Data Link Protocols

- Is a set of specifications used to implement the data link layer
- Data link protocols differ by message delineation, frame length, and frame field structure.
- Another fundamental difference is between asynchronous and synchronous transmission data link protocols.

Asynchronous Protocols

- In asynchronous transmission (sometimes called start-sto transmission), each character is sent independently.
- The transmission sequence begins with
  - a start bit
  - next the character is sent
  - then the parity bit
  - and finally a stop bit are sent.
    - The **start** bit is usually a 0 and the **stop** bit a 1.
- Between transmissions (called "idle time"), a series of stop bits are sent.
- When a new character is sent, the start bit is used by the receiver for **synchronization**.

Asynchronous Protocols

- Protocols that belong to asynchronous protocols
  - XMODEM
  - YMODEM
  - ZMODEM
  - BLAST
  - Kermit

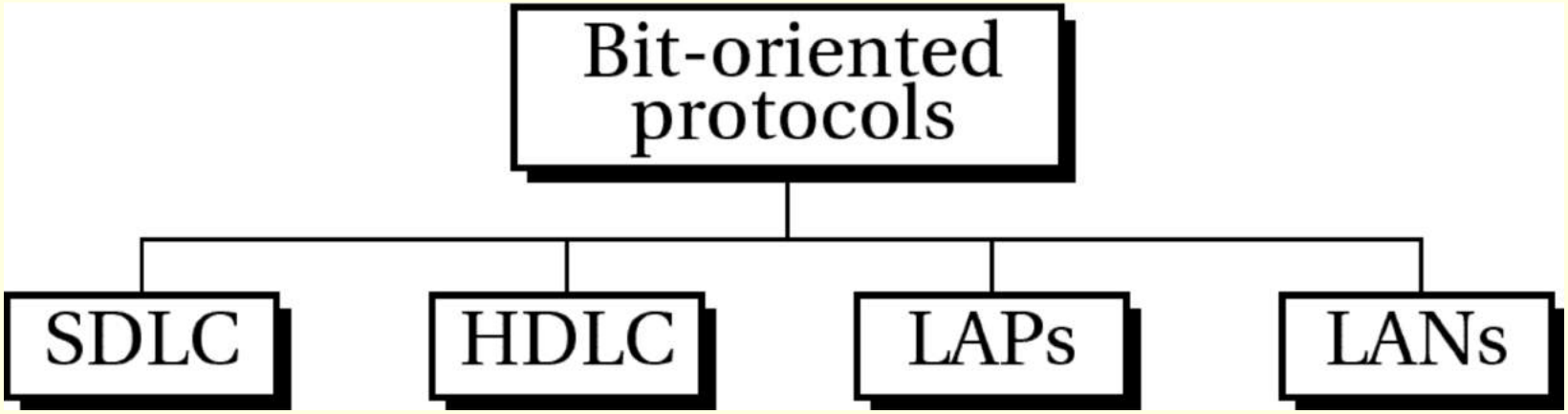
Synchronous Protocols

- In synchronous transmission
  - data is sent in a large block called a frame
- Synchronous transmission is used on both
  - point-to-point
  - multipoint circuits
    - In multipoint circuits, addressing information needs to be included in the frame.
- Synchronous packets sometimes begin and end with a series of synchronization (SYN) characters that are used to help the receiver recognize incoming data.

Synchronous Protocols

- Synchronous transmission protocols can be:
  - **character-oriented:**
    - Also known as **byte-oriented protocols**
    - Interpret a transmission frame as a succession of characters
  - **bit-oriented:**
    - Interpret a transmission frame as a succession of individual bits
    - Control information in a bit-oriented protocol can be one or multiple bits depending on the information embodied in the pattern

Bit-oriented protocols



HDLC : *High-level Data Link Control*

- It is a bit-oriented data link protocol
- Designed to support both half duplex and full duplex communication over point-to-point and multipoint links.
- It implements the ARQ mechanisms.
- The HDLC protocol embeds information in a data frame that allows devices to control data flow and correct errors

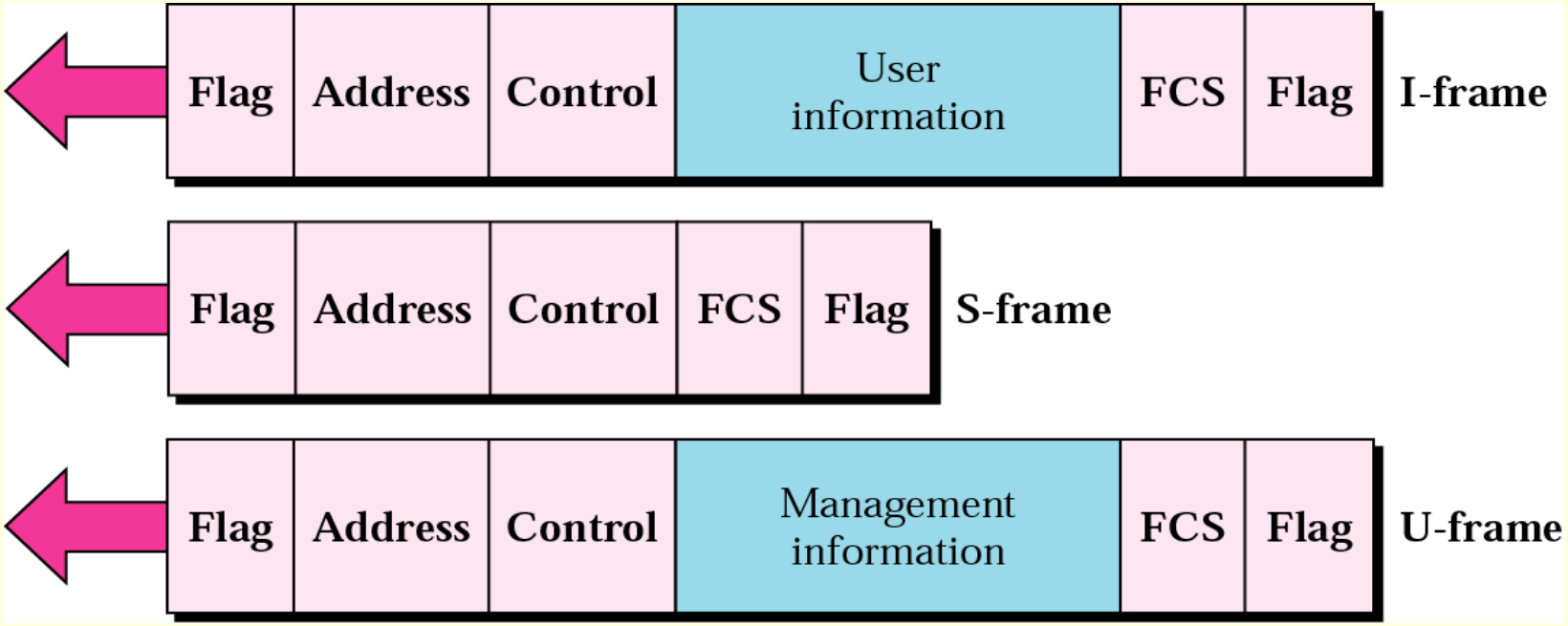
HDLC : *High-level Data Link Control*

- In 1979, the ISO made HDLC the standard as a Bit-oriented control protocol
- The HDLC provides a transparent transmission service at the data link layer
- The users of the HDLC service provides PDUs which are **encapsulated** to form data link layer frames. These frames are separated by HDLC "flags" and are modified by "zero bit insertion" to guarantee transparency

HDLC : *High-level Data Link Control*

- Each piece of data is encapsulated in an HDLC frame by adding a trailer and a header.
- **The header** contains an HDLC address and an HDLC control field.
- **The trailer** is found at the end of the frame, and contains a (CRC) which detects any errors which may occur during transmission.
- The frames are separated by HDLC flag sequences which are transmitted between each frame and whenever there is no data to be transmitted.

HDLC frame types



HDLC *Frame Fields*

Flag field

- is 8 bits of a fixed pattern (0111 1110).
- There is one flag at the beginning and one at the end frame.
- The ending flag of one Frame can be used as the beginning flag of the next frame.
- To guarantee that the flag does not appear anywhere else in the frame
- HDLC uses a process called **Bit Stuffing**.
- Every time a sender wants to transmit a bit sequence having more than 6 consecutive 1's, it inserts 1 redundant 0 after the 5_{th} 1

Exceptions:

- When the **bit sequence** is really a **flag.**
- when **transmission** is being **aborted.**
- when the **channel** is being put into **idle.**

Bit Stuffing

- the process of adding one extra zero whenever there are 5 consecutive 1's in the data, so that the receiver doesn't mistake the data for a flag.

A frame before bit stuffing:

01111110 01111100 101101111 110010

After

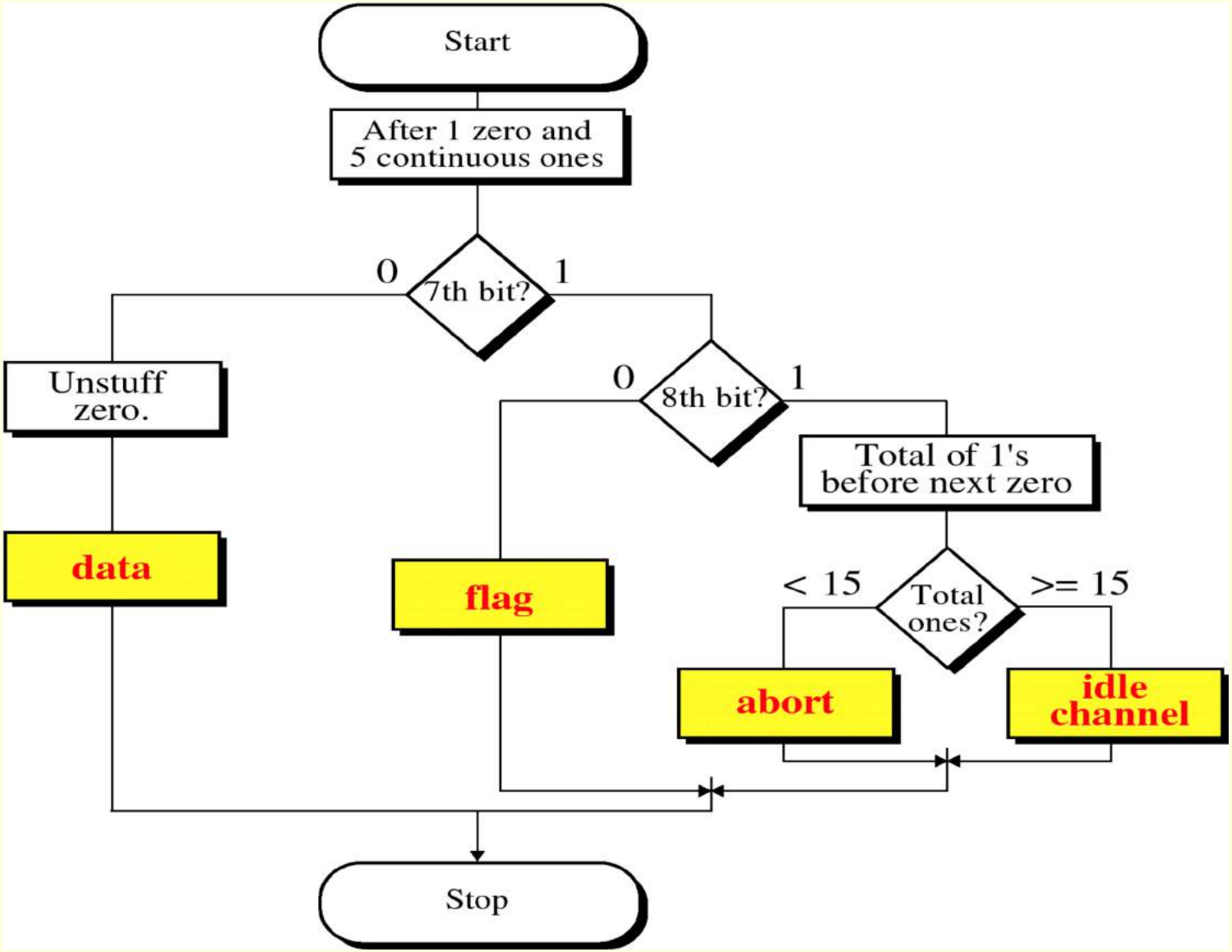
011111010 011111000 101101111 1010010

How does the receiver identify a stuffed bit?

- Receiver reads incoming bits and counts 1's.
- When number of consecutive 1s **after** a zero is 5, it checks the next bit (7^{th} bit).
- If **7^{th} bit = zero** ➔ receiver recognizes it as a **stuffed bit**, discard it and resets the counter.
- If the **7^{th} bit = 1** ➔ then the receiver checks the 8^{th} bit; If the **8^{th} bit = 0**, the sequence is recognized as a **flag**.

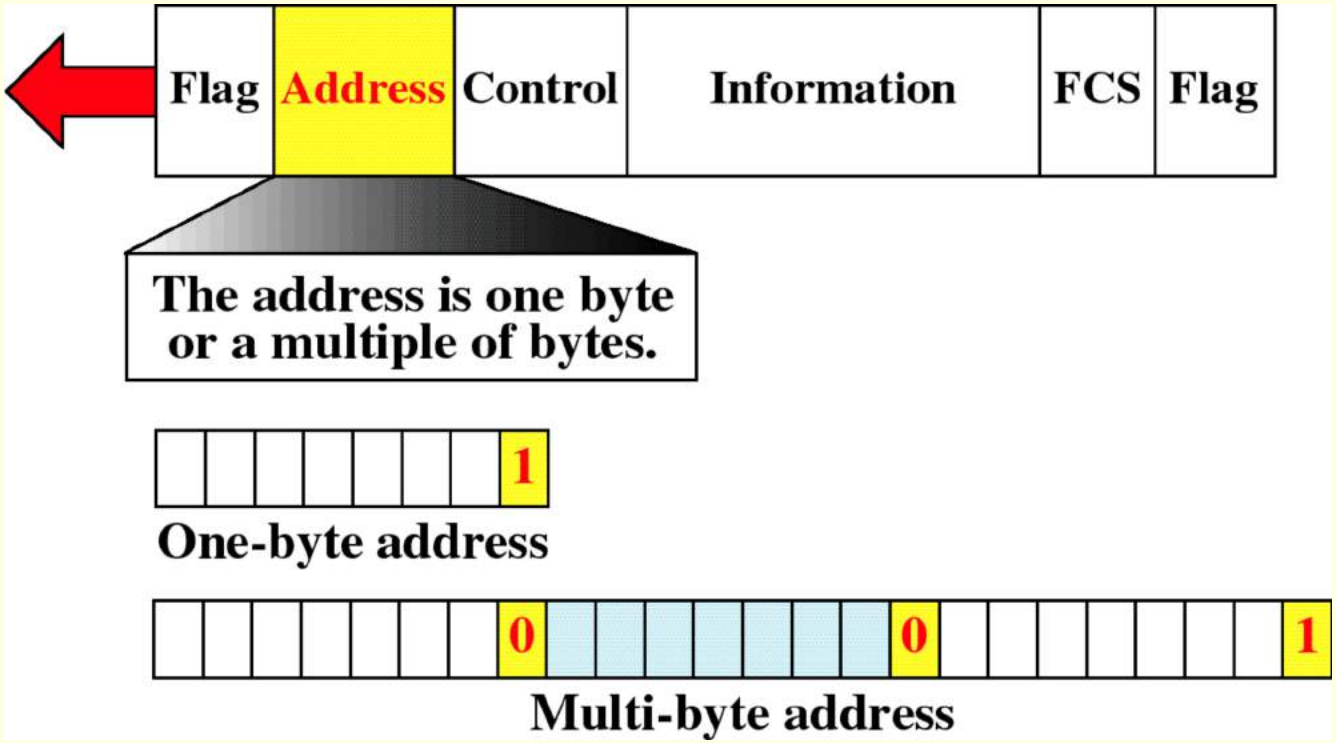
01111010 011111000 101101111 10010010

How does the receiver identify a stuffed bit?

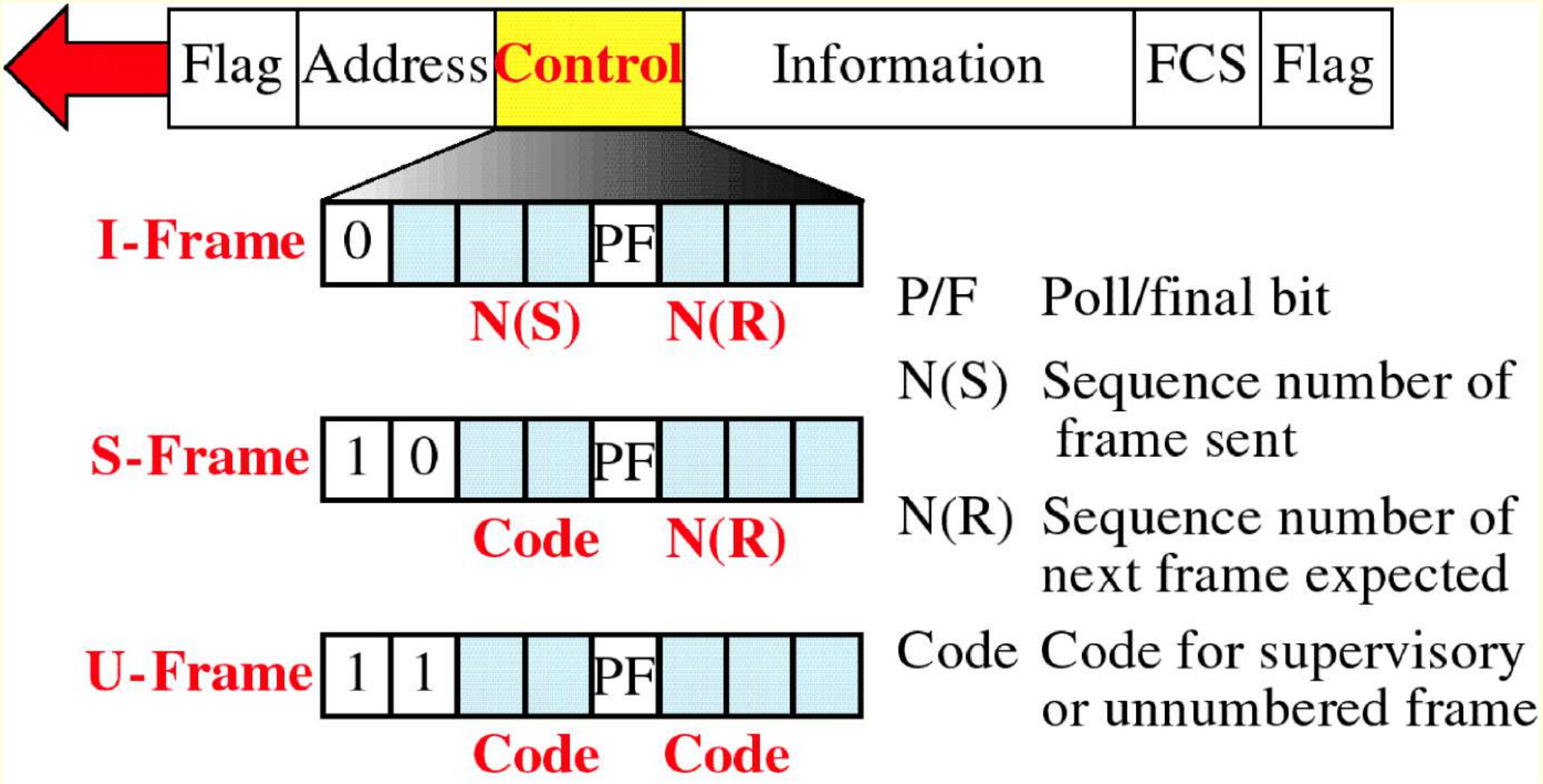


Address field

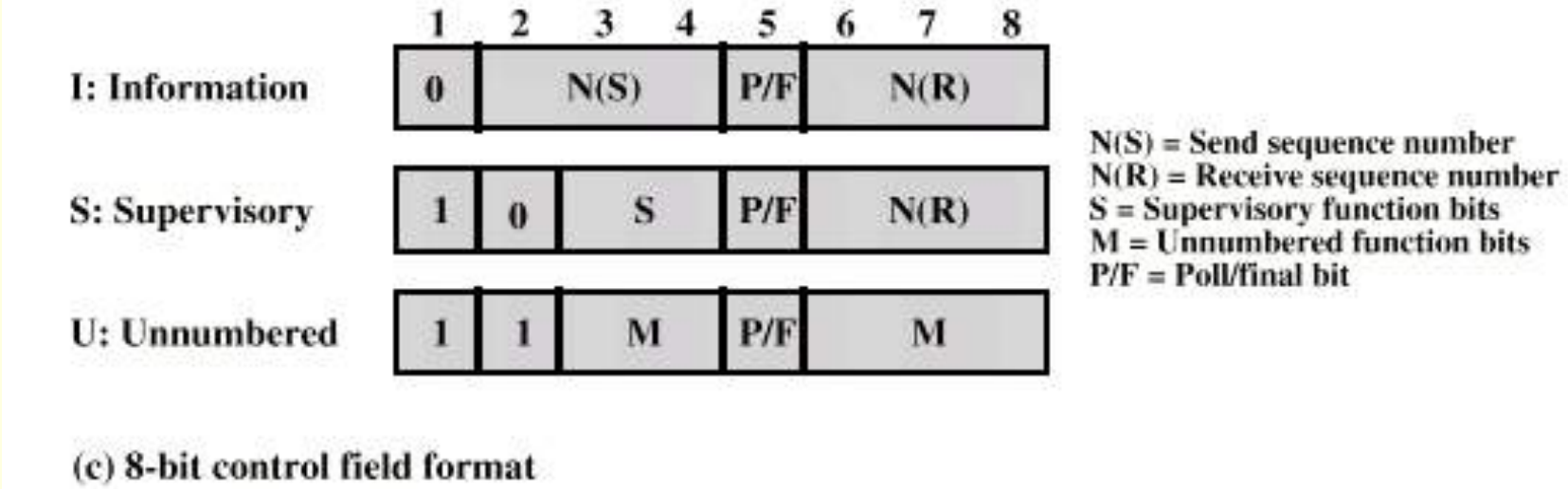
- Address field is one byte or more
- If the address is more than one byte, all bytes will end with 0,except the last one



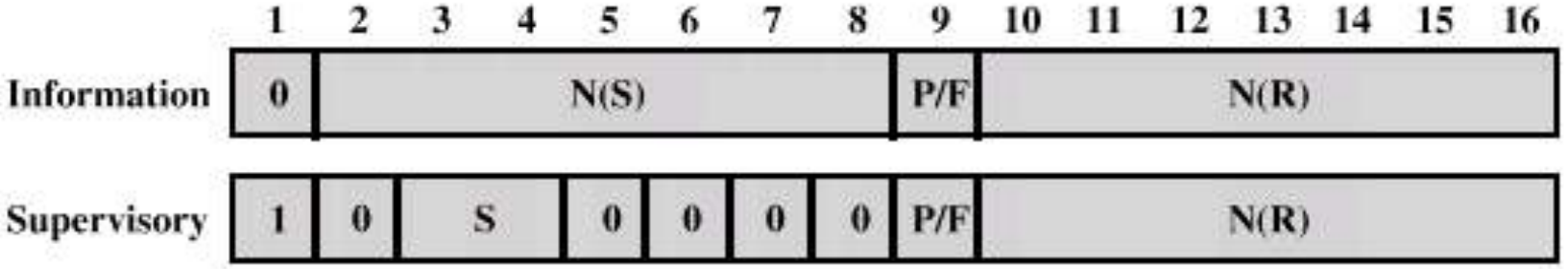
HDLC Control Field



Control Field Diagram



(c) 8-bit control field format



(d) 16-bit control field format

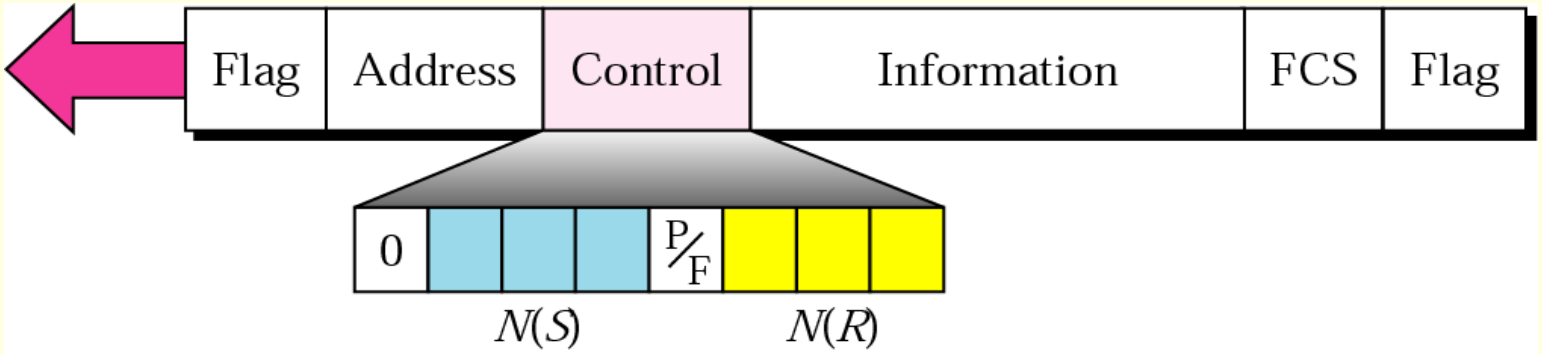
Control Field

- all three types contain a bit called (Poll/Final) P/F bit

I-Frame

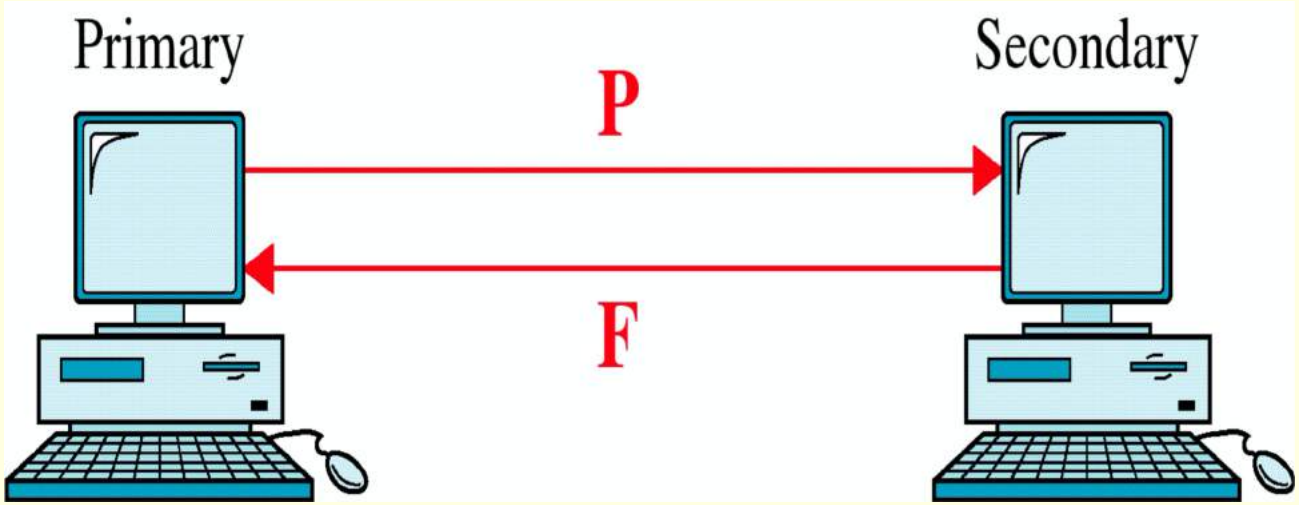
- **N(S)** : sequence # of the **sent frame**
- **N(R)** : sequence # of frame **expected in return**
  - ➔ **N(R)** is ACK field
- If last frame received is error free
  - ➔N(R) number will be the next frame in sequence
- If the frame was not received correctly
  - ➔ N(R) number will be the number of damaged frame indicating the need for retransmission

I *frame*

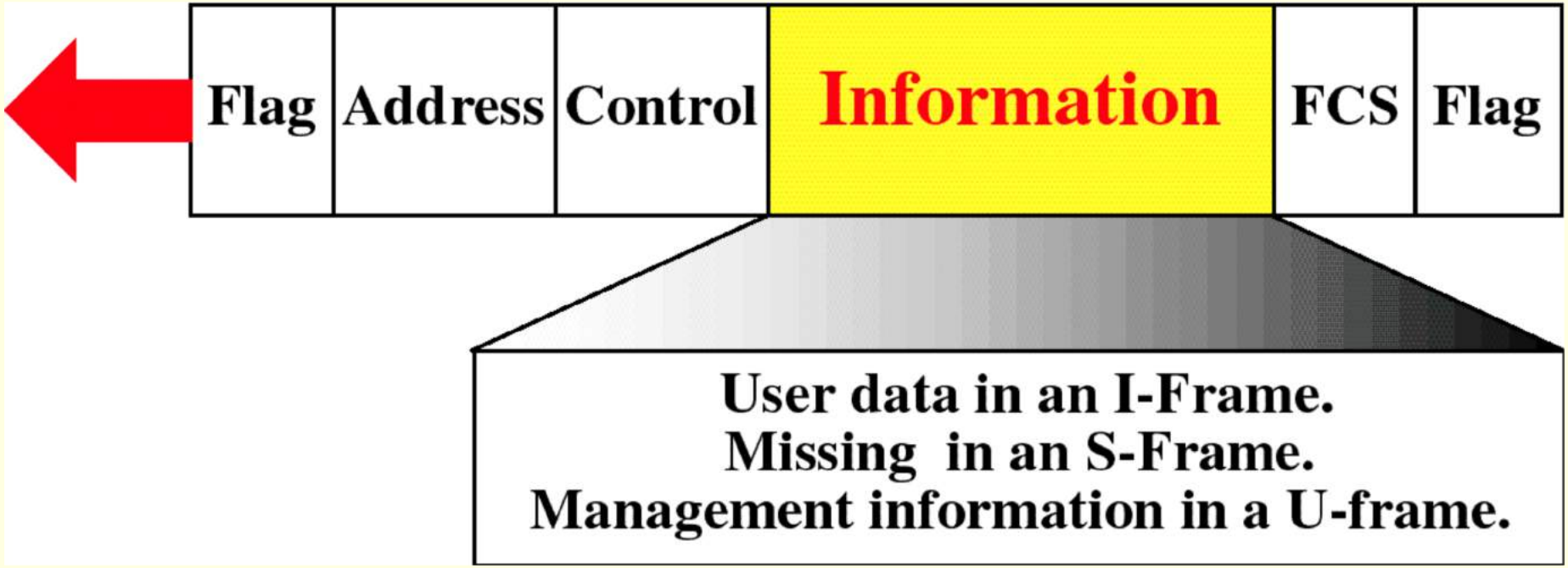


Poll/Final

- P/F = 1 ➔POLL or Final
  - **Poll** if frame is sent by the primary
  - **Final** if frame is sent by the secondary



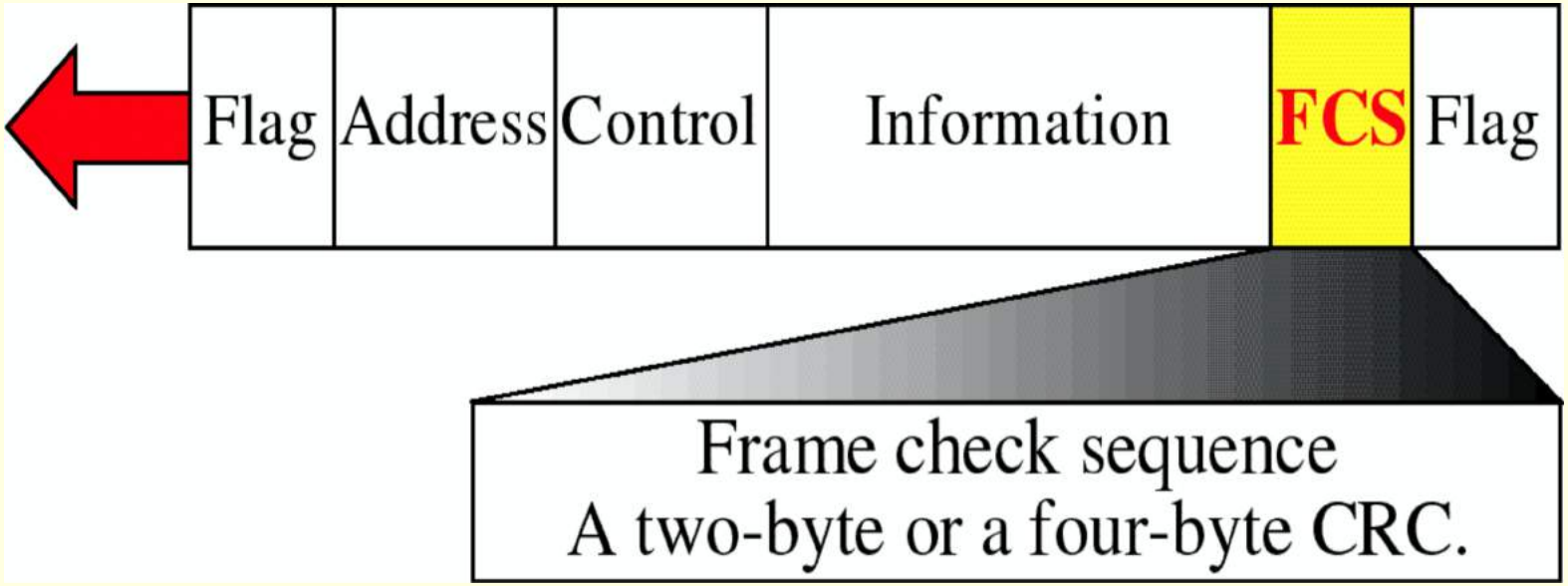
Information Field



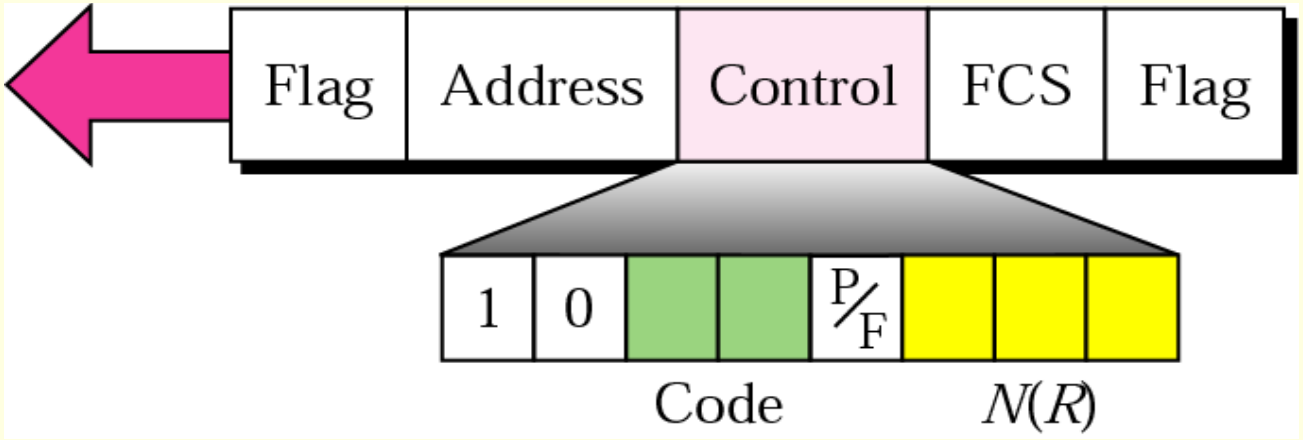
Information Field

- Contains **user data** in **I**-frame and **network management information** in a **U**-frame.
- It is possible to include flow and error control information in an I-frame that also contains data.
- In 2-way exchange of data (1/2 or full-duplex), the 2nd station can ACK receipt of data from the 1st station in the control field of its own data frame rather than sending a separate frame just for ACK.
- Combining data to be sent & ACK of the frame received in one single frame is called **PIGGYBACKING**.

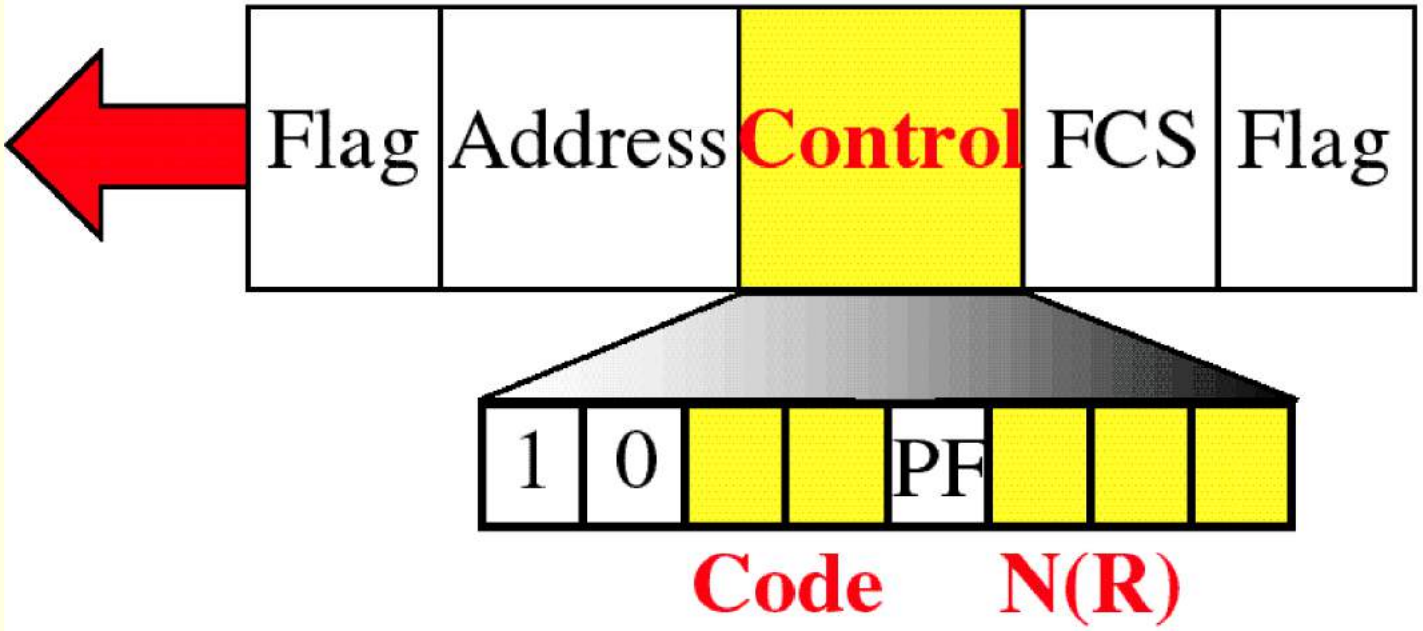
HDLC FCS Field



S-frame control field in HDLC



S-Frame

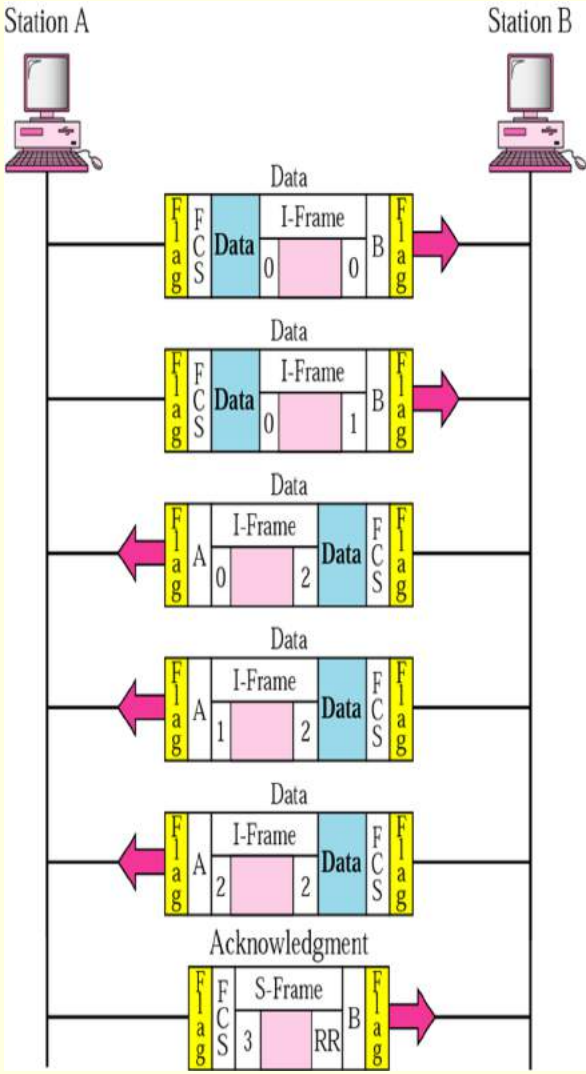


Code	Command	
00	RR	Receive ready
01	REJ	Reject
10	RNR	Receive not ready
11	SREJ	Selective-reject

- **Receive Ready (RR)**
  - Positive ACK of a received I- frame
- **Receive Not Ready (RNR)**
  - Is RR frame with additional duties
  - It ACK the receipt of a frame and announces that the receiver is busy
- **Reject (REJ)**
  - This is a NAK frame that can be used in Go-back-n
- **Selective reject (SREJ)**
  - This is a NAK frame used in Selective Repeat ARQ

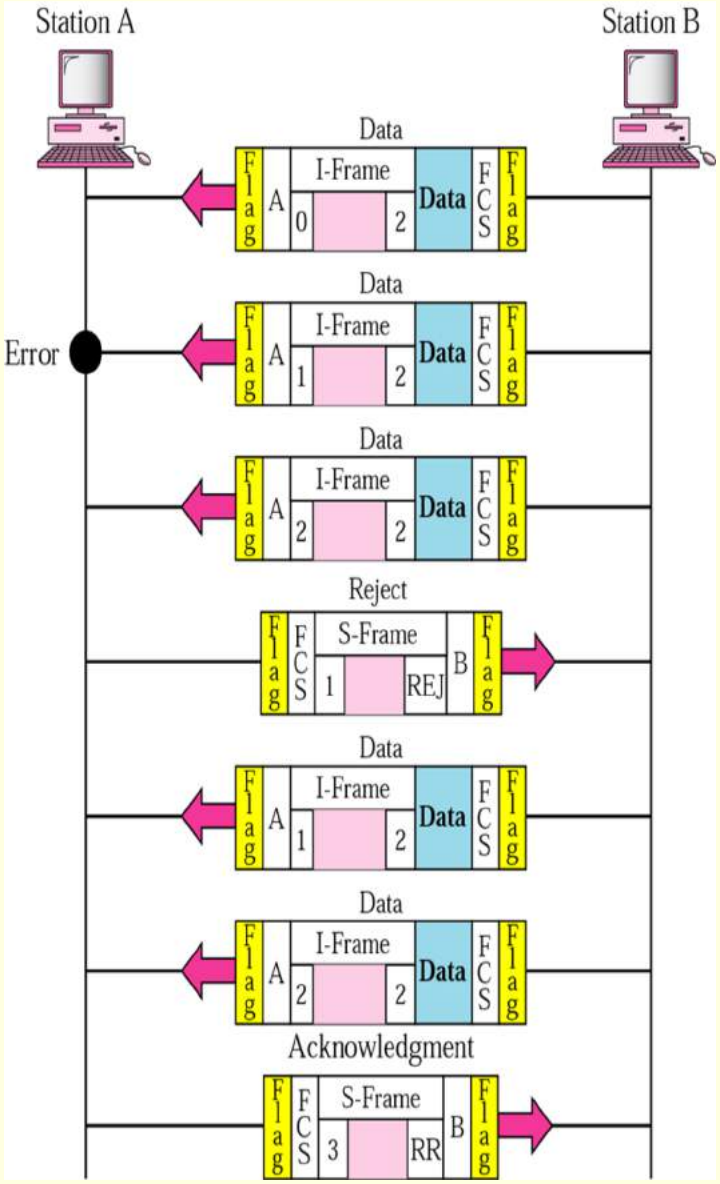
Example

- The figure shows an exchange using piggybacking where is no error
  - Station A begins the exchange of information with an I-frame numbered 0 followed by another I-frame numbered 1.
  - Station B piggybacks its acknowledgment of both frames onto an I-frame of its own.
  - Station B's first I-frame is also numbered 0 [N(S) field] and contains a 2 in its N(R) field, acknowledging the receipt of A's frames 1 and 0 and indicating that it expects frame 2 to arrive next.
  - Station B transmits its second and third I-frames (numbered 1 and 2) before accepting further frames from station A.
  - Its N(R) information, therefore, has not changed: B frames 1 and 2 indicate that station B is still expecting A frame 2 to arrive next.



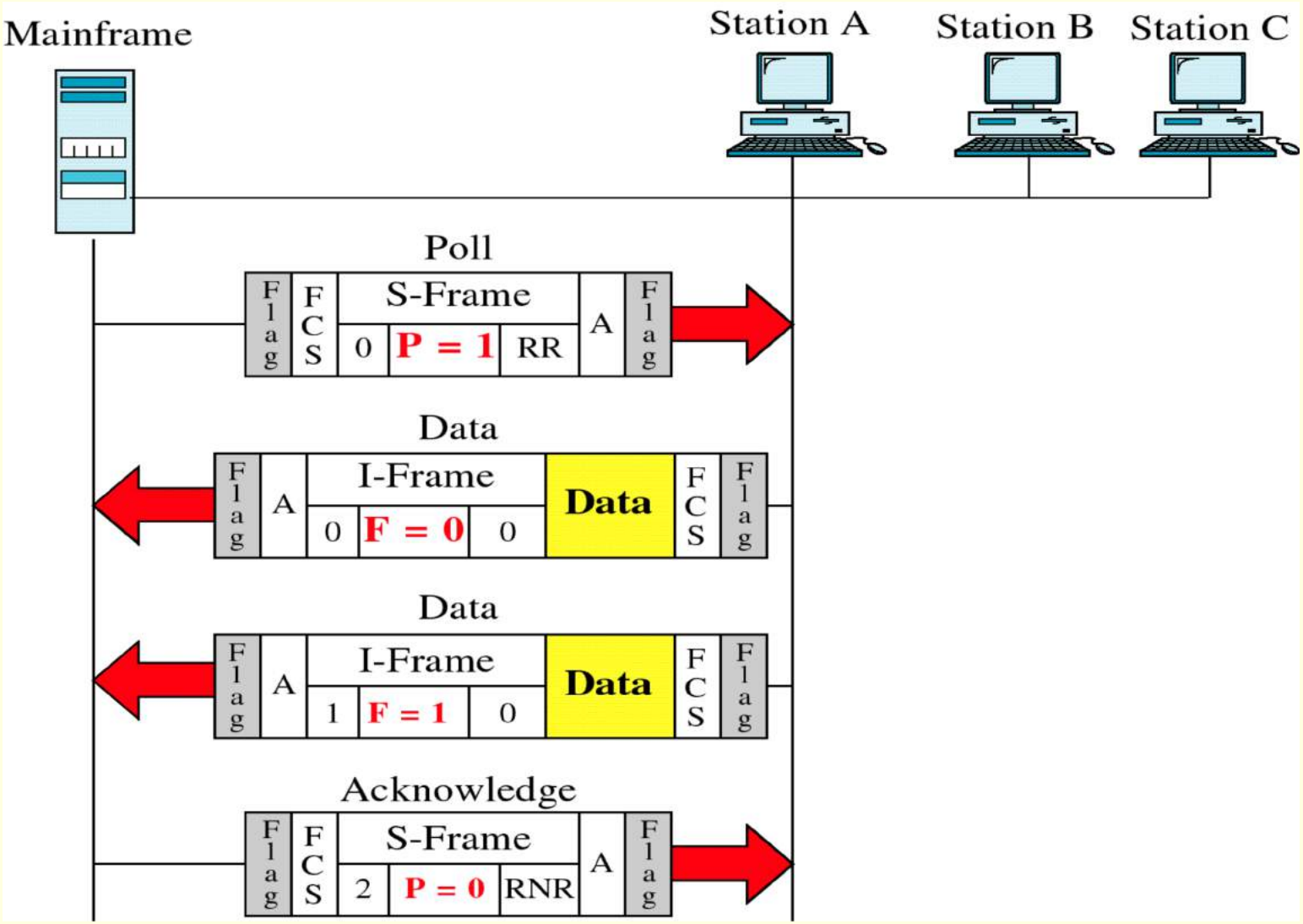
Example

- In the previous Example, suppose frame 1 sent from station B to station A has an error.
- Station A informs station B to resend frames 1 and 2 (the system is using the Go-Back-N mechanism)
- Station A sends a reject supervisory frame to announce the error in frame 1



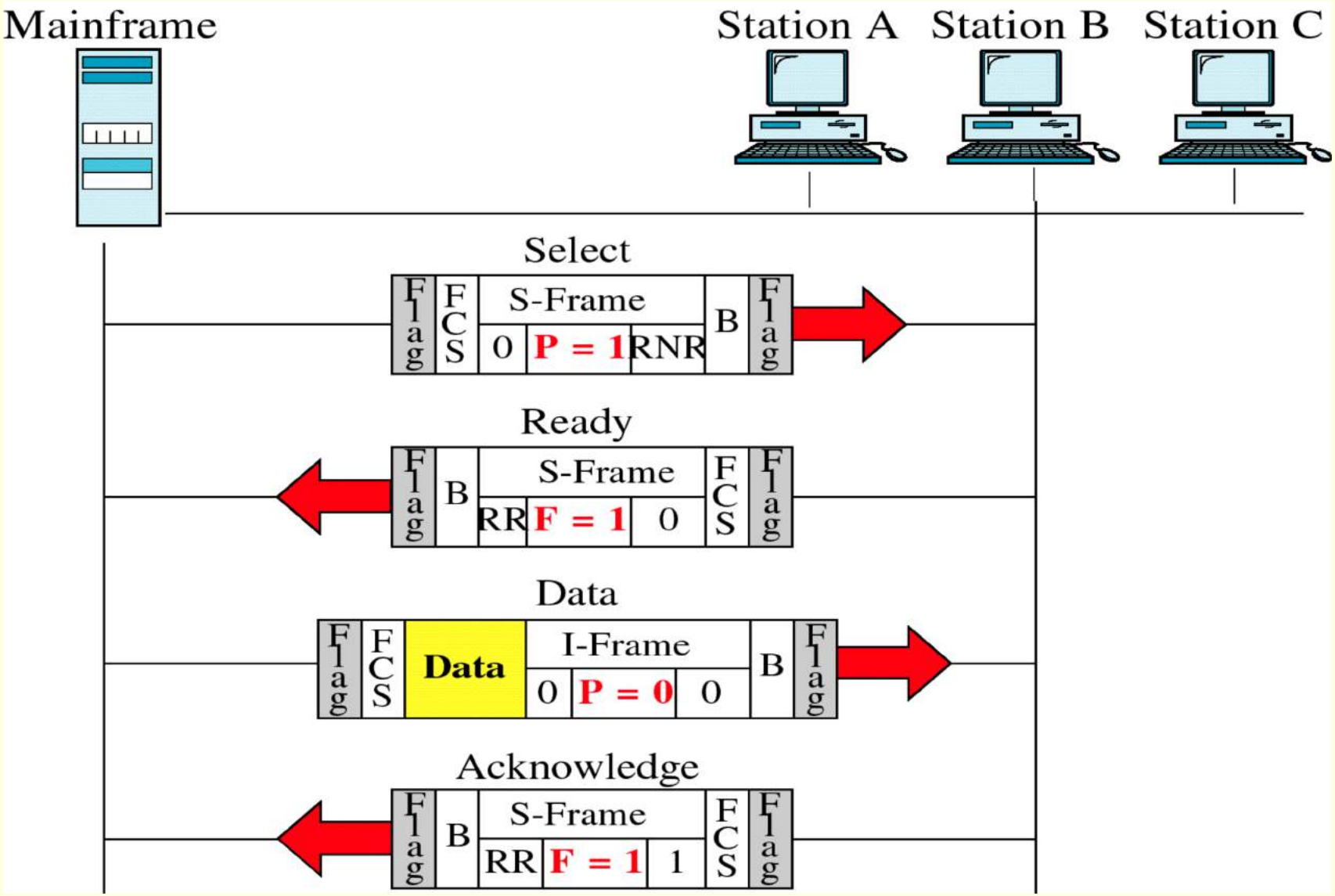
Polling Example

asking the secondary if it has anything to send



Selecting Example

A primary wishes to send data to secondary



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

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

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

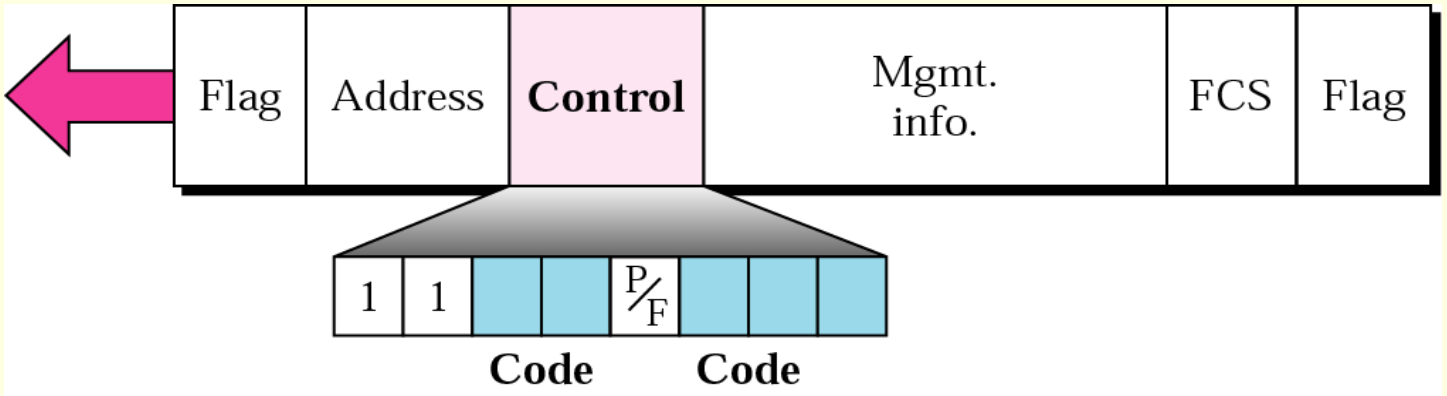
HDLC Transfer Modes (2)

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

HDLC Transfer Modes (3)

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

U-frame control field in HDLC



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

U-frame control command and response

Command/response	Meaning
SNRM	Set normal response mode
SNRME	Set normal response mode (extended)– control field 2 bytes
SABM	Set asynchronous balanced mode
SABME	Set asynchronous balanced mode (extended)
UP	Unnumbered poll
UI	Unnumbered information
UA	Unnumbered acknowledgment
RD	Request disconnect
DISC	Disconnect
DM	Disconnect mode
RIM	Request information mode
SIM	Set initialization mode
RSET	Reset
XID	Exchange ID
FRMR	Frame reject

HDLC Operation

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

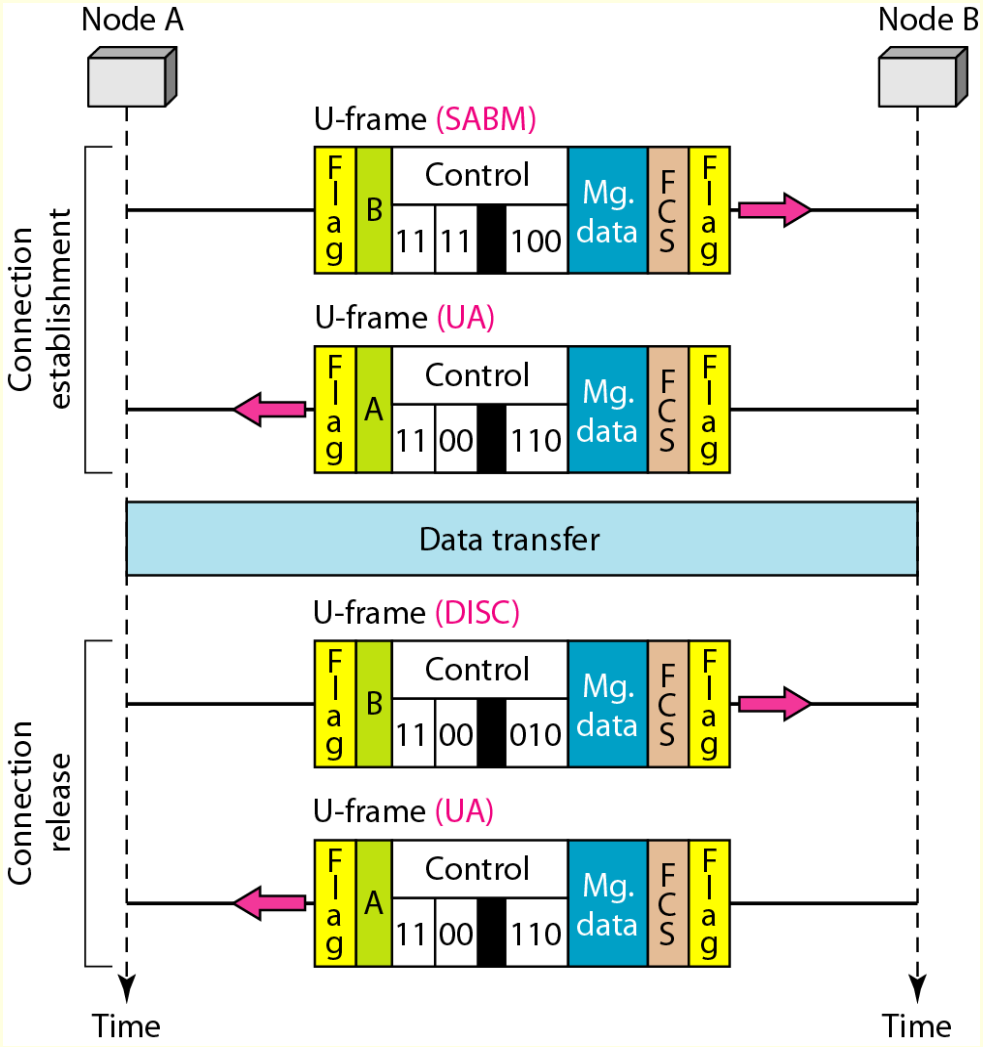
U-frame **Mode setting**

- Mode-setting commands sent by the primary or combined station wishing to control an exchange
- If a combined station wishes to establish a temporary primary-to-secondary relationship with another station it sends a U-frame containing code 00-001 (Normal Response Mode)

U-frame **Disconnection**

- There three disconnection codes
  - One command from acting primary or combined station
    - disconnection (DISC 00 010) is sent by the 1st station to the 2nd station to terminate the connection
  - Two responses from the receiving station
    - request disconnect (RD 00 010) is a request by the 2nd station to the 1st that a DISC be issued.
    - disconnect mode (DM 11 000) is transmitted by the addressed station as a negative response to mode-setting command

Example of connection and disconnection



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)

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)

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

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

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)

Point-to-Point Protocol (PPP)

Basics of PPP

- Used on point-to-point links such as modem dialup, DSL, and cable modem
- SLIP (serial line Internet protocol) was first but could only support IP and only static IP address assignment
- PPP solves both above problems

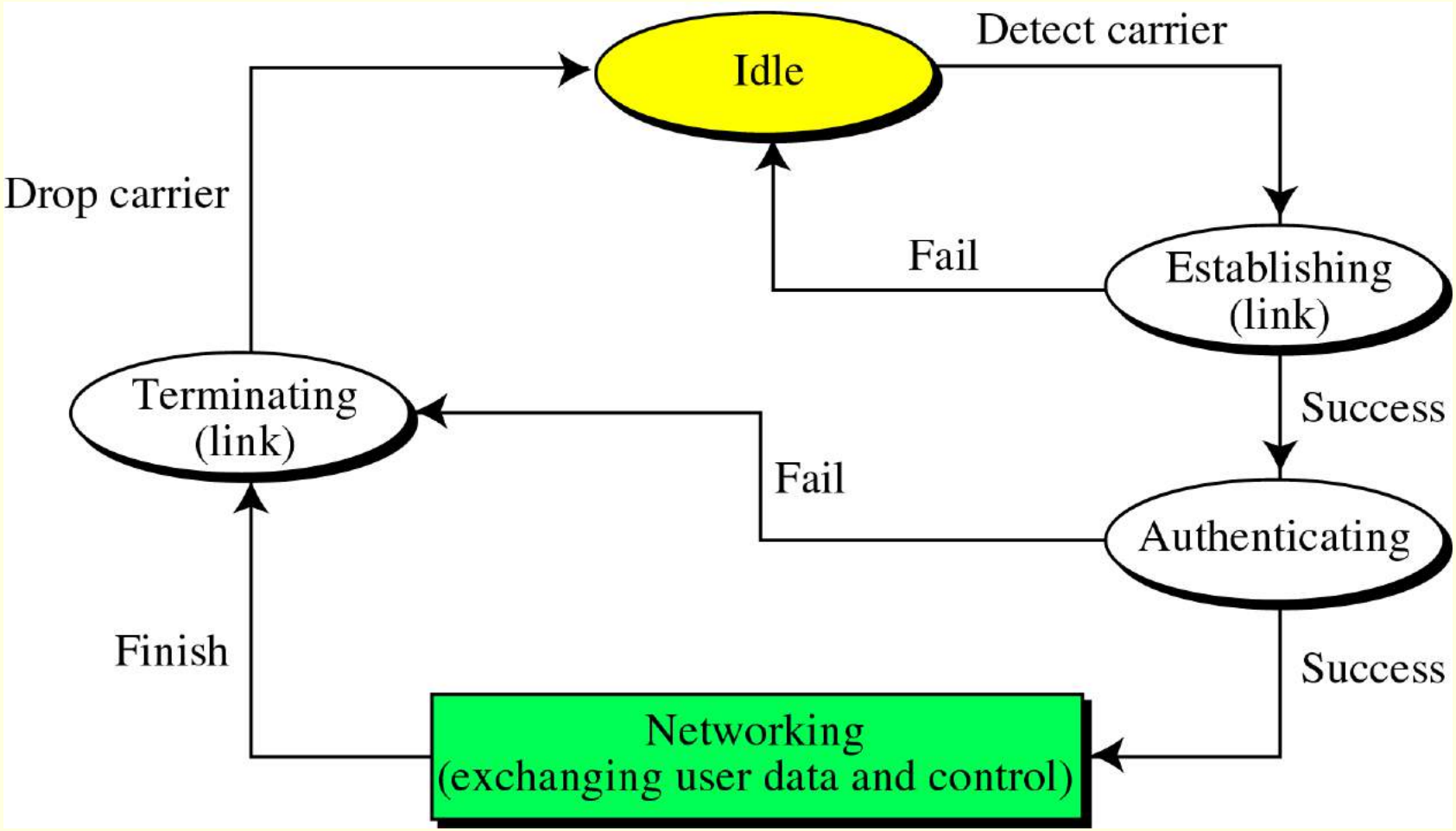
PPP States

- Idle state – link is not being used
- Establishing state – one endpoint starts a dialog; options are exchanged between endpoints; several packets may be exchanged
- Authenticating state – optional, two sides agree to authenticate (described later)

PPP States

- Networking state – primary state, exchange of user control and data packets can now be performed
- Terminate state – one side wishes to tear down connection; several packets exchanged (housekeeping)
- (See figure next slide)

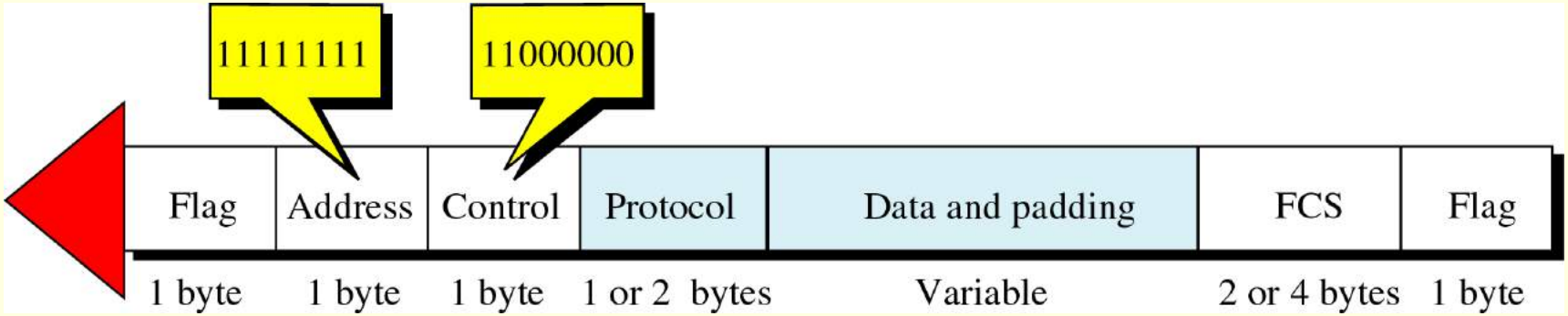
Transition States



PPP Layers

- PPP has only two layers – physical and data link
- Physical layer is not defined – it is whatever the user uses
- Data link layer looks like HDLC, except address field = 11111111 (broadcast), control field = 11000000 (a HDLC U-frame)

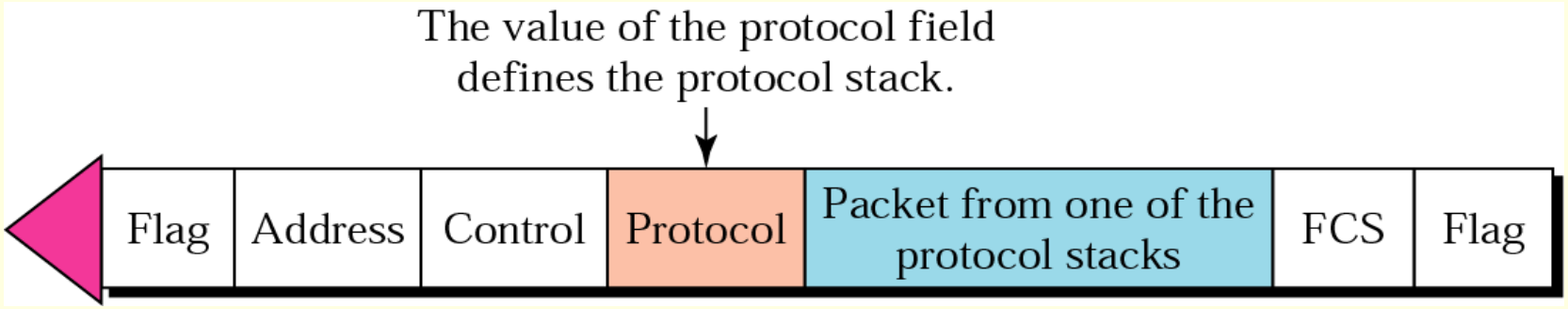
PPP Frames


11111111
11000000
Flag
Address
Control
Protocol
Data and padding
FCS
Flag
1 byte
1 byte
1 byte
1 or 2 bytes
Variable
2 or 4 bytes
1 byte

PPP Layers

- The Data field carries the packets from one of three other protocols - Link Control Protocol, authentication protocols, and Network Control Protocol, all described shortly

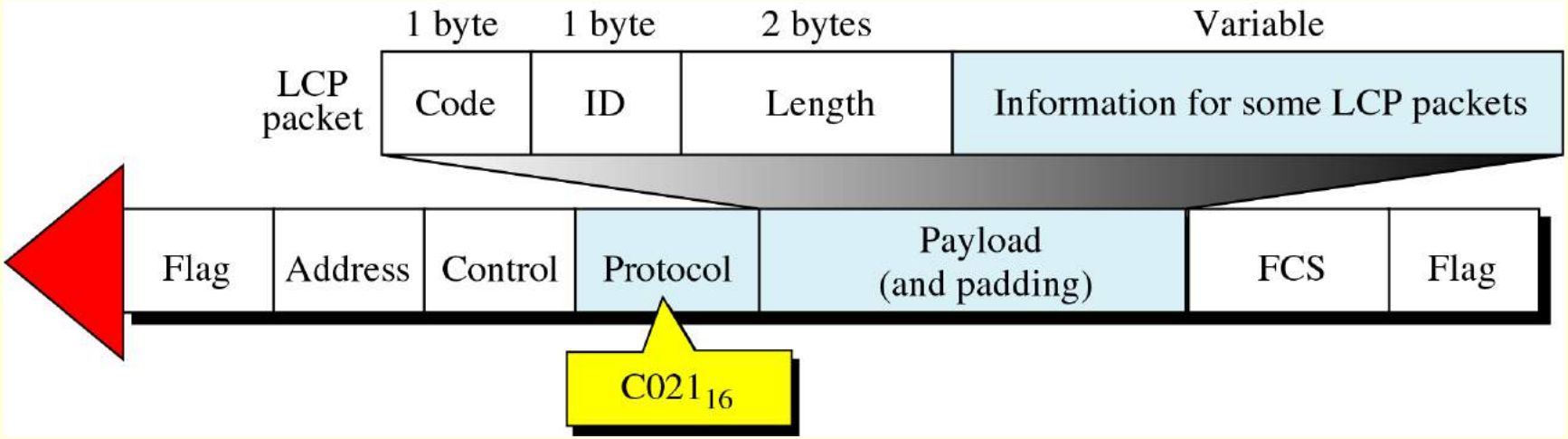
Protocol stack



Link Control Protocol (LCP)

- Responsible for establishing, maintaining, configuring, terminating link, and negotiation
- All LCP packets are carried in payload field of PPP frame – PPP field Protocol = hex C021

LCP Packet Encapsulated in a Frame



LCP packets and their codes

Code	Packet Type	Description
01_{16}	Configure-request	Contains the list of proposed options and their values
02_{16}	Configure-ack	Accepts all options proposed
03_{16}	Configure-nak	Announces that some options are not acceptable
04_{16}	Configure-reject	Announces that some options are not recognized
05_{16}	Terminate-request	Requests to shut down the line
06_{16}	Terminate-ack	Accepts the shut down request
07_{16}	Code-reject	Announces an unknown code
08_{16}	Protocol-reject	Announces an unknown protocol
09_{16}	Echo-request	A type of hello message to check if the other end is alive
$0A_{16}$	Echo-reply	The response to the echo-request message
$0B_{16}$	Discard-request	A request to discard the packet

Common options

Option	Default
Maximum receive unit	1500
Authentication protocol	None
Protocol field compression	Off
Address and control field compression	Off

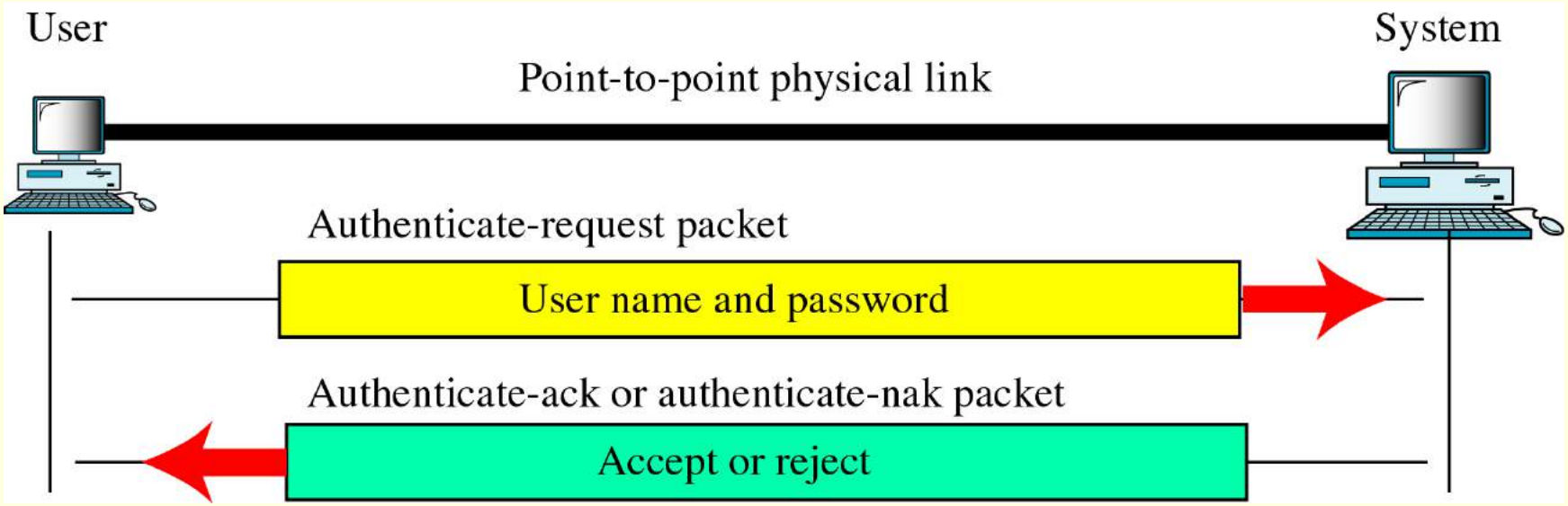
Authentication

- Potentially important since this is dial-up communication
- Two possible protocols for authentication:
  - Password Authentication Protocol (PAP)
  - Challenge Handshake Authentication Protocol (CHAP)

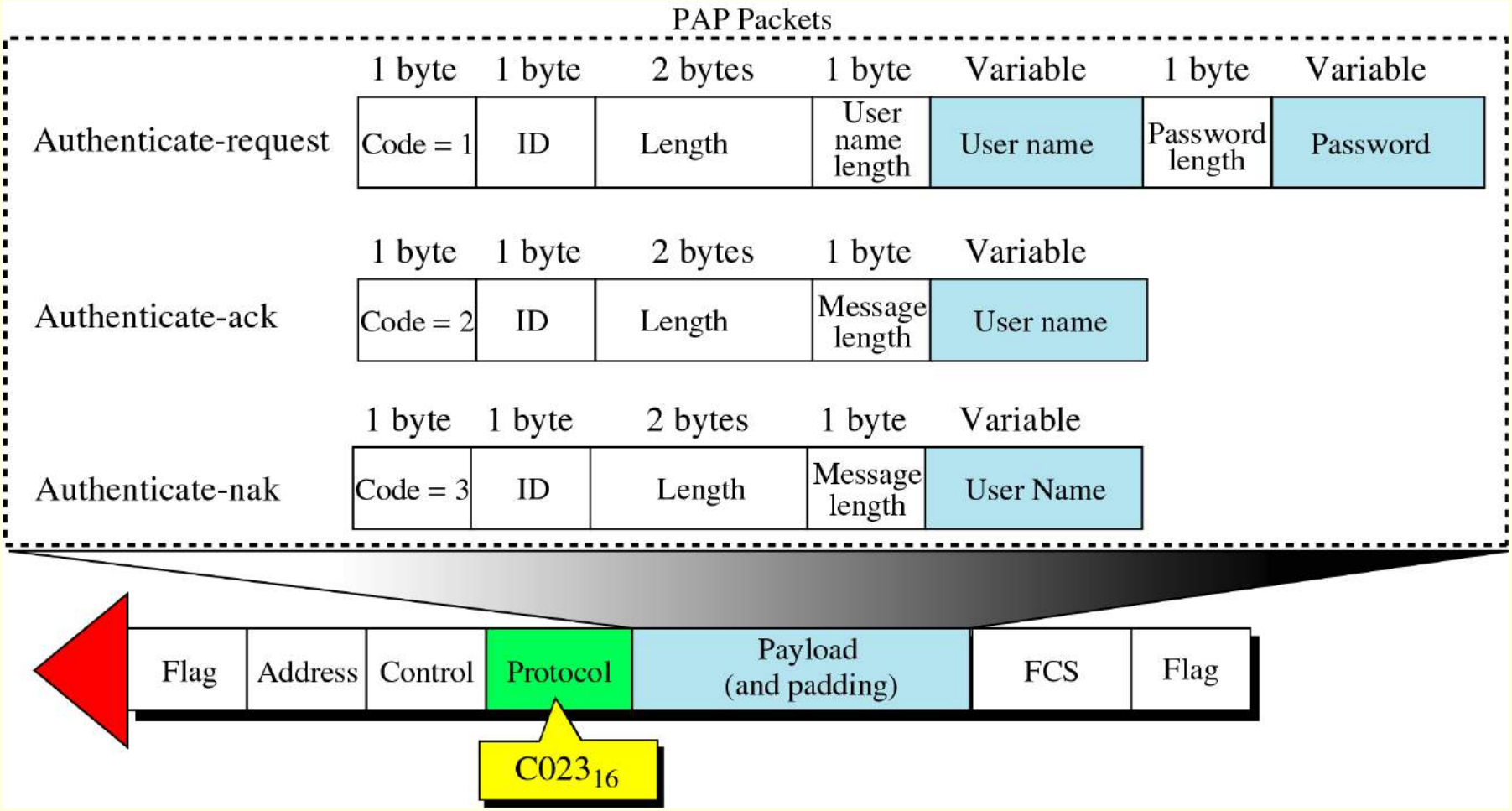
Authentication – PAP

- Two-step process
  - User sends ID and password
  - System verifies
- PAP packets are encapsulate in a PPP frame
- There are 3 types of PAP packets (see the next two slides)

PAP


User
System
Point-to-point physical link
Authenticate-request packet
User name and password
Authenticate-ack or authenticate-nak packet
Accept or reject

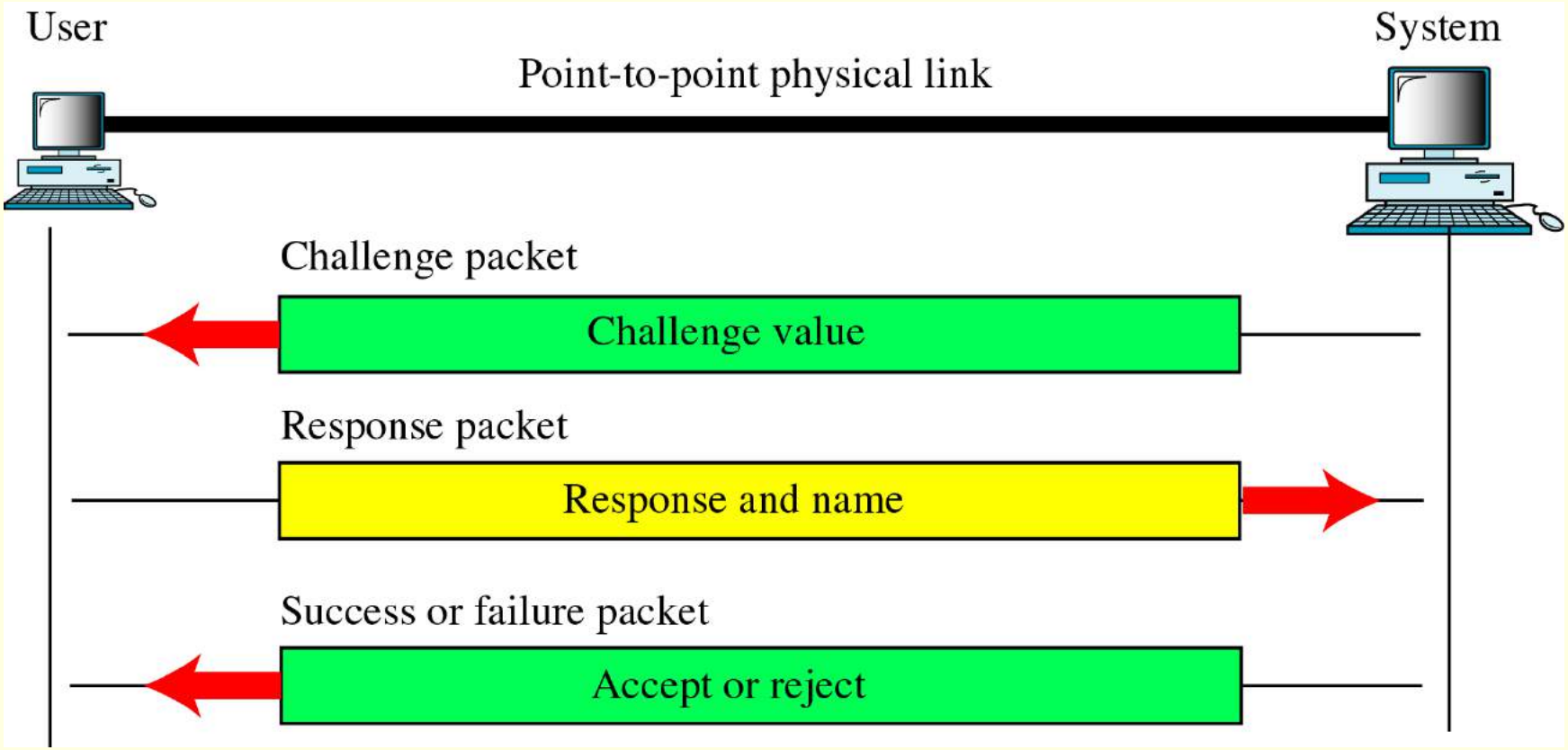
PAP Packets


PAP Packets
1 byte
1 byte
2 bytes
1 byte
Variable
1 byte
Variable
Authenticate-request
Code = 1
ID
Length
User name length
User name
Password length
Password
1 byte
1 byte
2 bytes
1 byte
Variable
Authenticate-ack
Code = 2
ID
Length
Message length
User name
1 byte
1 byte
2 bytes
1 byte
Variable
Authenticate-nak
Code = 3
ID
Length
Message length
User Name
Flag
Address
Control
Protocol
Payload (and padding)
FCS
Flag
C023 16

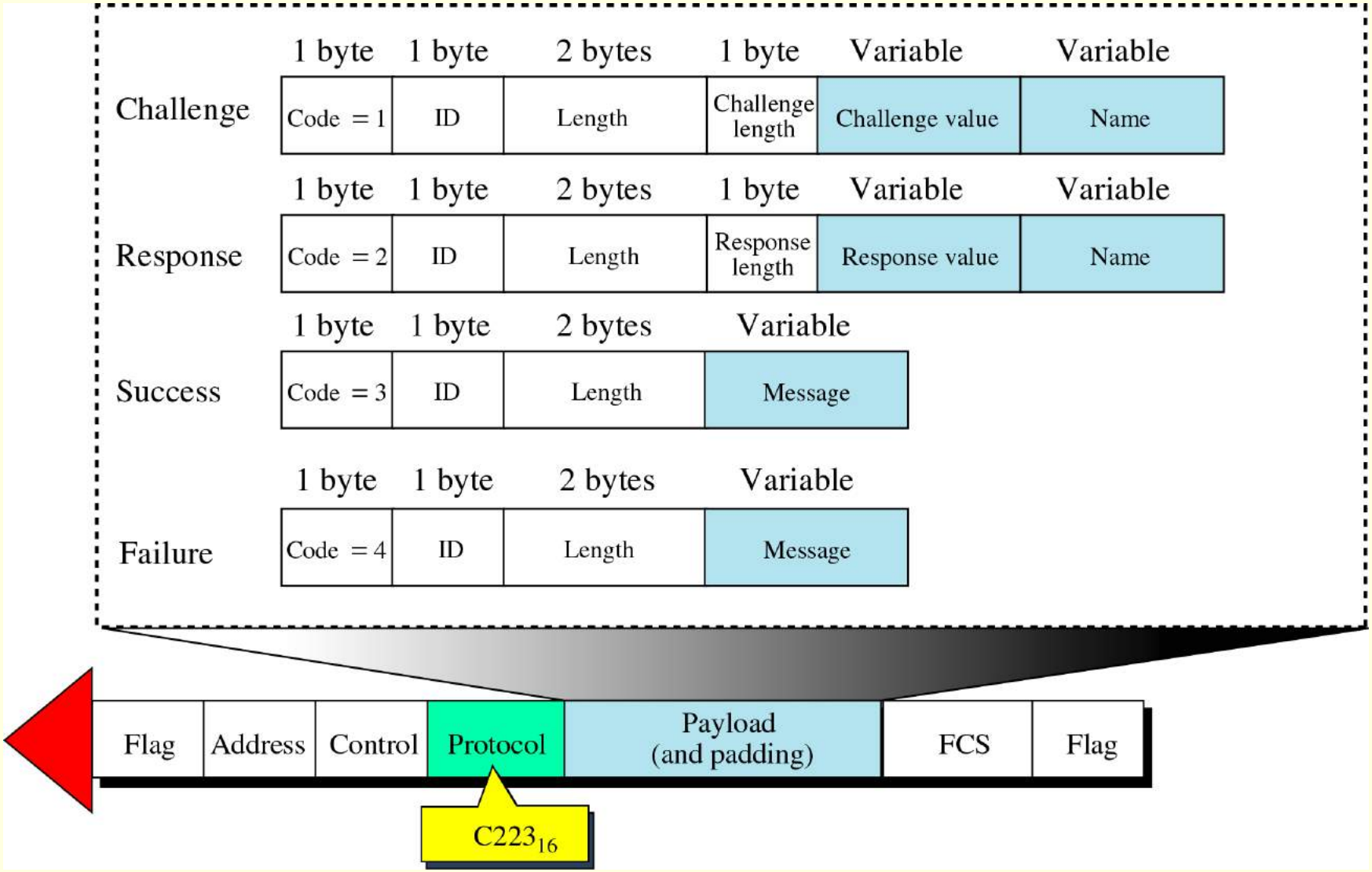
Authentication – CHAP

- Three-way handshake
  - System sends a challenge packet
  - User applies a predefined function that takes the challenge value and the user's own password and creates a result
  - System does the same; then compares its result to user's result

CHAP


User
System
Point-to-point physical link
Challenge packet
Challenge value
Response packet
Response and name
Success or failure packet
Accept or reject

CHAP Packets



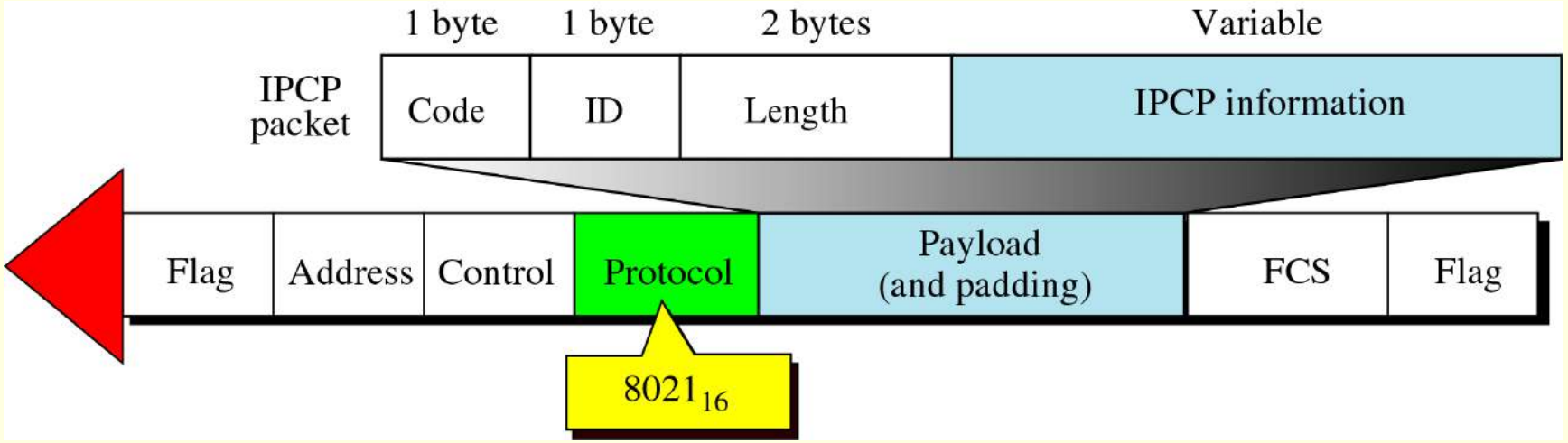
IPCP (An NCP Protocol)

- Now that a link has been established and optional security has been established, we need to establish a *network layer connection*
- IPCP, or Internetwork Protocol Control Protocol, is an NCP (Network Control Protocol)

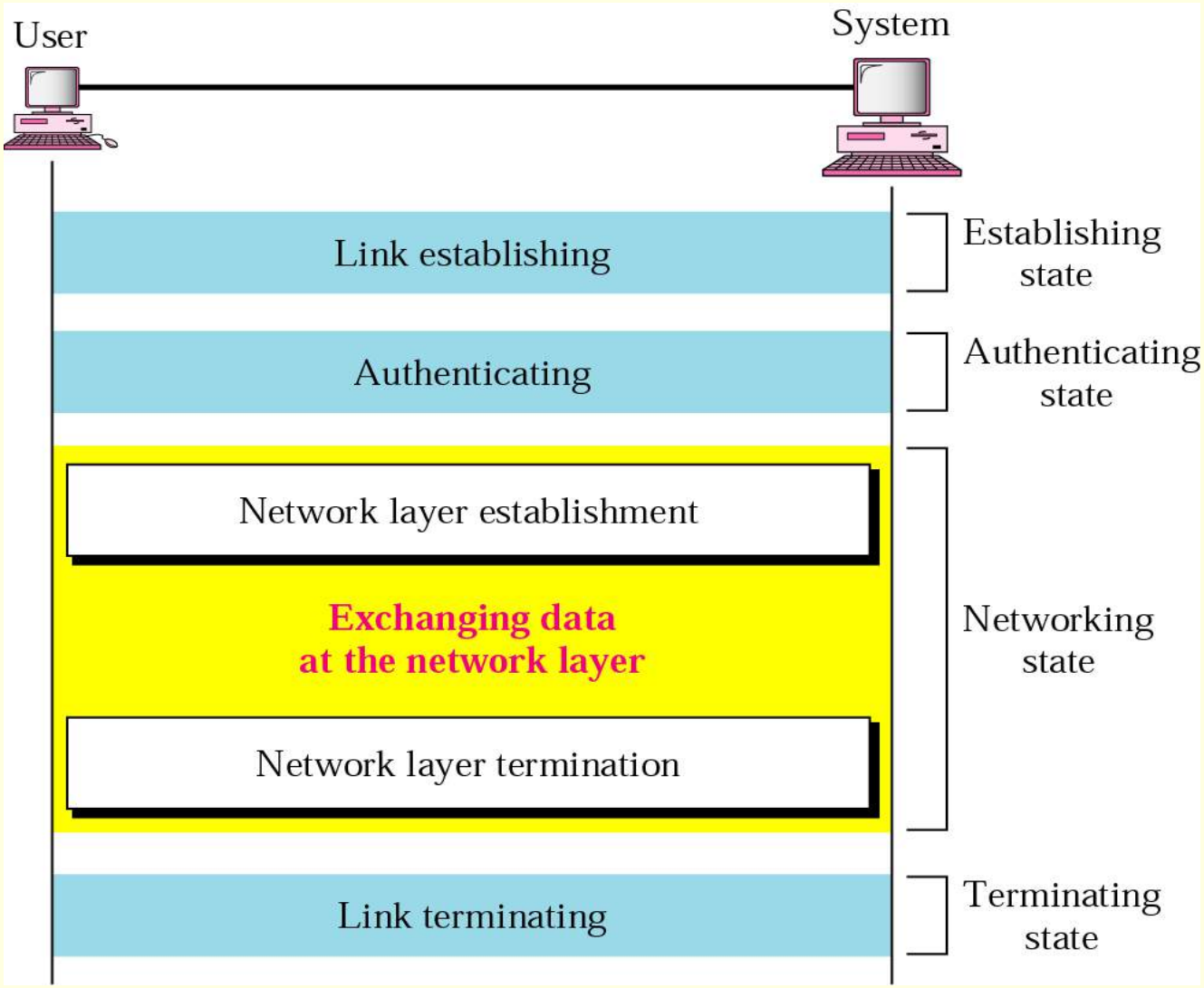
IPCP

- Seven packet types:
  - Configure-request (01)
  - Configure-ACK (02)
  - Configure-NAK (03)
  - Configure-reject (04)
  - Terminate-request (05)
  - Terminate-ACK (06)
  - Code-reject (07)

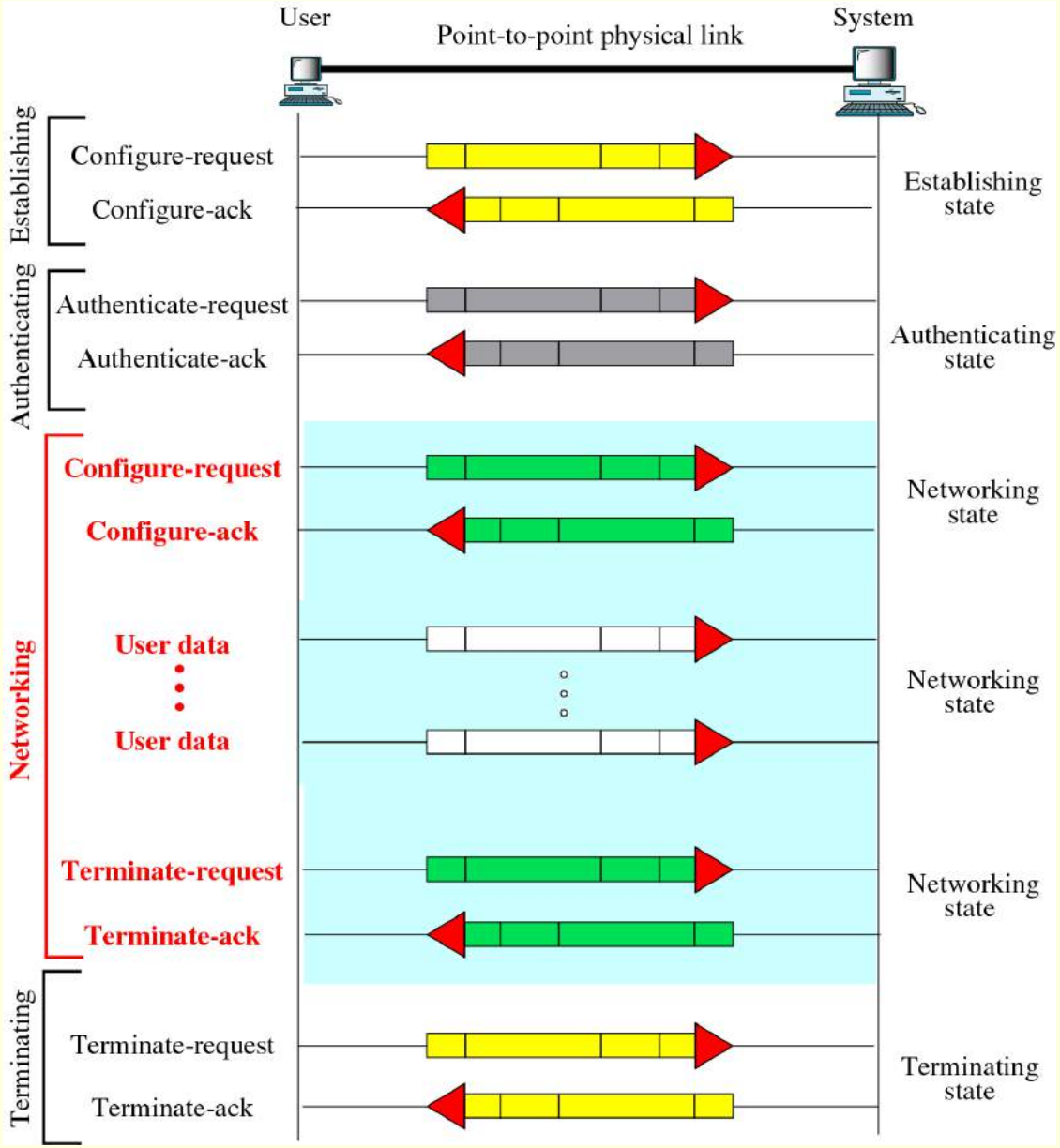
IPCP Packet Encapsulated in PPP Frame



An example


User
System
Link establishing
Authenticating
Network layer establishment
Exchanging data
at the network layer
Network layer termination
Link terminating
Establishing
state
Authenticating
state
Networking
state
Terminating
state

An Example


User
Point-to-point physical link
System
Establishing
Configure-request
Configure-ack
Establishing state
Authenticating
Authenticate-request
Authenticate-ack
Authenticating state
Networking
Configure-request
Configure-ack
Networking state
User data
User data
Networking state
Terminate-request
Terminate-ack
Networking state
Terminating
Terminate-request
Terminate-ack
Terminating state