Part I Syllabus

Lecture	Date	Subject
1	10/08/2016	Introduction
2	10/08/2016	Layered network architecture & Physical resilience
3	17/08/2016	Data link layer – flow control
4	17/08/2016	Data link layer – error control
5	**24/08/2016**	**Data link layer – HDLC**
6	24/08/2016	Local area network – introduction
7	31/08/2016	Local area network – MAC
8	31/08/2016	Local area network – Ethernet
9	07/09/2016	Local area network – WLAN
10	07/09/2016	Packet switch network - Introduction
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12	14/09/2016	Review and examples

Lost in Translation

CE3005/CPE302 Computer Networks

Lecture 4

High-Level Data Link Control (HDLC)

Contents

- **High-Level Data Link Control (HDLC)**
  - Features and functions
  - Station Type
  - Channel Configuration
  - Frame Format
  - HDLC Operations: frame flow
  - Bit stuffing
- **Overview of Data Link Layer**
  - Summary table

Data Link Control Protocols

- **Advance Data Communication Control Procedures (ADCCP):**
  - ANSI X3.66 adopted by the US National Bureau of Standards (FIPS PUB 71-1)
- **Link access procedure balanced (LAP-B)**
  - Adopted by CCITT, a part of x.25
- **Synchronous data link control (SDLC): IBM**
- **Point-to-Point Protocol (PPP)**
  - RFC 1661
- **High level data link control (HDLC):**
  - ISO- 33009/ISO-4335, most widely used

HDLC Features

- **Reliable protocol**
  - Selective Repeat or Go-Back-N
- **Full-duplex communication**
  - Receive and transmit at the same time
- **Bit-oriented protocol**
  - Use bits to stuff flags occurring in data
- **Flow control**
  - Adjust window size based on receiver capability
- **Synchronization**
  - physical layer clocking and synchronization to send and receive frames

HDLC Overview

- **Defines three types of stations**
  - Primary
  - Secondary
  - Combined
- **Defines three types of data transfer mode**
  - Normal Response mode
  - Asynchronous Response mode
  - Asynchronous Balanced mode
- **Three types of frames**
  - Unnumbered
  - Information
  - Supervisory

HDLC: Three Types of Stations

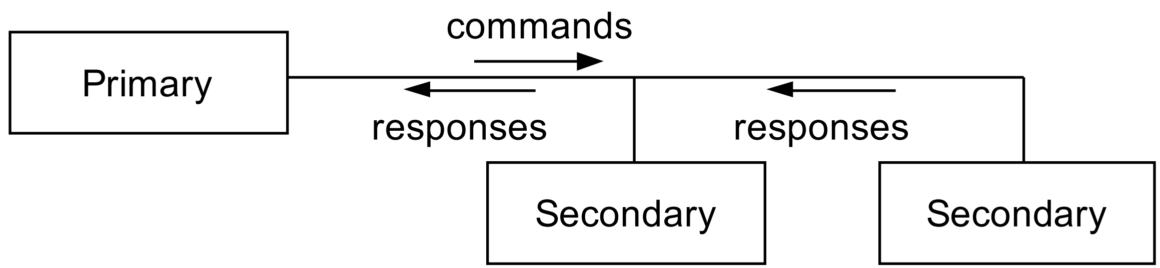
- **Primary station**
  - Has the responsibility of controlling the operation of data flow the link.
  - Handles error recovery
  - Frames issued by primary station called *commands*.
- **Secondary station**
  - Operates under the control of the primary station.
  - Frames issued by a secondary station are called *responses*.
  - The primary station maintains a separate logical link with each secondary station.
- **Combined station**
  - Acts as both as primary and secondary station.
  - Does not rely on other for sending data

HDLC: Channel Configuration

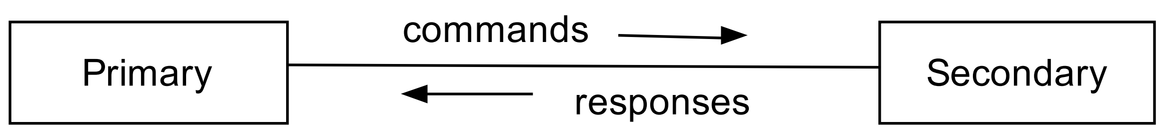
- **Unbalanced Configuration**
  - Used with one primary and one or more secondary stations.
  - Supports full duplex and half duplex operation.
- **Symmetrical (hardly used in practice)**
  - Essentially, two logical stations + unbalanced channels.
- **Balanced Configuration**
  - Communication between two combined stations.
  - Mostly with full duplex point-to-point channels.
  - The most commonly used one in practice.

HDLC: Channel Configuration

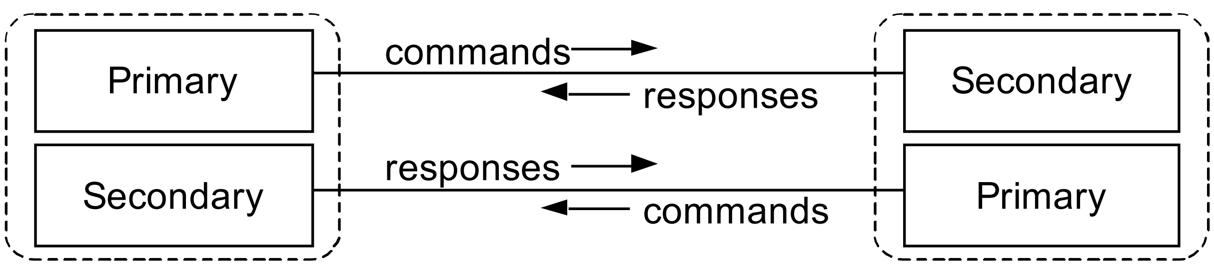
Unbalanced (point-to-multipoint)



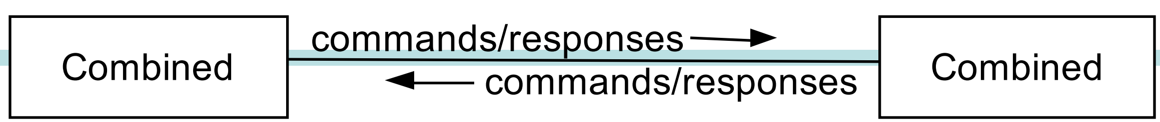
Unbalanced (point-to-point)



Symmetrical



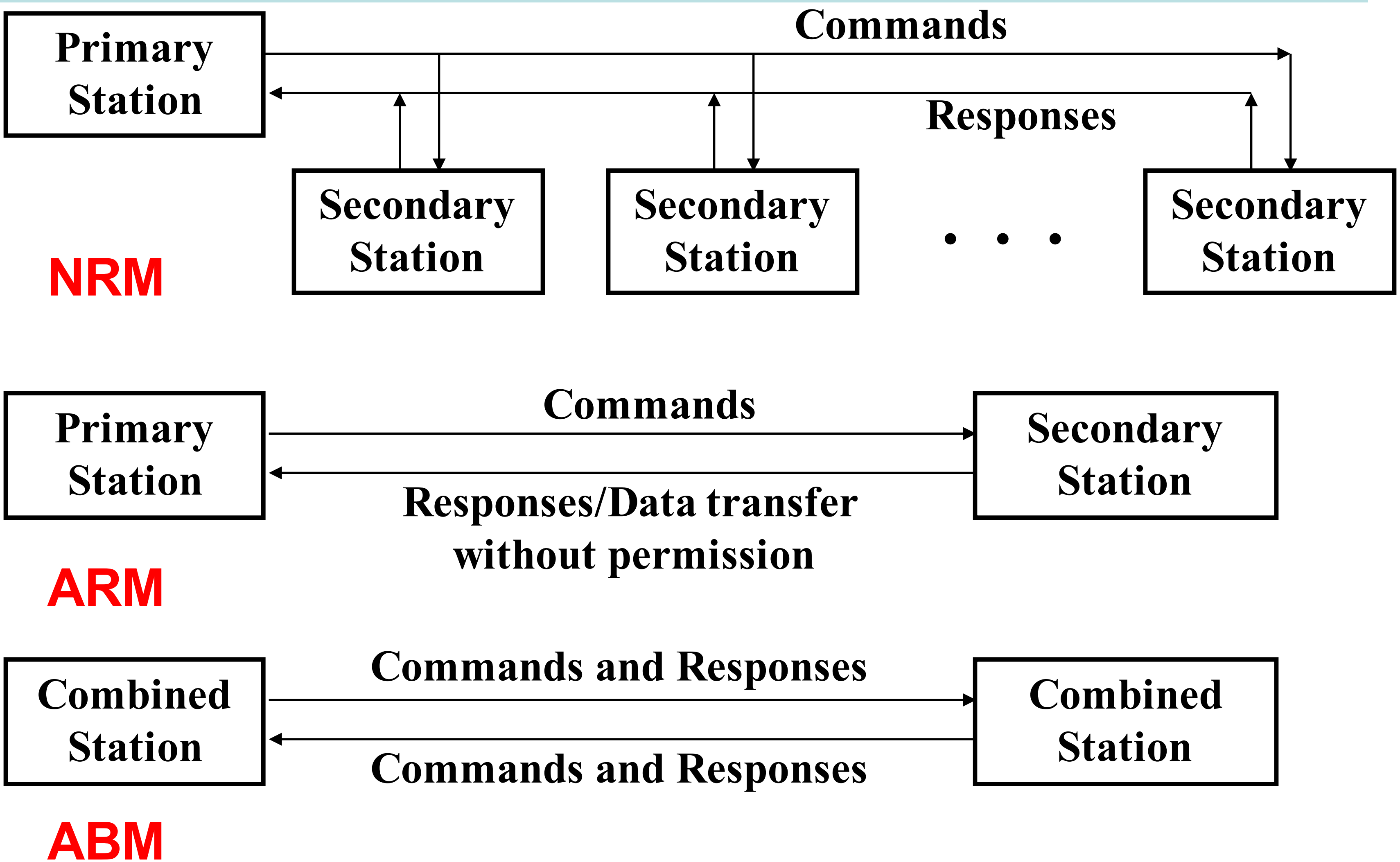
Balanced



HDLC: Modes for Data Transfer

- **Normal Response Mode (NRM)**
  - Mainly used in terminal-mainframe networks.
  - Secondaries can only transmit when specifically instructed by the primary station in response to a polling
  - Unbalanced configuration, good for multi-point links
- **Asynchronous Response Mode (ARM)**
  - Same as NRM except that the secondaries can initiate transmissions without direct polling from the primary
  - Reduces overhead as no frames need to be sent to allow secondary nodes to transmit
  - Transmission proceeds when channel is detected idle , used mostly in point-to-point-links
- **Asynchronous Balanced Mode (ABM)**
  - Mainly used in point-to-point links, for communication between combined stations

HDLC: Modes of Data Transfer



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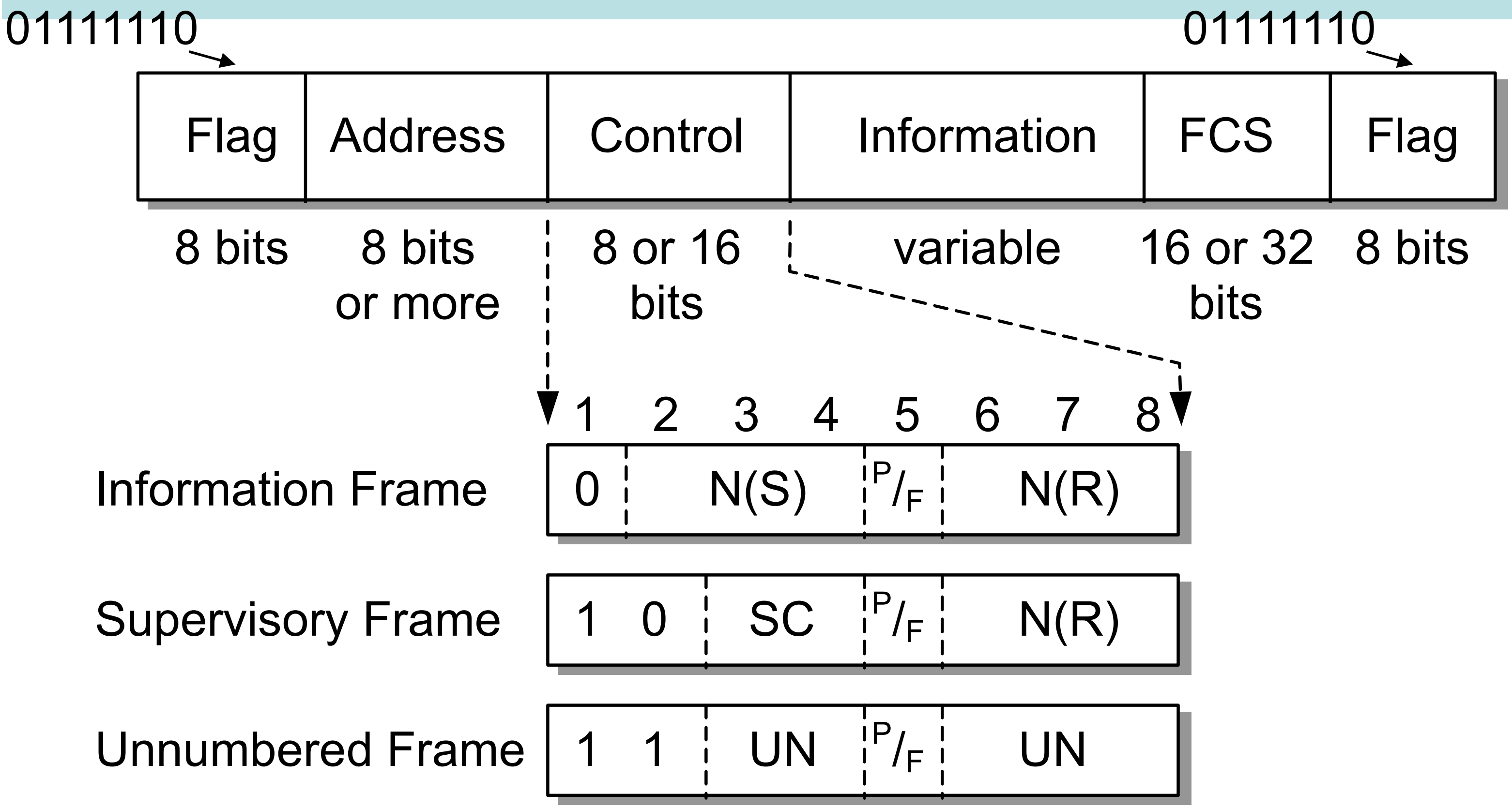
HDLC: Frame Format

- Assumes synchronous transmission.
- Frames are enclosed by flags (01111110)
- There are three types of frames:
  - Information Frames: used to transfer data.

    N(S) carries the frame number (seq. #)

    N(R) provides the acknowledgement (with seq. #)
  - Supervisory Frames: used for positive and negative acknowledgements.
  - Unnumbered Frames: are used for link connection management, e.g. setting up the connection and protocol parameters.

HDLC: Frame Format



SC = Supervisory Code (2 bits)
UN = Unnumbered Code (5 bits)

N(S) = Send Sequence Number
N(R) = Receive Sequence Number

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Poll/Final Bit

- **Use depends on context**
- **Command frame**
  - P bit : used for poll from primary
  - 1 to solicit (poll) response from peer
- **Response frame**
  - F bit : used for response from secondary
  - 1 indicates response to soliciting command

HDLC: I-frame

- **Contains the sequence number of transmitted frames and a piggybacked ACK**

1	2 3 4	5	6 7 8
0	N(S)	P/F	N(R)

HDLC: S-frame

- **Used for flow and error control**

1	2	3 4	5	6 7 8
1	0	SC	P/F	N(R)

- RR (00) --- receive ready
- RNR (01) --- receive not ready
- REJ (10) --- reject on frame N(R)
- SREJ (11) --- selective reject on N(R)

HDLC: Supervisory Frames (SC)

- **RR: Receive Ready (SC=00):**
  - Station sends a RR frame to indicate it is ready to receive data.
  - Also used to acknowledge received frames.
- **REJ: Reject (SC=01):**
  - Used to provide negative acknowledgement in go-back-n ARQ.
- **RNR: Receive Not Ready (SC=10):**
  - To pause the flow of information frames.
- **SREJ: Selective Reject (SC=11):**
  - Used to provide negative acknowledgement in selective reject ARQ.

HDLC: U-frame

- **Mode setting, recovery, connect/disconnect**

1	2	3	4	5	6	7	8
1	1	M		P/F	M		

Unnumbered function bits

HDLC: Unnumbered Frames (UN)

- **SARM**: Set Asynch. Balanced Mode (11000)
  - To establish an ARM connection
- **UA**: Unnumbered ACK (00110)
  - To acknowledge a received command
- **DISC**: Disconnect (00010)
  - To terminate a connection
- **SARME**: Set ABM Extended (11110)
  - To establish an extended ARM connection (use 16-bit control field)

– **More** on textbook

HDCL: Address Field

- Each station has unique address.
- In unbalanced configuration, the address is always of the secondary station.
- In balanced configuration, the address is:
  - If it is a command (i.e., poll bit is set in the frame), then the address is of the destination station.
  - If it is a response (i.e., final bit is set in the frame), the address identifies the sending station.
  - If the P/F bit is not set, the address identifies destination station.
- More to be covered in LAN

HDLC: Information Field

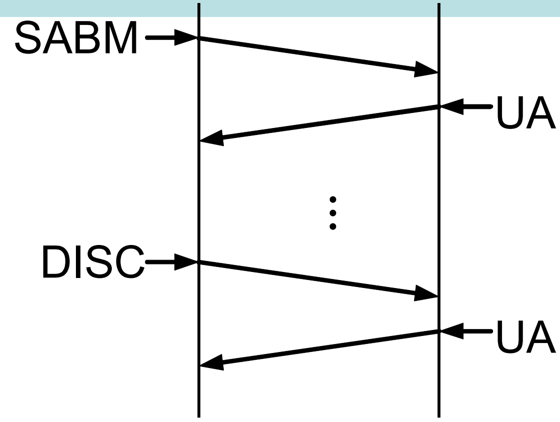
- Only in information and some unnumbered frames
- Must contain integral number of octets
- Variable length

Frame Check Sequence Field

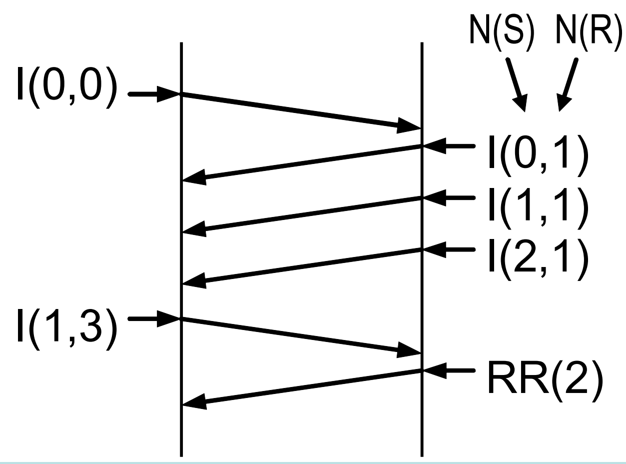
- **FCS**
  - Error detection
  - 16 bit CRC
  - Optional 32 bit CRC

HDLC Operations

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



(a) Connection establishment and termination



(b) Data exchange

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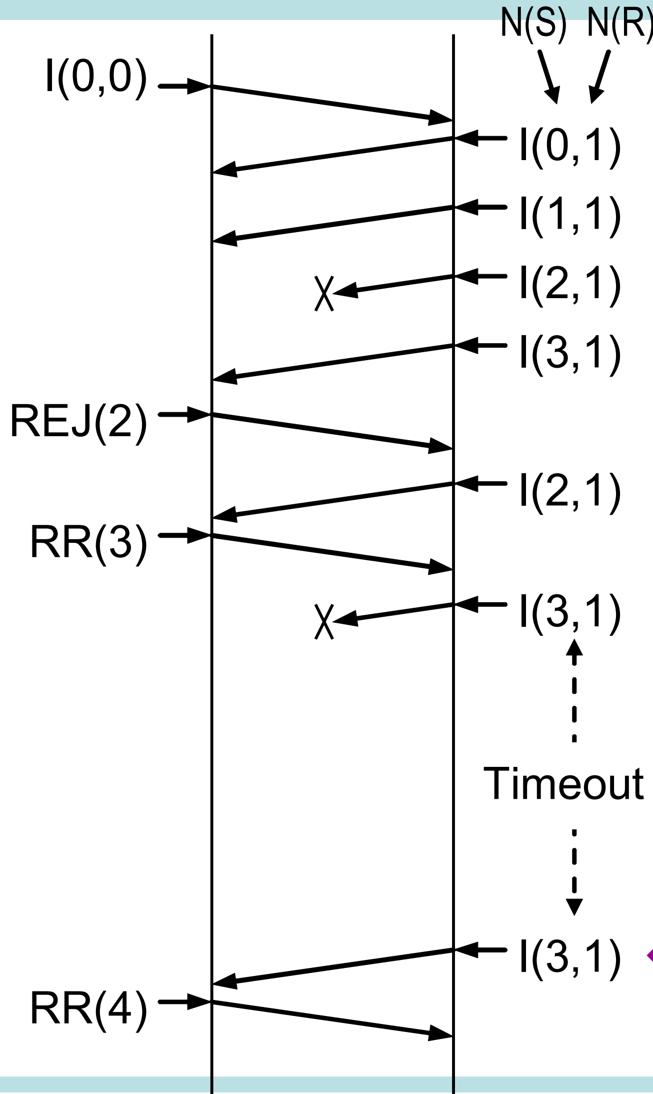
HDLC Operations: Example



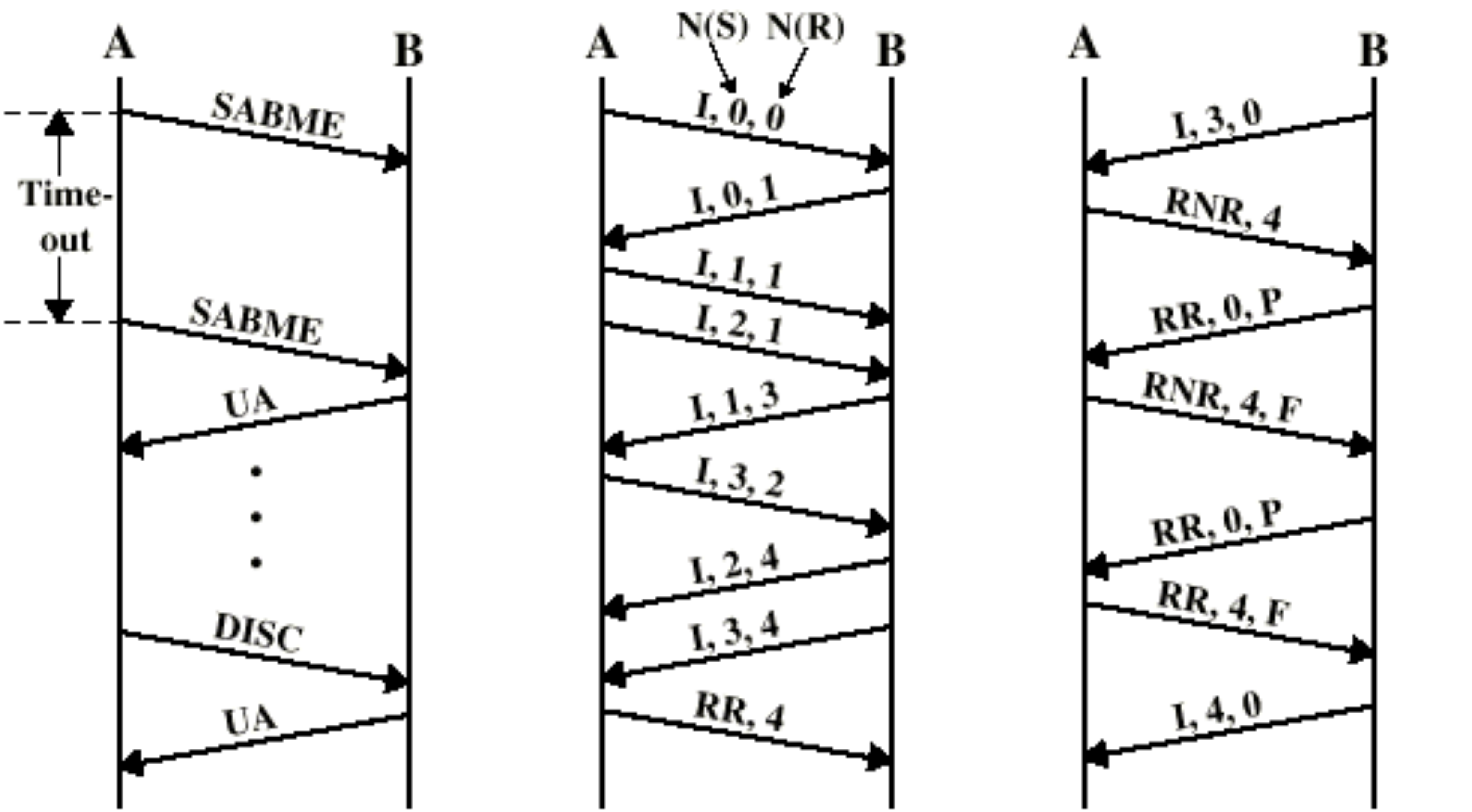
Frame #2 was missing, go back #2 → REJ(2)

Now I'm ready → for frame #3 RR(3)

← No ACK received for frame #3, retransmit frame #3

(c) Data exchange on a noisy channel

Additional Examples



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

HDLC: Bit Stuffing

- What happens if the data/control fields contains flag sequence, i.e., 01111110?

- Bit stuffing is used to avoid confusion.
  - 0 is inserted at the sending end 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.

Bit Stuffing in HDLC: Examples

Example-1: More than five consecutive 1's

First tx bit → Data

0 0 1 1 1 1 1 1 1 0 0

First tx bit → Transmitted Data

0 0 1 1 1 1 1 0 1 1 0 0

Stuffed bit

Example-2: Five consecutive 1's

First tx bit → Data

0 1 1 1 1 1 0 1 1 0 0

First tx bit → Transmitted Data

0 1 1 1 1 1 0 0 1 1 0 0

Stuffed bit

Example:

0 1 1 1 1 1 1 0 1 1 1 1 1 1 1 0 …

0 0

HDLC Derivatives

- **Many modern data link protocols follow HDLC standard, including:**
  - *LAPB* (Link Access Procedure-Balanced) used in X.25
  - *LAPF-Core* (LAP for Frame Mode Bearer Services) used in Frame Relay
  - *PPP* (Point-to-point Protocol, RFC 1661-1663) used in the Internet
  - *LLC* (Logical Link Control) used in LANs (Local Area Networks)

Overview of Data Link Layer

		Protocol Description	Link Utilization: Percentage of the time during which the link transmits useful information.	Bits for SN	Max Window Size	SN Range	Note
Flow Control	Stop-and-Wait	• Source transmits frame • Destination receives frame and replies with ACK • Source waits for ACK before sending next frame • Destination can stop flow by not sending ACK	$U = \frac{1}{1+2a}$	1	$W = 1$		$a = \frac{T_{prop}}{T_{frame}}$ $T_{prop} = \frac{Distance}{c}$ $T_{frame} = \frac{Length}{Bit\ Rate}$ Note: • convert bytes to bits in calculation • unify all the units in calculation $U = \frac{T_{frame}}{T_{cycle}}$ $U = \frac{r}{R}$ Note: • U is normalized throughput • R is transmission rate • r is throughput
	Sliding Window	• Sender can send up to W frames without receiving ACK • ACK includes number of next frame expected	$U = \begin{cases} 1, & W \geq 1+2a \\ \frac{W}{1+2a}, & W < 1+2a \end{cases}$	k	2^k	$[0, 2^k - 1]$	
ARQ	Stop-and-Wait	• Destination sends an ACK if frame received correctly • Source transmits next frame if ACK is received; otherwise, if no ACK is received within timeout, resource retransmits the frame	$U = \frac{1-P}{1+2a}$	1	1		
	Go-Back-N	• Source transmits frames sequentially based on sliding window • Destination sends ACK normally for error-free frames; otherwise, it sends NAK • Source retransmits that frame with all subsequent frames if NAK is received	$U = \begin{cases} \frac{1-P}{1+2aP}, & W \geq 1+2a \\ \frac{W(1-P)}{(1+2a)(1-P+WP)}, & W < 1+2a \end{cases}$	k	$2^k - 1$	$[0, 2^k - 1]$	
	Selective-Reject	• Receiver informs transmitter of rejected frame n by sending 'SREJ n' • After receiving an erroneous frame, subsequent frames are accepted by receiver and buffered	$U = \begin{cases} 1-P, & W \geq 1+2a \\ \frac{W(1-P)}{(1+2a)}, & W < 1+2a \end{cases}$	k	2^{k-1}	$[0, 2^k - 1]$	

Learning Objectives

- **HDLC**
  - HDLC Overview
  - Framework format: different fields
  - SN/RN labeling in HDLC over noisy channel
- **DLL Overview**
  - Flow Control
  - Error Control
  - HDLC Operations