Data Communications

Chapter 7 - Flow and Error Control

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Data Link Control Protocols

- Requirements and objectives for effective data communication between two directly connected transmitting-receiving stations:
  1. Frame synchronization
  2. Flow control
  3. Error control
  4. Addressing
  5. Control and data
  6. Link management

Flow Control

- Technique for assuring that a transmitting entity does not over-whelm a receiving entity with data
- In the absence of flow control, the receiver's buffer may fill up and overflow while it is processing old data

Model of Frame Transmission

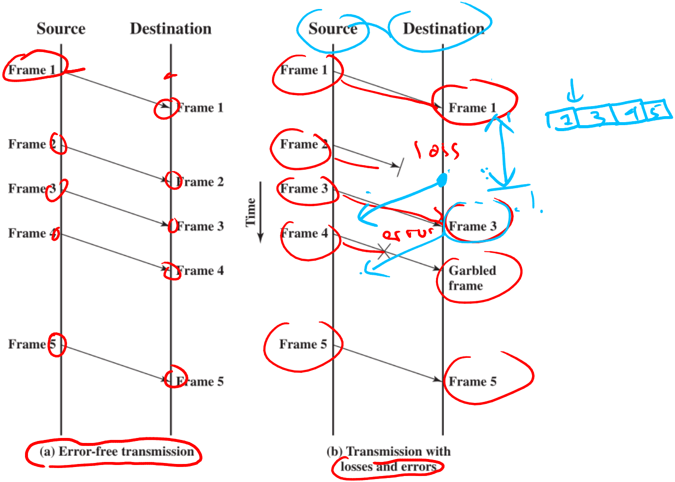
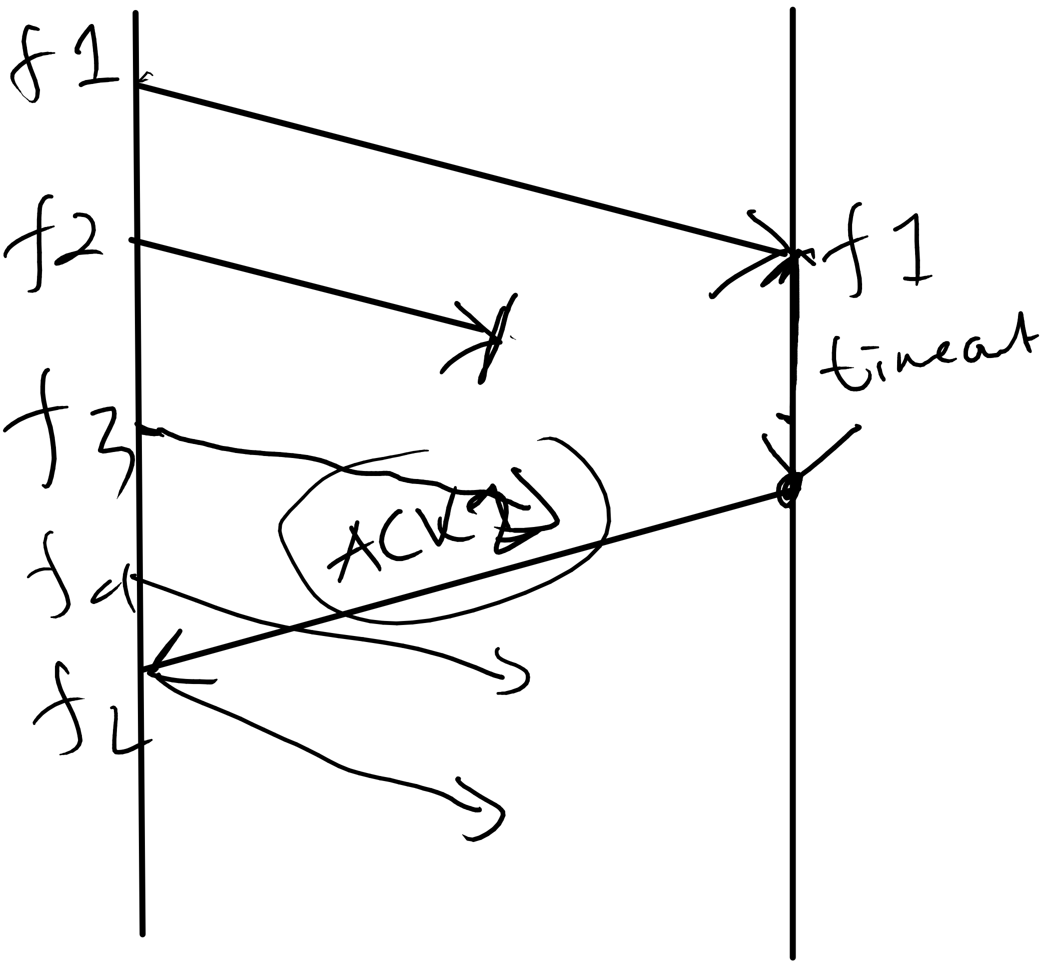


Figure 7.1 Model of Frame Transmission

Stop-and-Wait Flow Control

- Simplest form of flow control
  1. Source transmits frame
  2. Destination receives frame and replies with acknowledgement (ACK)
  3. Source waits for ACK before sending next frame
  4. Destination can stop flow by not send ACK


f1
f2
f3
f4
f2
f1
timeout
ACK2

Stop-and-Wait Flow Control

- It is often the case that a source will break up a large block of data into smaller blocks and transmit the data in many frames
  - The buffer size of the receiver may be limited
  - The longer the transmission, the more likely that there will be an error, necessitating retransmission of the entire frame
  - On a shared medium it is usually desirable not to permit one station to use the medium for an extended period, thus causing long delays at the other sending station

Stop-and-Wait Link Utilization

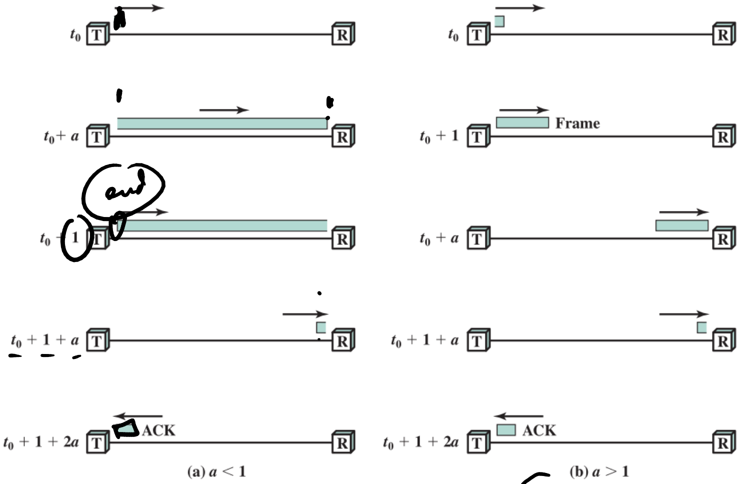


Figure 7.2 Stop-and-Wait Link Utilization (transmission time = 1; propagation time = a)

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

3-bit seq, W = 7 frames

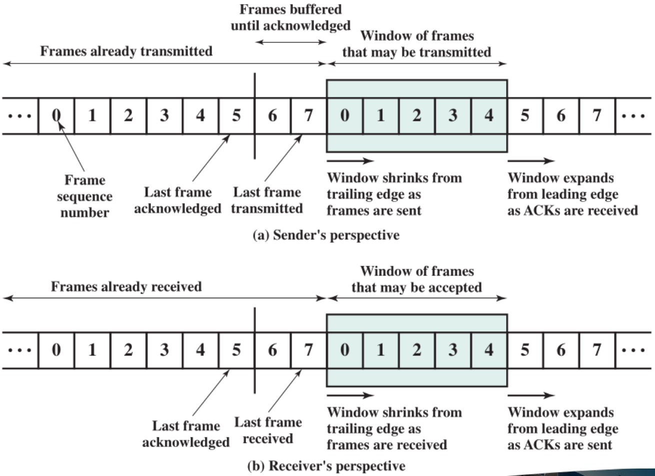


Figure 7.3 Sliding-Window Depiction

Sliding Window Example

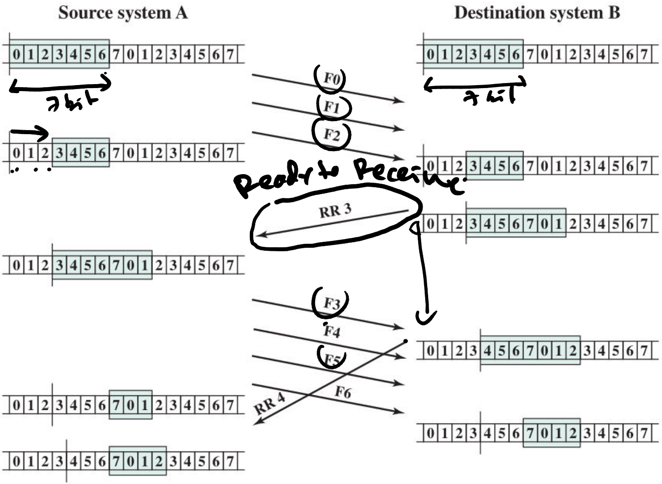


Figure 7.4 Example of a Sliding-Window Protocol

Sliding Window Utilization

- Window size W, transmission time $= 1$, propagation time $= a$
- Case 1: $W >= 2a + 1$
  - Sender A can transmit continuously with no pause and normalized throughput is 1.0
- Case 2: $W < 2a + 1$
  - Sender A exhausts its window at $t = W$ and cannot send additional frames until $t = 2a + 1$.
  - Normalized throughput is $W/(2a + 1)$

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
- Common techniques use:
  - Error detection
  - Positive acknowledgment
  - Retransmission after timeout
  - Negative acknowledgement & retransmission

Automatic Repeat Request (ARQ)

- Collective name for error control mechanisms, including:
  - stop and wait ✓
  - go back N ✓
  - selective reject (selective retransmission) ✓
- Effect of ARQ is to turn an unreliable data link into a reliable one

Stop and Wait ARQ

- 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 ARQ

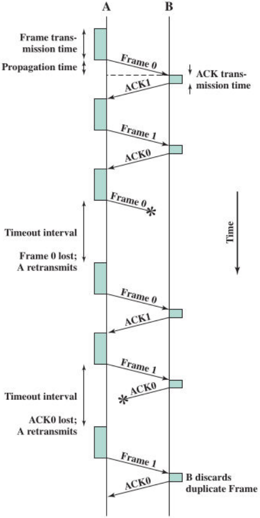
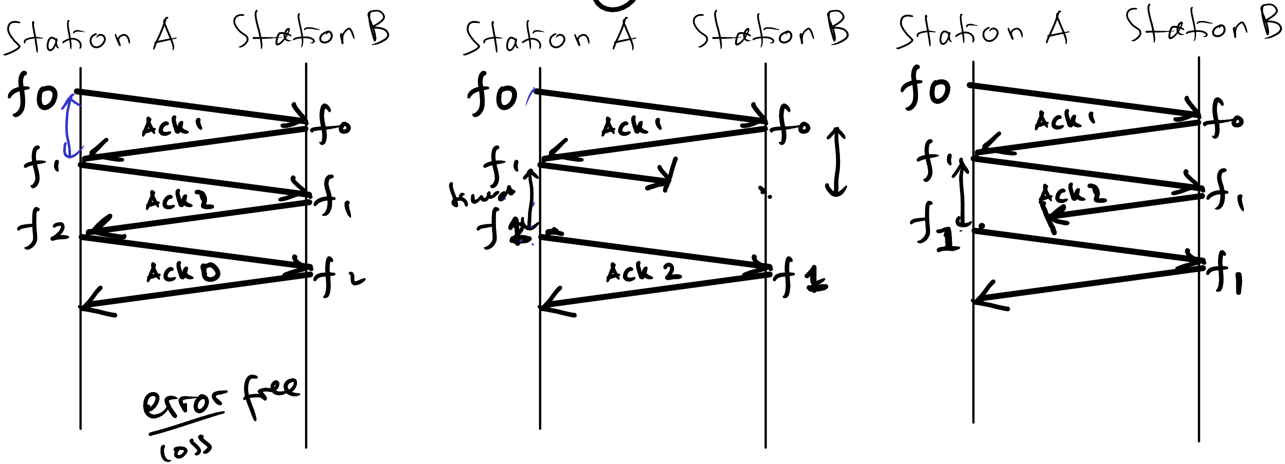


Figure 7.5 Stop-and-Wait ARQ

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

3. **[20 poin]** Dilakukan pertukaran informasi dari *station* A ke *station* B berupa pengiriman 3 *frame* secara berurutan (*frame* 0, *frame* 1 dan *frame* 2). Jika *error control* yang digunakan adalah **stop-and-wait ARQ**, ilustrasikan pertukaran informasi yang terjadi dengan asumsi
   a. Terjadi **lost** saat pengiriman **frame 1**.
   b. Terjadi **lost** saat pengiriman **acknowledgement 2**.

a



Go-Back-N ARQ

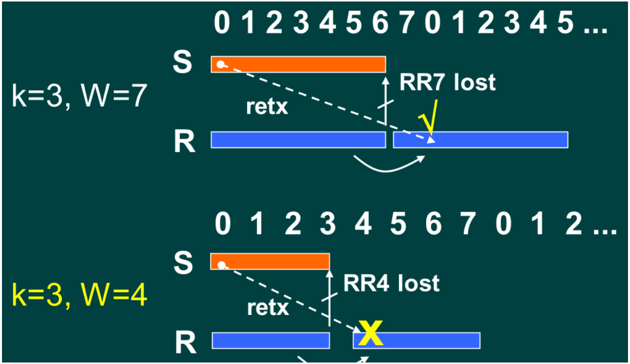
- Most commonly used error control
- Based on sliding-window
- Use window size to control number of outstanding frames
- While no errors occur, the destination will acknowledge incoming frames as usual
  - RR=receive ready, or piggybacked acknowledgment
- If the destination station detects an error in a frame, it may send a negative acknowledgment
  - REJ=reject
  - Destination will **discard that frame and all future frames until the frame in error is received correctly**
  - Transmitter must **go back and retransmit** that frame and all subsequent frames

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
  - Less widely used
- Useful for satellite links with long propagation delays

Selective-Reject (ARQ)

- Window Size Limitation
  - For a k-bit sequence number, the maximum window size is limited to $2k - 1$.



Go Back N vs Selective Reject

Go Back N Selective Reject

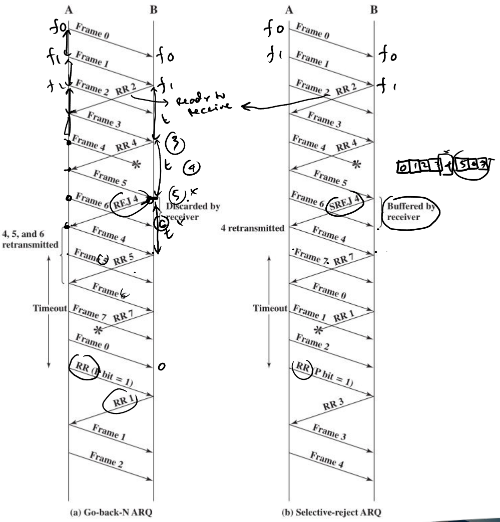
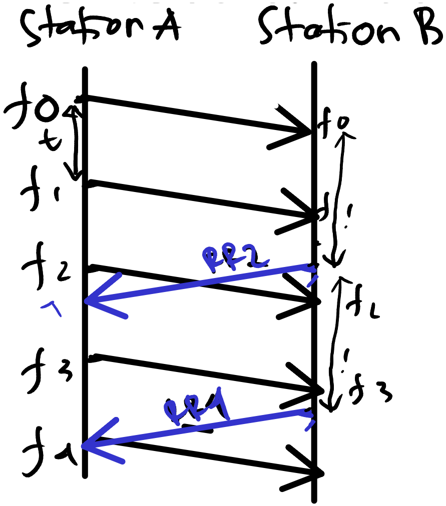
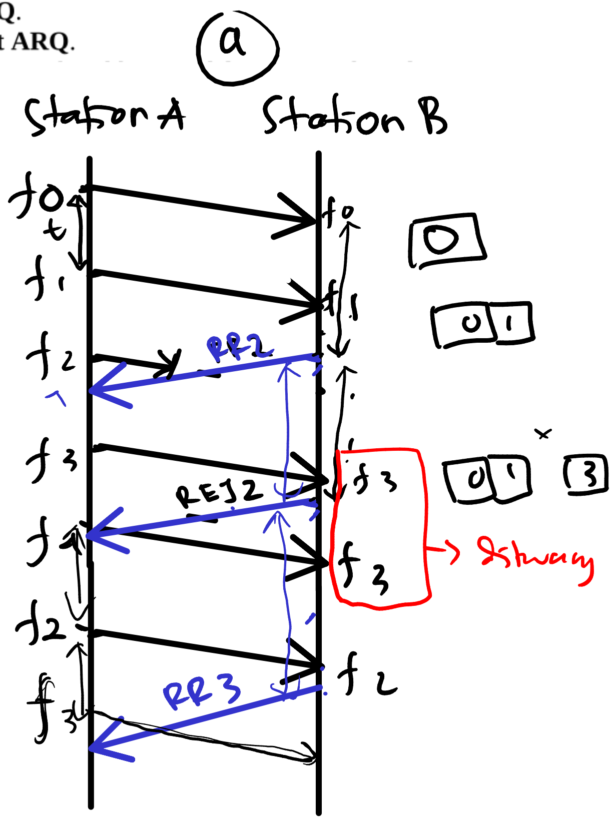


Figure 7.6 Sliding-Window ARQ Protocols

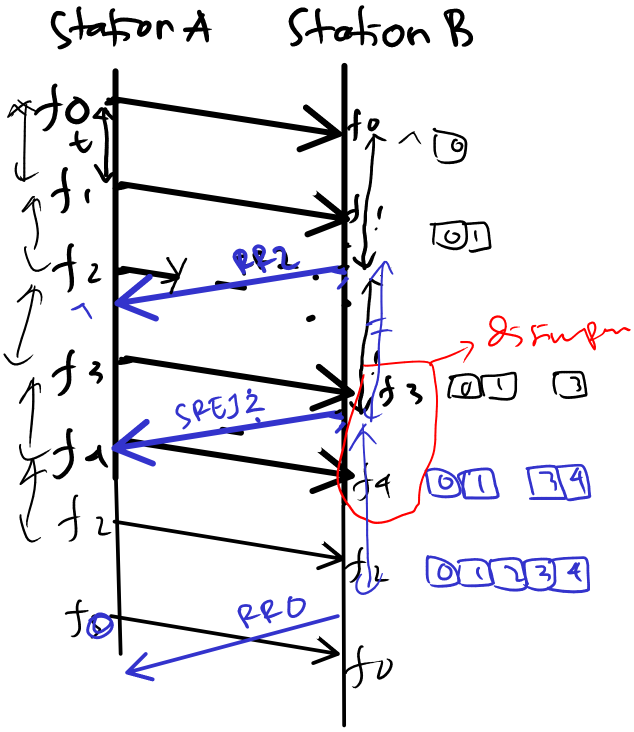
4. **[20 poin]** Dilakukan pertukaran informasi dari *station* A ke *station* B berupa pengiriman 5 *frame* secara berurutan (*frame* 0, *frame* 1, *frame* 2, *frame* 3 dan *frame* 4). Jika terjadi *lost* saat pengiriman *frame* 2, ilustrasikan pertukaran informasi yang terjadi dengan asumsi
   a. *Error control* yang digunakan adalah **go-back-N ARQ**.
   b. *Error control* yang digunakan adalah **Selective-reject ARQ**.



a



b


Station A
Station B
f0
t
f1
f2
RR2
f3
SREJ2
f4
f2
RR0
f0
0
0 1
3
0 1 3 4
0 1 2 3 4

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

Flag	Address	Control	Information	FCS	Flag
8 bits	8 extendable	8 or 16	Variable	16 or 32	8

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

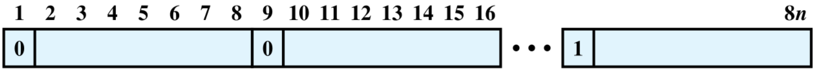
After bit-stuffing:

1111101111101101111101011111010

Figure 7.8 Bit Stuffing

Address Field

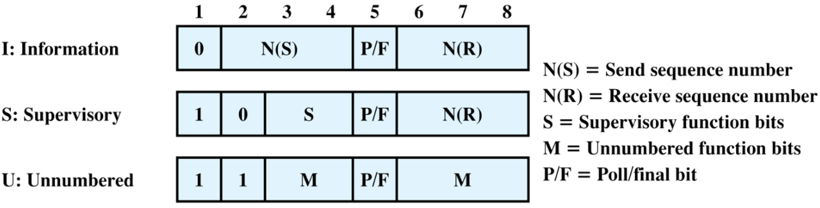
- identifies secondary station that sent or will receive frame
- usually 8 bits long
- may be extended to multiples of 7 bits
  - LSB indicates if is the last octet (1) or not (0)
- all ones address 11111111 is broadcast



(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 and FCS Fields

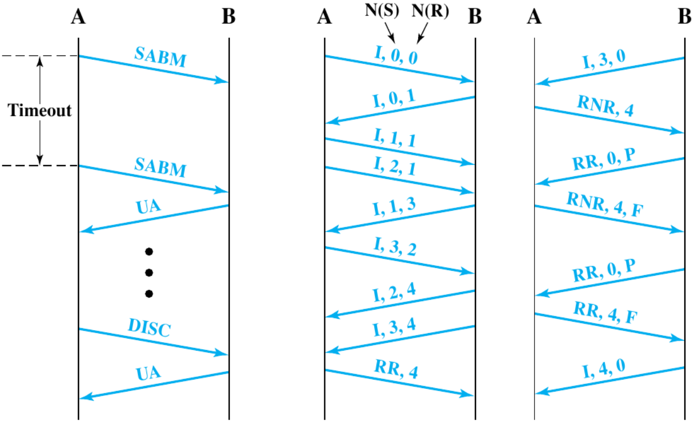
- Information Field
  - In information and some unnumbered frames
  - Must contain integral number of octets
  - Variable length
- Frame Check Sequence Field (FCS)
  - Used for error detection
  - Either 16 bit CRC or 32 bit CRC

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 requested or fault noted

HDLC Operation Example

N(S) = Sending Sequence Number | N(R) = Receive Sequence Number

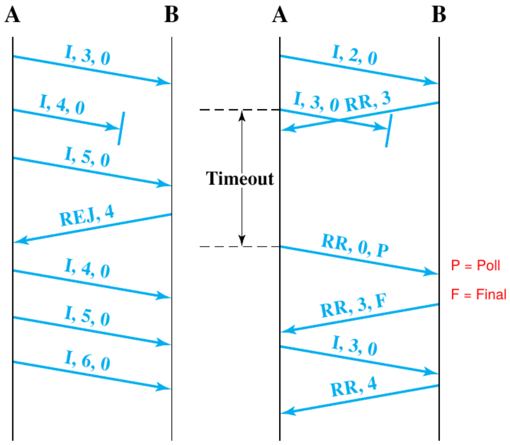


(a) Link setup and disconnect (b) Two-way data exchange (c) Busy condition

P = Poll

F = Final

HDLC Operation Example



(d) Reject recovery (e) Timeout recovery

Summary

- Introduced need for
- Flow control
- Error control
- HDLC

Tugas Mandiri

- Stallings, W. (2014). Data and Computer Communications, 10th Edition, New Jersey: Upper Saddle River
  - Chapter 7 Data Link Control Protocols
- Gupta, P. C. (2006). Data Communications and Computer Networks. New Delhi: Prentice Hall of India
  - Chapter 5 Error Control
- Tanenbaum, A. S. & Wetherall, D. J. (2013). Computer Networks, Fifth Edition. London: Pearson.
  - Chapter 3 The Data Link Layer

Tugas Terstruktur

Tampilkan Tugas 6