EECS, University of Ottawa

ELG5374 –Fall 2021

Computer Communication Network

Data Link Control

Note: some material in the slides has been taken from various other sources

1

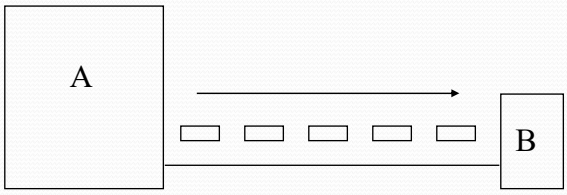
Outline

- Flow Control
- Error Control

2

Flow Control/1

- Definition:
  - flow control is a technique for assuring that a transmitting station does not overwhelm a receiving station with data



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3

Flow Control/2

- two flow control mechanisms
  - stop-and-wait
    - also referred as “alternating bit” or “send and wait”
  - sliding window

1-4

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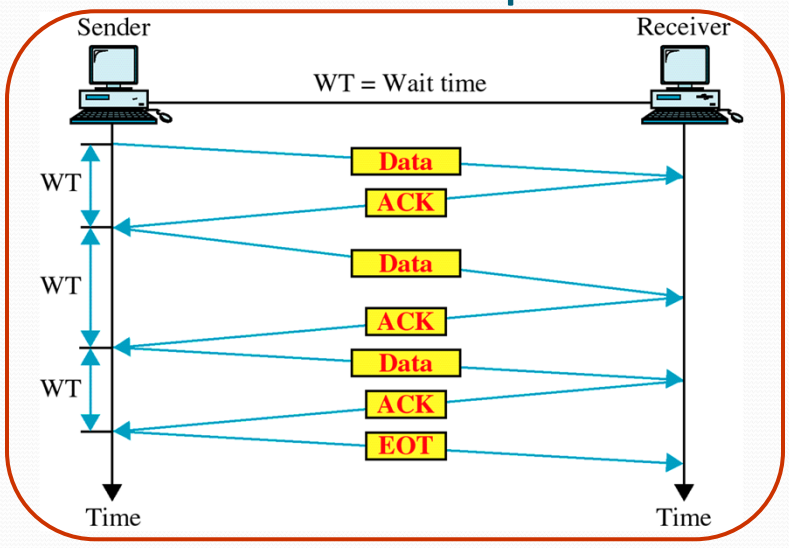
Flow Control: Stop-and-Wait



Anything Negative?

1-5

5

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

1-6

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Flow Control: Sliding Window

- 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

1-7

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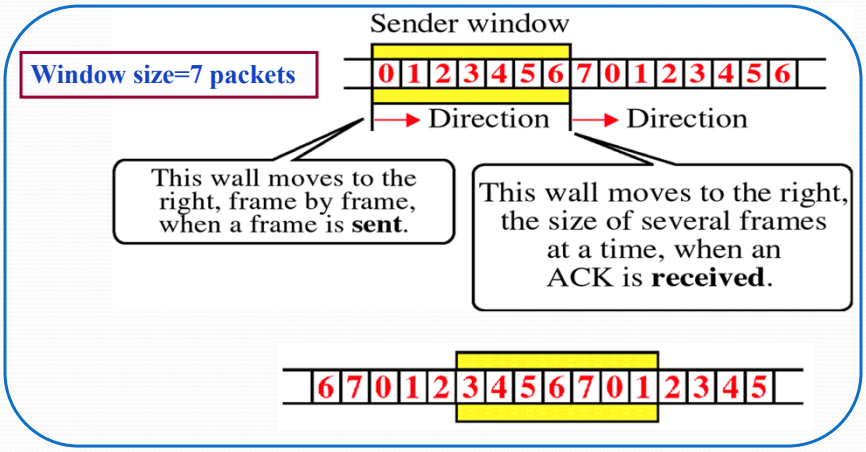
Sender's Sliding Window progress



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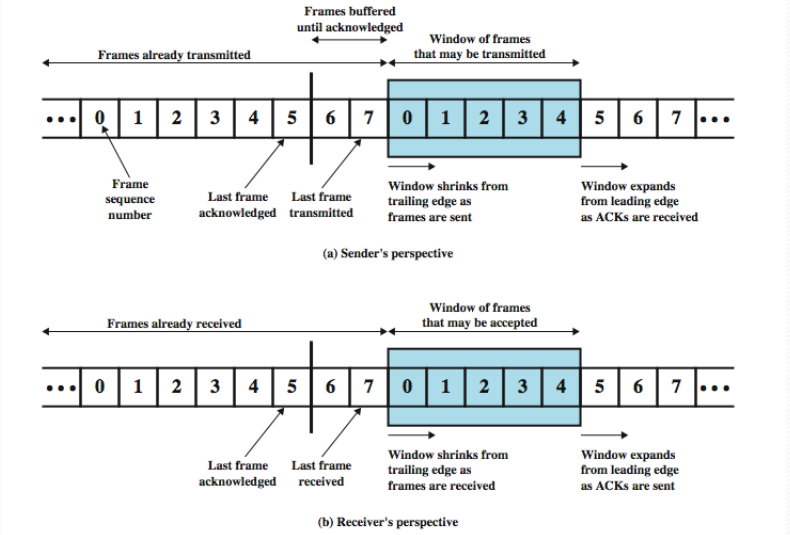
Sliding Window Diagram



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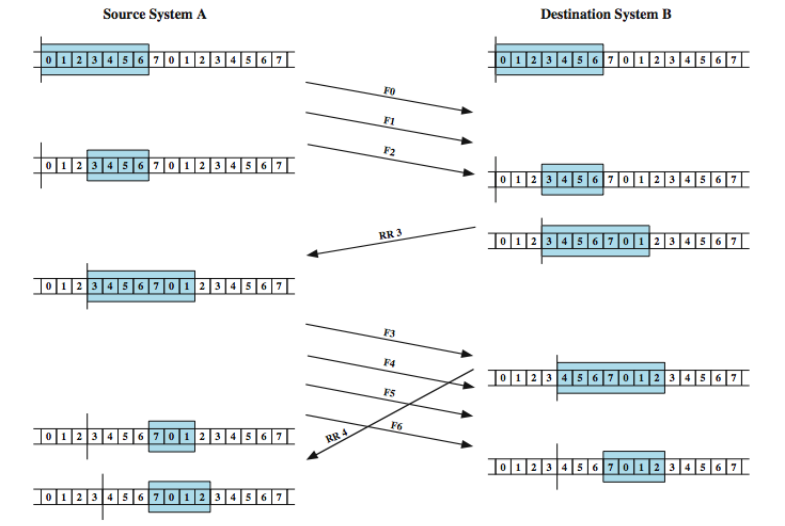
Sliding Window: Example



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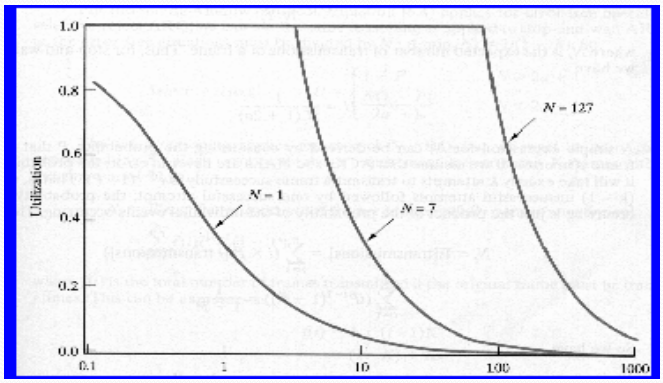
Line Utilization as a Function of Window Size



1-11

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Error Control

1-12

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Error Control

- Error control techniques use some or all of these mechanisms

Automatic repeat request (ARQ)
- error detection
- positive acknowledgment
- retransmission after timeout
- negative acknowledgment and retransmission

- Some versions of ARQ
  - Stop-and-Wait ARQ
  - Go-back-N ARQ
  - Selective-reject ARQ

1-13

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Stop and Wait

- Source transmits single frame
- Wait for ACK
- If received frame damaged, discard it
  - Transmitter has timed-out
  - If no ACK within timeout, retransmit
- If ACK damaged, transmitter will not recognize it
  - Transmitter will retransmit
  - Receiver gets two copies of frame
  - use alternate numbering and ACK0 / ACK1

1-14

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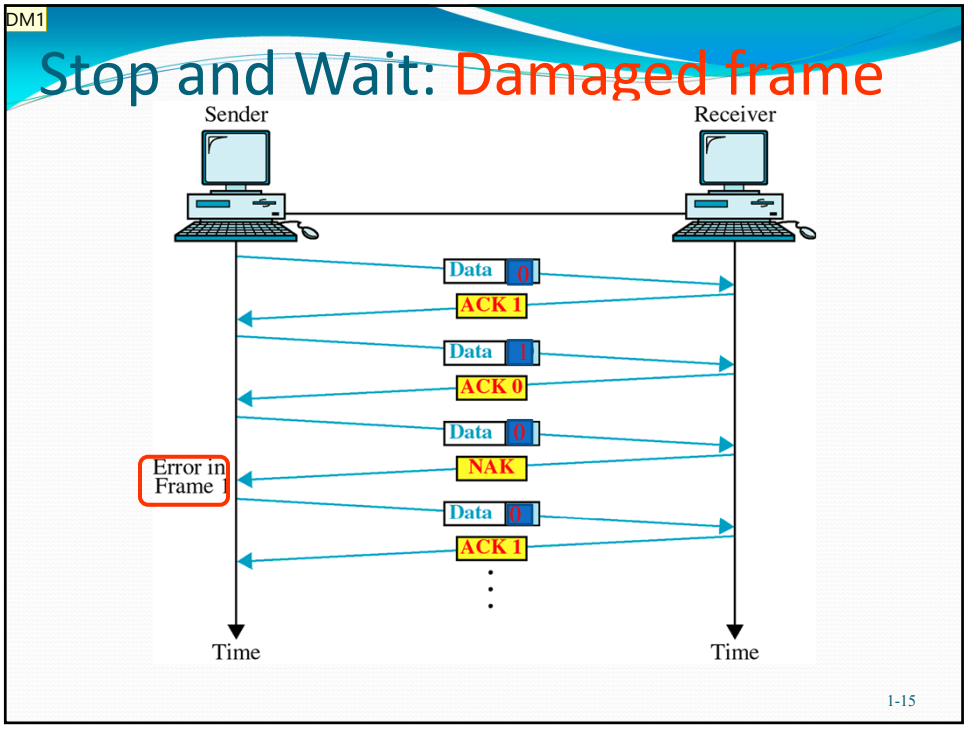
DM1
Stop and Wait: Damaged frame
Sender
Receiver
Data 0
ACK 1
Data 1
ACK 0
Data 0
NAK
Error in Frame 1
Data 0
ACK 1
Time
Time
1-15

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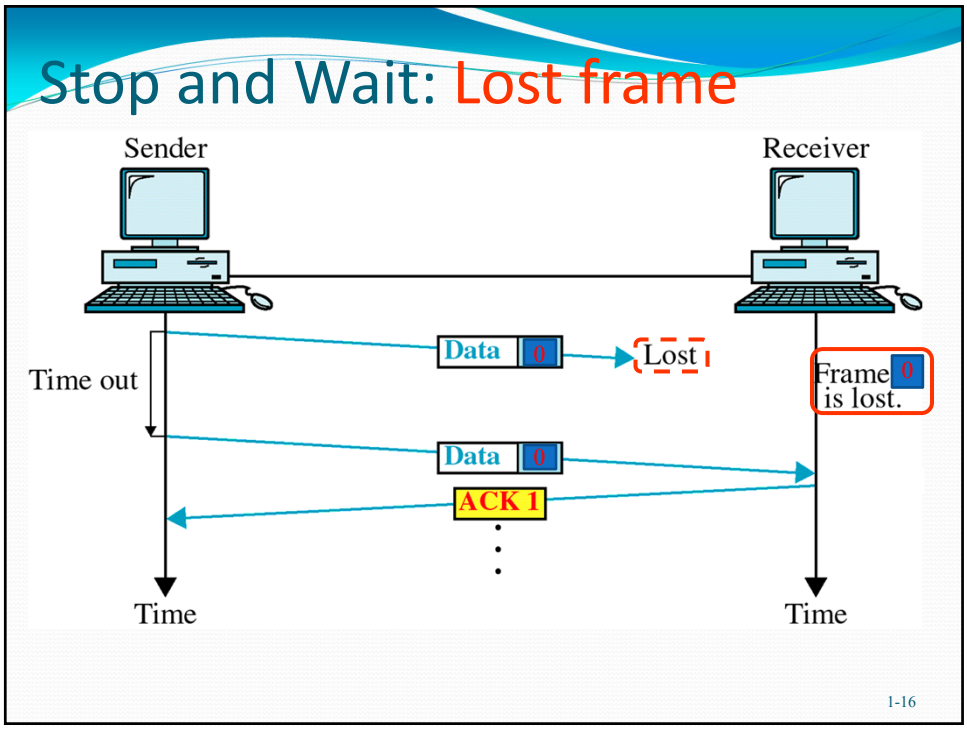
Stop and Wait: Lost frame
Sender
Receiver
Data 0
Lost
Time out
Frame 0 is lost.
Data 0
ACK 1
Time
Time
1-16

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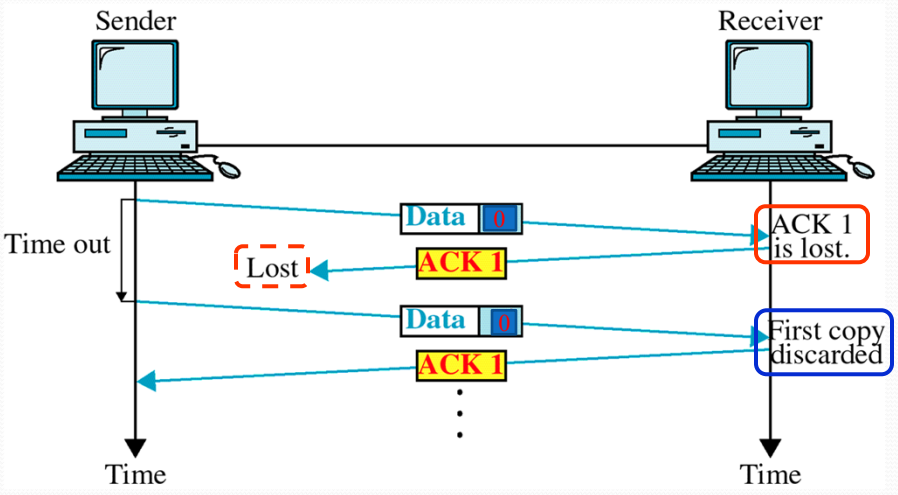
Slide 15

DM1 Dimitrios Makrakis, 2021-02-04

Stop and Wait: Lost ACK



1-17

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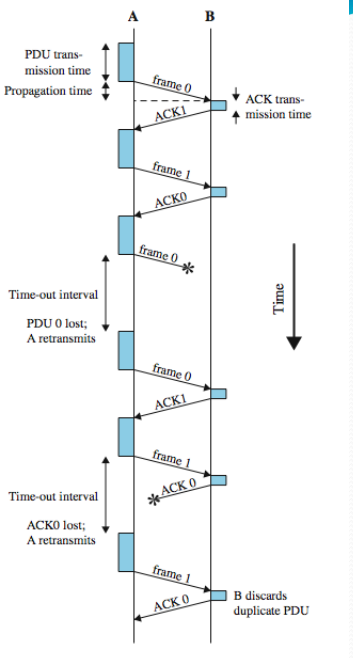
Stop and Wait – Example

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



1-18

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Stop and Wait - Pros and Cons

- Simple
- Inefficient use of resources (low utilization, especially for systems with long propagation delays)

1-19

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Go Back N

- Based on sliding window
- If no error, ACK as usual, indicating next frame expected
- 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

1-20

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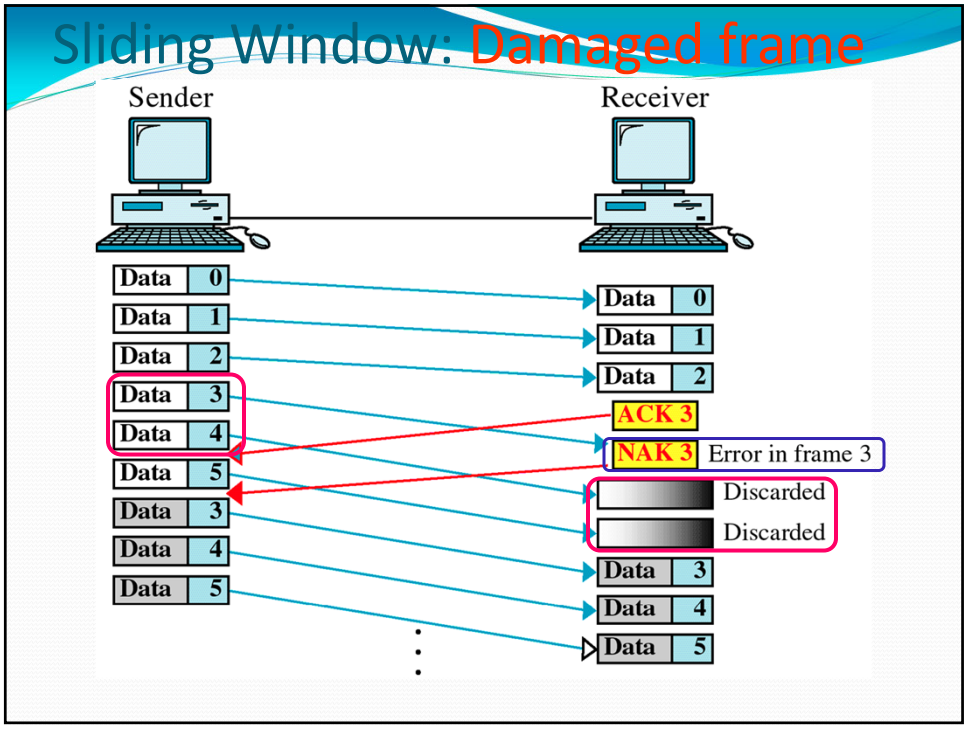

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Go Back N - Damaged Frame

- Receiver detects error in frame *i*
- Receiver sends rejection-*i (RRi)*
- Transmitter gets rejection-*i*
- Transmitter retransmits frame *i* and all subsequent frames

1-22

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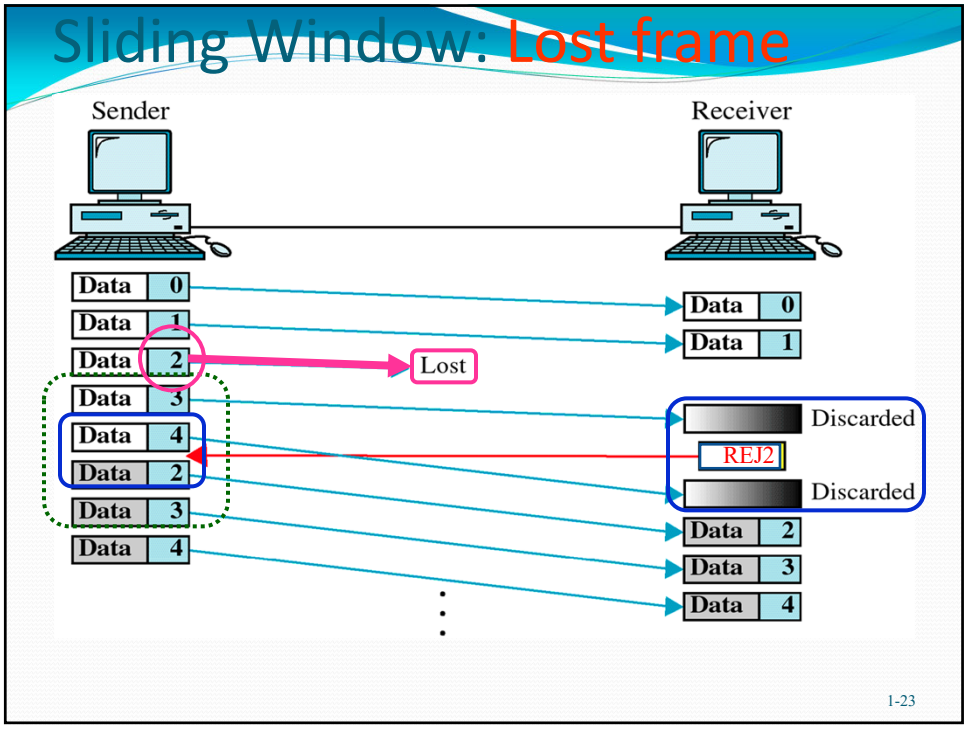

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Go Back N - Lost Frame (1)

- Frame *i* lost
- Transmitter sends *i+1*
- Receiver gets frame *i+1* out of sequence
- Receiver send rejection *i (RRi)*
- Transmitter goes back to frame *i* and retransmits frame *i* and all subsequent frames

1-24

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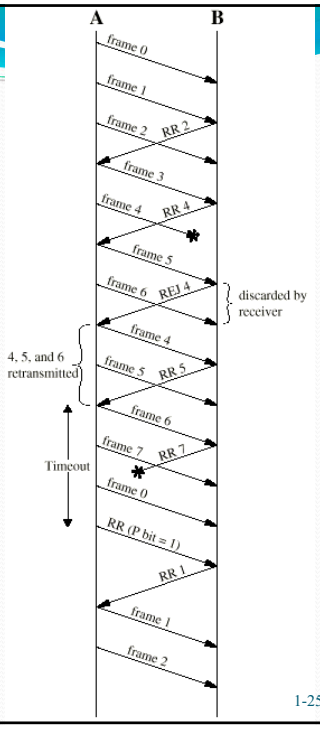
Go Back N - Example



1-25

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Go Back N - Lost Frame (2)

- Frame *i* lost and no additional frame sent
- Receiver gets nothing and returns neither acknowledgement nor rejection
- Transmitter times out and sends acknowledgement frame with P bit set to 1
- Receiver interprets this as command which it acknowledges with the number of the next frame it expects (frame *i*)
- Transmitter then retransmits frame *i*

1-26

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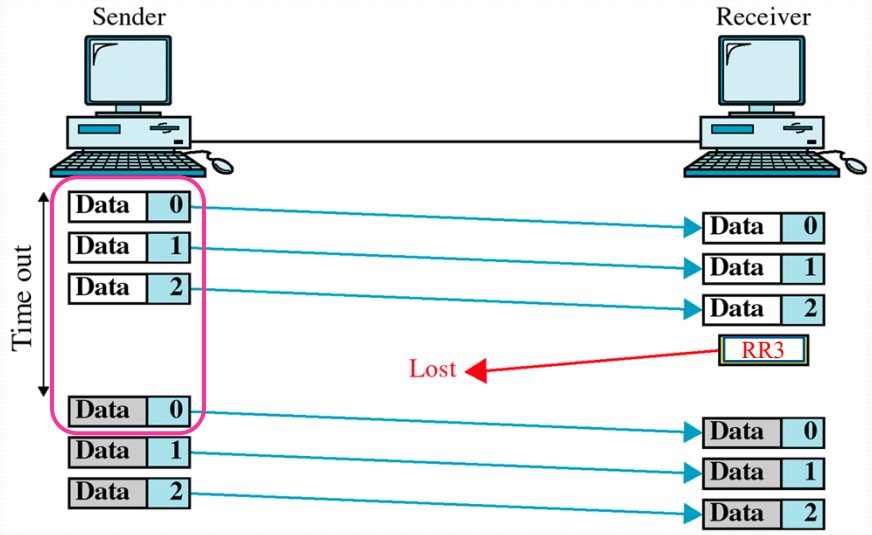
Sliding Window: Lost ACK



1-27

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Go Back N – Damaged or Lost Acknowledgement

- Receiver gets frame *i* and sends acknowledgement (*i*+1) which is lost
- Acknowledgements are cumulative, so next acknowledgement (*i*+*n*) may arrive before transmitter times out on frame *i*
- If transmitter times out, it sends acknowledgement with P bit set as before
- This can be repeated a number of times before a reset procedure is initiated
- NOTE: either damaged or lost, for sender is the same since it can't reconstruct the Acknowledgement frame to be able to "read" it.

1-28

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Go Back N - Damaged Rejection

- As for lost frame

1-29

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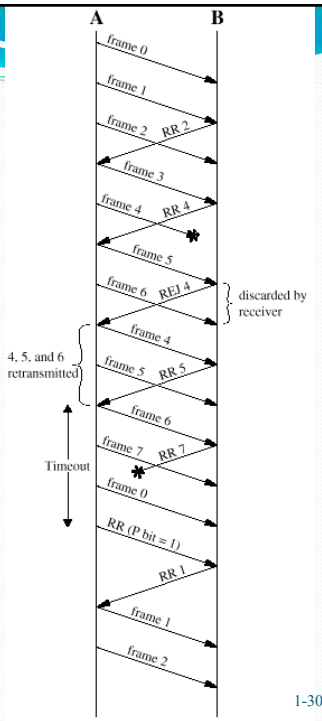
Go Back N - Diagram



1-30

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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
- saves bandwidth
- useful for satellite links with long propagation delays

1-31

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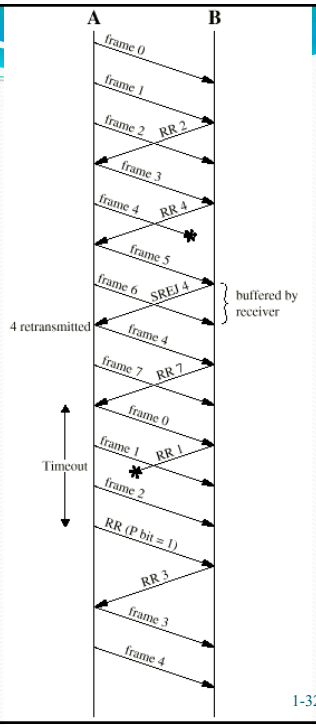
Selective Reject: Example



1-32

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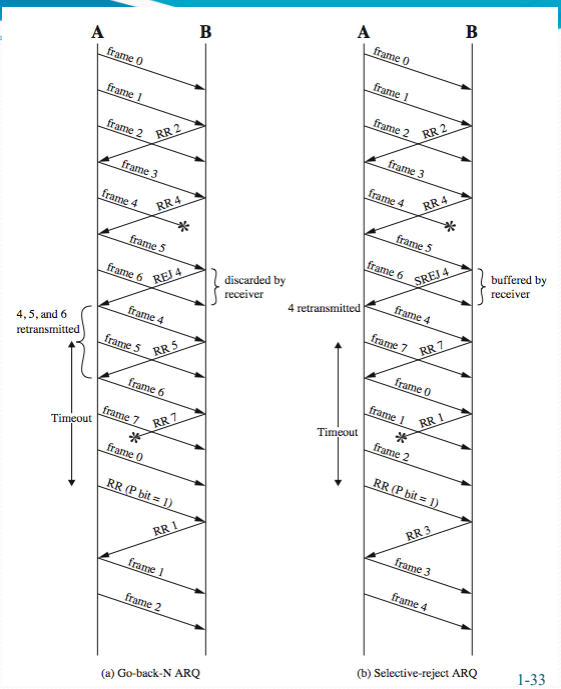
Go Back N vs Selective Reject



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High Level Data Link Control

- HDLC
- ISO 33009, ISO 4335

1-34

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HDLC Station Types

- Primary station
  - Controls operation of link
  - Frames issued are called commands
  - Maintains separate logical link to each secondary station
- Secondary station
  - Under control of primary station
  - Frames issued called responses
- Combined station
  - May issue commands and responses

1-35

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HDLC Link Configurations

- Unbalanced
  - One primary and one or more secondary stations
  - Supports full duplex and half duplex
- Balanced
  - Two combined stations
  - Supports full duplex and half duplex

1-36

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HDLC Transfer Modes (1)

- Normal Response Mode (NRM)
  - Unbalanced configuration
  - Primary initiates transfer to secondary
  - Secondary may only transmit data in response to command from primary
  - Used on multi-drop lines
  - Host computer as primary
  - Terminals as secondary

1-37

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HDLC Transfer Modes (2)

- Asynchronous Balanced Mode (ABM)
  - Balanced configuration
  - Either station may initiate transmission without receiving permission
  - Most widely used
  - No polling overhead

1-38

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HDLC Transfer Modes (3)

- Asynchronous Response Mode (ARM)
  - Unbalanced configuration
  - Secondary may initiate transmission without permission form primary
  - Primary responsible for line
  - rarely used

1-39

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Frame Structure

- Synchronous transmission
- All transmissions in frames
- Single frame format for all data and control exchanges

1-40

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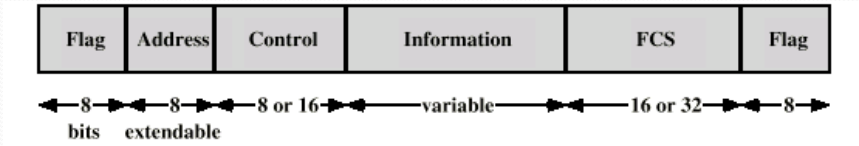
Frame Structure Diagram



1-41

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Flag Fields

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

1-42

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Bit Stuffing

- Example with possible errors

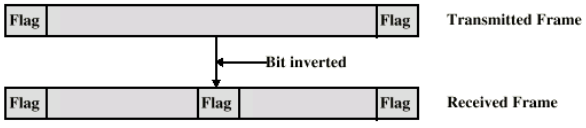
Original Pattern:

111111111111011111101111110

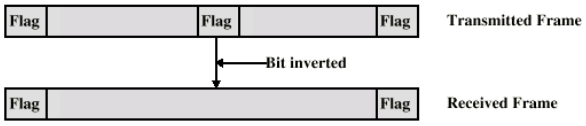
After bit-stuffing

111110111110110111110101111010

(a) Example



(b) An inverted bit splits a frame in two



(c) An inverted bit merges two frames

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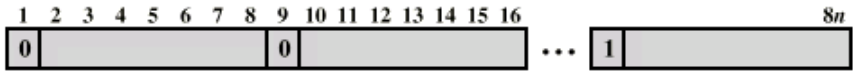
Address Field

- Identifies secondary station that sent or will receive frame
- Usually 8 bits long
- May be extended to multiples of 7 bits
  - LSB of each octet indicates that it is the last octet (1) or not (0)
- All ones (1111111) is broadcast



(b) Extended Address Field

1-44

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Control Field

- Different for different frame type
  - Information - data to be 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 one or two bits of control filed identify frame type
- Remaining bits explained later

1-45

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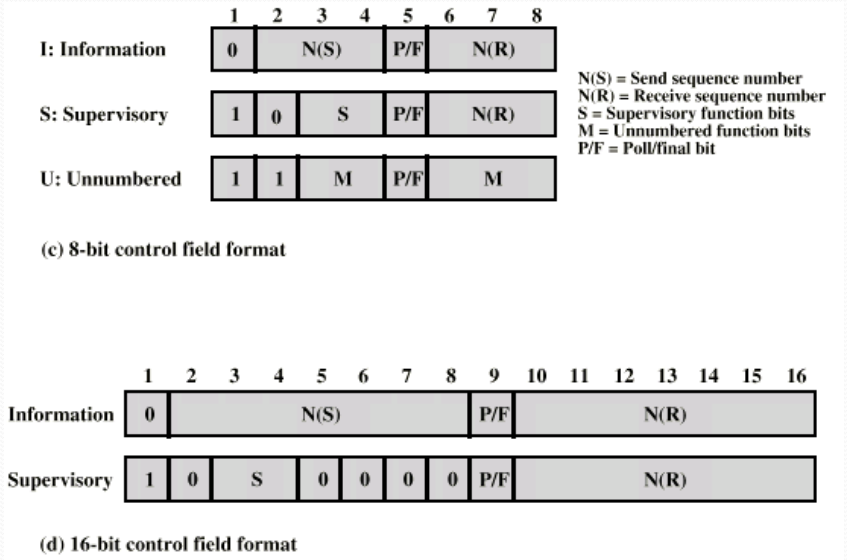
Control Field Diagram



1-46

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Poll/Final Bit

- Use depends on context
- Command frame
  - P bit
  - 1 to solicit (poll) response from peer
- Response frame
  - F bit
  - 1 indicates response to soliciting command

1-47

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Information Field

- Only in information and some unnumbered frames
- Must contain integral number of octets
- Variable length

1-48

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Frame Check Sequence Field

- FCS
- Error detection
- 16 bit CRC
- Optional 32 bit CRC

1-49

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HDLC Operation

- Exchange of information, supervisory and unnumbered frames
- Three phases
  - Initialization
  - Data transfer
  - Disconnect

1-50

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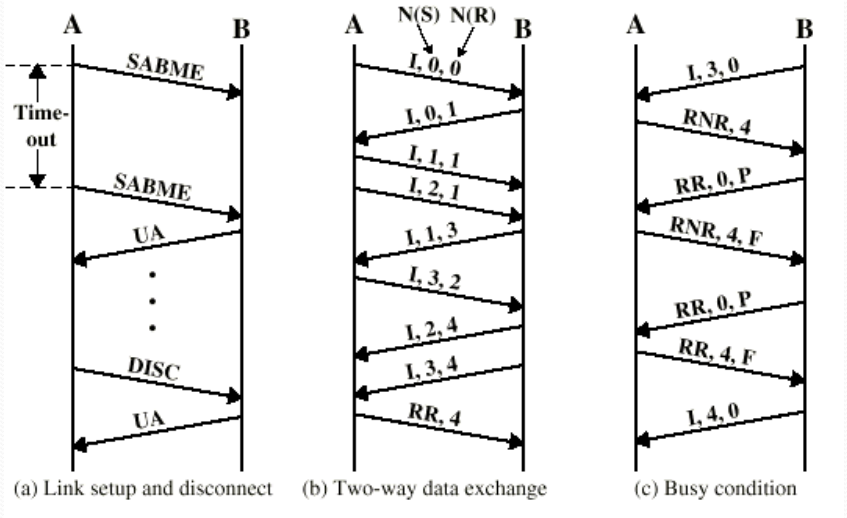
Examples of Operation (1)



1-51

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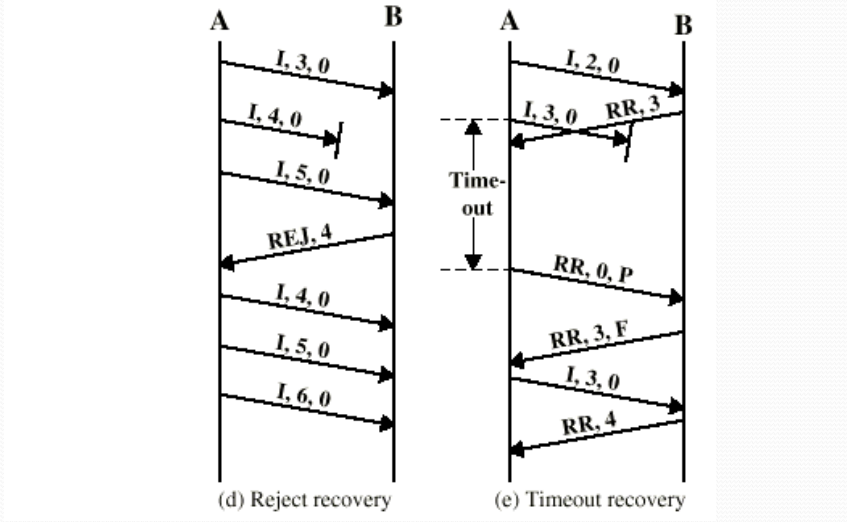
Examples of Operation (2)



1-52

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Other DLC Protocols (LAPB,LAPD)

- Link Access Procedure, Balanced (LAPB)
  - Part of X.25 (ITU-T)
  - Subset of HDLC - ABM
  - Point to point link between system and packet switching network node
- Link Access Procedure, D-Channel
  - ISDN (ITU-D)
  - ABM
  - Always 7-bit sequence numbers (no 3-bit)
  - 16 bit address field contains two sub-addresses
    - One for device and one for user (next layer up)

1-53

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Other DLC Protocols (LLC)

- Logical Link Control (LLC)
  - IEEE 802
  - Different frame format
  - Link control split between medium access layer (MAC) and LLC (on top of MAC)
  - No primary and secondary - all stations are peers
  - Two addresses needed
    - Sender and receiver
  - Error detection at MAC layer
    - 32 bit CRC
  - Destination and source access points (DSAP, SSAP)

1-54

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Other DLC Protocols (Frame Relay) (1)

- Streamlined capability over high speed packet witched networks
- Used in place of X.25
- Uses Link Access Procedure for Frame-Mode Bearer Services (LAPF)
- Two protocols
  - Control - similar to HDLC
  - Core - subset of control

1-55

55

Other DLC Protocols (Frame Relay) (2)

- ABM
- 7-bit sequence numbers
- 16 bit CRC
- 2, 3 or 4 octet address field
  - Data link connection identifier (DLCI)
  - Identifies logical connection
- More on frame relay later

1-56

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Other DLC Protocols (ATM)

- Asynchronous Transfer Mode
- Streamlined capability across high speed networks
- Not HDLC based
- Frame format called "cell"
- Fixed 53 octet (424 bit)
- Details later

1-57

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Summary

- Framing
  - synchronous transmission Vs asynchronous transmission
- Error detection
  - parity checks; LRC; CRC
- Flow control
  - stop-and-wait; sliding-window
- Error control
  - stop-and-wait; go-back-N; selective reject
- HDLC
  - synchronous transmission; CRC; go-back-N; selective reject

1-58

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