HDLC & PPP & LLC

- Data Link Layer

Chapter 11 & 12 of ***Data Communications and Networking, 4th Edition, Behrouz A. Forouzan (ISBN: 0-07-251584-8)***

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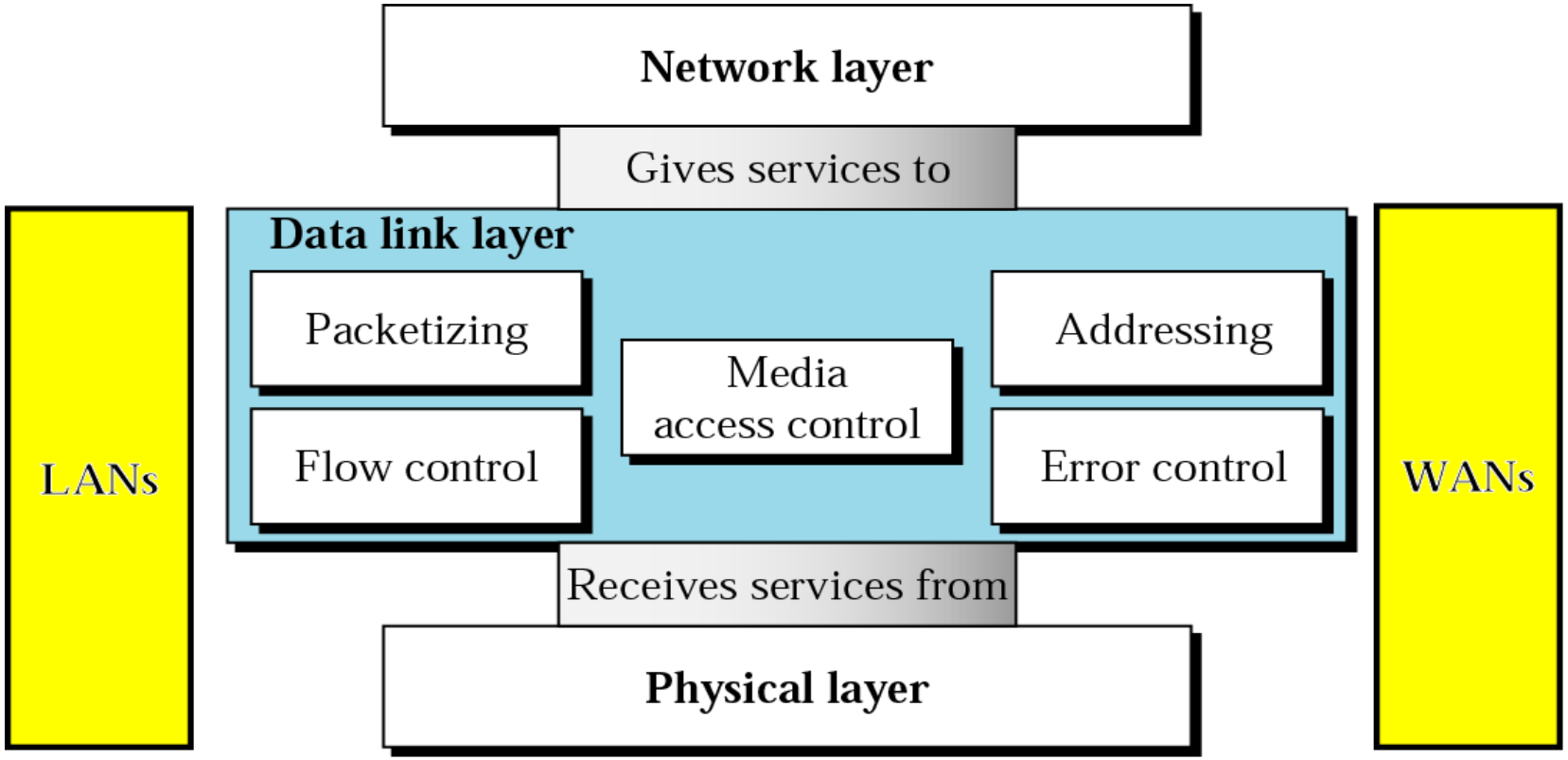
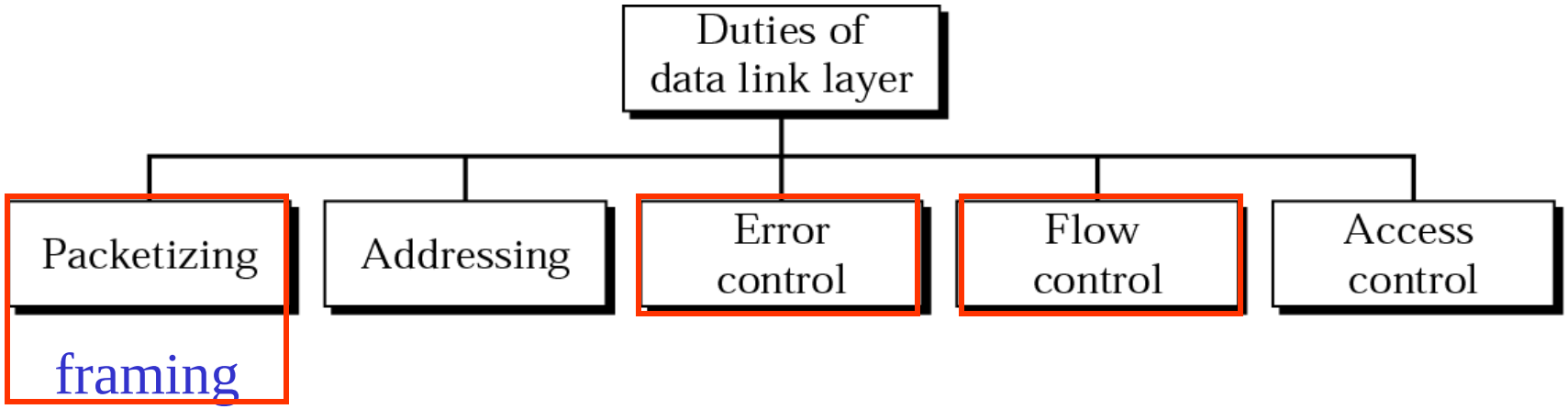
Review of of the data-link layer



Review of Data link layer duties



- **Data link protocols have three functions:**
  - Error Control**: Detecting and correcting transmission errors. (Error & flow)**
  - Media Access Control**: Controlling when computers transmit. Who should send now(Access control)**
  - Message Delineation**: Identifying the beginning and end of a message. (Packetizing & Addressing)**

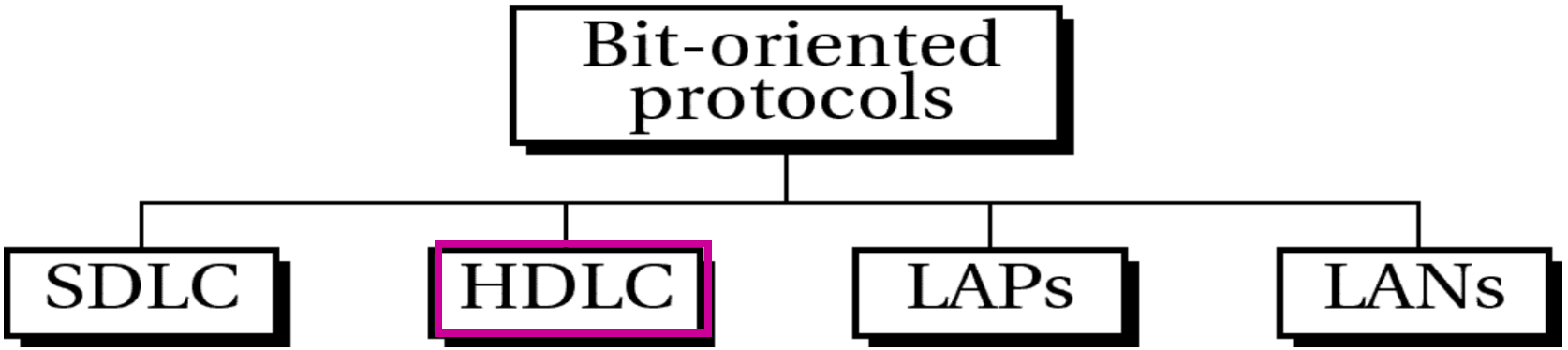
Review of 에러제어

- 전송중 발생된 데이타 프레임 에러의 검출 및 복구
- 비트에러 검출 :
  - - Parity Check
  - - Block sum check
  - - Cyclic Redundancy Check (CRC)
- 에러 검출시 자동 재전송 요청 (Automatic Repeat Request ; ARQ)
  - - Stop-and-Wait ARQ
  - - Go-back-N ARQ
  - - Selective Repeat ARQ
- 에러 검출시 수신단에서 에러 복구 : forward error correction

Review of 흐름제어

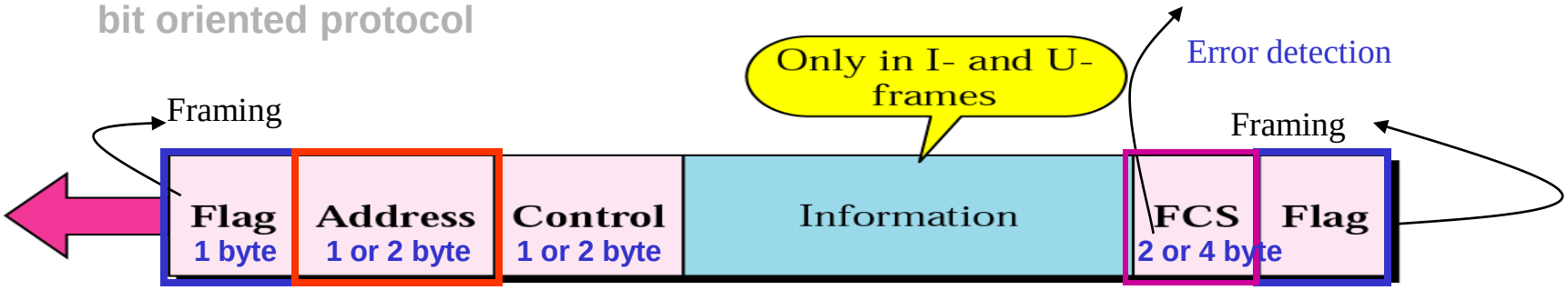
- 데이타 전송시 수신측에서는 데이타를 버퍼에 일시저장
- 수신측 데이타 버퍼가 넘치지 않도록 전송 속도를 조절
- X-ON/X-OFF방식 :
  - - Control-S (X-OFF), Control-Q (X-ON)
  - - Receive-Ready (RR), Receive-Not-Ready (RNR)
  - - 단순함의 장점
  - - 전파지연 (propagation delay)가 길어질 경우 링크효율의 감소
- Sliding Window 방식
  - - 수신측으로부터의 응답없이도 한번에 여러개의 프레임을 전송
  - - 전파지연 (propagation delay)가 길어질 경우에 링크효율의 향상
  - - 최대 전송 프레임 갯수를 제한 : Window Size

HDLC



In 1979, the ISO announces high-level data link control (HDLC), which was based on SDLC. Adoption of HDLC by the ISO committees led to its adoption and extension by other organizations. The ITU-T was one of the first organizations to embrace HDLC. Since 1981, ITU-T has developed a series of protocols called link access protocols (LAPs: LAPB, LAPD, etc.) all based on HDLC. Other protocols (frame relay, PPP, etc.) also derived from HDLC.

HDLC Frame Format



- **Flag: 8-bit sequence with a special bit pattern 01111110**
  - Identify both the beginning and end of a frame as a synchronization
  - Bit-stuffing needed within the information field
- **Address field: 1 byte (identifying 128 stations)**
  - If primary station to secondary: to destination
  - If secondary station to primary: from address
  - 7bits + 1 bit for extension

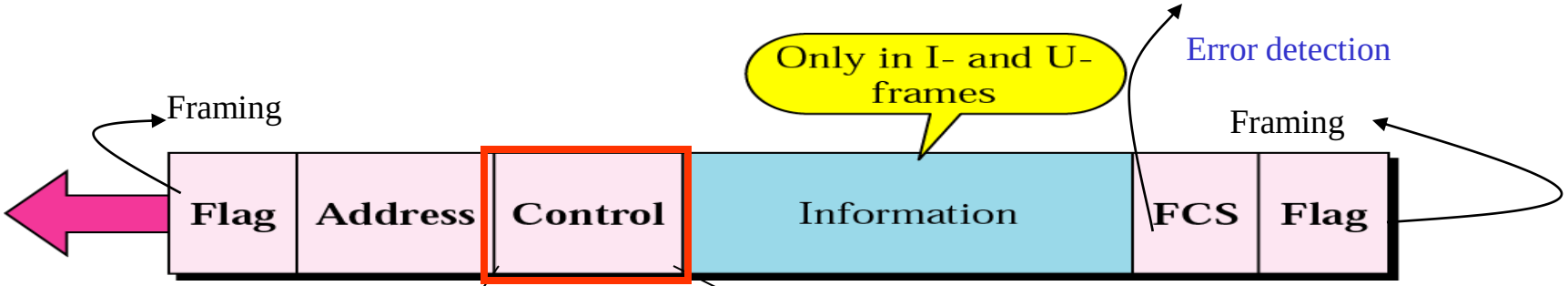
x	x	x	x	x	x	x	1

or

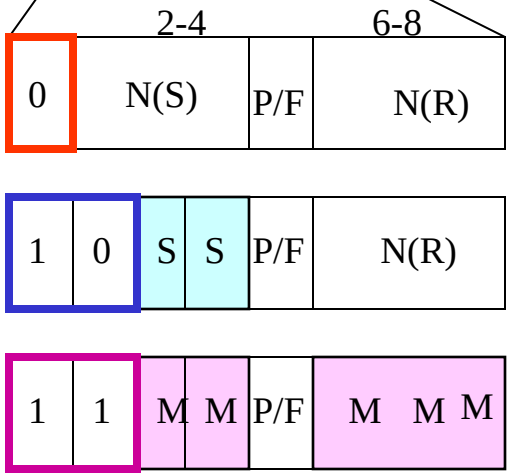
x	x	x	x	x	x	x	0	x	x	x	x	x	x	x	1

- **FCS:Either a 2- or 4-byte ITU-T CRC**

HDLC Frame Type



N(S): sequence number
N(R): seq. no. of expected frame (at receiver side)



Information frame
designed to carry user data (piggybacking)

S-Control frame
used for flow and error control

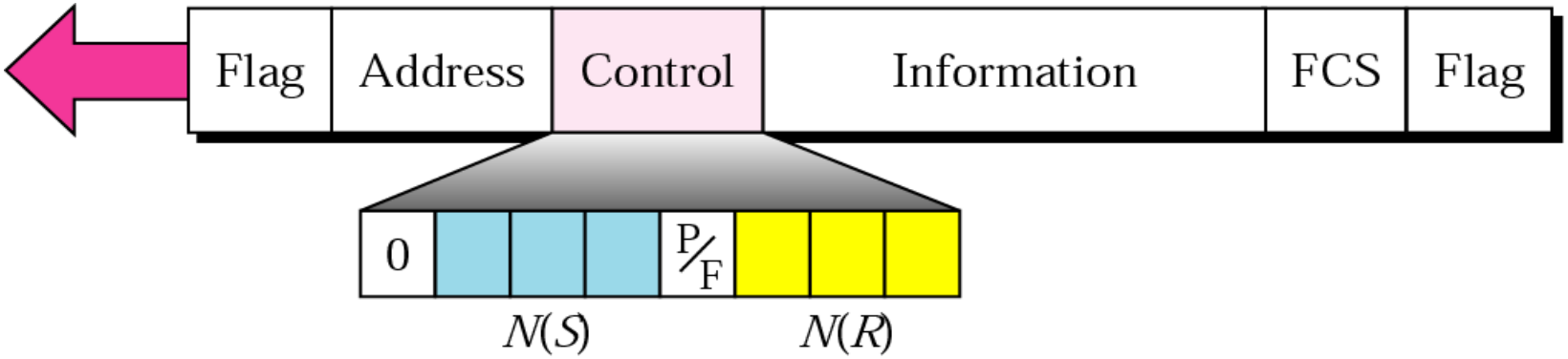
U-Control frame
used to initialize the connection (management & control)

Receive ready is an ACK; sent when there is no data to piggyback the ACK on

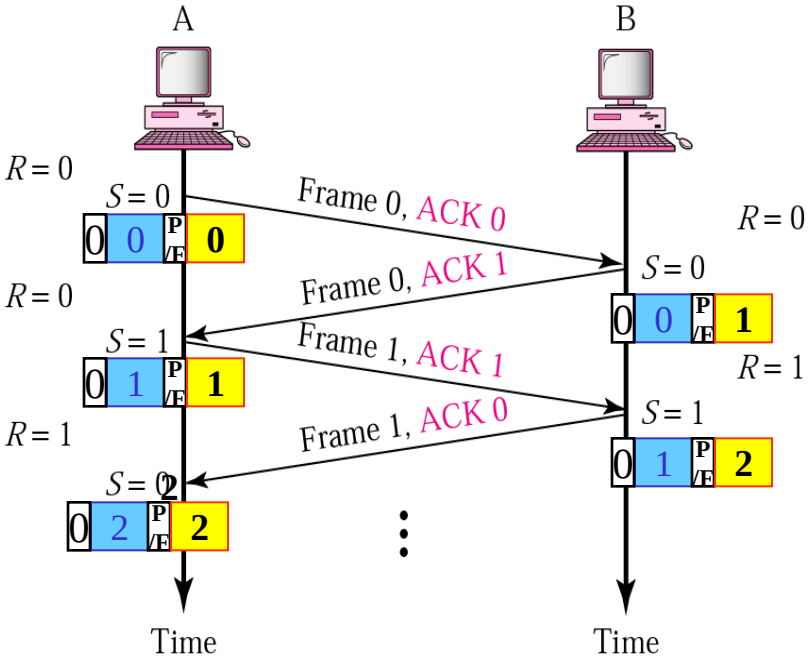
SS	Meaning
00	RR: Receive ready
01	Reject (NAK)
10	RNR (x-off)
11	SREJ (Sel. Rej.)

P/F: Poll/Final bit
-Poll (primary->secondary) contain destination address)
-Final (secondary->primary) (0: not final, 1: final)
Unnumbered frames are used to
set up connections, SABM, SABME, UA
E: Extended; control field is two bytes; N(S), N(R) is 7 bits each.

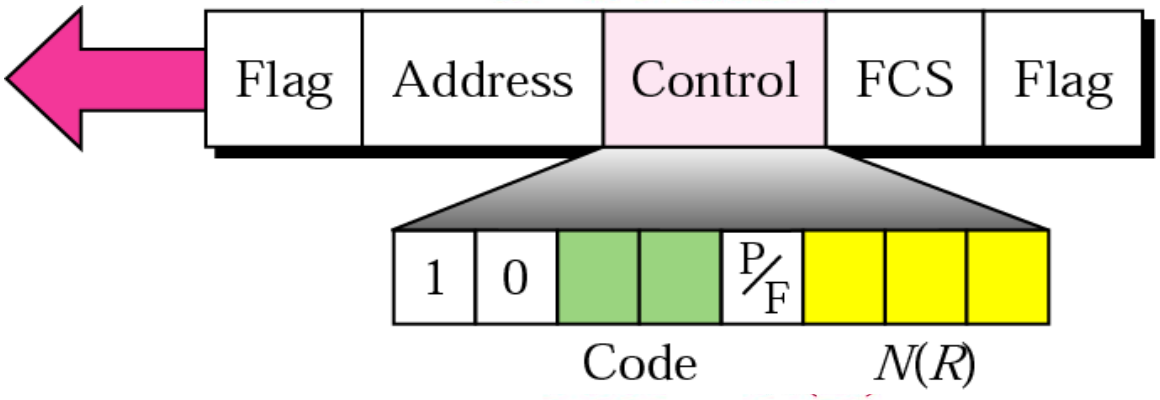
I-frame



- **Information frame designed to carry user data (piggybacking)**



S-Frame used for flow and error control

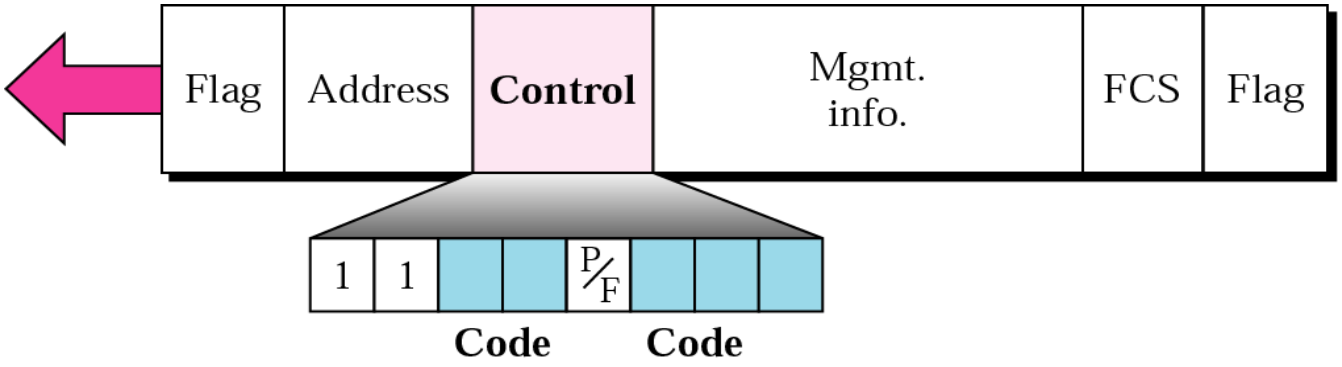


Code	Command	
00	RR	Receive ready
01	REJ	Reject
10	RNR	Receive not ready
11	SREJ	Selective-reject

- **RR**
  - ACK: when the receiver has no data to send
  - **(P->S)** Poll: primary asks the secondary if it has anything to send **(P=1)**
  - **(S->P)** Negative response to poll: secondary has nothing to send (F=1)
  - **(S->P)** Positive response to select: secondary is able to receive a transmission (F=1)
- **Reject**
  - Go-back-N ARQ Error correction (retransmission)
- **RNR:**
  - **ACK up to N(*R*) but no more until an RR**
  - **(P->S) Select: alerts the secondary (P=1)**
  - **(S->P) Negative response to select: unable to receive (F=1)**
- **Selective Reject:**
  - Negative ACK in a selective-repeat ARQ

U-frame

used to initialize the connection



- **Mode setting**
- **Unnumbered -exchange**
- **Disconnection**
- **Initialization**
- **miscellaneous**

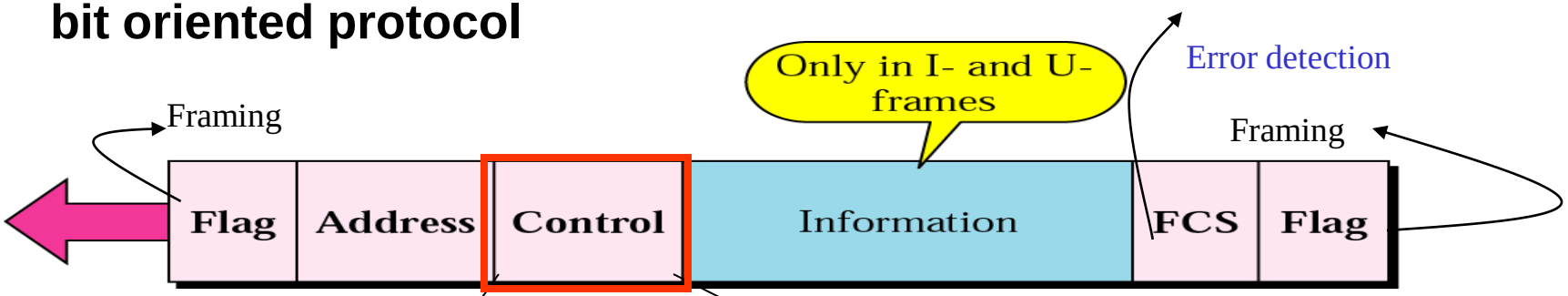
Code		Command	Response
00	001	SNRM	
11	011	SNRME	
11	100	SABM	DM
11	110	SABME	
00	000	UI	UI
00	110		UA
00	010	DISC	RD
10	000	SIM	RIM
00	100	UP	
11	001	RSET	
11	101	XID	XID
10	001		FRMR

Table 11.1 *U-frame control command and response*

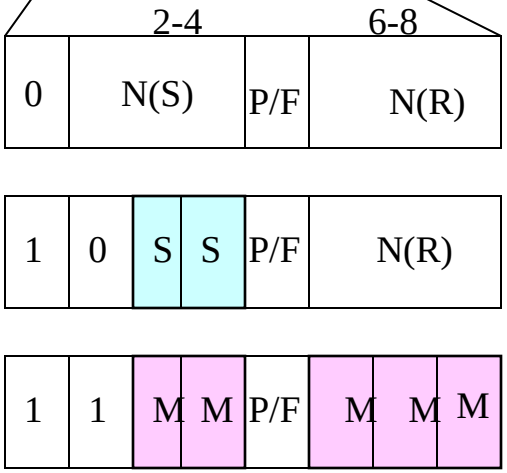
Code	*Command*	*Response*	*Meaning*
00 001	SNRM		Set normal response mode
11 011	SNRME		Set normal response mode, extended
11 100	SABM	**DM**	Set asynchronous balanced mode or **disconnect mode**
11 110	SABME		Set asynchronous balanced mode, extended
00 000	UI	**UI**	Unnumbered information
00 110		**UA**	**Unnumbered acknowledgment**
00 010	DISC	**RD**	Disconnect or **request disconnect**
10 000	SIM	**RIM**	Set initialization mode or **request information mode**
00 100	UP		Unnumbered poll
11 001	RSET		Reset
11 101	XID	**XID**	Exchange ID
10 001	FRMR	**FRMR**	Frame reject

Summary HDLC Frame Format

bit oriented protocol



N(S): sequence number
N(R): seq. no. of expected frame (at receiver side)



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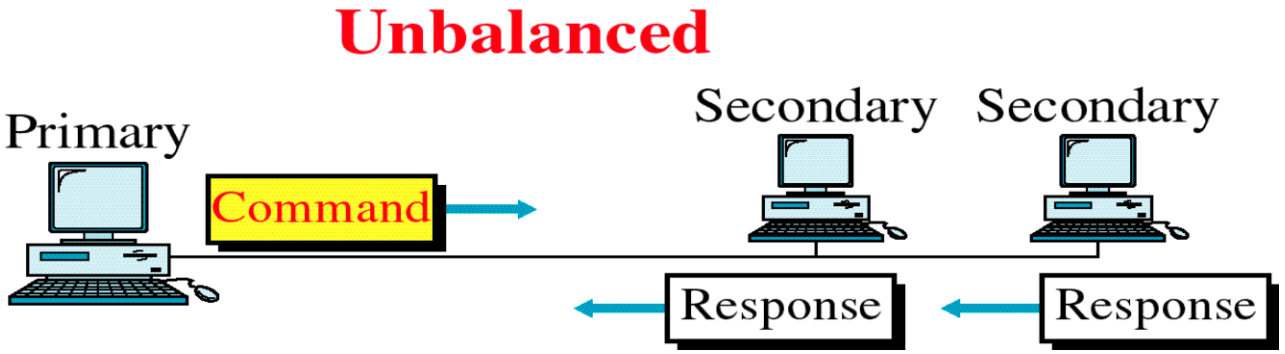
HDLC Configuration

Point-to-point & Point-to-multipoint

- **Normal Response Mode (NRM)**



- **Asynchronous Balanced Mode (ABM)**

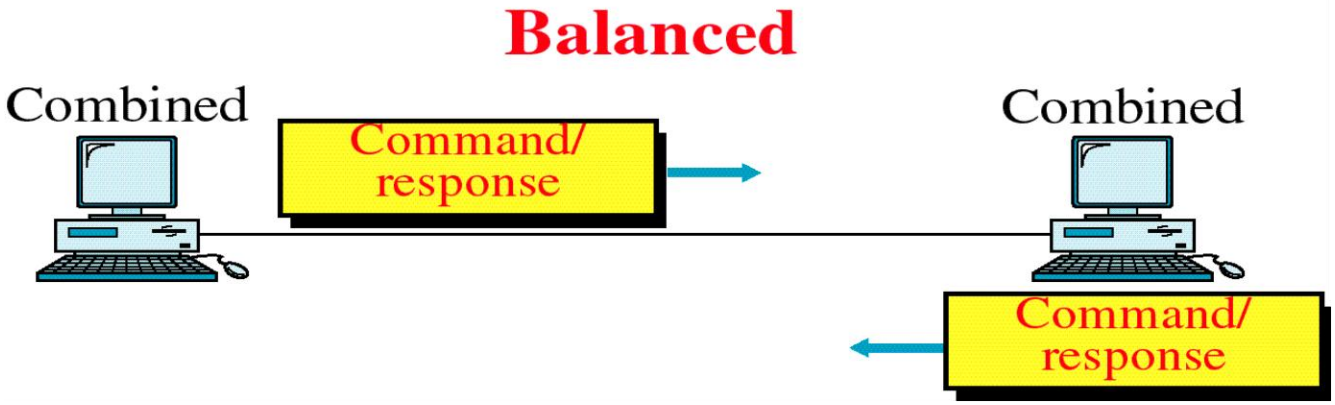
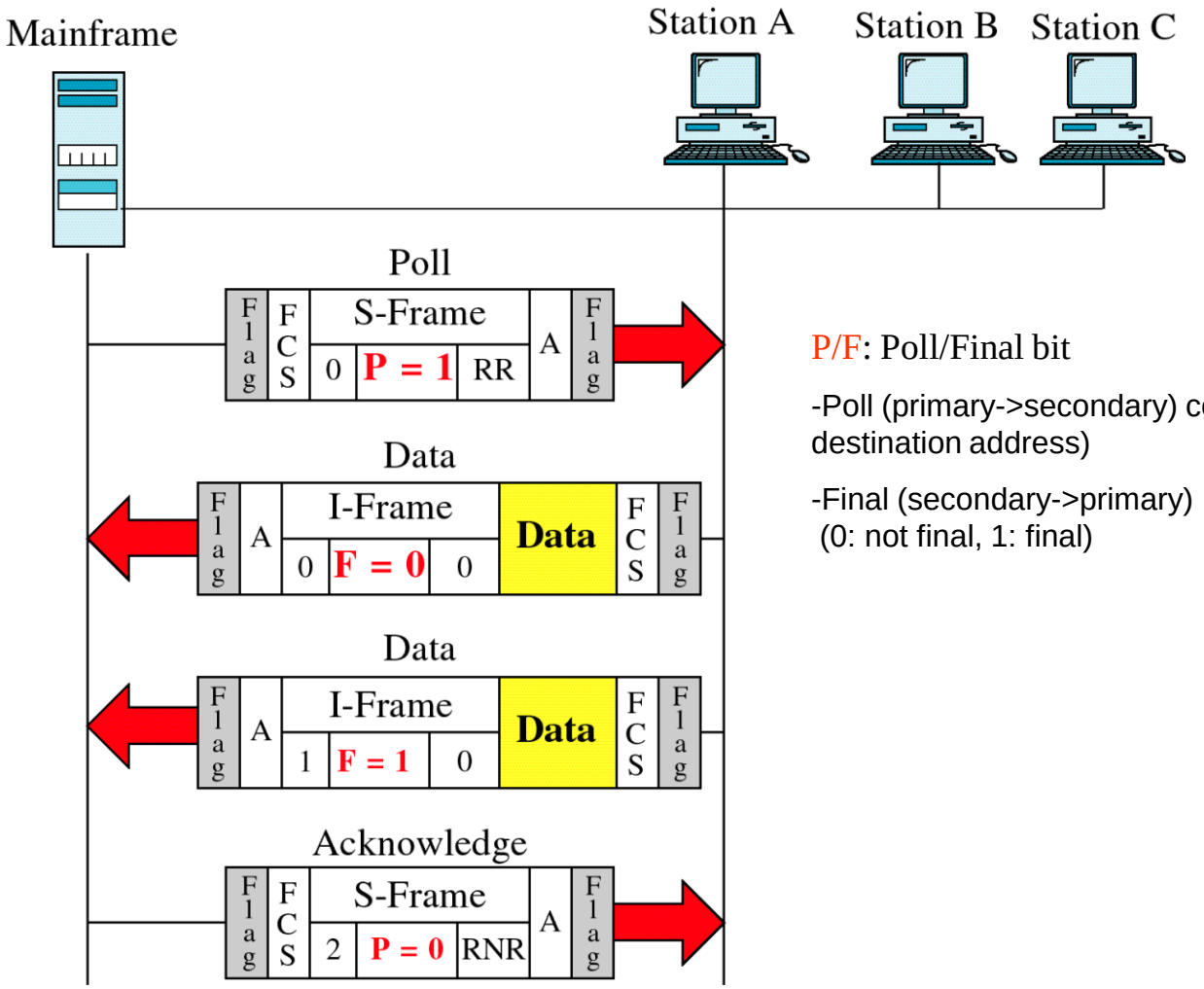


Figure 11-27

Polling Example



P/F: Poll/Final bit

-Poll (primary->secondary) contain destination address)

-Final (secondary->primary)
(0: not final, 1: final)

Figure 11-28

Selecting Example

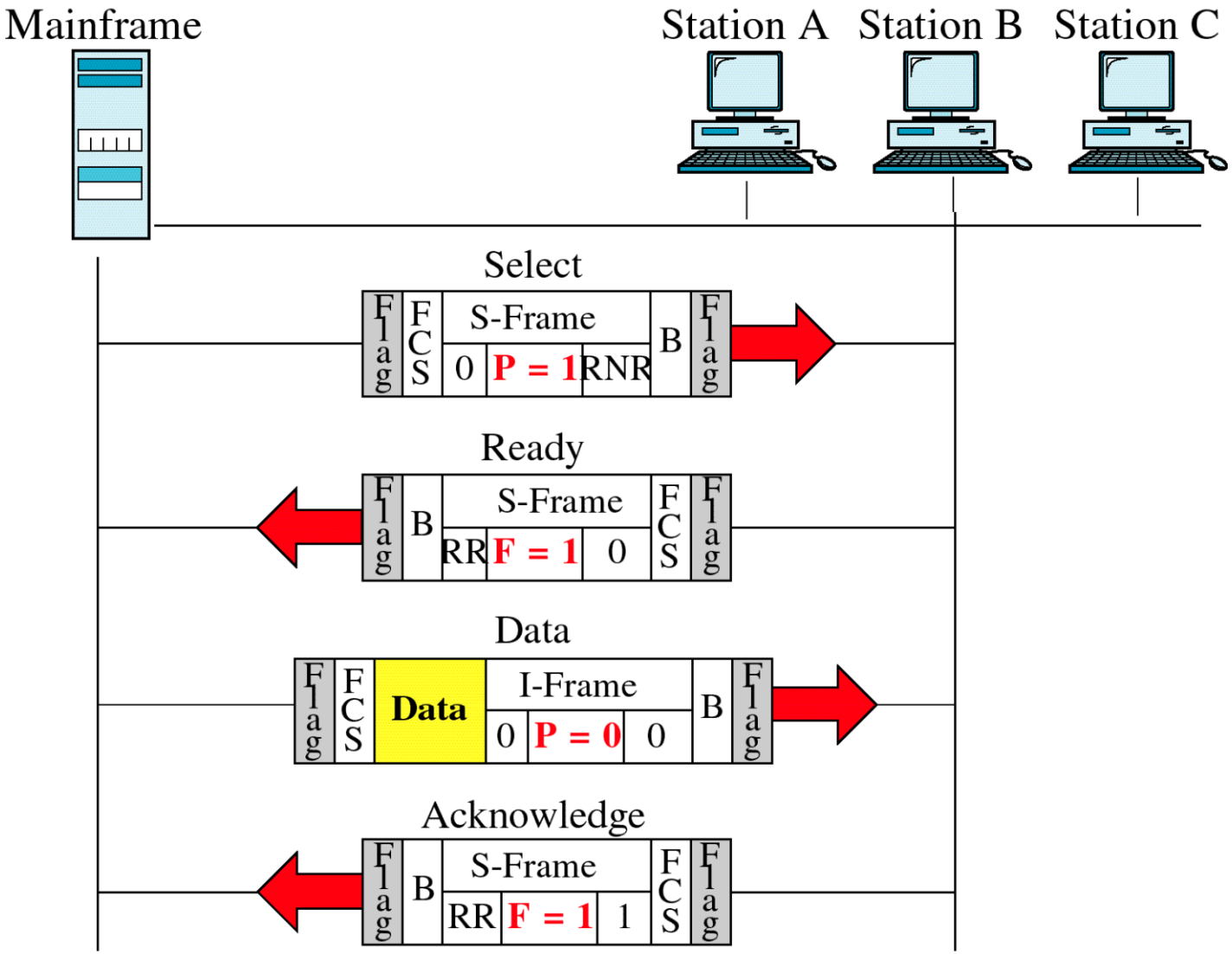


Figure 11-29

Peer-to-Peer Example

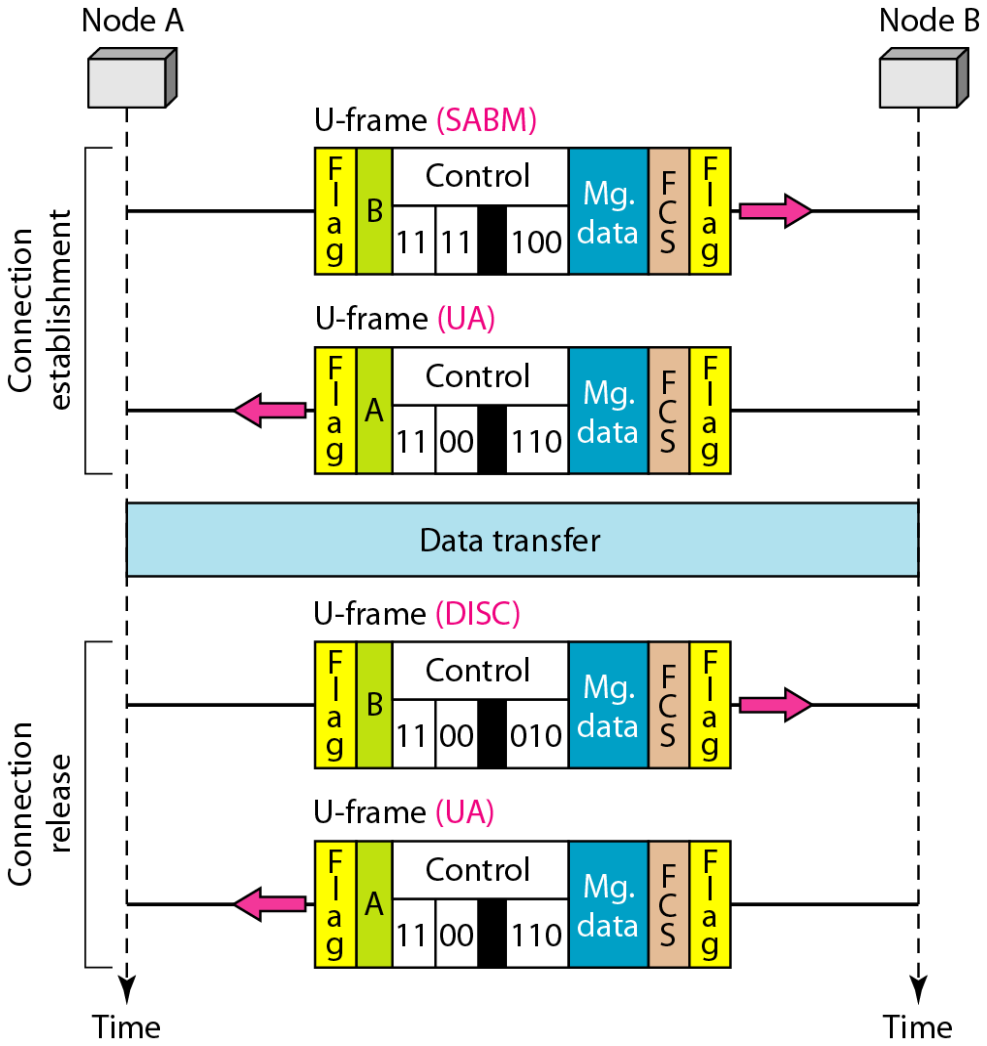


Figure 11-29-continued

Peer-to-Peer Example

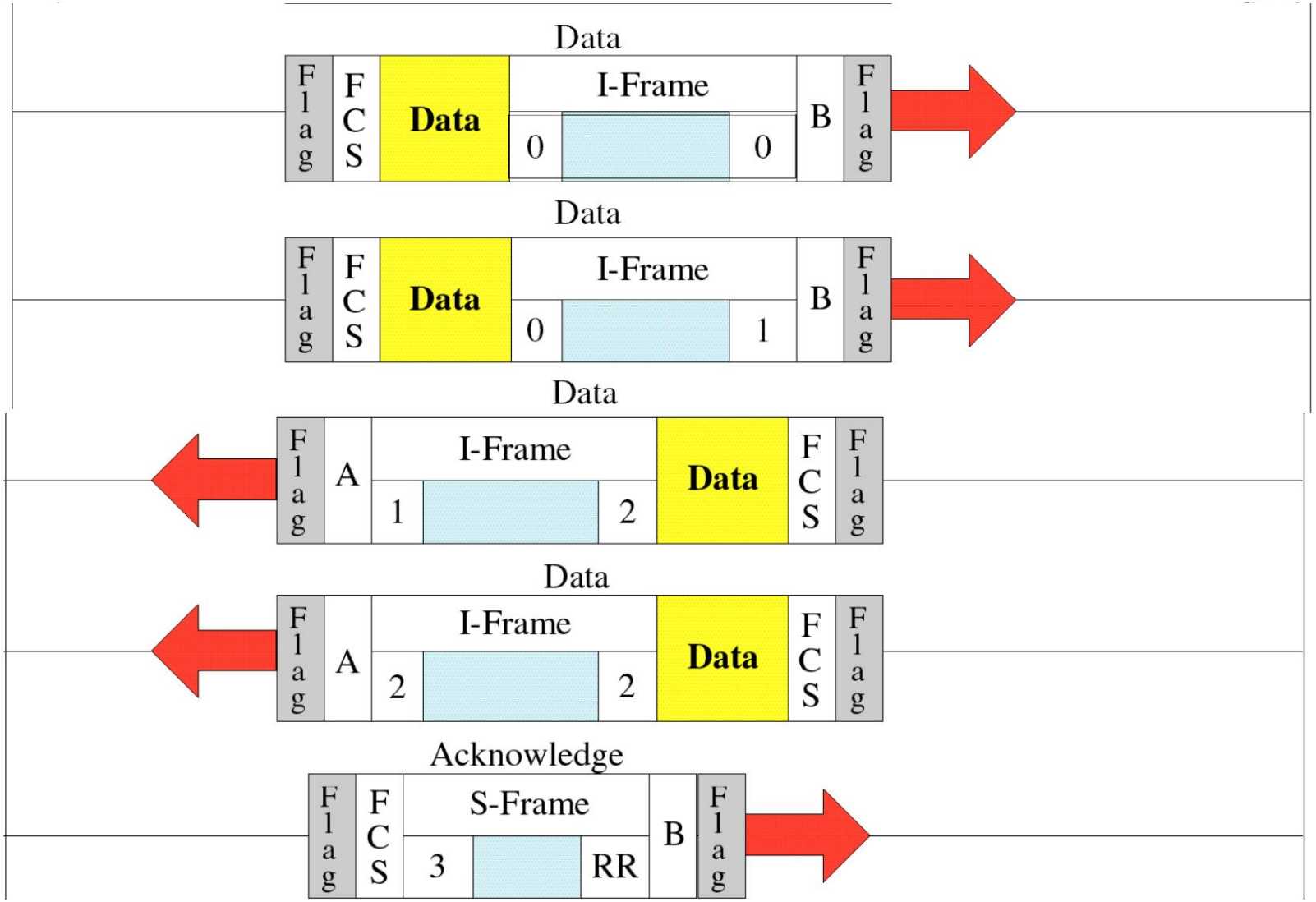


Figure 11.30 *Example of piggybacking without error*

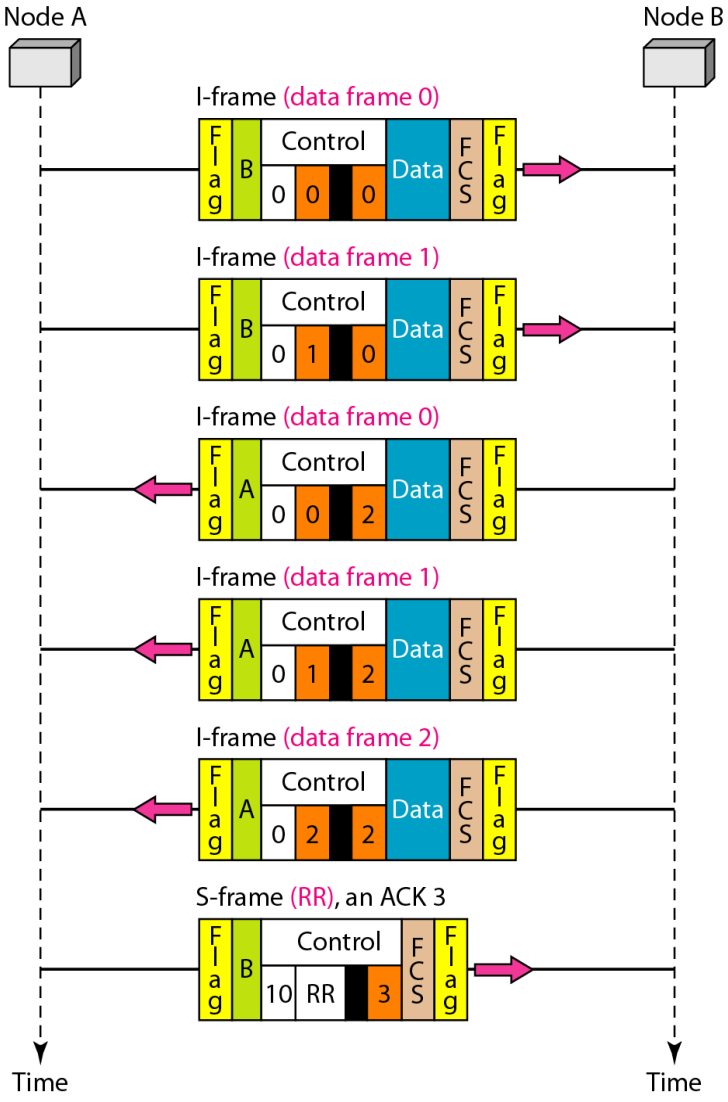
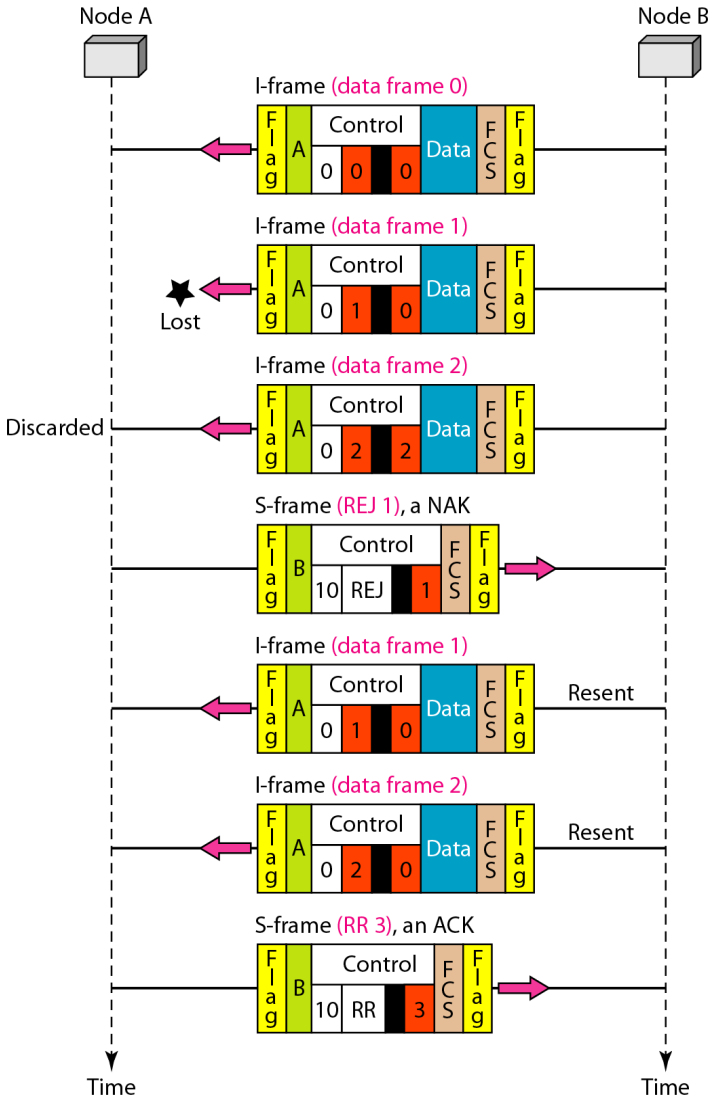


Figure 11.31 *Example of piggybacking with error*

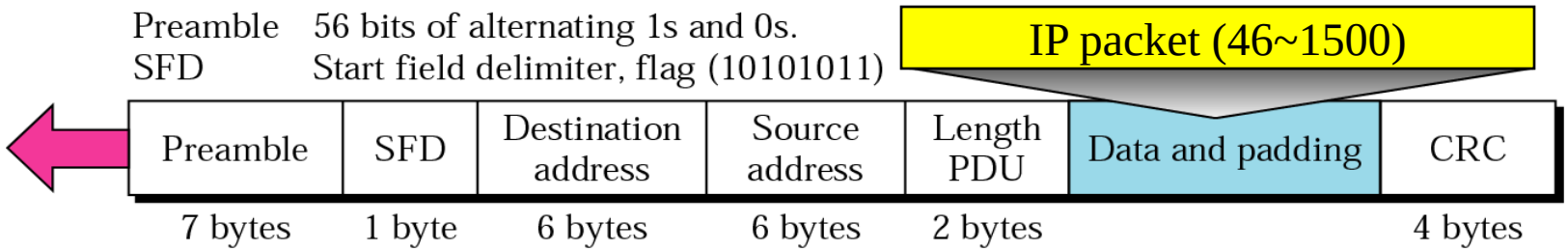


Ethernet Link Layer Control

1.4.2.17 LLC:
That part of a data station that supports the logical link control functions of one or more logical links. The LLC generates command PDUs and response PDUs for sending and interprets received command
PDUs and response PDUs. Specific responsibilities assigned to an LLC include
1) Initiation of control signal interchange,
2) Organization of data flow,
3) Interpretation of received command PDUs and generation of appropriate response PDUs, and
4) Actions regarding error control and error recovery functions in the LLC sublayer.

Ethernet Framing

- **Frame format**
  - **Similar to HDLC**



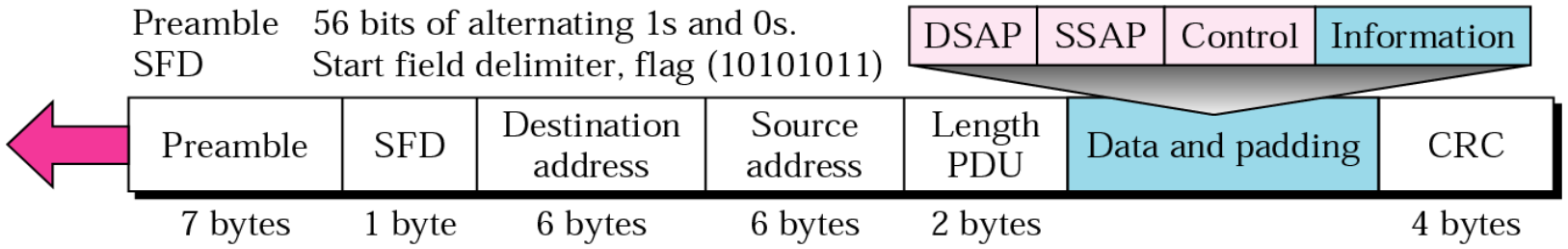
1. Preamble: (7bytes) trains clock-recovery circuits **10101010**
2. Start of Frame Delimiter: indicates start of frame **10101011**
3. Destination Address: 48-bit globally unique address assigned by manufacturer.
   - 1b=0: unicast/multicast
   - 1b=1: local/global address
4. Type: Indicates protocol of encapsulated data (e.g. IP = 0x0800)
5. Pad: Zeroes used to ensure minimum frame length (=46bytes)
6. Cyclic Redundancy Check(4byte): check sequence to detect bit errors.

LLC Control (IEEE 802.2)

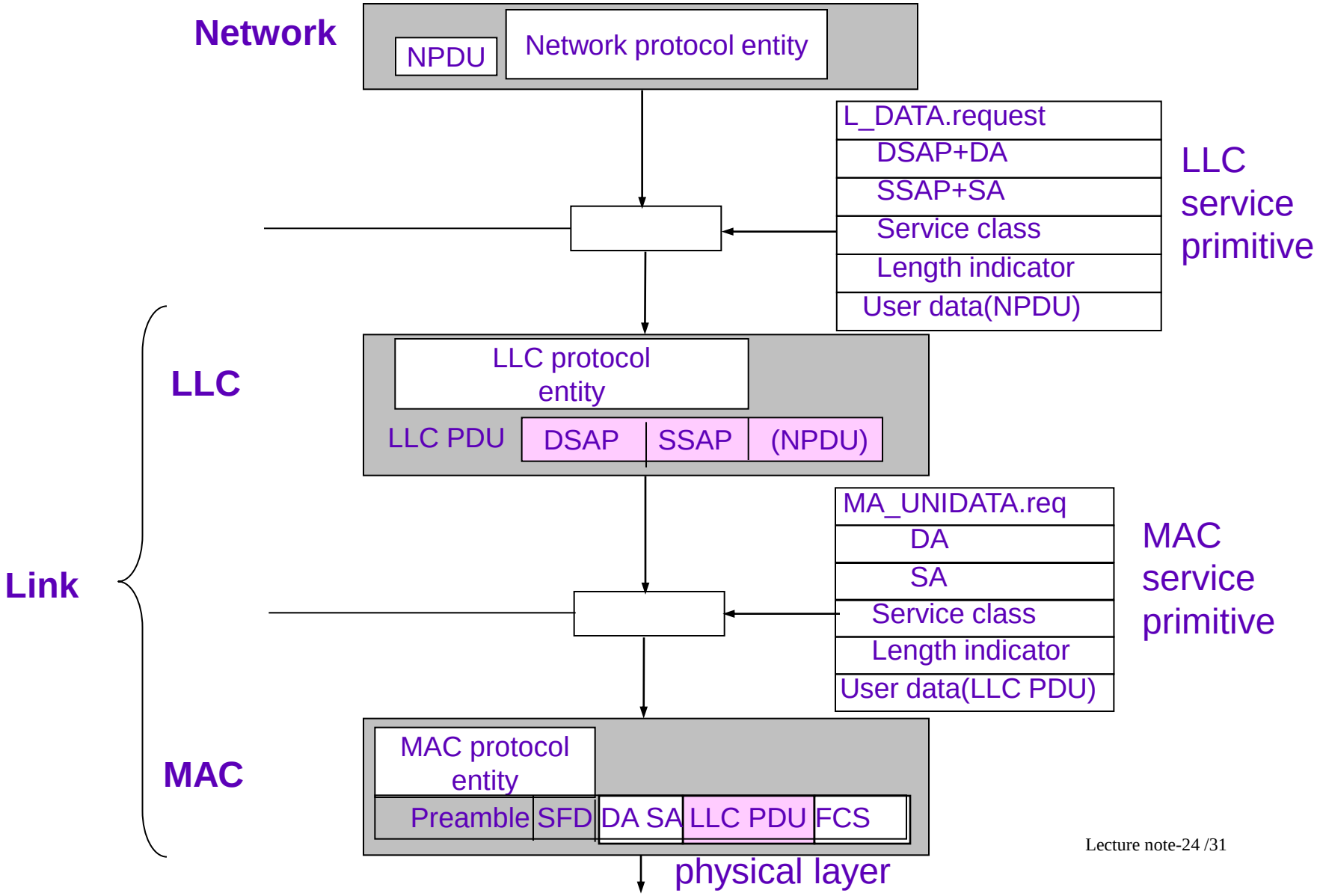
- **LLC: Logical Link Control.**
  - **Part of the 802 protocol family for LANs.**
  - **Link control functions divided between the MAC layer and the LLC layer.**
  - **LLC layer operates on top of MAC layer.**

DSAP address	SSAP address	Control	Information
8 bits	8 bits	8 or 16 bits	M*8 bits

DSAP address	=	Destination service access point address field
SSAP address	=	Source service access point address field
Control	=	Control field [16 bits for formats that include sequence numbering, and 8 bits for formats that do not (see 5.2)]
Information	=	Information field
*	=	Multiplication
M	=	An integer value equal to or greater than 0. (Upper bound of M is a function of the medium access control methodology used.)



Interlayer primitives and parameters



Logical Link Control Services

Class of LLC

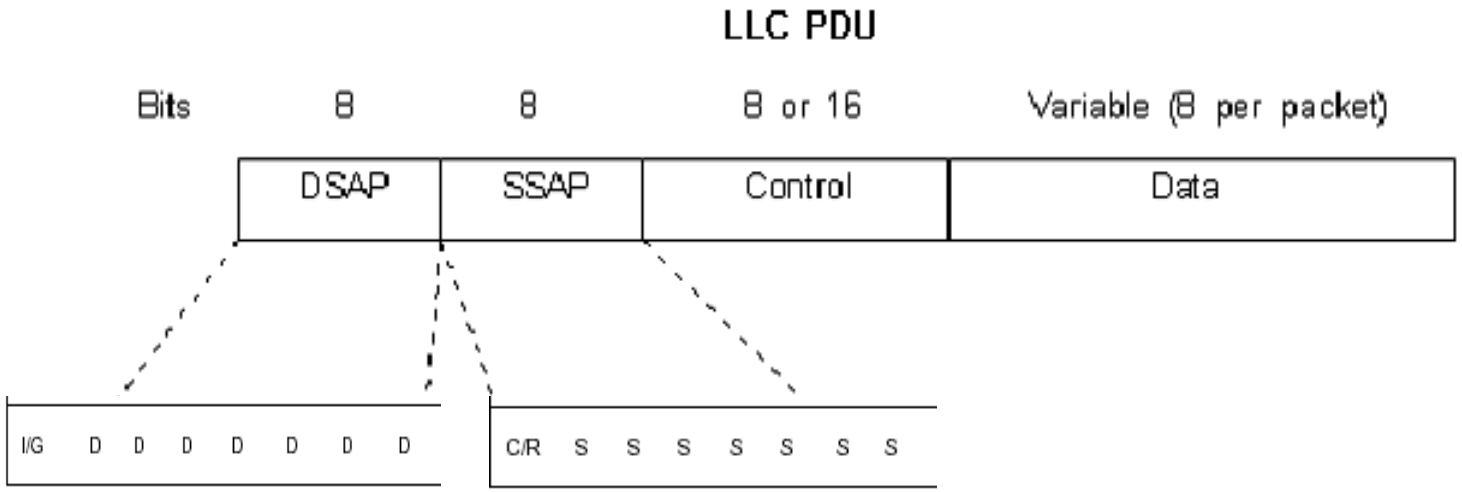
Types of operation supported	I	II	III	IV
1	X	X	X	X
2		X		X
3			X	X

Xs indicate valid combinations

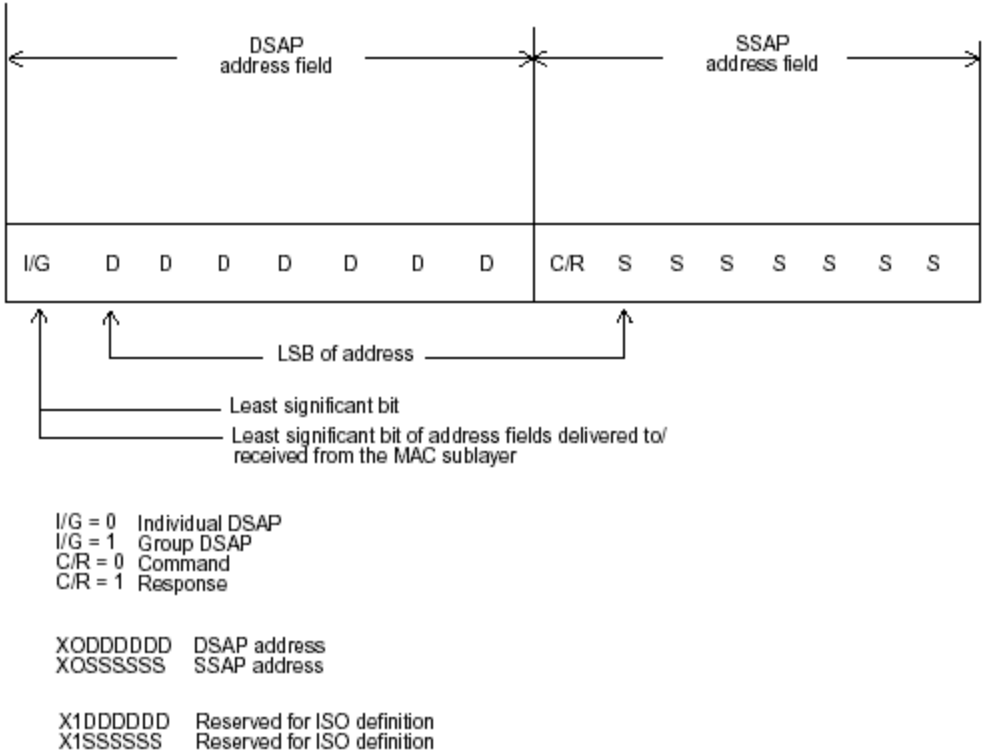
- **Type 1 operation:** *unacknowledged connectionless service*.
  - **Delivery is not guaranteed, requires minimum logic, relies on higher protocol levels to provide reliability if necessary**
  - **Unnumbered frames transfer user data. No acknowledgement, flow control, or error control, there is error detection (with packet discard) at the MAC level.**
- **Type 2 operation:** *Connection mode service*,
  - **a logical connection between two nodes, providing flow control and reliability mechanisms, Uses a SABME PDU to request connection, Destination returns an Unnumbered ACK if connection is accepted or a DM (disconnect) PDU. Data exchange as in HDLC. Session ends with a DISC**
  - **Go-Back-N ARQ (no selective repeat ARQ)**
- **Type 3 operation:** *Acknowledged connectionless service*
  - **Provides an acknowledged datagram service (Stop & Wait ARQ)**
  - **New unnumbered PDU the Acknowledged Connectionless Information PDU is defined. Datagrams are sent and acknowledged using this AC PDU**

LLC Header

각 바이트 마다 LSB 를 먼저 보냄



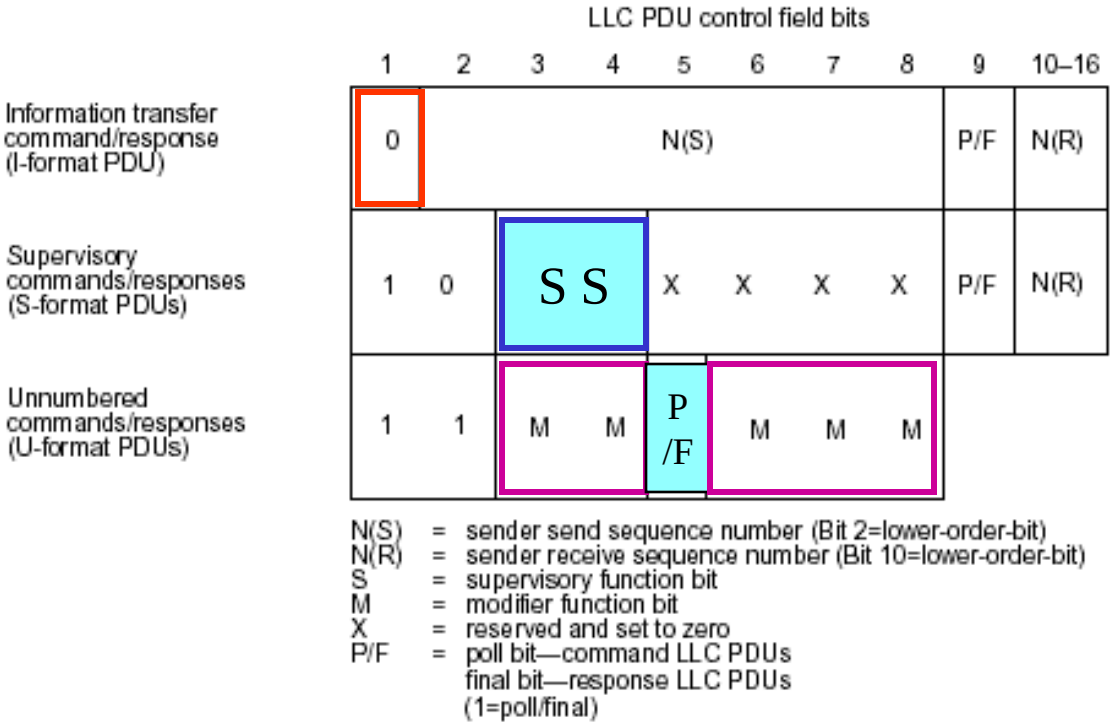
SAP (Service Access Point)



SAP	Protocol
00	Null SAP
04	SNA
05	SNA
06	TCP
08	SNA
0C	SNA
42	Spanning Tree
7F	ISO 802.2
80	XNS
AA	SNAP
E0	IPX
F0	NetBIOS
F8	RPL
FC	RPL
FE	OSI
FF	Global SAP

- **DSAP:** The DSAP, or Destination Service Access Point, is a 1 byte field that simply acts as a pointer to a memory buffer in the receiving station. It tells the receiving NIC in which buffer to put this information. This functionality is crucial in situations where users are running multiple protocol stacks, etc.
- **SSAP:** The SSAP, or Source Service Access Point is analogous to the DSAP, and specifies the Source of the sending process.

Control Byte



N(S) = sender send sequence number (Bit 2=lower-order-bit)
N(R) = sender receive sequence number (Bit 10=lower-order-bit)
S = supervisory function bit
M = modifier function bit
X = reserved and set to zero
P/F = poll bit—command LLC PDUs
final bit—response LLC PDUs
(1=poll/final)

SS	Meaning
00	RR: Receive ready
10	RNR (x-off)
01	Reject (NAK)

M M	P /F	M M M	Meaning
1 1		0 0 0	UI
1 0		1 1 0	SABME Command
0 0		0 1 0	DISC Command
1 1		0 0 0	DM
1 0		0 0 1	FRMR
0 0		1 1 0	UA
1 1		1 0 1	XID

Command/Response

- **Commands(0)**
- **Responses(1)**

	0 N(S) P/F N(R)	– I-Information	– I-Information	I
	1 0 0 0 0 0 0 0-P/F N(R)	– RR	– RR	S
	1 0 1 0 0 0 0 0 -P/F N(R)	– RNR	– RNR	
	1 0 0 1 0 0 0 0 -P/F N(R)	– REJ	– REJ	
Type 1	1 1 0 0 P 0 0 0-	– UI		U
	1 1 1 1 * 1 0 1-	– XID	– XID	
	1 1 0 0 * 1 1 1-	– TEST	– TEST	
Type 2	1 1 1 0 P 1 1 0-	– SABME		
	1 1 0 0 P 0 1 0-	– DISC		
	1 1 0 0 F 1 1 0-		– UI ACK.	
	1 1 1 1 F 0 0 0-		– DM	
	1 1 1 0 F 0 0 1-		– FRMR	
Type 3	1 1 1 0 * 1 1 0-	– AC_L_s0	– AC_L _s0	
	1 1 1 0 * 1 1 1-	– AC_L _s1	– AC_L _s1	

The following table lists the LLC command PDUs:

LSB와 MSB Swap

Operation	Command	Response	Format	Control Field Hex. Value
Type 1 (CL)	Unnumbered Information (UI)		Unnumbered (U)	03
	Exchange Identification (XI)	Exchange Identification (XI)	Unnumbered (U)	AF, BF
	Test (TEST)	Test (TEST)	Unnumbered (U)	E, F3
Type 2 (CO)	Information (I)	Information (I)	Information (I)	00 00 to FE FF
	Receiver Ready (RR)	Receiver Ready (RR)	Supervisory (S)	01 00 to 01 FF
	Receiver Not Ready (RNR)	Receiver Not Ready (RNR)	Supervisory (S)	05 00 to 05 FF
	Reject (REJ)	Reject (REJ)	Supervisory (S)	09 00 to 09 FF
	Set Asynchronous Balance Mode Extended (SABME)	Unnumbered Acknowledgement (UA)	Unnumbered (U)	6F, 7F (SABME) and 63, 73 (UA)
	Disconnect (DISC)	Disconnected Mode (DM)	Unnumbered (U)	43, 53 (DISC) and 0F, 1F (DM)
		Frame Reject (FRMR)	Unnumbered (U)	87, 97
Type 3 (AC)	Ack Connectionless, seq 0 (AC0)	Ack Connectionless, seq 0 (AC0)	Unnumbered (U)	67, F7
	Ack Connectionless, seq 0 (AC1)	Ack Connectionless, seq 0 (AC1)	Unnumbered (U)	E7, F7

LLC Type 1

- **Control:**
  - **Type 1 (datagram): 1byte**
    - UI: Unnumbered information
    - XID: exchange identification (Response & Commend)
      - **Command: the recipient of the identity of the transmitter(+LLC type) of the XID command**
      - **Response: the required reply to an XID command**

      The XID command PDU is used to convey the types of LLC services supported and the receive window size on a peer data-link connection to the destination LLC and to cause the destination LLC to response with the XID response PDU
    - TEST: to check whether a packet can be sent to the recipient and returned (include an arbitrary data)
  - **Command/Response: a bit in the SSAP (since no transmission from a group SAP)**

XID: exchange identification

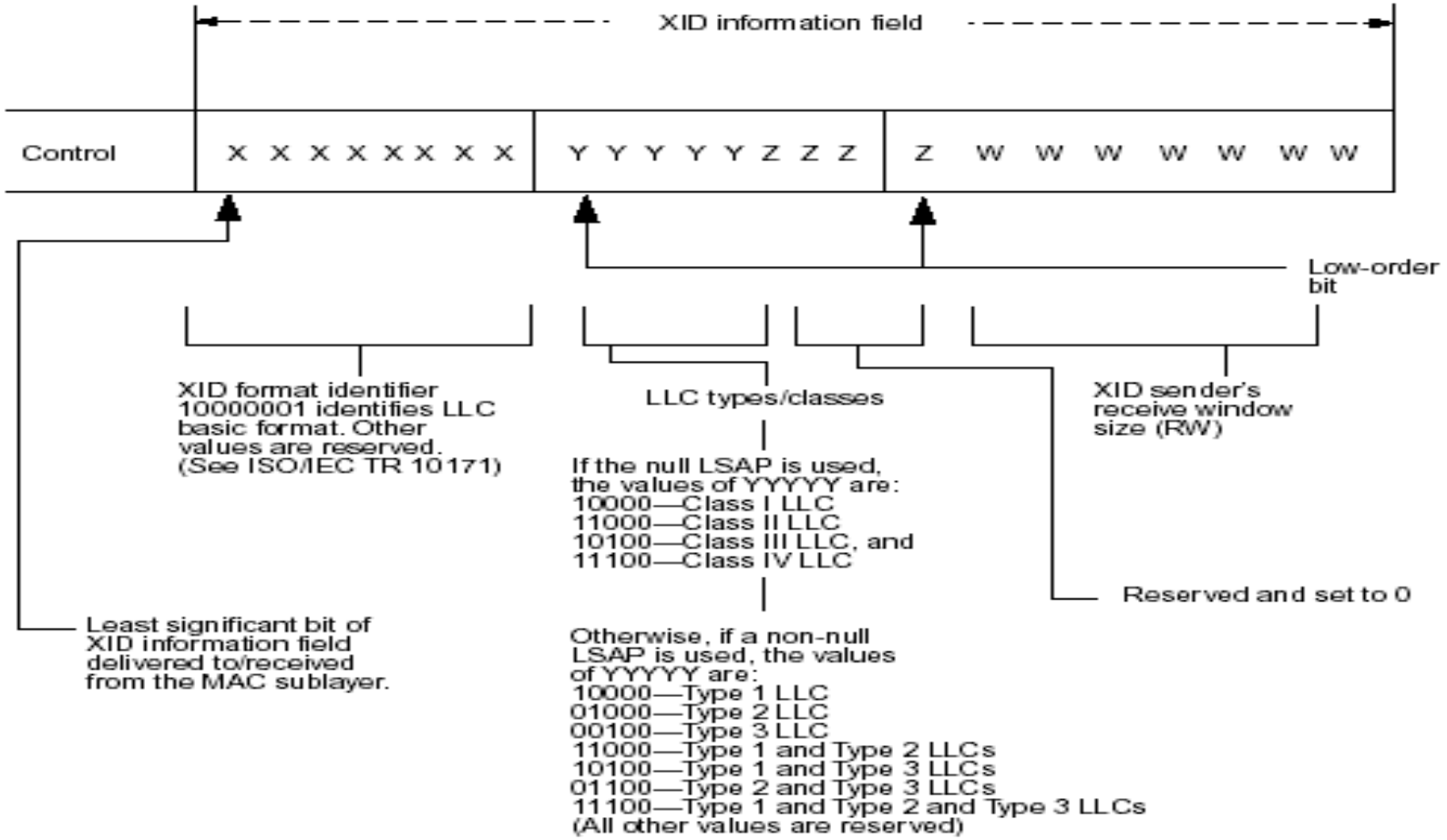


Figure 11—XID information field basic format

LLC Type 2(with ARQ)

- **Control:**
  - **Type 2 (connection-oriented): 1 or 2 byte**
    - I (Information): a data packet (two 7bit of sequence number, N(S) and N(R))
    - RR: an acknowledgment indicate that all packets with sequence numbers lower than that have been received
    - RNR: an acknowledgment indicate that all packets with sequence numbers lower than that have been received and that the receiver is temporarily busy and not transmit until the receiver indicates by transmitting an RR
    - REJ: an acknowledgment indicate that the receiver is requesting retransmission of packets starting with the number in the receive sequence number
    - SABME: request that a connection be started.
    - DISC request that a connection be ended.
    - DM (disconnected mode): in response to a DISC,
    - FRMR: indicate receipt of an invalid packet (e.g., out of order)
    - UA: acknowledges a DISC or SABME

Supervisory frame

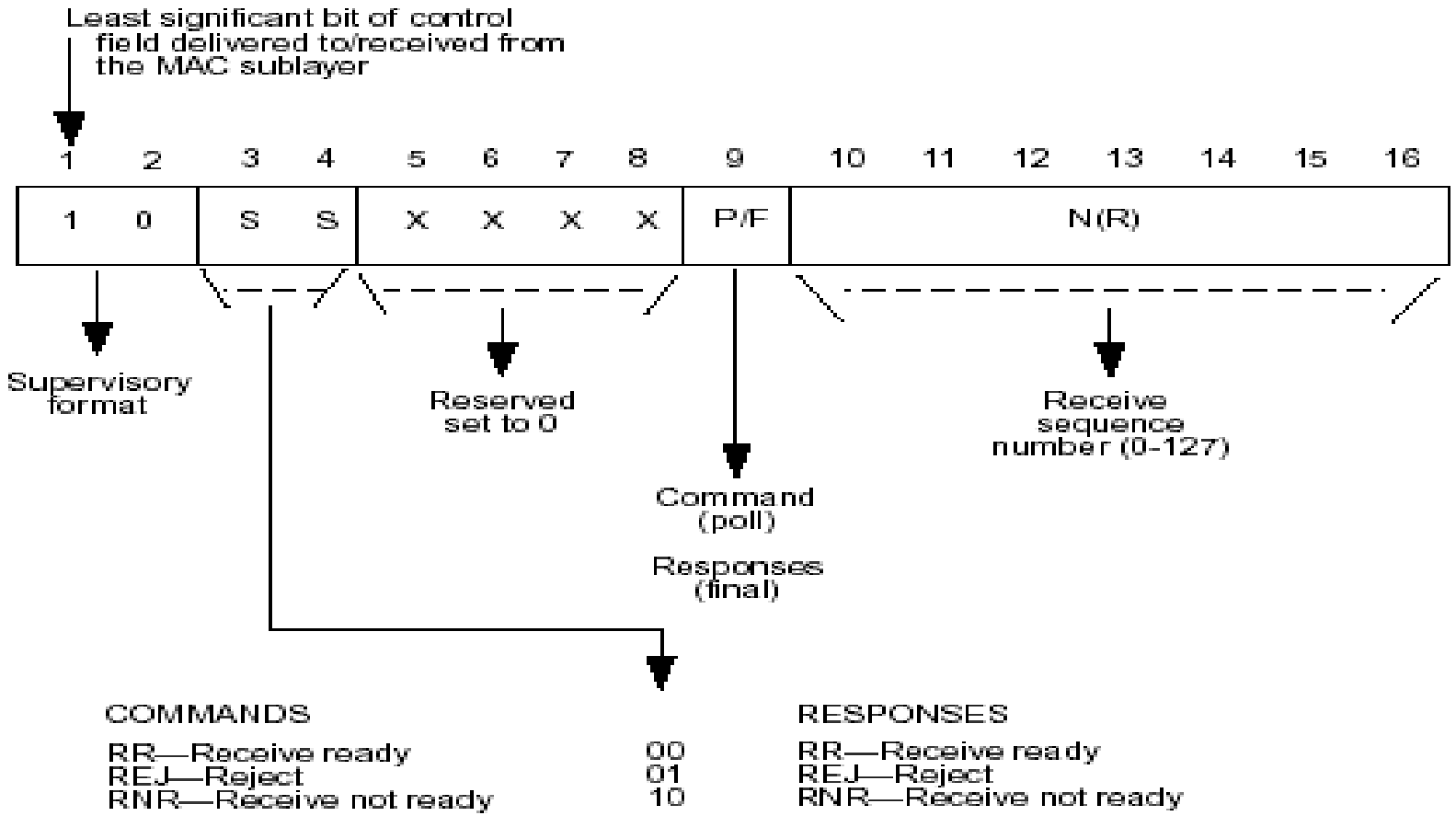


Figure 14—Supervisory format control field bits

Unnumbered frame

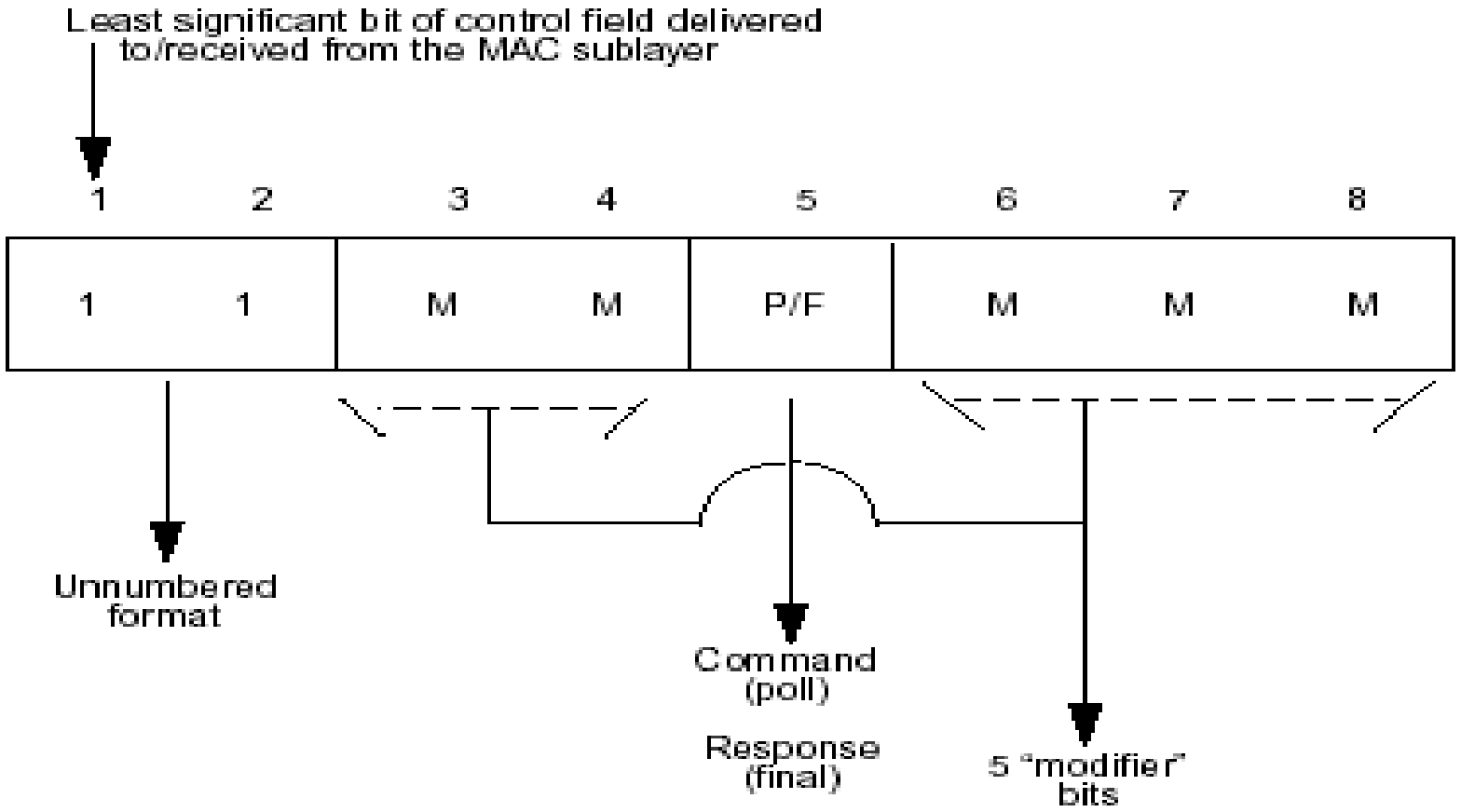
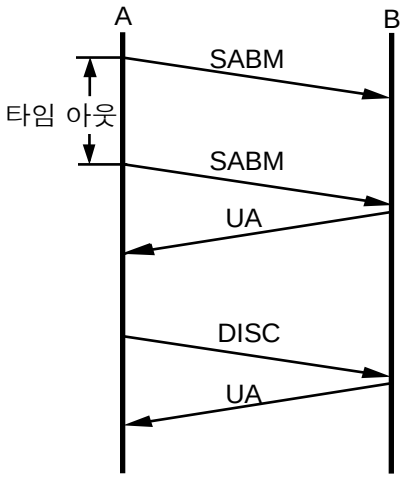
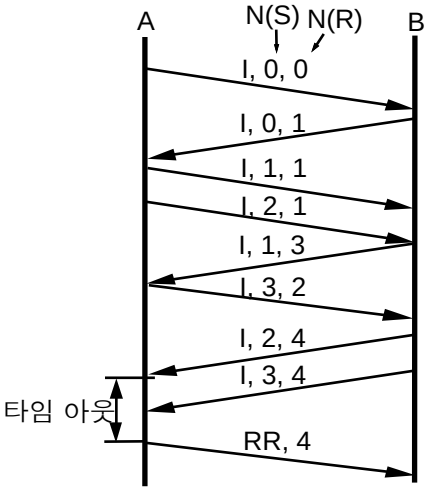


Figure 15—Unnumbered format control field bits

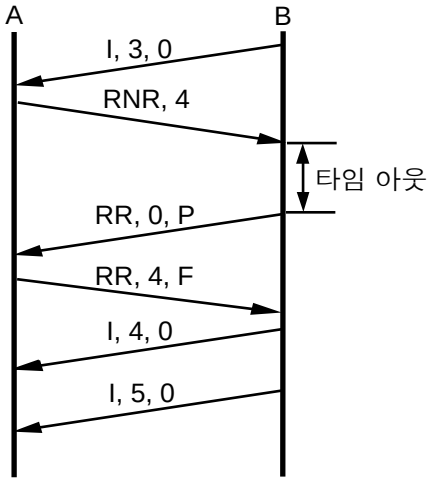
Type 2 Operation: Connection Management



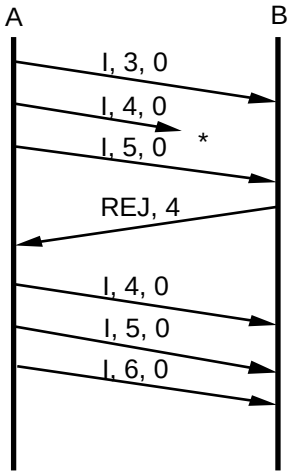
(a) 링크 설정과 해제



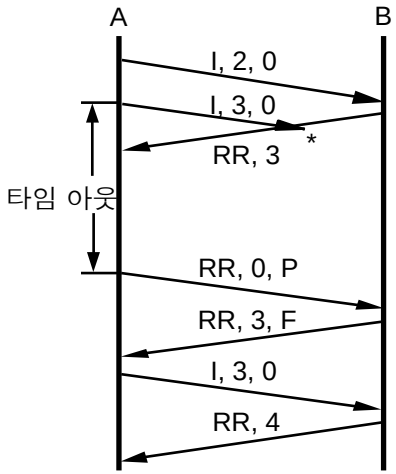
(b) 전이중 데이타 교환



(c) RNR을 이용한 흐름 제어



(d) REJ를 이용한 에러 제어



(e) 타임 아웃을 이용한 에러 제어

PPP Protocol

Point-to-point Protocol

Point to Point Data Link Control

- one sender, one receiver, one link: easier than broadcast link:
  - no Media Access Control
  - no need for explicit MAC addressing
  - e.g., dialup link, ISDN line
- popular point-to-point DLC protocols:
  - PPP (point-to-point protocol)
  - HDLC: High level data link control (Data link used to be considered "high layer" in protocol stack!

PPP= Used to control and manage the transfer of data through a physical link (phone line)

PPP non-requirements

- **no error correction/recovery**
- **no flow control**
- **out of order delivery OK**
- **no need to support multipoint links (e.g., polling)**

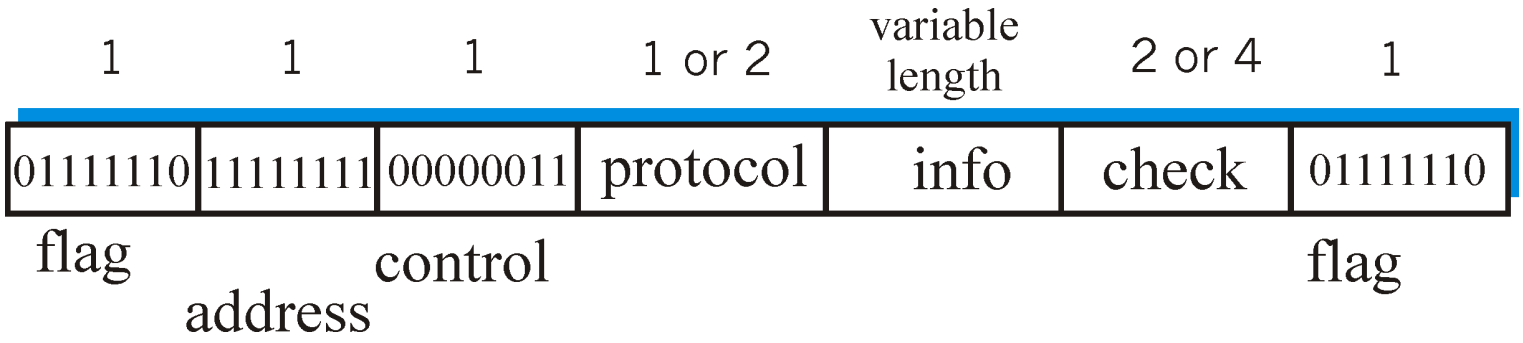
Error recovery, flow control, data re-ordering all relegated to **higher layers**!|

PPP Design Requirements [RFC 1557]

- **packet framing:** encapsulation of network-layer datagram in data link frame
  - carry network layer data of any network layer protocol (not just IP) *at same time*
  - ability to demultiplex upwards
- **bit transparency:** must carry any bit pattern in the data field
- **error detection** (no correction)
- **connection liveness:** detect, signal link failure to network layer
- **network layer address negotiation:** endpoint can learn/configure each other's network address

PPP Data Frame

- **Flag:** delimiter (framing)
- **Address:** does nothing (only one option)
- **Control:** does nothing; in the future possible multiple control fields
- **Protocol:** upper layer protocol to which frame delivered (eg, PPP-LCP, IP, IPCP, etc)
- **info:** upper layer data being carried
- **check:** cyclic redundancy check for error detection

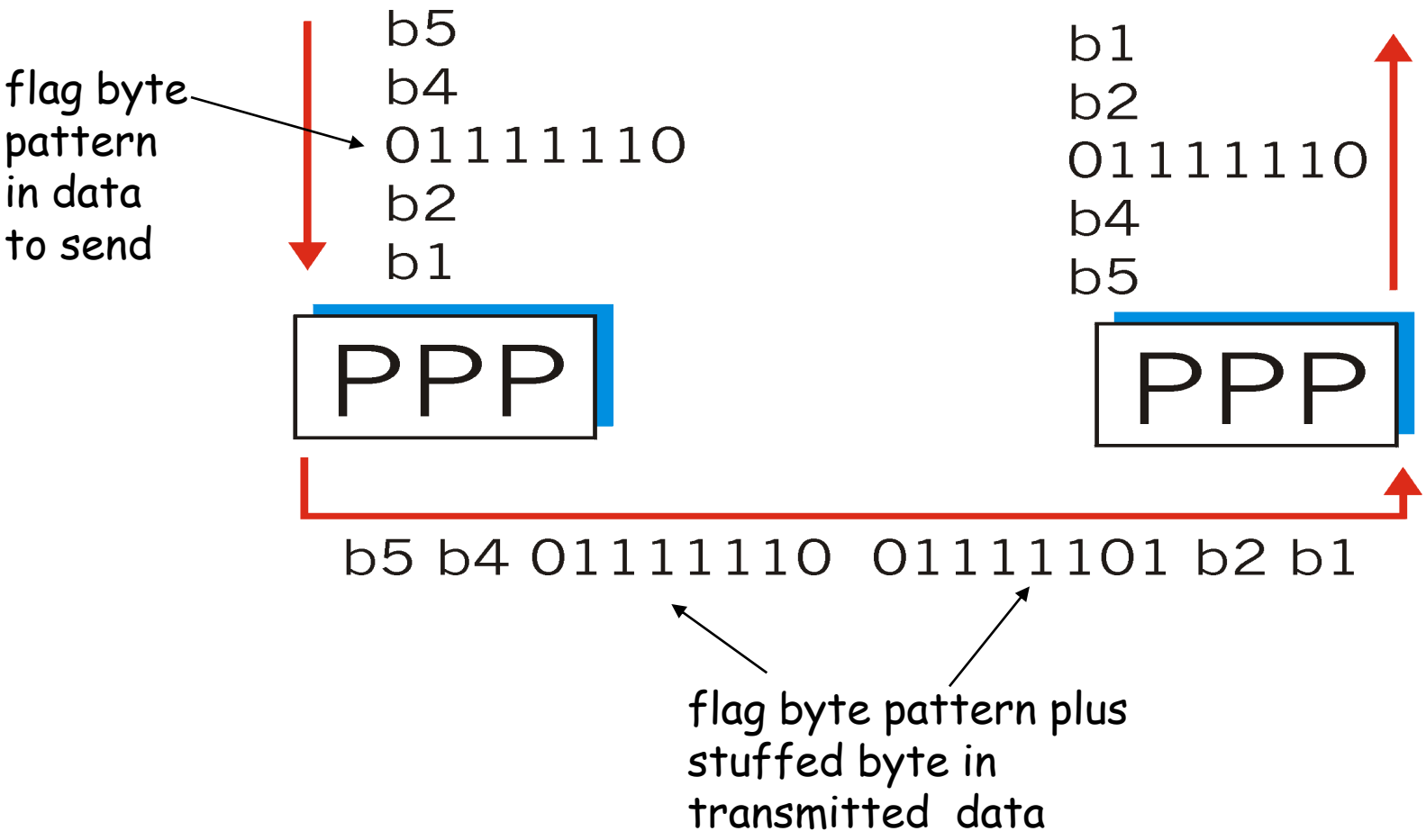


Byte Stuffing

- "data transparency" requirement: data field must be allowed to include flag pattern <01111110>
  - Q: is received <01111110> data or flag?

- Sender: adds ("stuffs") extra < 01111110> byte after each < 01111110> *data* byte
- Receiver:
  - two 01111110 bytes in a row: discard first byte, continue data reception
  - single 01111110: flag byte

Byte Stuffing



PPP Data Control Protocol

Before exchanging network-layer data, data link peers must

- **configure PPP link (max. frame length, authentication)**
- **learn/configure network layer information**
  - for IP: carry IP Control Protocol (IPCP) msgs (protocol field: 8021) to configure/learn IP address

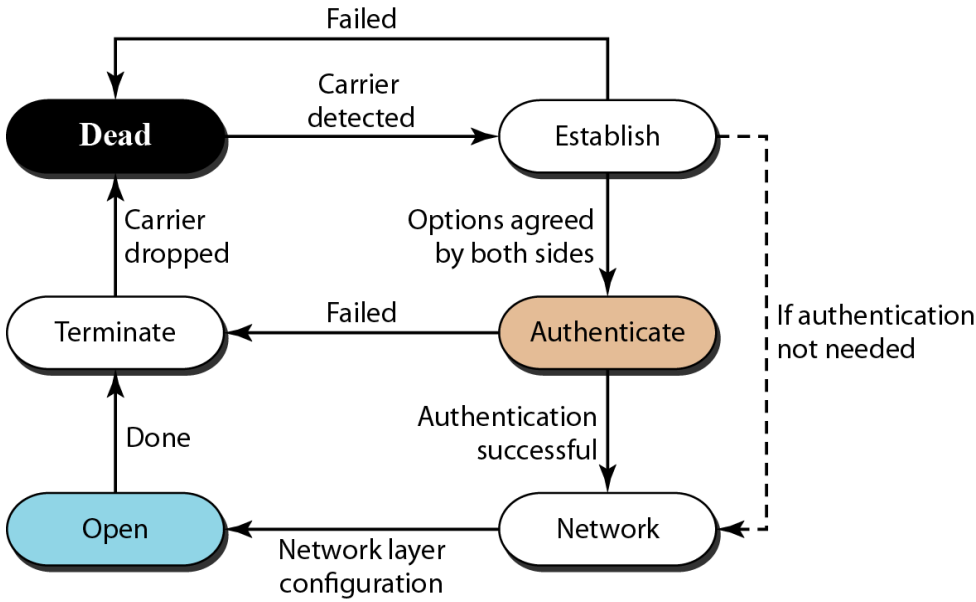
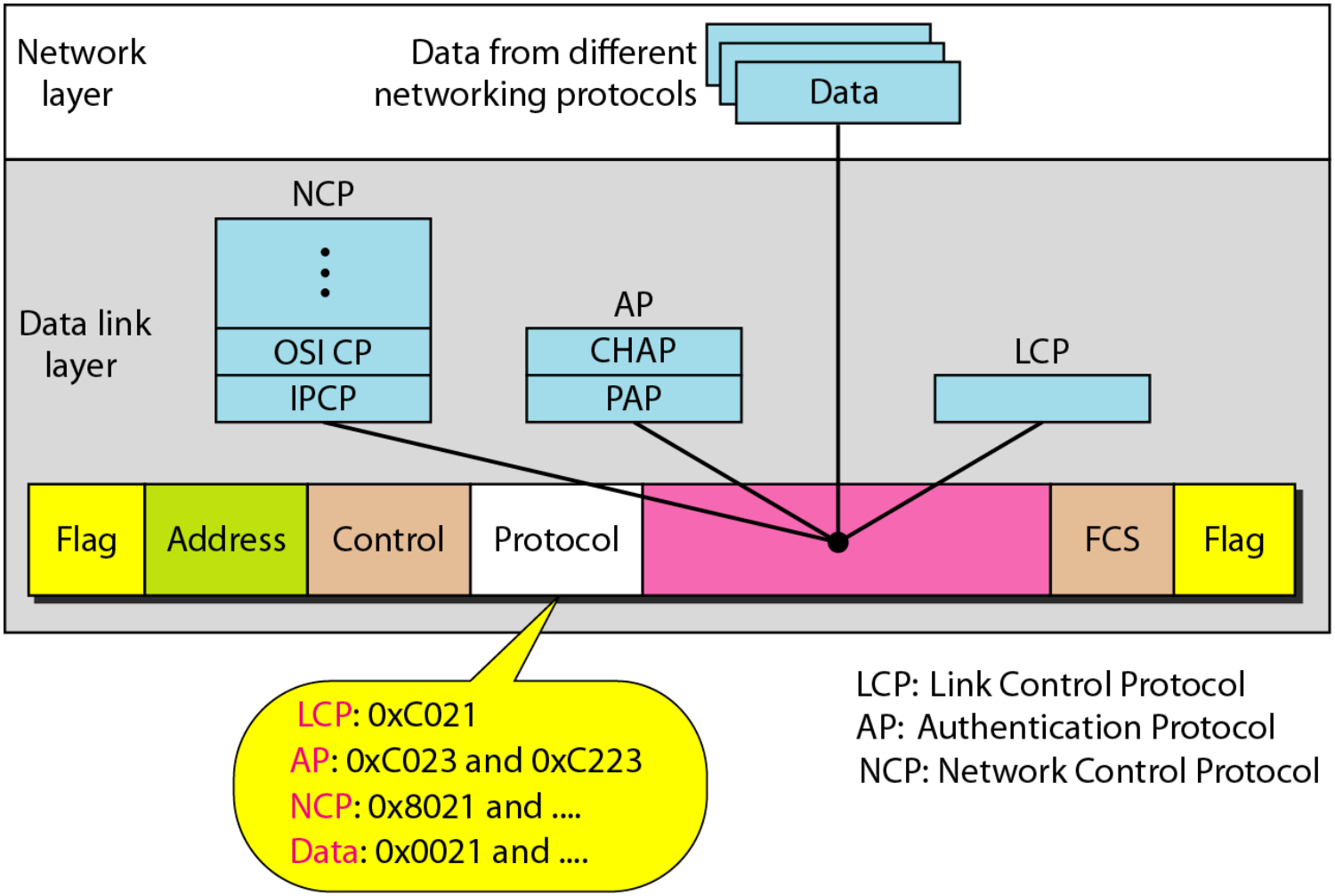


Figure 11.34 *Multiplexing in PPP*



PPP Transition States

- **Refer to Figure 12.2 for the transition states**
- Idle state**: link is not used**
- Establishing state**: when one of the end point starts the communication**
- Authenticating state**: is optional**
- Networking state**: is the heart of the transition states; exchanging data and control packets**
  - **Configuration state (exchange control)**
  - **Open state (exchange data)**
- Terminating state**: end for house cleaning and closing the link**

Link Control Protocol (LCP)

- **Is responsible for establishing, maintaining, configuring, and terminating links**
- **Provide negotiation mechanisms to set options between the two end points**
- **All LCP packets are carried in the payload field of the PPP frame (see Figure 15.5)**

See Table 12.1 LCP packets and their codes

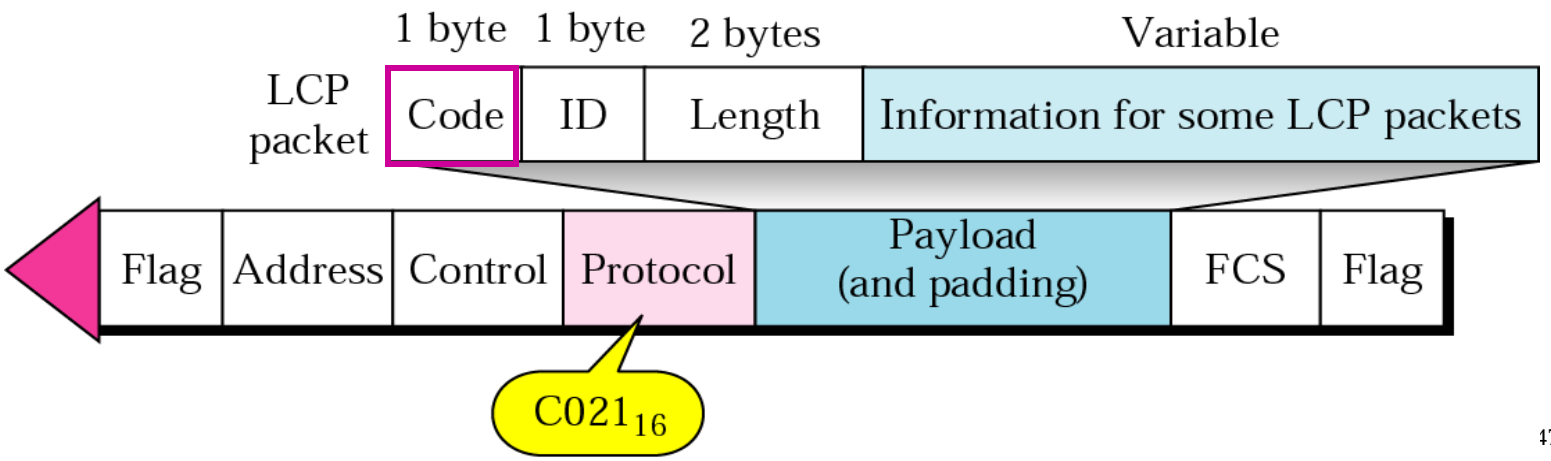


Table 11.2 *LCP packets*

Code	*Packet Type*	*Description*
0x01	Configure-request	Contains the list of proposed options and their values
0x02	Configure-ack	Accepts all options proposed
0x03	Configure-nak	Announces that some options are not acceptable
0x04	Configure-reject	Announces that some options are not recognized
0x05	Terminate-request	Request to shut down the line
0x06	Terminate-ack	Accept the shutdown request
0x07	Code-reject	Announces an unknown code
0x08	Protocol-reject	Announces an unknown protocol
0x09	Echo-request	A type of hello message to check if the other end is alive
0x0A	Echo-reply	The response to the echo-request message
0x0B	Discard-request	A request to discard the packet

Option	*Default*
Maximum receive unit (payload field size)	1500
Authentication protocol	None
Protocol field compression	Off
Address and control field compression	Off

Authentication

- **Play important role in PPP for verification of user identity**
- **Has two protocols:**
  - Password Authentication Protocol (PAP) **(see Figure 12.6)**
    - Is simple with two steps
    - First step involves the used sending an authentication identification (username) and a password
    - The second step involves the system checking the validity of the identification and password and either accepts or denies

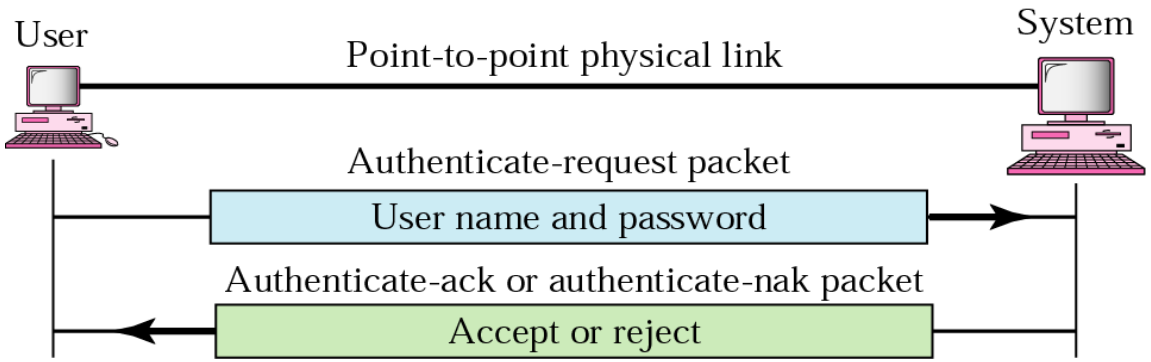
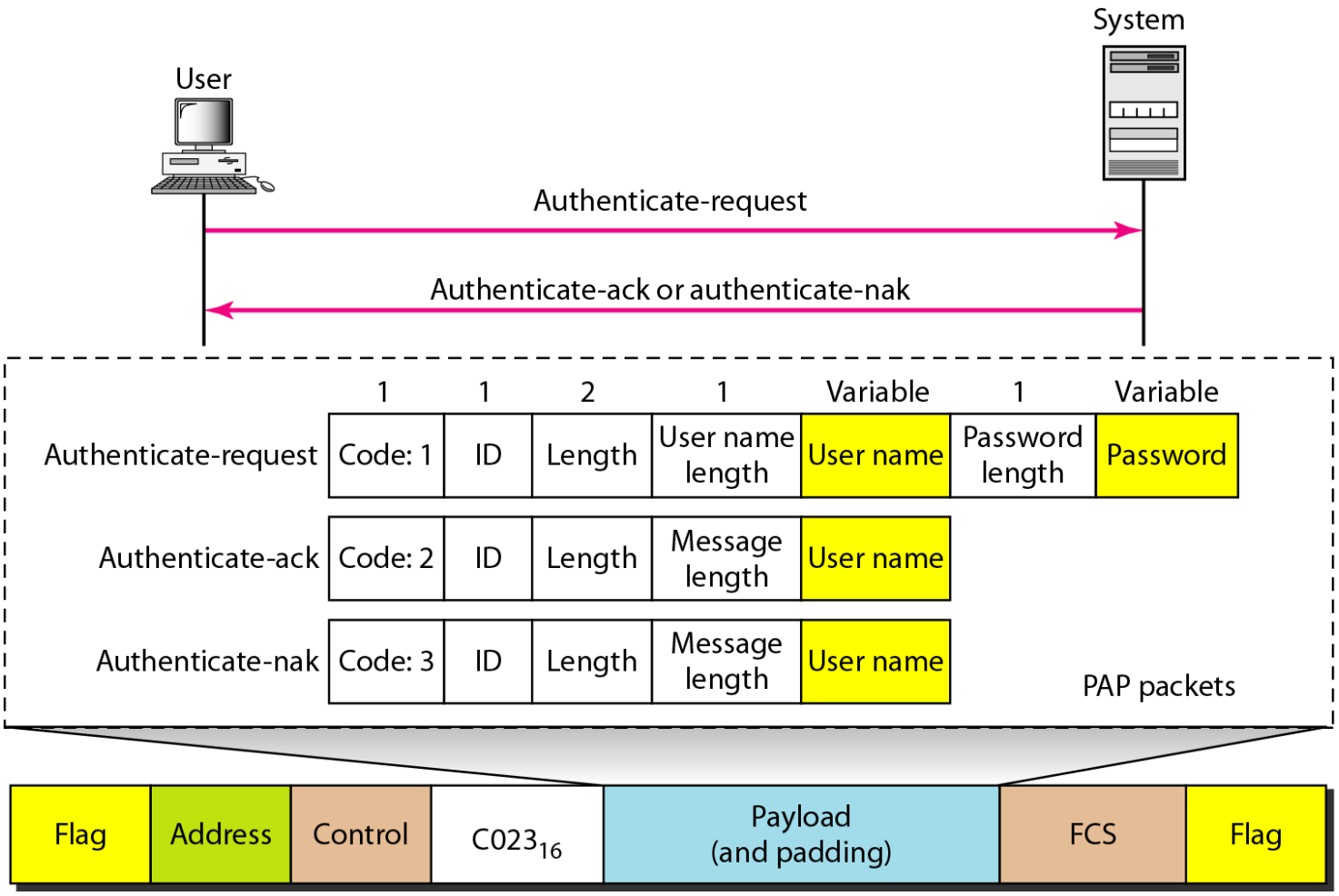


Figure 11.36 *PAP packets encapsulated in a PPP frame*



Authentication

- Challenge Handshake Authentication Protocol (CHAP) **(see Figure 12.8):**
  - **Three ways handshake authentication protocol that provides more security than PAP (Password is kept secret and never sent on-line)**
  - **The first step involves the system sends to the user a challenge packet containing a challenge value**
  - **The user applies a predefined function that takes the challenge value and the user's own password and creates a result and send a response packet to the system**
  - **The system applied the same function to the password of the user; if the result is the same the sent packet, access granted**

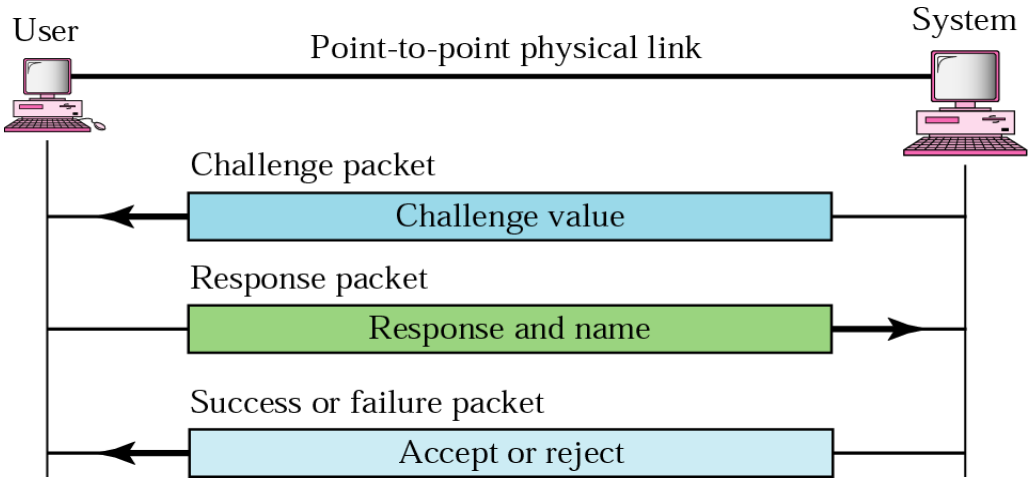
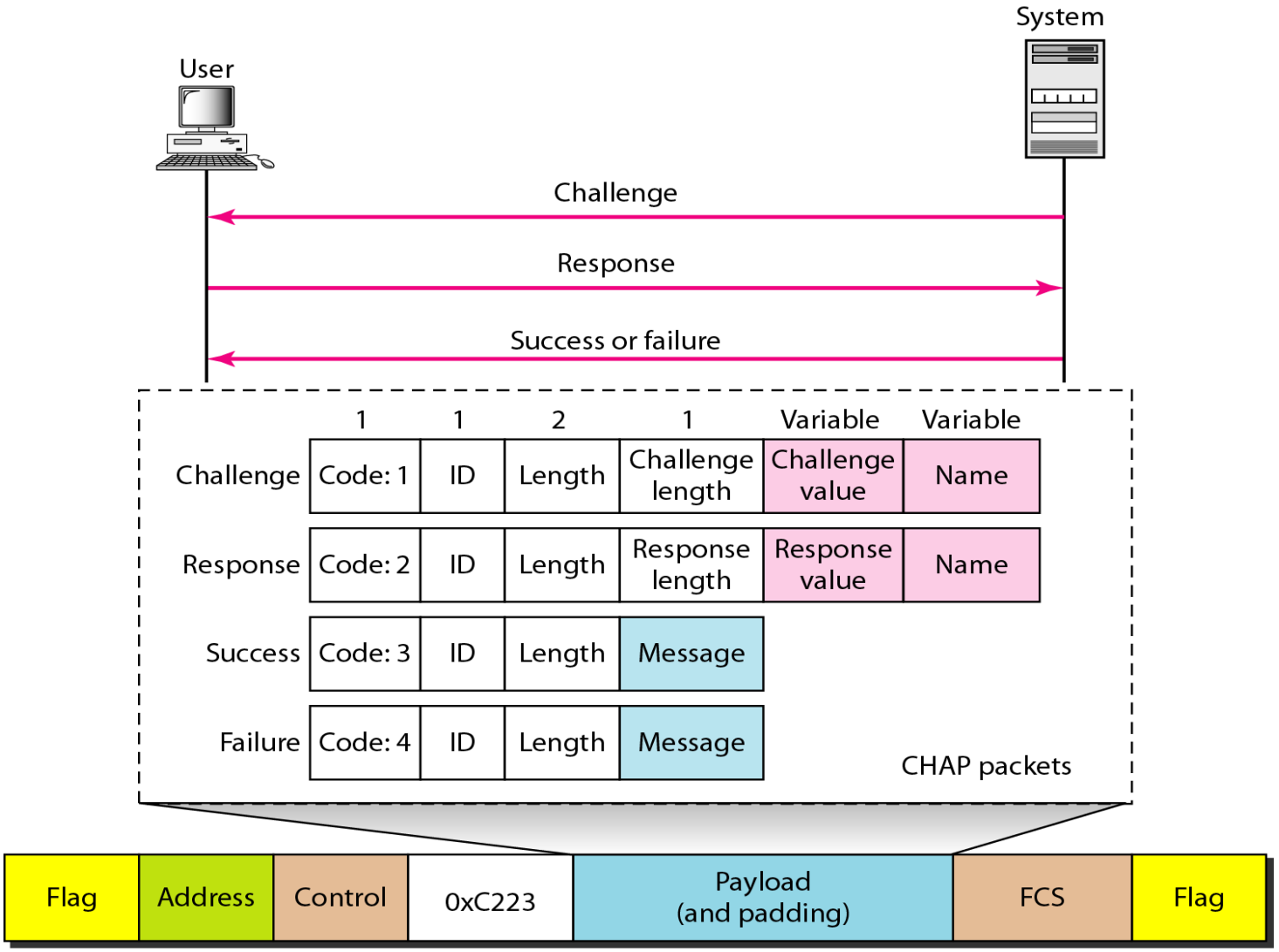


Figure 11.37 *CHAP packets encapsulated in a PPP frame*



Network Control Protocol (NCP)

- **A set of control protocols to allow the encapsulation of data coming from network layer protocols into the PPP frame.**
  - **for IP: carry IP Control Protocol (IPCP) msgs (protocol field: 8021) to configure/learn IP address (see Fig. 12.9)**

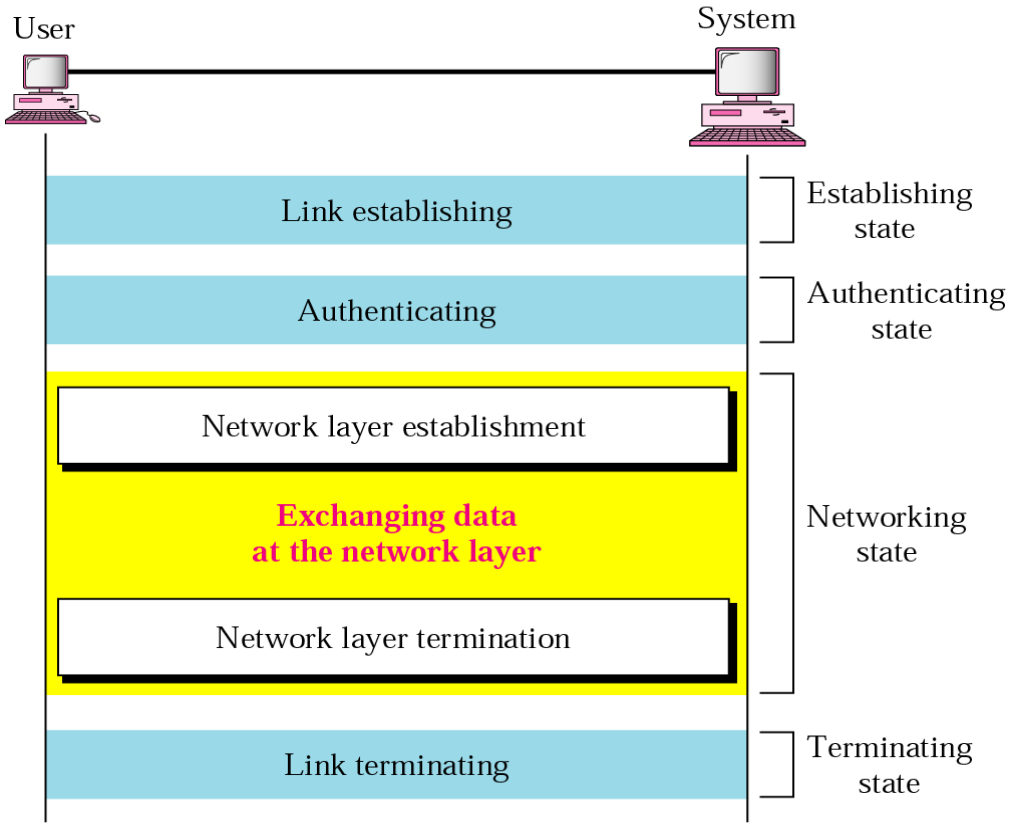


Figure 11.38 *IPCP packet encapsulated in PPP frame*

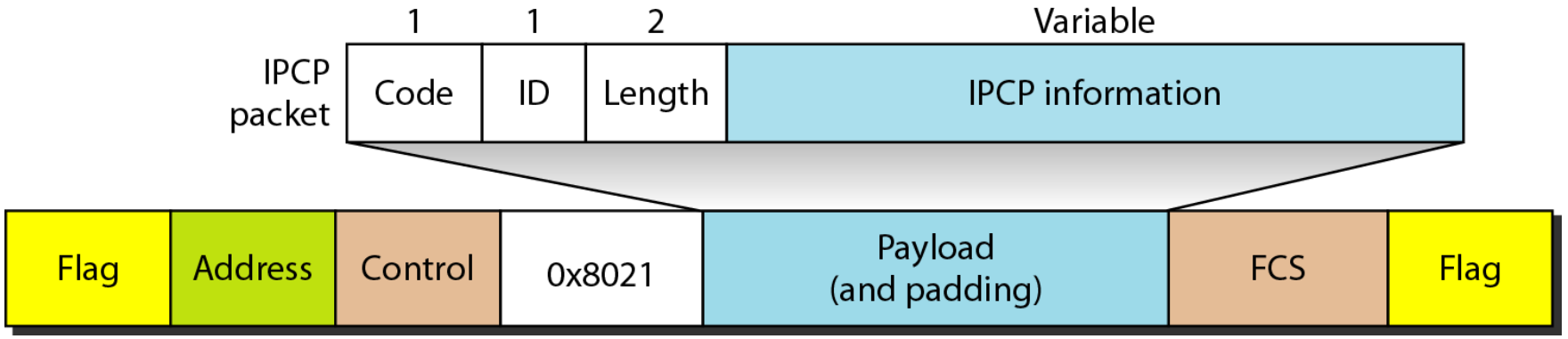


Figure 11.39 *IP datagram encapsulated in a PPP frame*

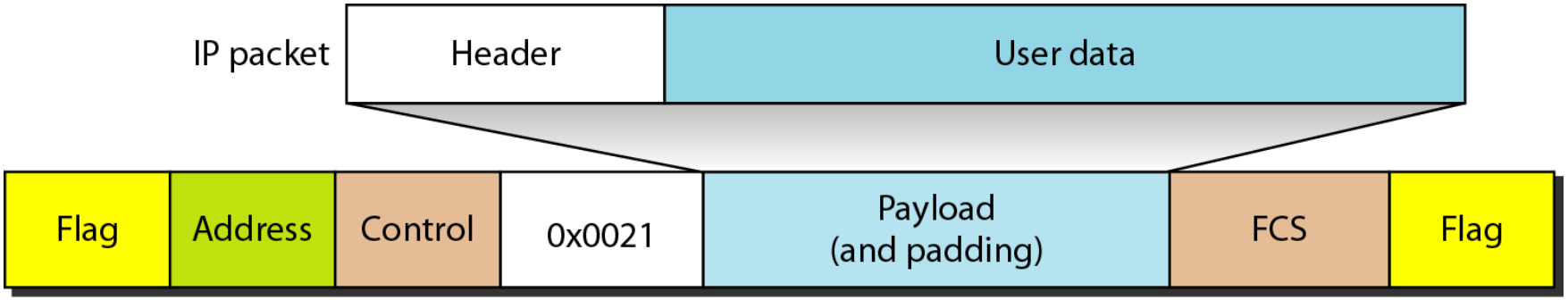
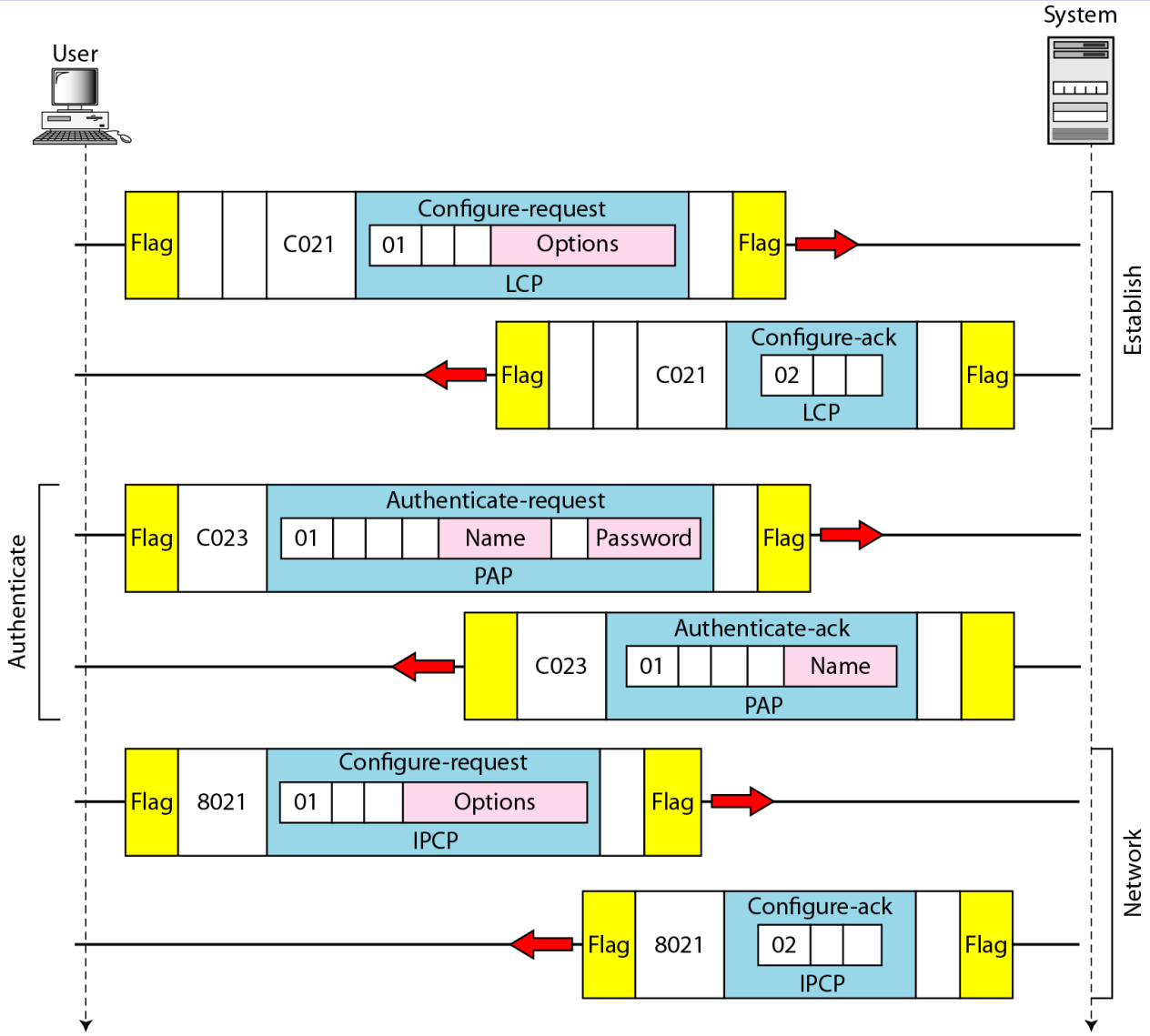


Figure 11.41 *An example*



Supplementary

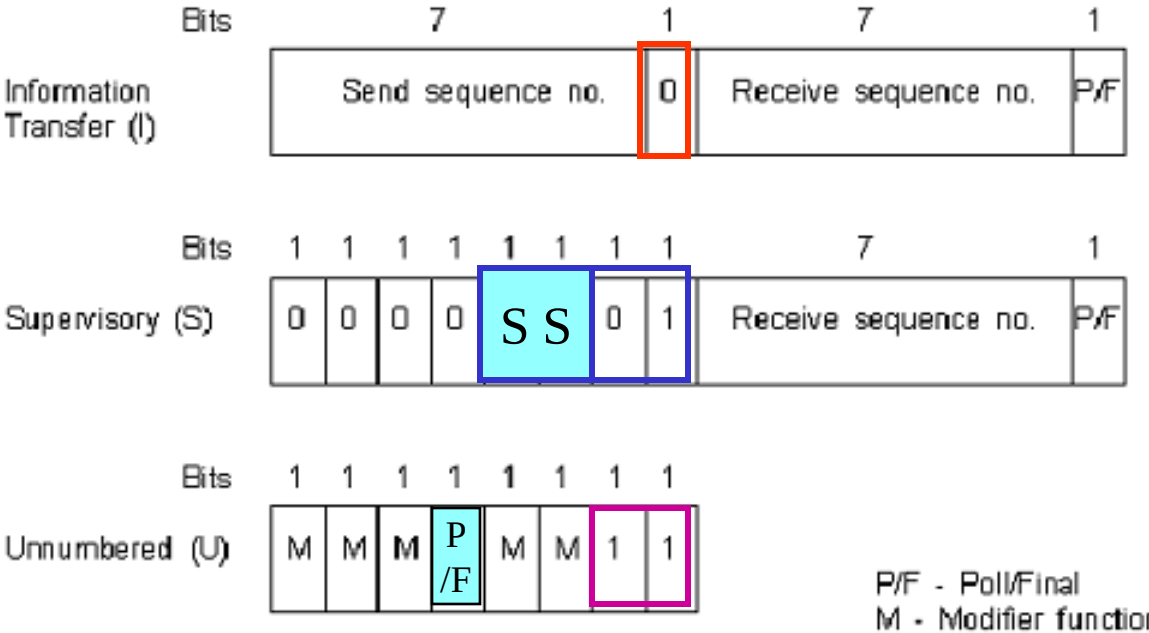
Other DLL Protocols 1

- **LAPB: Link Access Procedure, Balanced.**
  - **Part of the X.25 standard.**
  - **Subset of HDLC.**
  - **Link between user system and switch.**
  - **Same frame format as HDLC.**
- **LAPD: Link Access Procedure, D-Channel.**
  - **Part of the ISDN standard.**

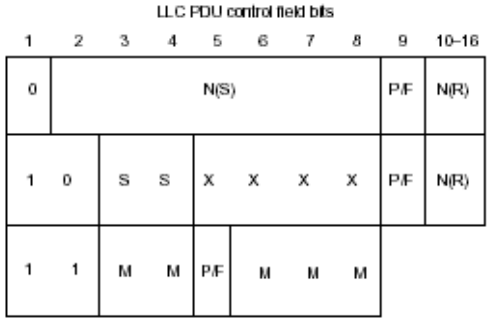
Other DLL Protocols 2

- **SLIP: Serial Line IP**
  - **Dial-up protocol.**
  - **No error control.**
  - **Not standardized.**
- **PPP: Point-to-Point Protocol**
  - **Internet standard for dial-up connections.**
  - **Provides framing similar to HDLC.**

Control Byte extension



P/F - Poll/Final
M - Modifier function bit
S - Supervisory function bit



SS	Meaning
00	RR: Receive ready
01	RNR (x-off)
10	Reject (NAK)

M M M	P/F	M M	Meaning
0 0 0		1 1	UI
0 1 1		0 1	SABME Command
0 1 0		0 0	DISC Command
0 0 0		1 1	DM
1 0 0		0 1	FRMR
0 1 1		0 0	UA
1 0 1		1 1	XID