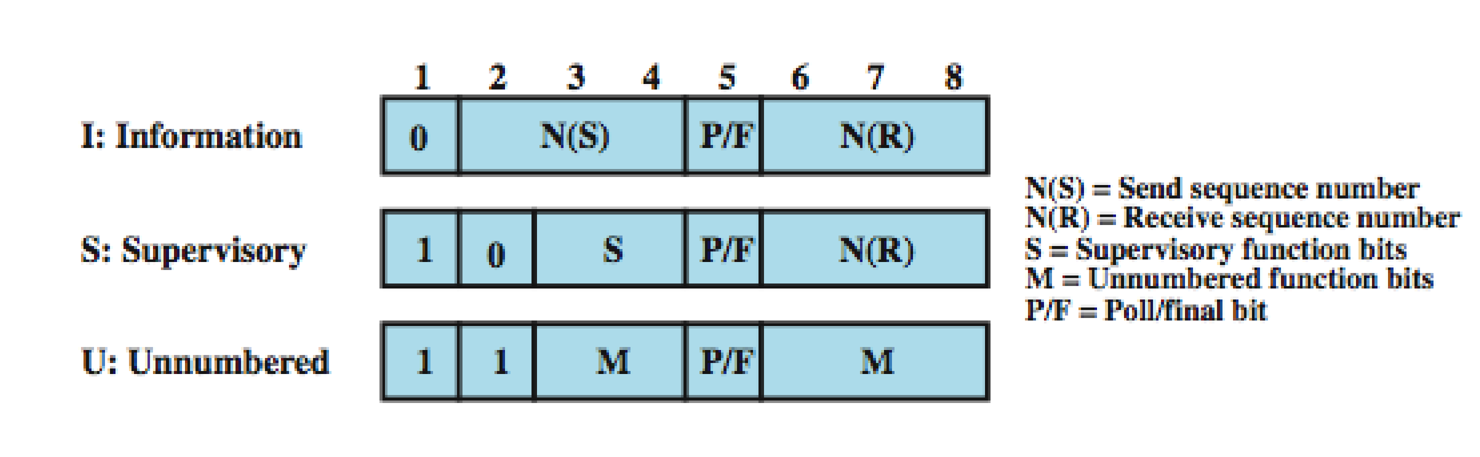
- identifies secondary station that sent or will receive frame
- usually 8 bits long
- may be extended to multiples of 7 bits
  - LSB indicates if is the last octet (1) or not (0)
- all ones address 11111111 is broadcast



(b) Extended Address Field

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



(c) 8-bit control field format

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
- seq number usually 3 bits
  - can extend 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)						

(d) 16-bit control field format

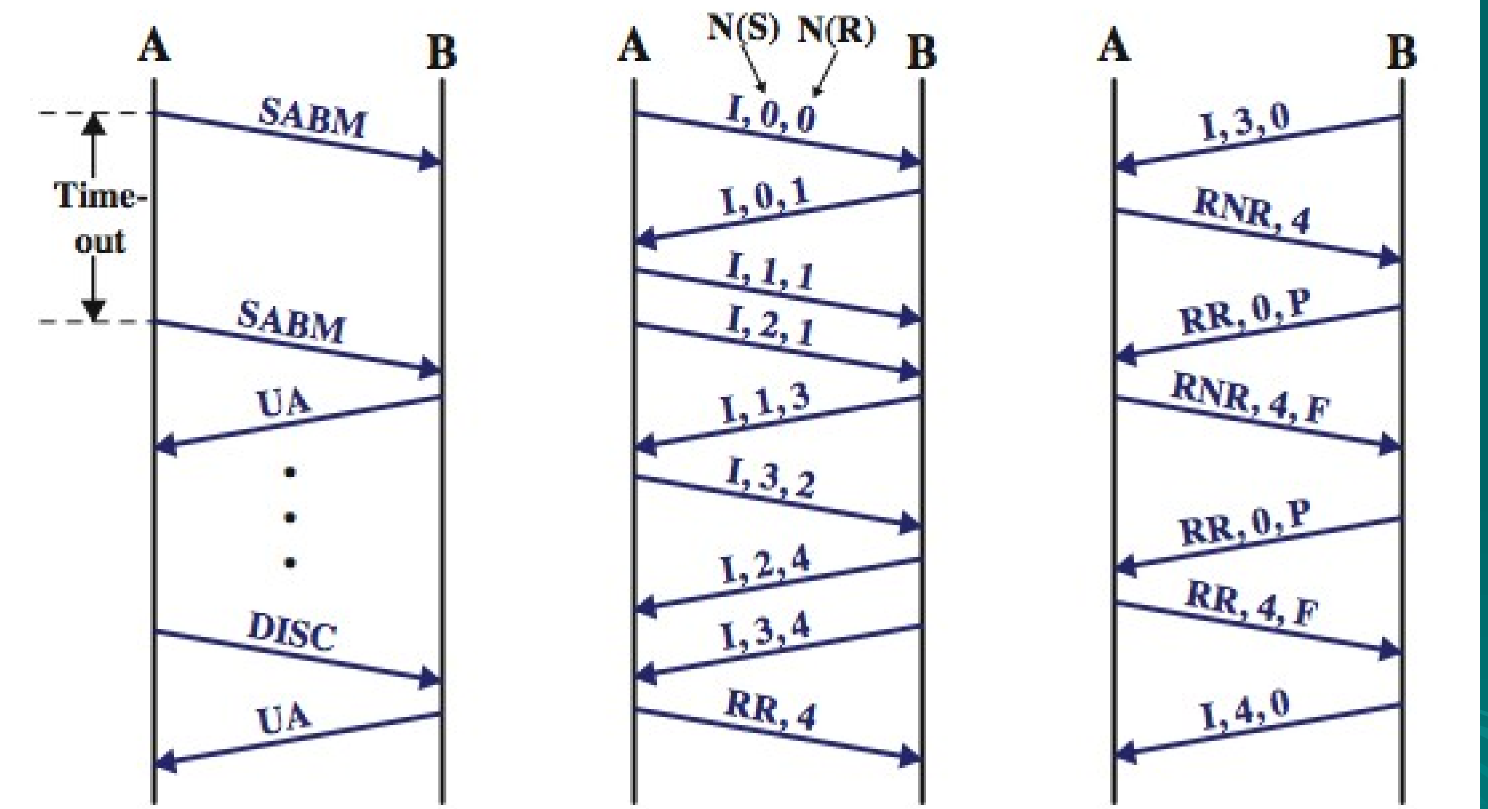
Information & FCS Fields

- 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

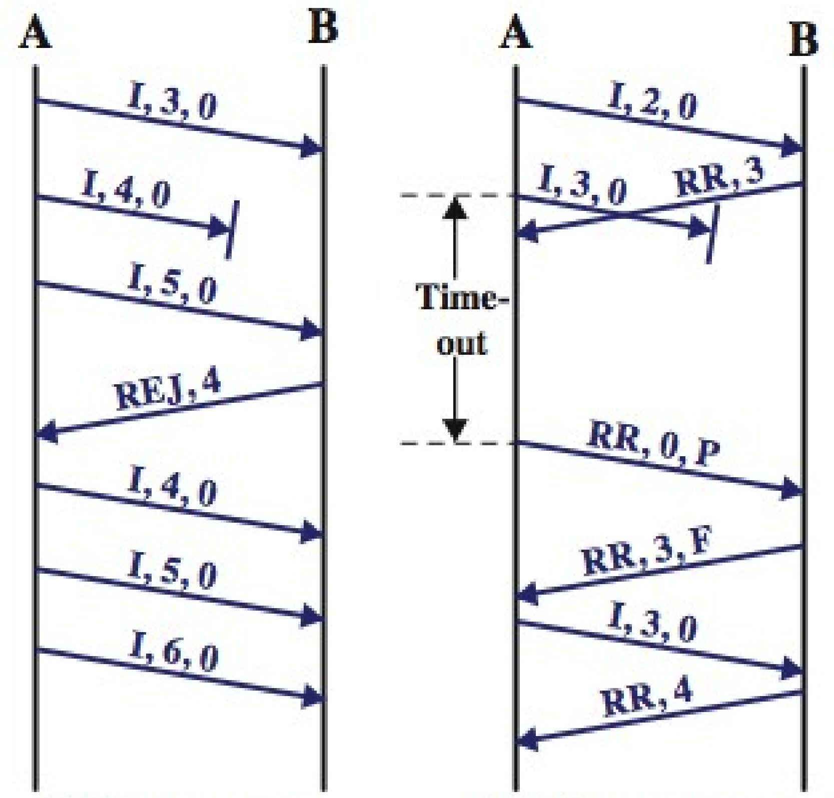
- consists of exchange of information, supervisory and unnumbered frames
- have three phases
  - initialization
    - by either side, set mode & seq
  - data transfer
    - with flow and error control
    - using both I & S-frames (RR, RNR, REJ, SREJ)
  - disconnect
    - when ready or fault noted

HDLC Operation Example



(a) Link setup and disconnect (b) Two-way data exchange (c) Busy condition

HDLC Operation Example



(d) Reject recovery (e) Timeout recovery

Summary

- introduced need for data link protocols
- flow control
- error control
- HDLC