DATA AND COMPUTER COMMUNICATIONS

Lecture 3 Data Link Layer - Data Link Control Protocols

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Based on Lecture slides by William Stallings

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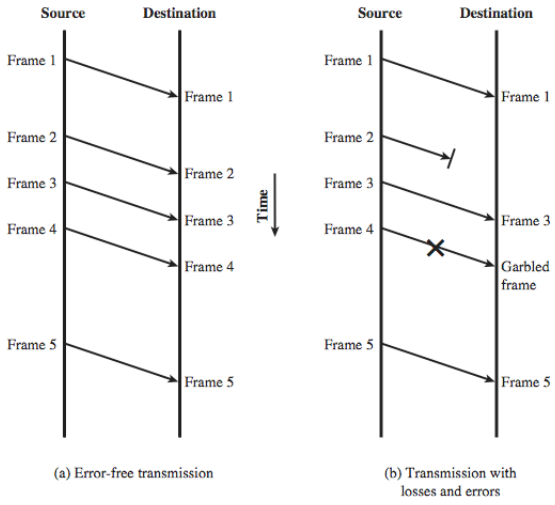
DATA LINK CONTROL PROTOCOLS

- 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

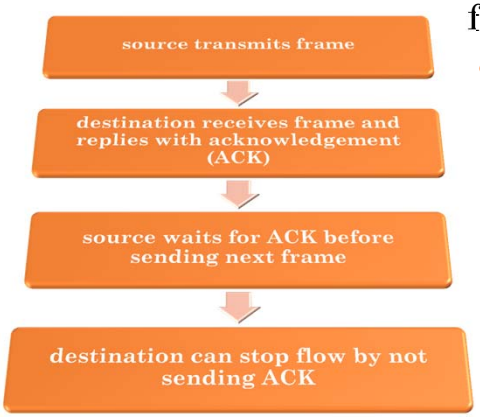


(a) Error-free transmission

(b) Transmission with losses and errors

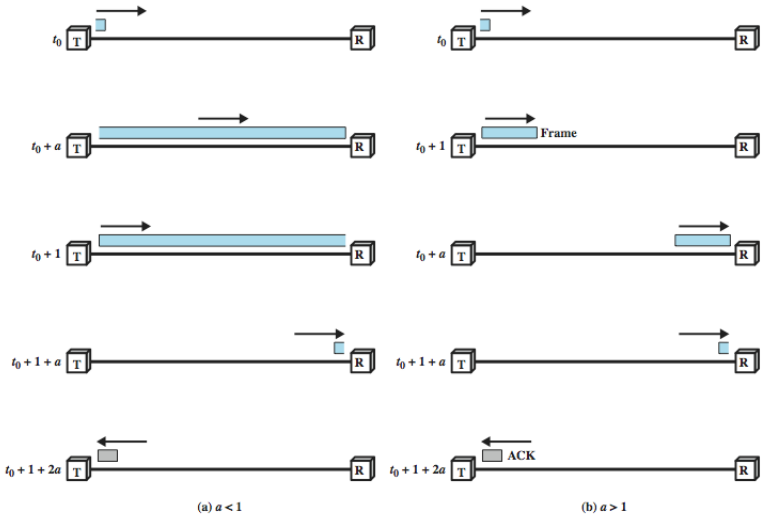
Stop and Wait

- simplest form of flow control



- works well for a message sent in a few large frames
  - stop and wait becomes inadequate if large block of data is split into small frames by source

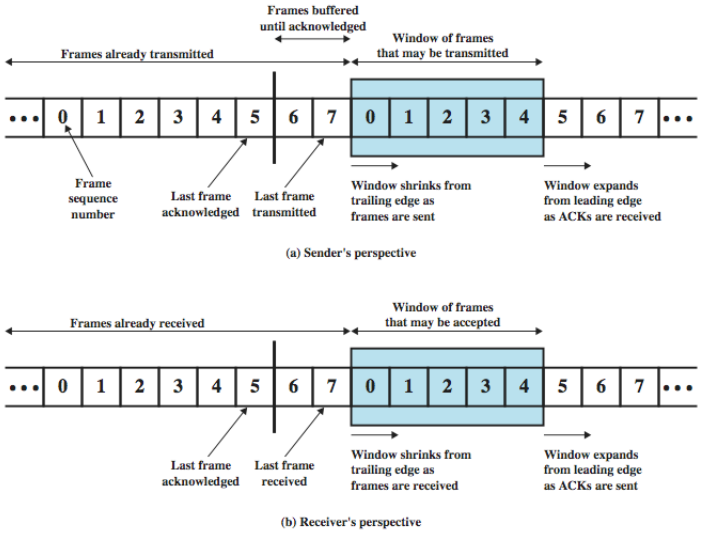
Stop and Wait Link Utilization



Sliding Windows Flow Control

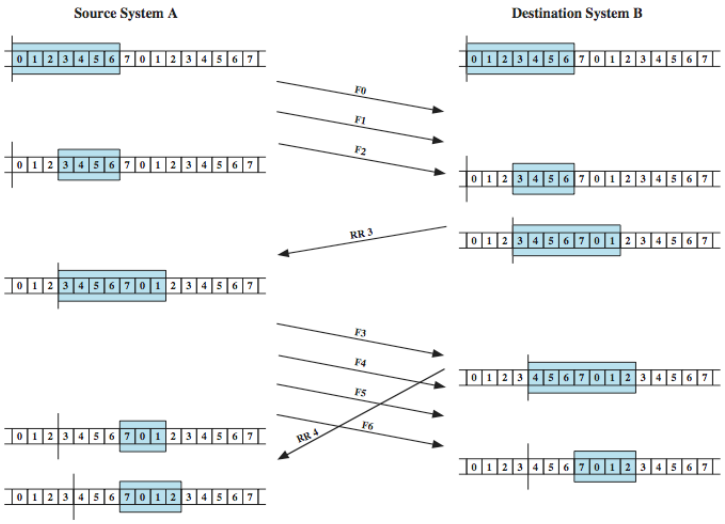
- allows multiple numbered frames to be in transit
- receiver has buffer W long
- transmitter sends up to W frames without ACK
- ACK includes number of next frame expected
- sequence number is bounded by size of field (k)
  - frames are numbered modulo 2^k
  - giving max window size of up to $2^k - 1$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

http://www.humboldt.edu/~aeb3/telecom/SlidingWindow.html



Error Control

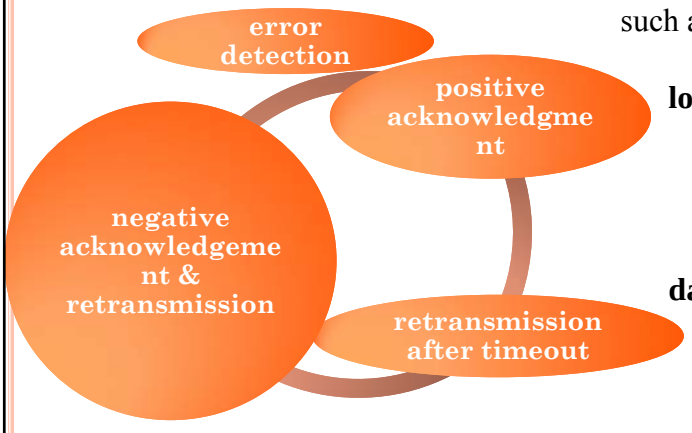
- detection and correction of errors such as:
  - lost frames
  - damaged frames
- common techniques use:
  - error detection
  - positive acknowledgment
  - retransmission after timeout
  - negative acknowledgement & retransmission

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

Error Control Techniques

detection and correction of errors such as:

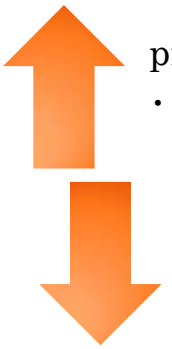


lost frames
-a frame fails to arrive at the other side

damaged frames
-frame arrives but some of the bits are in error

STOP AND WAIT

- see example with both types of errors

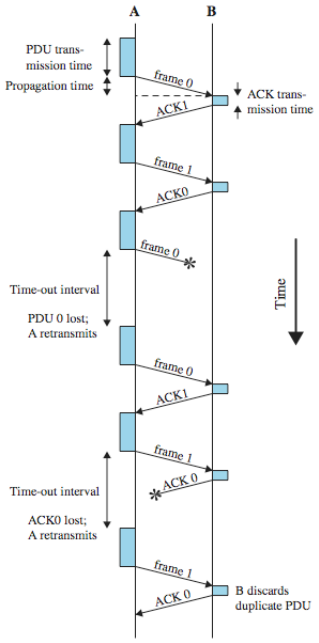


pros

- simplistic

cons

- inefficient



GO BACK N

- most commonly used error control
- based on sliding-window
- use window size to control number of outstanding frames
- 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

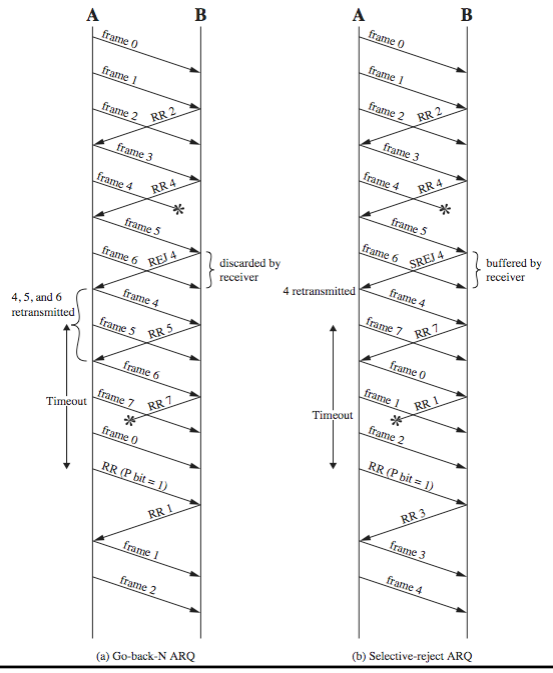
Damaged Rejection

- reject for damaged frame is lost
- handled as lost frame when transmitter times out

Selective Reject (ARQ)

- 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 vs Selective Reject



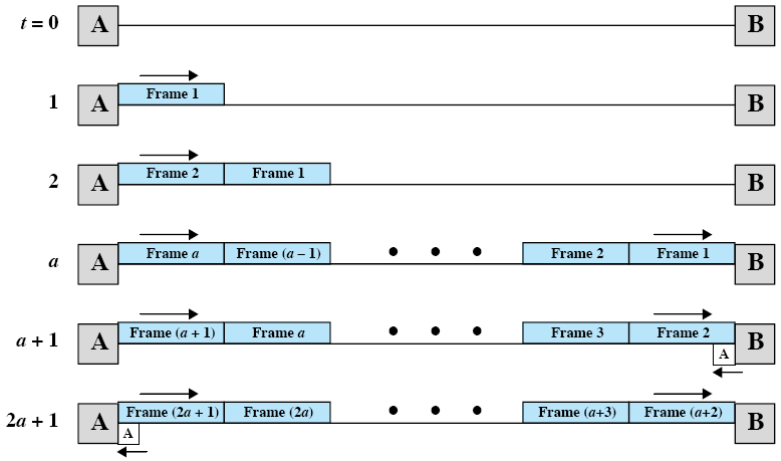
Performance Issues

- Stop-and-Wait Flow Control
  - T: the total time to send data, $T=nT_F$
  - T_F: the total time to send one frame and receive an acknowledgement
  - $T_F=t_{prop}+t_{frame}+t_{proc}+t_{prop}+t_{ack}+t_{proc}$
  - Ignoring t_{proc} and t_{ack}, $T=n(2t_{prop}+t_{frame})$
  - Utilization $U=nt_{frame}/T=t_{frame}/(2t_{prop}+t_{frame})=1/(1+2a)$ where $a=t_{prop}/t_{frame}$

Performance Issues

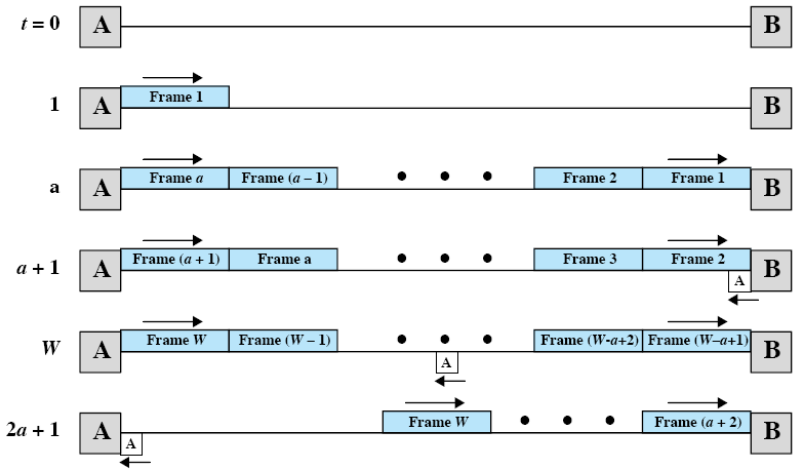
- Error-Free Sliding-Window Flow Control
  - The throughput on the line depends on both the window size W and the value of a
  - Case 1: $W \geq 2a+1$. The acknowledgement for frame 1 reaches A before A has exhausted its window.
  - Case 2: $W<2a+1$. A exhausts its window at t=W and cannot send additional frames until t=2a+1.

Error-Free Sliding-Window Flow Control



(a) W≥2a+1

Error-Free Sliding-Window Flow Control



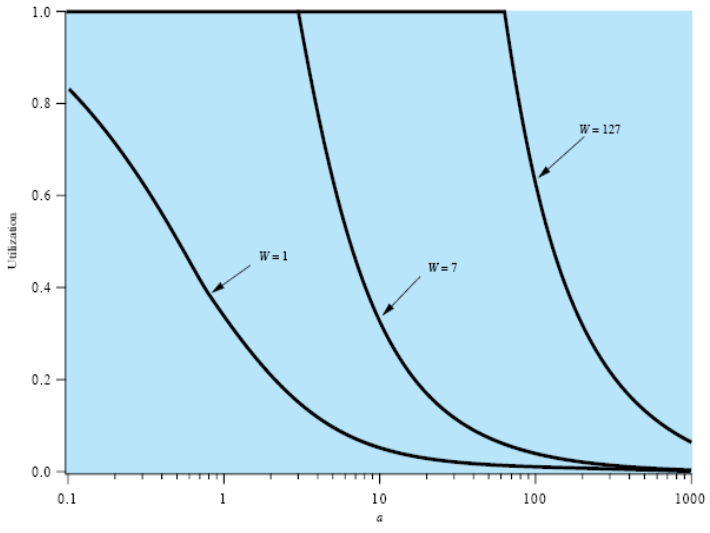
(b) W<2a+1

Error-Free Sliding-Window Flow Control

- Utilization

$$U = \begin{cases} 1 & W \geq 2a+1 \\ \dfrac{W}{(2a+1)} & W < 2a+1 \end{cases}$$

Error-Free Sliding-Window Flow Control



ARQ

- Stop-and-wait ARQ

$$U = \frac{T_f}{N_r T_t} = \frac{1}{N_r(1+2a)}$$

$$N_r = \frac{1}{1-P}$$

$$U = \frac{1-P}{1+2a}$$

ARQ

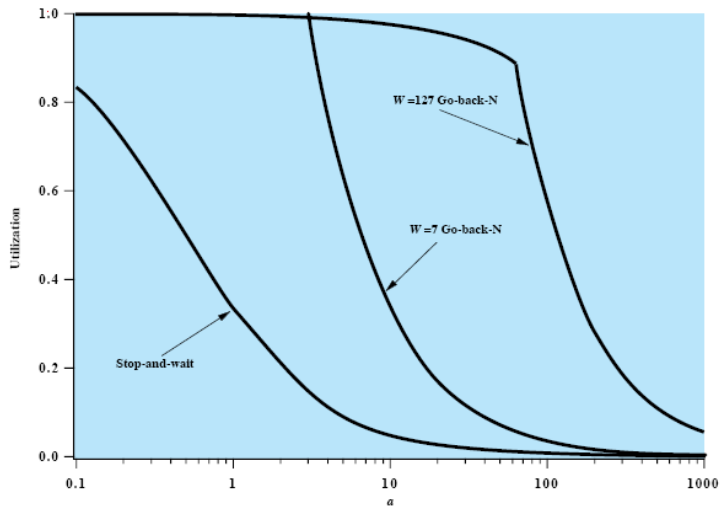
- Selective Reject

$$U = \begin{cases} 1-P & W \geq 2a+1 \\ \dfrac{W(1-P)}{2a+1} & W < 2a+1 \end{cases}$$

- Go-back-N

$$U = \begin{cases} \dfrac{1-P}{1+2aP} & W \geq 2a+1 \\ \dfrac{W(1-P)}{(2a+1)(1-P+WP)} & W < 2a+1 \end{cases}$$

ARQ



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)

- used with an unbalanced configuration
- primary initiates transfer

Asynchronous Balanced Mode (ABM)

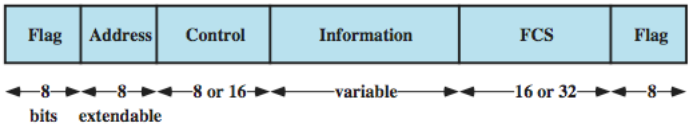
- used with a balanced configuration
- either station initiates transmission
- has no polling overhead
- most widely used

Asynchronous Response Mode (ARM)

- used with unbalanced configuration
- secondary may 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:

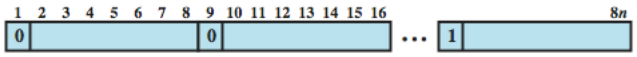
```
111111111111011111101111110
```

After bit-stuffing

```
111110111110110111111010111110 10
```

Address Field

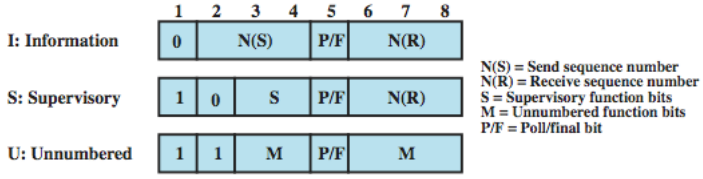
- identifies secondary station that sent or will receive frame
- usually 8 bits long
- may be extended to multiples of 7 bits
  - LSB indicates if is the last octet (1) or not (0)
- all ones address 11111111 is broadcast



(b) Extended Address Field

Control Field

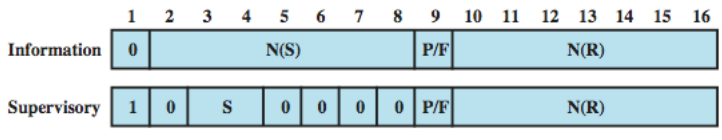
- different for different frame type
  - Information - data transmitted to user (next layer up)
    - Flow and error control piggybacked on information frames
  - Supervisory - ARQ when piggyback not used
  - Unnumbered - supplementary link control
- first 1-2 bits of control field identify frame type



(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

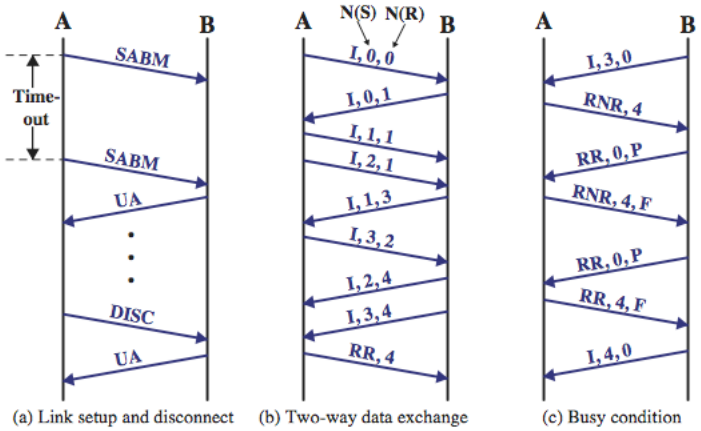


(d) 16-bit control field format

Information & FCS Fields

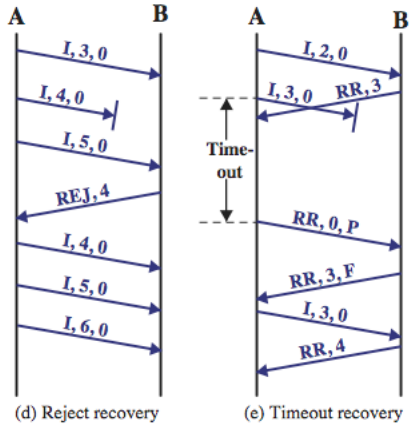
- Information Field
  - in information and some unnumbered frames
  - must contain integral number of octets
  - variable length
- Frame Check Sequence Field (FCS)
  - used for error detection
  - either 16 bit CRC or 32 bit CRC

HDLC Operation Example



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

HDLC Operation Example



Summary

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