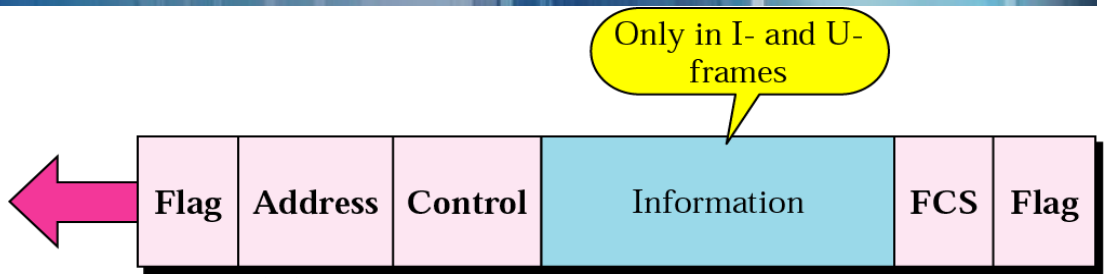
Review: HDLC

- Three Frame Types
  - I-Frame: Information Transfer Format
  - S-Frame: Supervisory Format
  - U-Frame: Unnumbered Format
- Implements Flow Control & Error Control mechanisms
  - Stop-And-Wait
  - Go-Back-N
  - Selective Repeat
- Bit-Stuffing - to avoid confusion of data and flag

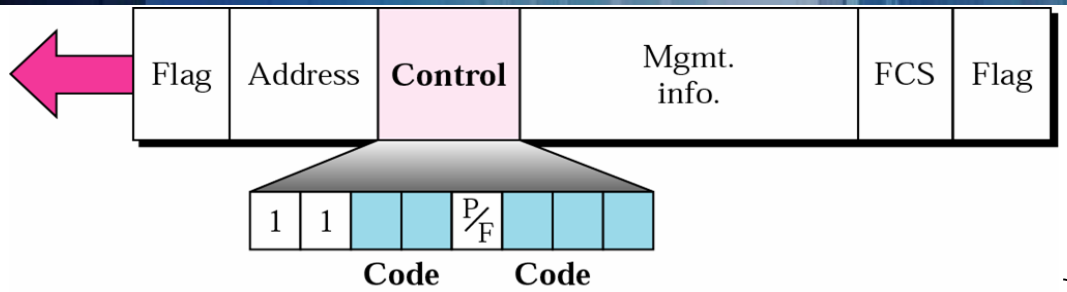
HDLC Frame



- Flag= 01111110
  - Specifies beginning and end of frame
- Address
  - Specifies secondary station
    as either sender or receiver
- Control
  - Specifies type of frame and seq.&ack. number
- Frame Check Sequence (FCS)
  - Either 16- or 32-bit CRC

* Figure is courtesy of B. Forouzan

U-Frame Control Field

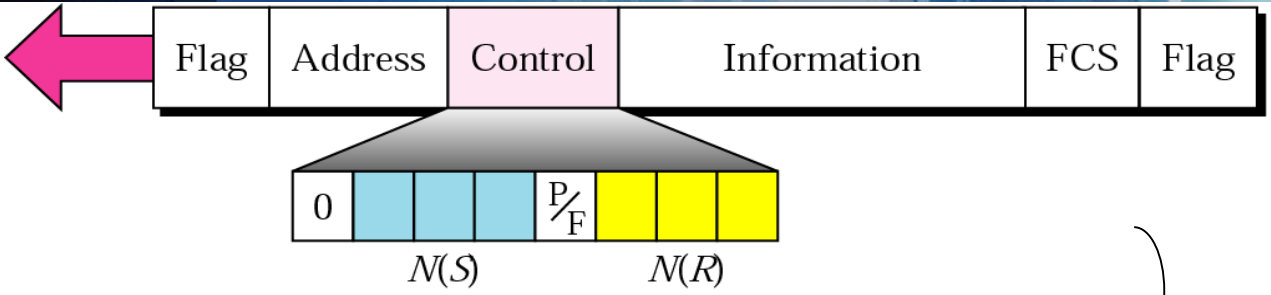


Code	Command/Response	Meaning
00 001	SNRM	Set normal response mode
11 100	SABM	Set asynchronous balanced mode
00 100	UP	Unnumbered poll
00 000	UI	Unnumbered information
00 110	UA	Unnumbered acknowledgment
00 010	DISC	Disconnect
10 000	SIM	Set initialization mode
11 001	RSET	Reset
11 101	XID	Exchange ID
10 001	FRMR	Frame reject

Managing Connection

* Figure is courtesy of B. Forouzan

I-Frame

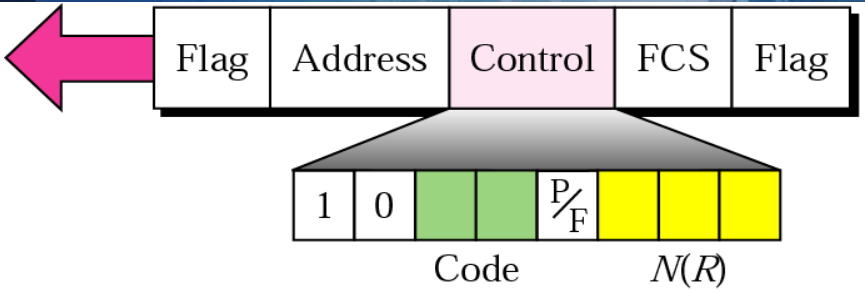


- N(S)
  - Sequence Number of Sender
- N(R)
  - Sequence Number of Receiver
- P/F
  - Poll/Final bit
  - Primary Station: Request for information
  - Secondary Station: response or final frame

Information Transfer

* Figure is courtesy of B. Forouzan

S-Frame Control Field

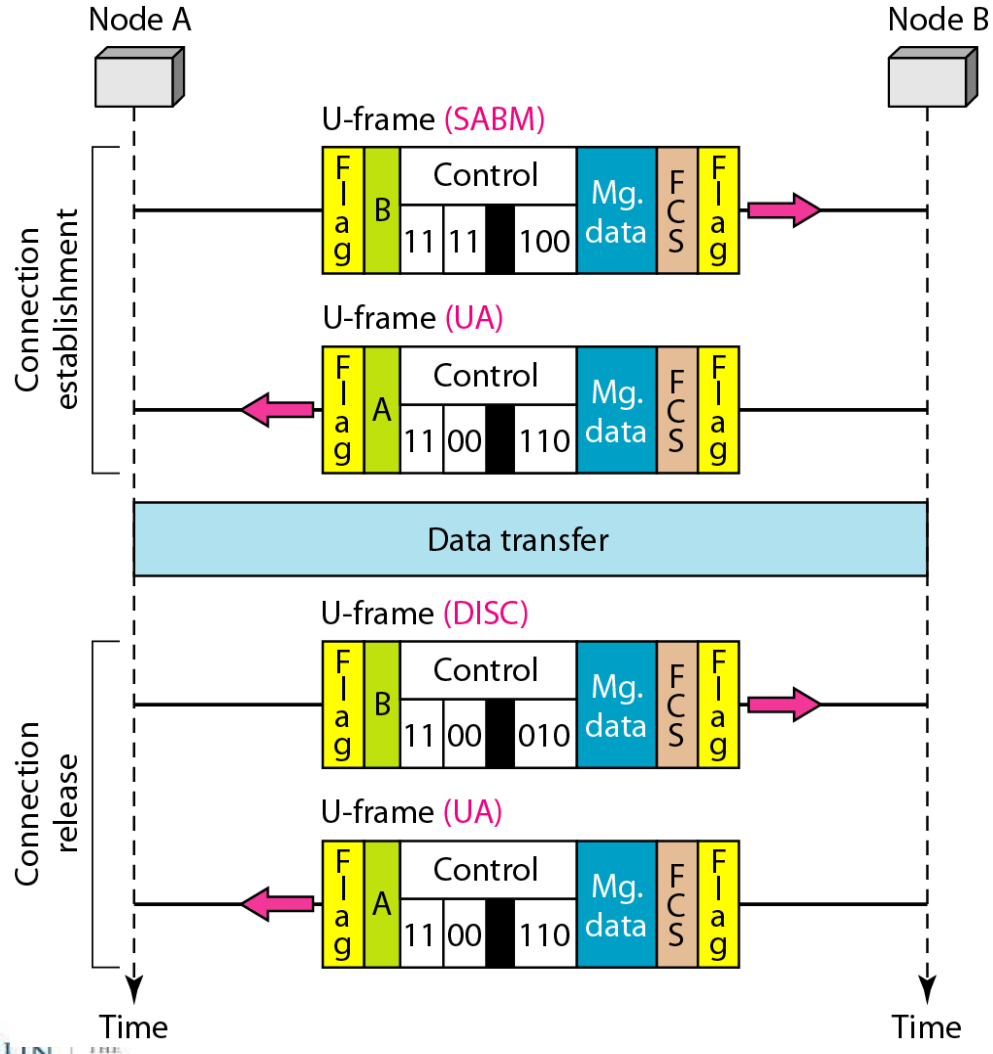


- Code 00 = Receive Ready (RR)
  - Acknowledge frames & waiting for more
- Code 10 = Receive Not Ready (RNR)
  - Acknowledge frames & busy right now
- Code 01 = Reject (REJ)
  - Go-Back-N NAK
- Code 11 = Selective Reject (SREJ)
  - Selective Repeat NAK

Flow&Error Control

* Figure is courtesy of B. Forouzan

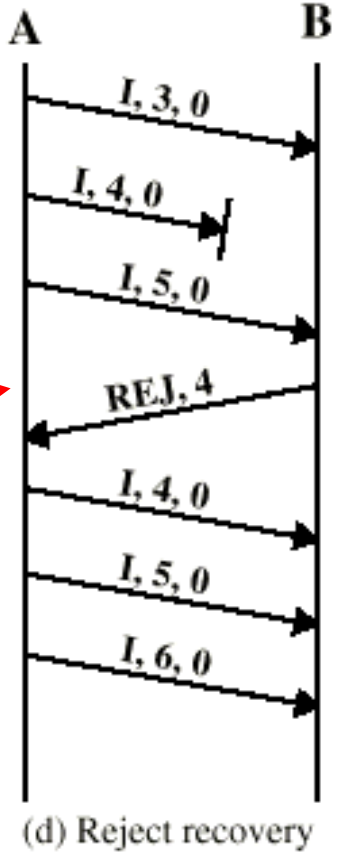
Connection & Disconnection



* Figure is courtesy of B. Forouzan

Examples of Operation

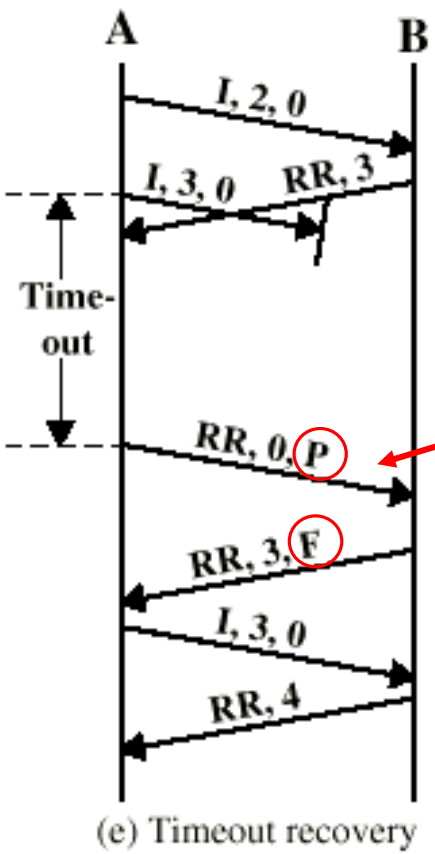
Unexpected Seq#



(d) Reject recovery

Received 5 but didn't receive 4

Timeout of ACK4

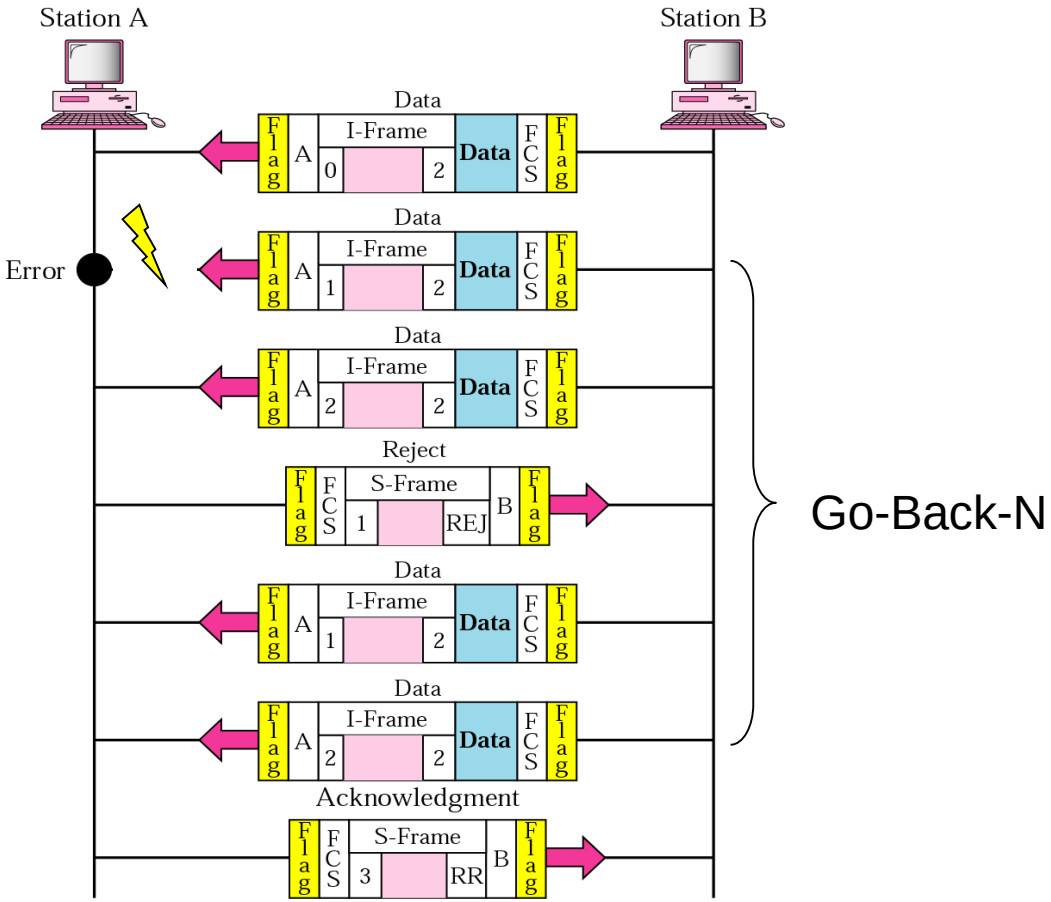


(e) Timeout recovery

Hello?? Anybody home??

* Figure is courtesy of W. Stallings

Piggybacking with Error



* Figure is courtesy of B. Forouzan

802.2 LLC Control Fields

LLC PDU control field bits

	1	2	3	4	5	6	7	8	9	10–16
Information transfer command/response (I-format PDU)	0	N(S)							P/F	N(R)
Supervisory commands/responses (S-format PDUs)	1	0	S	S	X	X	X	X	P/F	N(R)
Unnumbered commands/responses (U-format PDUs)	1	1	M	M	P/F	M	M	M		

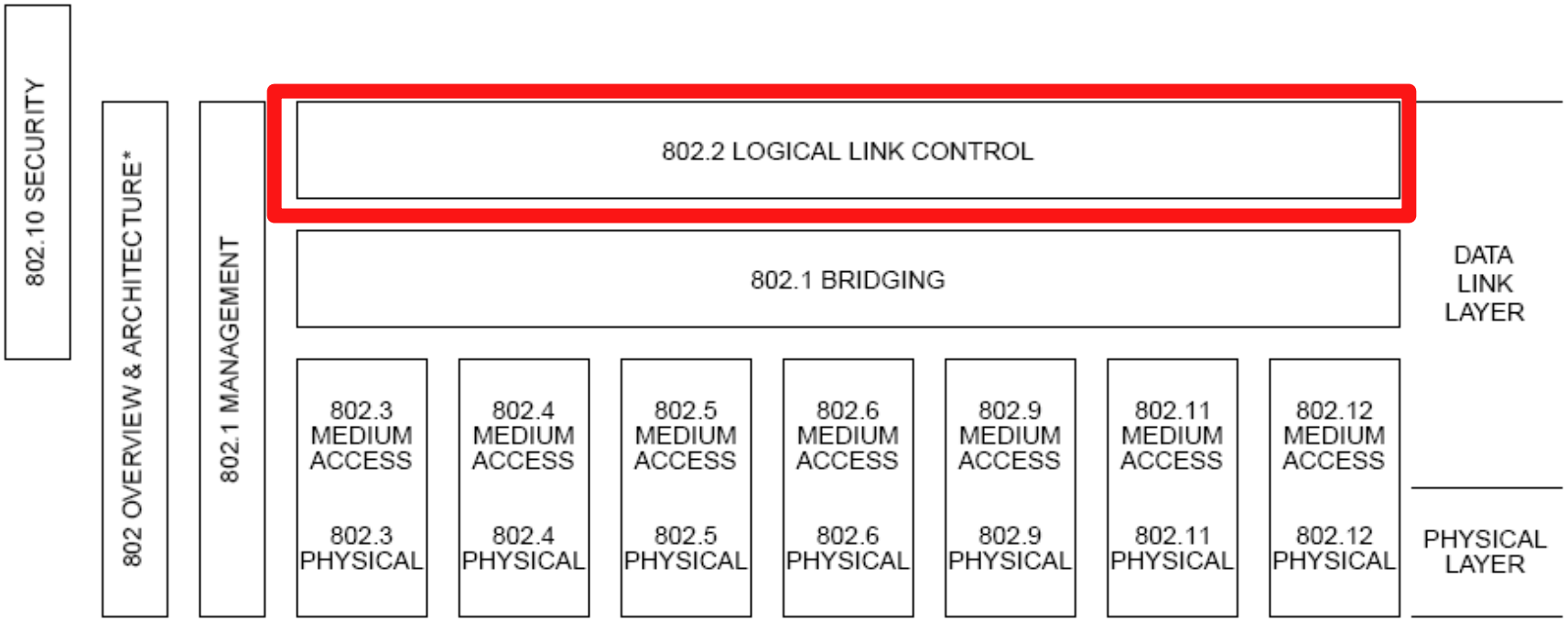
N(S) = sender send sequence number (Bit 2=lower-order-bit)
N(R) = sender receive sequence number (Bit 10=lower-order-bit)
S = supervisory function bit
M = modifier function bit
X = reserved and set to zero
P/F = poll bit—command LLC PDUs
final bit—response LLC PDUs
(1=poll/final)

m = 7
$2^m = 128$
max w-size= 64 frames

Figure 9—LLC PDU control field formats

ANSI/IEEE Std 802.2, 1998 Edition

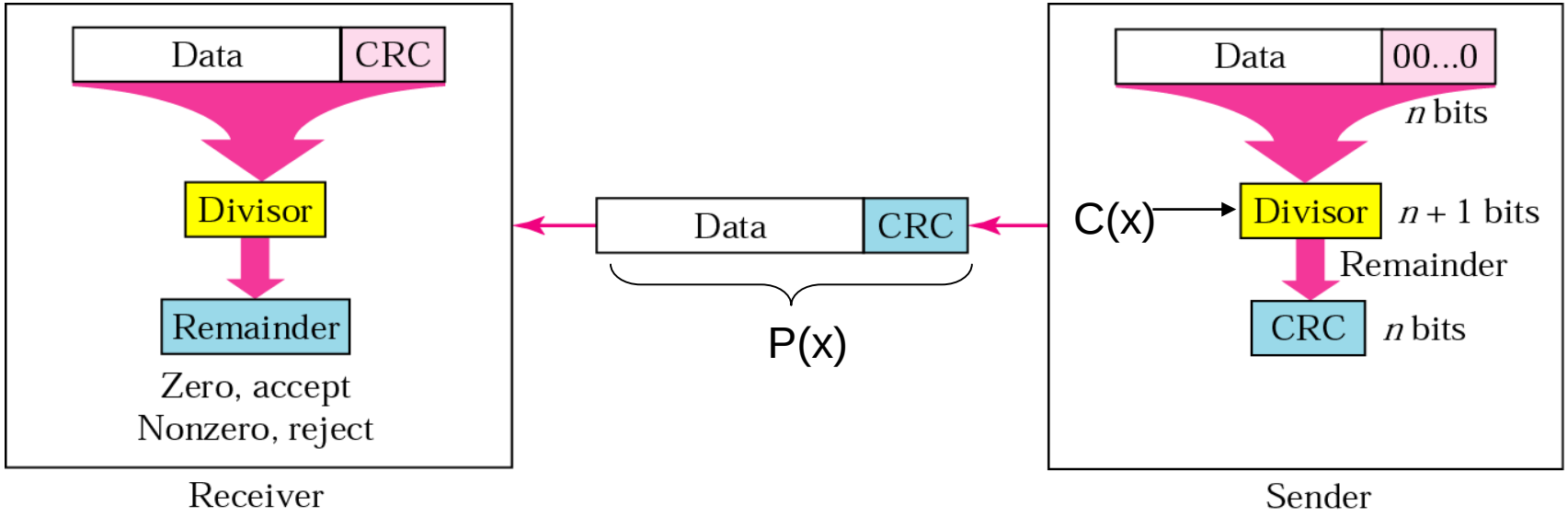
IEEE 802



- 802.3: Ethernet
- 802.11: Wifi
- 802.16: WiMAX
- 802.20: Mobile Broadband Wireless Access (MBWA)
- 802.15.1: Bluetooth
- 802.15.4: ZigBee

* Figure is courtesy of ANSI/IEEE Std 802.11

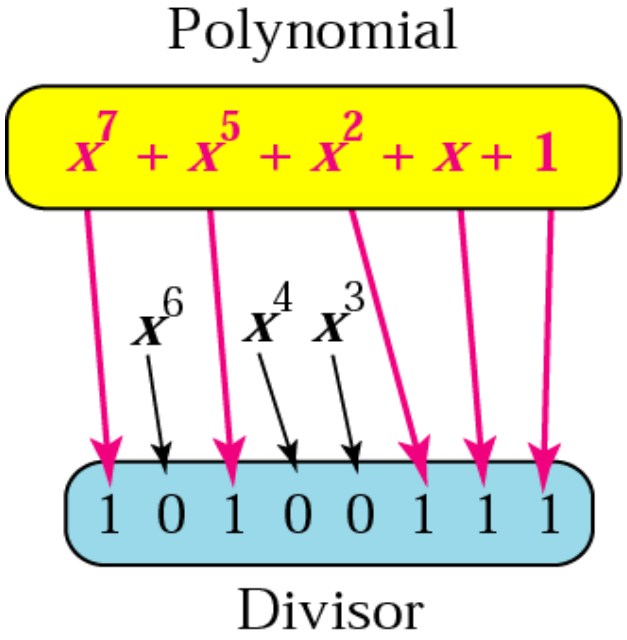
Cyclic Redundancy Check (CRC)



- P(x) divided by C(x) = 0
- (P(x)+remainder) divided by C(x) should be != 0

* Figure is courtesy of B. Forouzan

Polynomial Notation



- Rules for selecting divisor:
  - It should not be divisible by x
  - It should be divisible by x+1

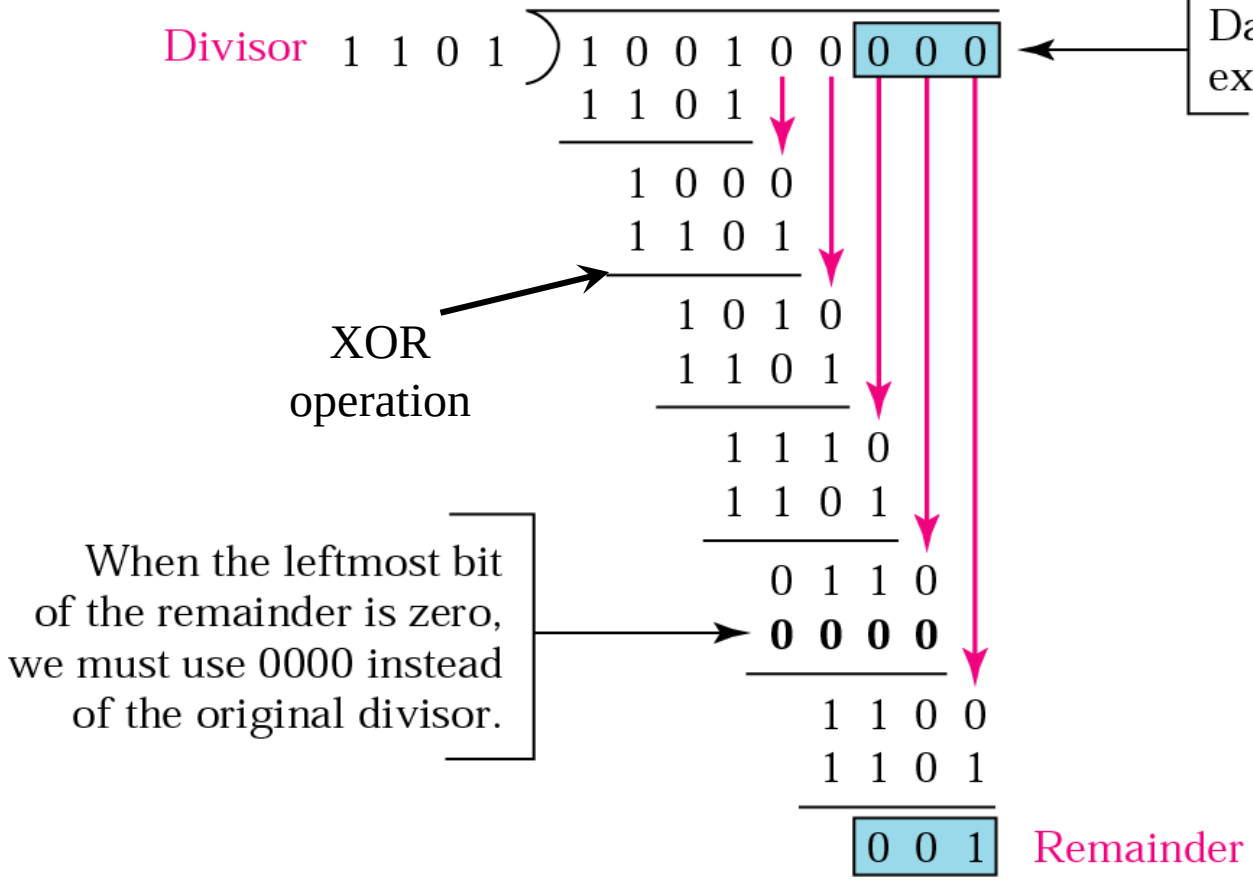
* Figure is courtesy of B. Forouzan

Standard Polynomials

Name	Polynomial	Application
CRC-8	$x^8 + x^2 + x + 1$	**ATM header**
CRC-10	$x^{10} + x^9 + x^5 + x^4 + x^2 + 1$	**ATM AAL**
CRC-16	$x^{16} + x^{12} + x^5 + 1$	**HDLC**
CRC-32	$x^{32} + x^{26} + x^{23} + x^{22} + x^{16} + x^{12} + x^{11} + x^{10} + x^8 + x^7 + x^5 + x^4 + x^2 + x + 1$	**LANs**

* Figure is courtesy of B. Forouzan

CRC: Sender



Data transmitted to receiver: 1 0 0 1 0 0 0 0 1

Data CRC

* Figure is courtesy of B. Forouzan

Division – Decimal&Binary

39 / 20 = 1 + 19

100111 / 10100 = 1 + 10011
32 4 2 1 16 4 16 2 1

CRC Calculation

- CRC Calculation→ Polynomial Division

  not Binary Division!!!

$$x^3 + 4x^2 + 3x + 12 \quad / \quad x^2 + 3 \quad = \quad x + 4$$

$$x^3 \qquad + 3x$$

$$4x^2 \qquad + 12$$

$$\text{-----}$$

$$0$$

CRC Calculation

- CRC Calculation→ Polynomial Division

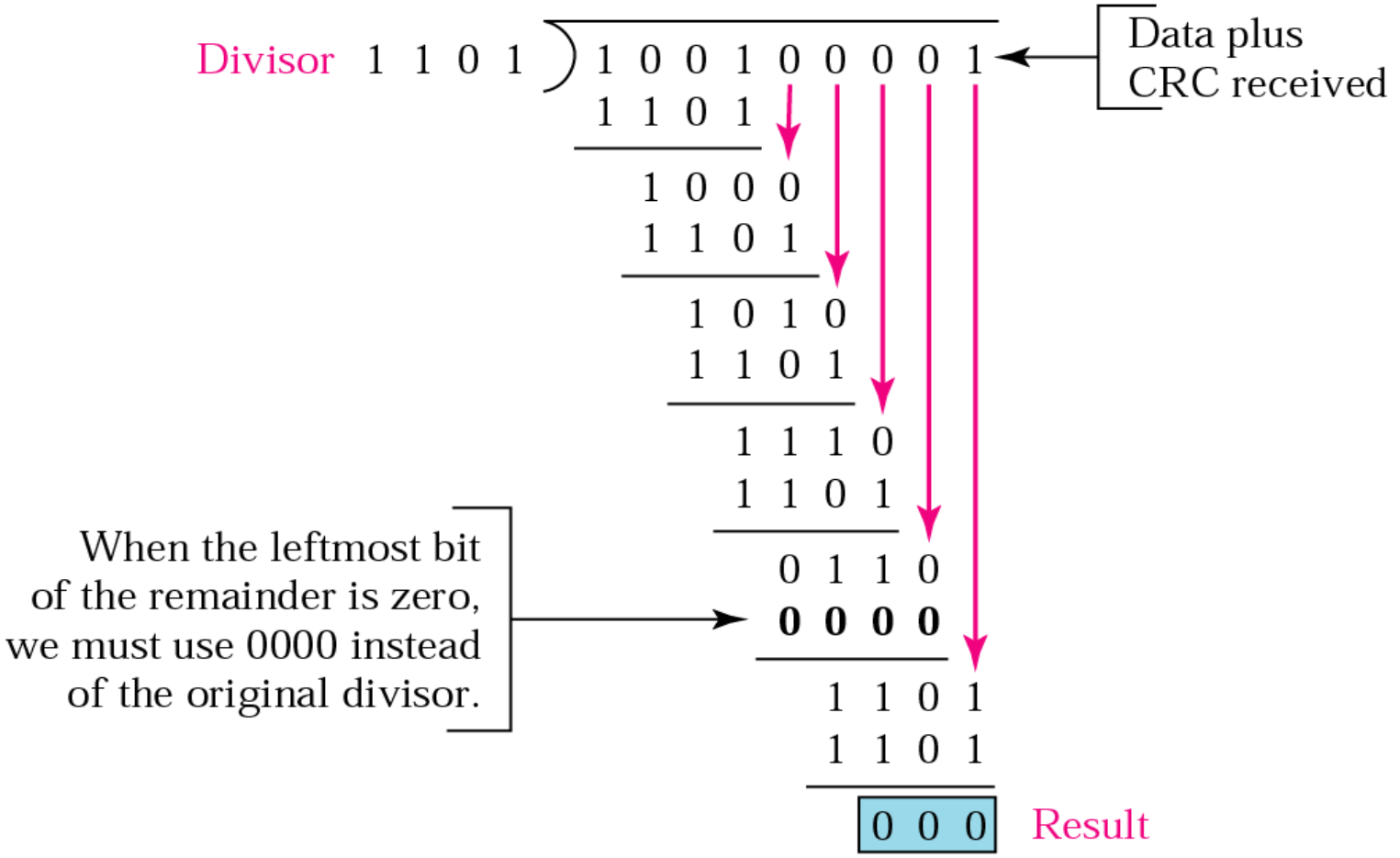
  not Binary Division!!!

- CRC: Coefficient r={0,1}

1000100000000001011

$x^{20} + x^{15} + x^4 + x + 1 \quad / \quad x^{16} + x^{12} + x^5 + 1$

CRC: Receiver



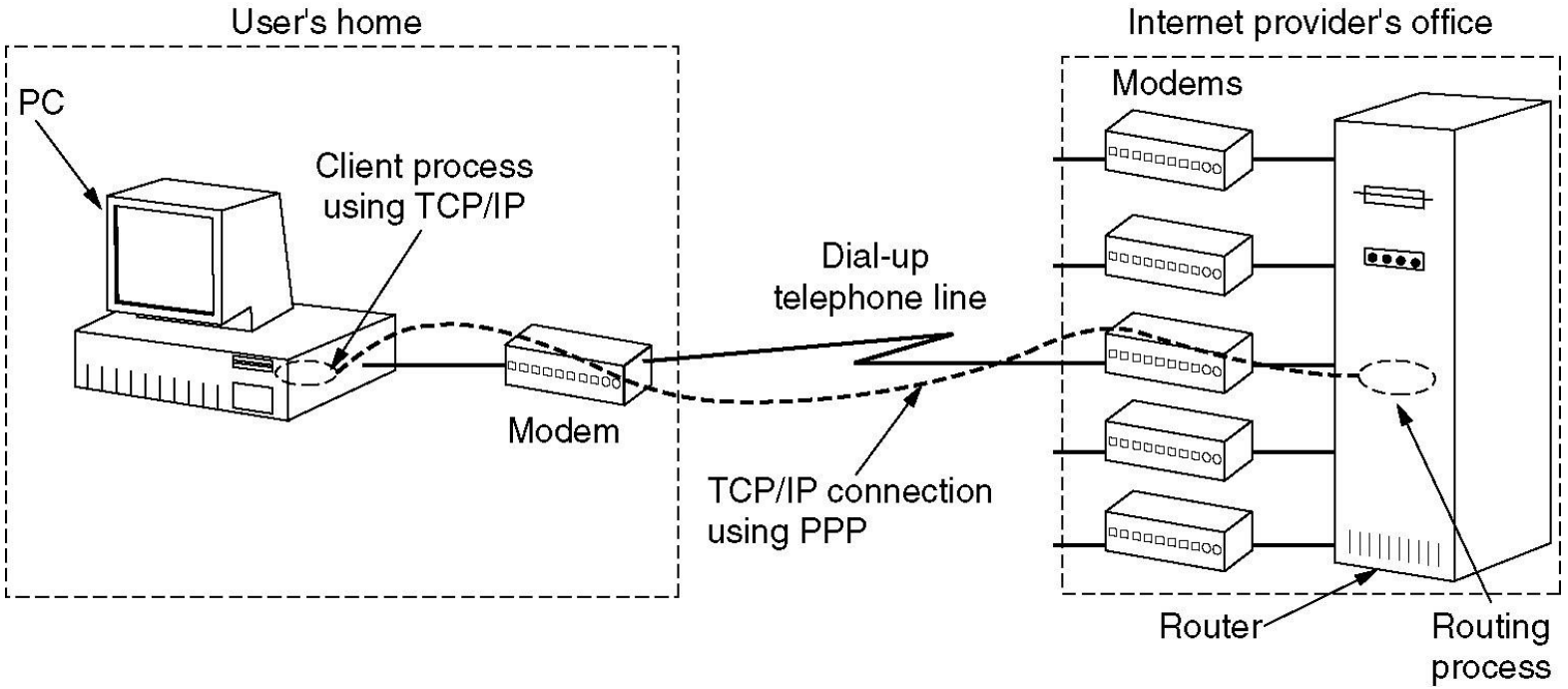
* Figure is courtesy of B. Forouzan

Point-to-Point Protocol (PPP)

Point-to-Point Protocol (PPP)

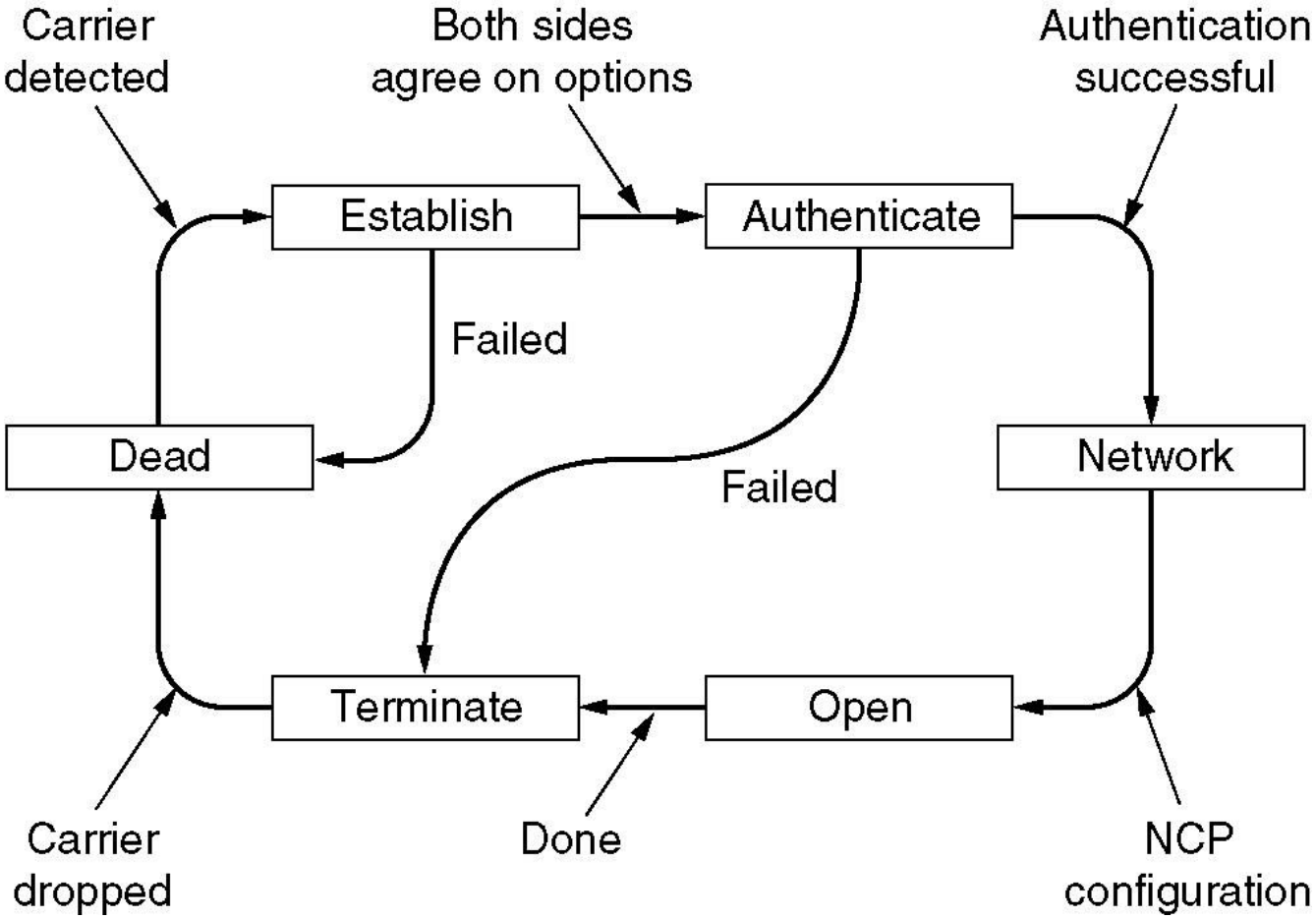
- Used for any kind of serial point to point connection e.g. dial-up, serial x-wire
- Based on HDLC
- Provides
  - Format negotiation
  - Authentication
  - Connection establishment/termination

PPP between Home & ISP



* Figure is courtesy of A. Tanenbaum

PPP – Life Cycle



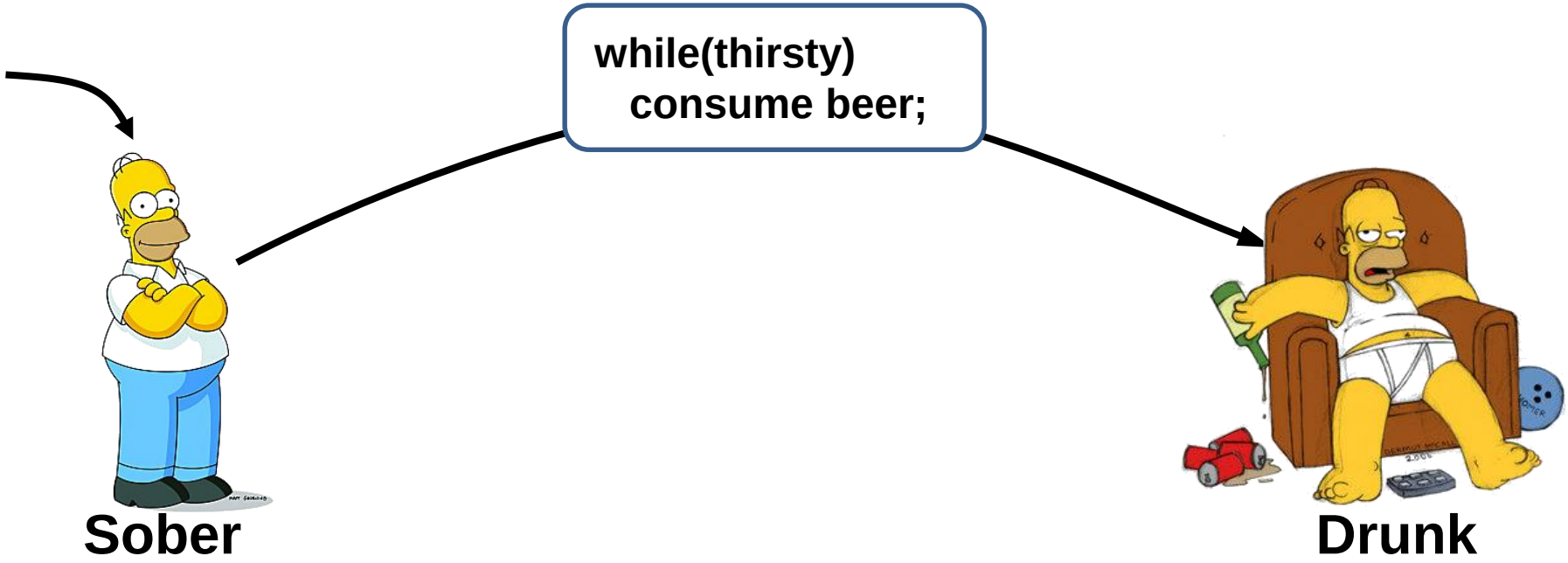
* Figure is courtesy of A. Tanenbaum

Simpson State Diagram

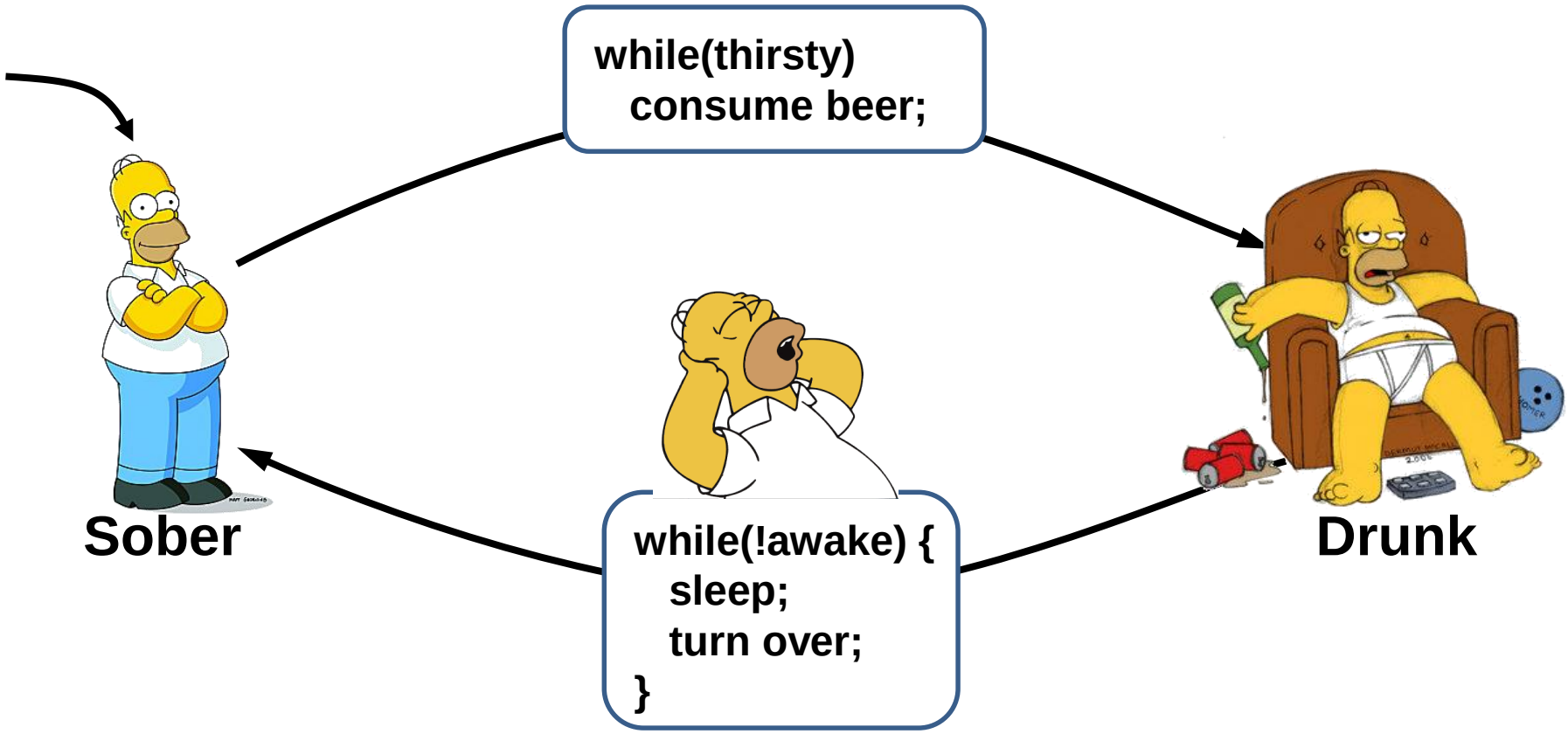
Sober

Simpson State Diagram

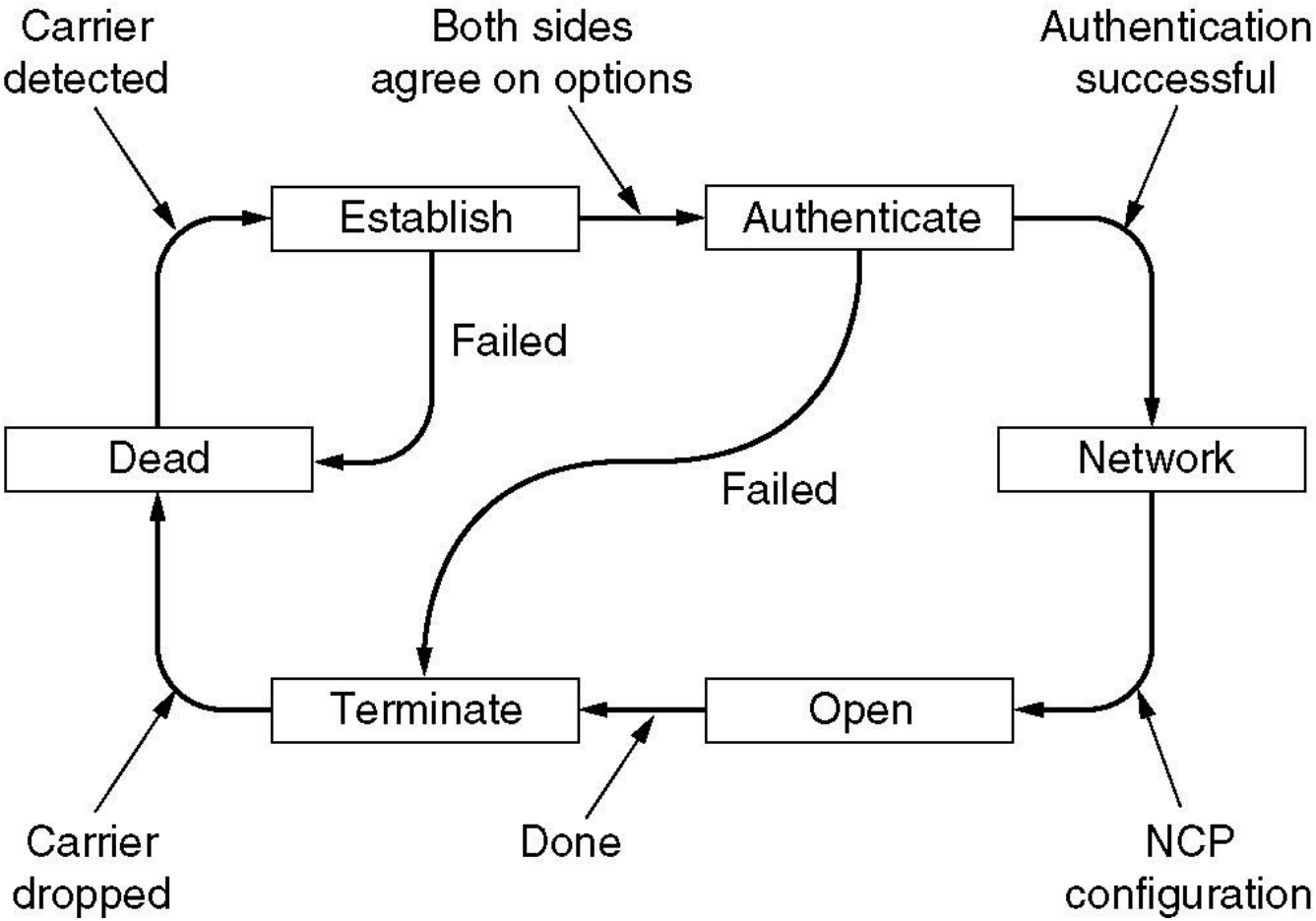
Simpson State Diagram



Simpson State Diagram

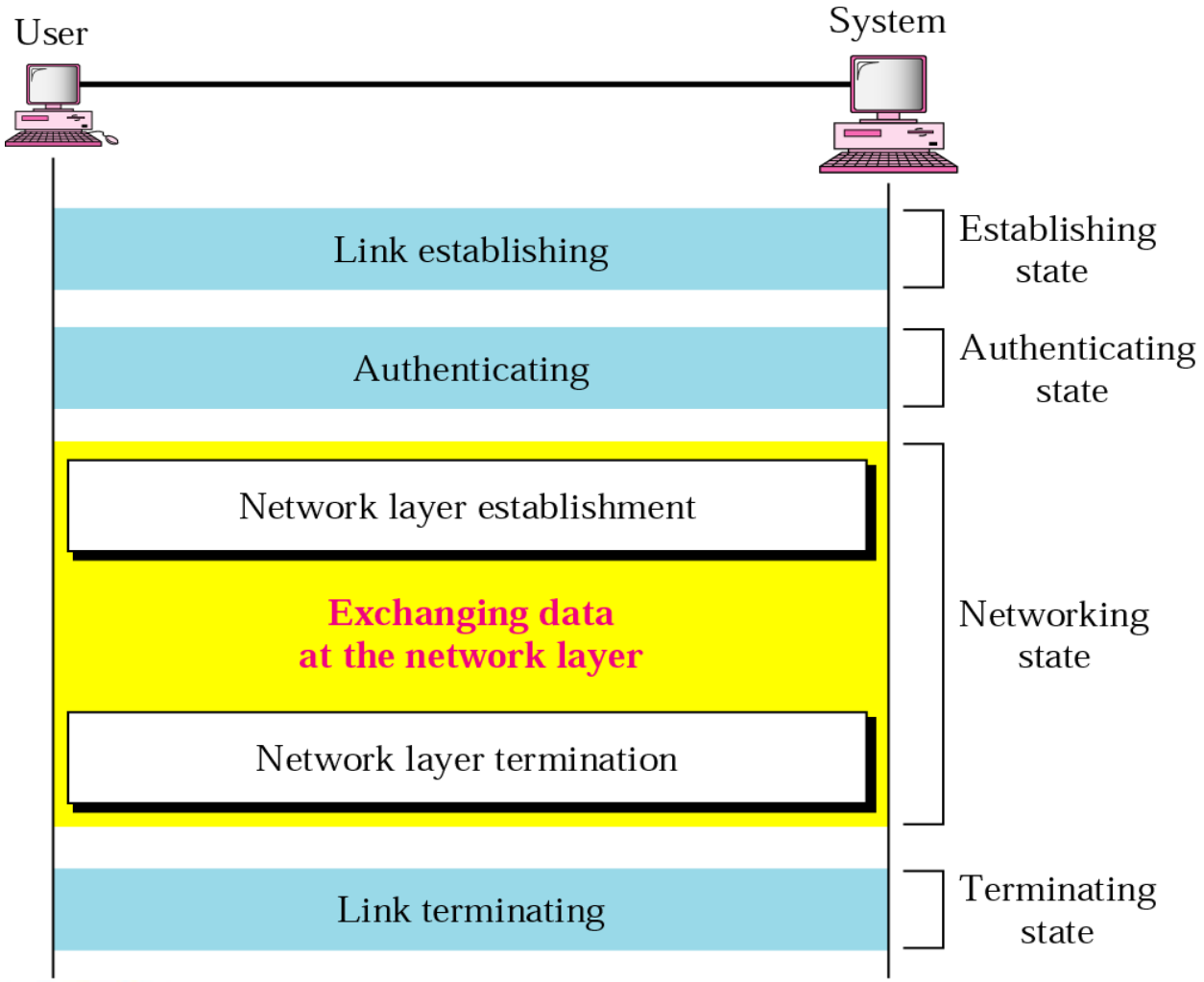


PPP – Life Cycle



* Figure is courtesy of A. Tanenbaum

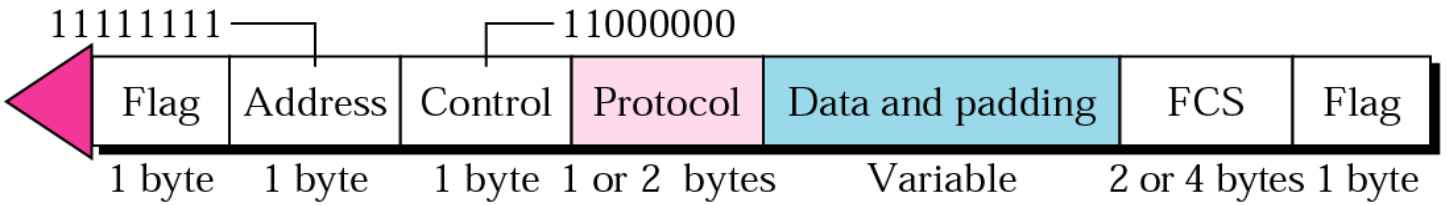
Tasks of PPP



* Figure is courtesy of B. Forouzan

PPP Frame

- Modified HDLC frame:

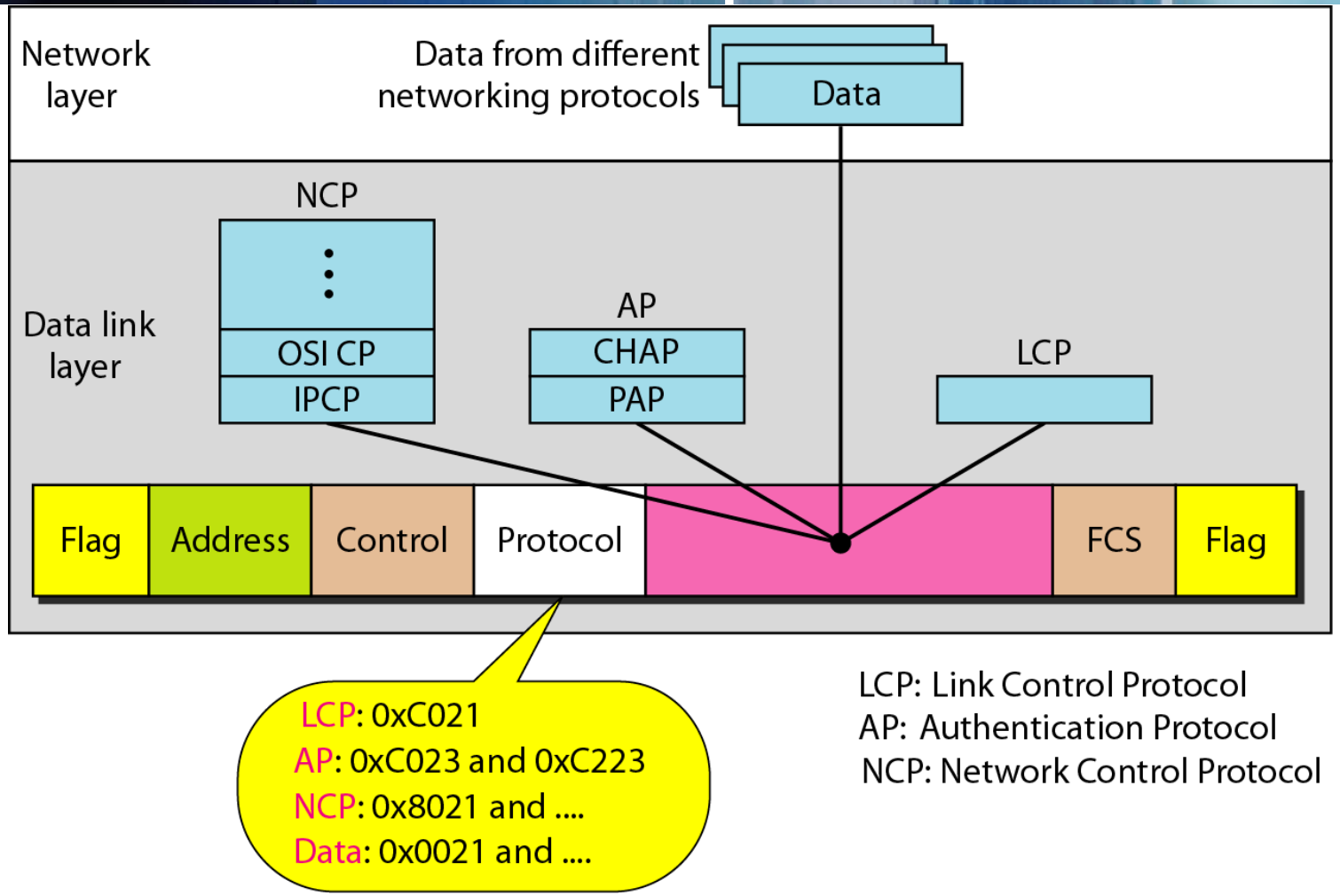


- Byte-oriented Protocol
  - Flag Byte: 01111110
  - Escape Byte: 01111101

- FCS: 16- or 32-bit CRC
  - $x^{16} + x^{12} + x^5 + 1$
    - 1 0001 0000 0010 0001 → **16 bits remainder ← 16-degree polynomial**
  - $x^{32}+x^{26}+x^{23}+x^{22}+x^{16}+x^{12}+x^{11}+x^{10}+x^8+x^7+x^5+x^4+x^2+x+1$

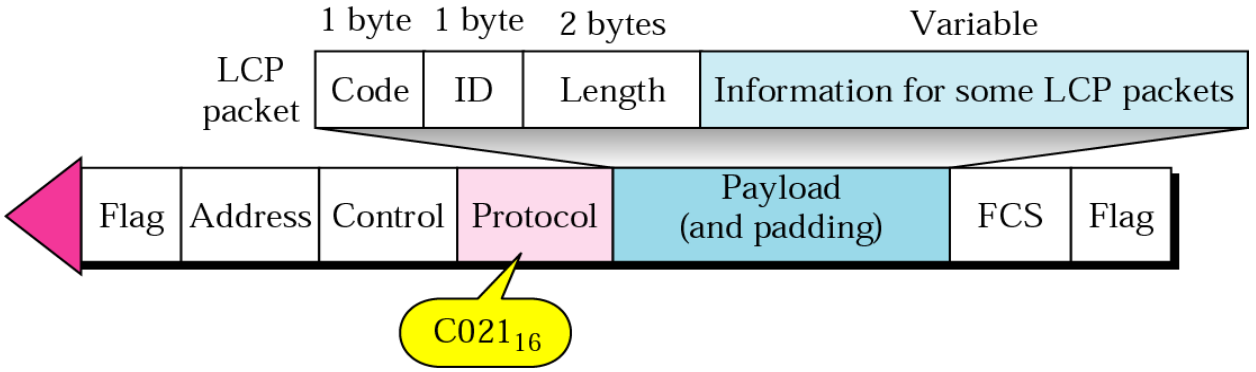
* Figure is courtesy of B. Forouzan

PPP Components



* Figure is courtesy of B. Forouzan

LCP Packet



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	Requests to shut down the line
0x06	Terminate-ack	Accepts the shut down request

* Figure is courtesy of B. Forouzan

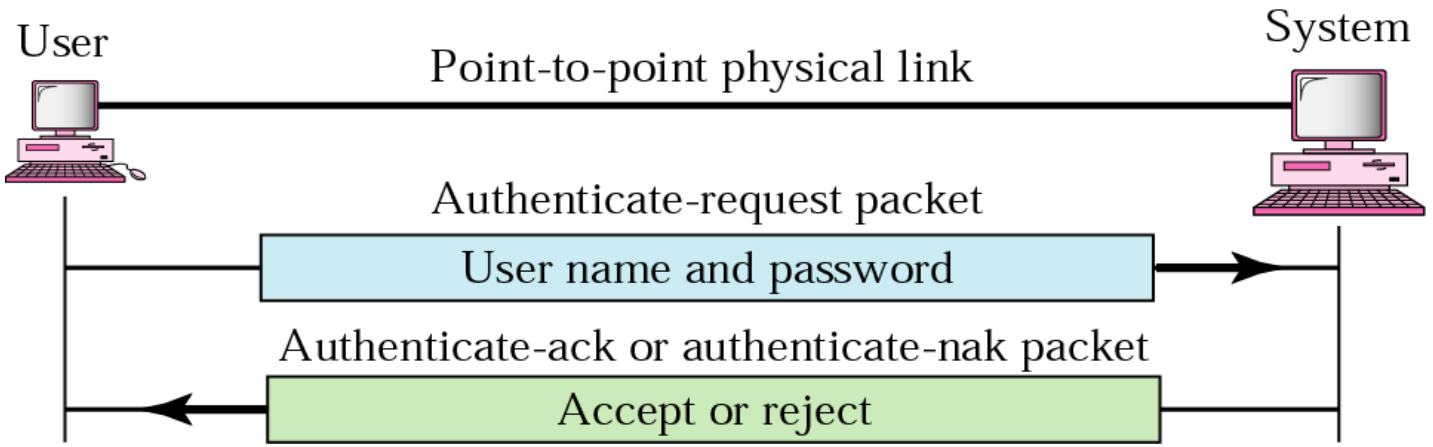
Common Options

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

LCP Debug Codes

Code	Packet Type	Description
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

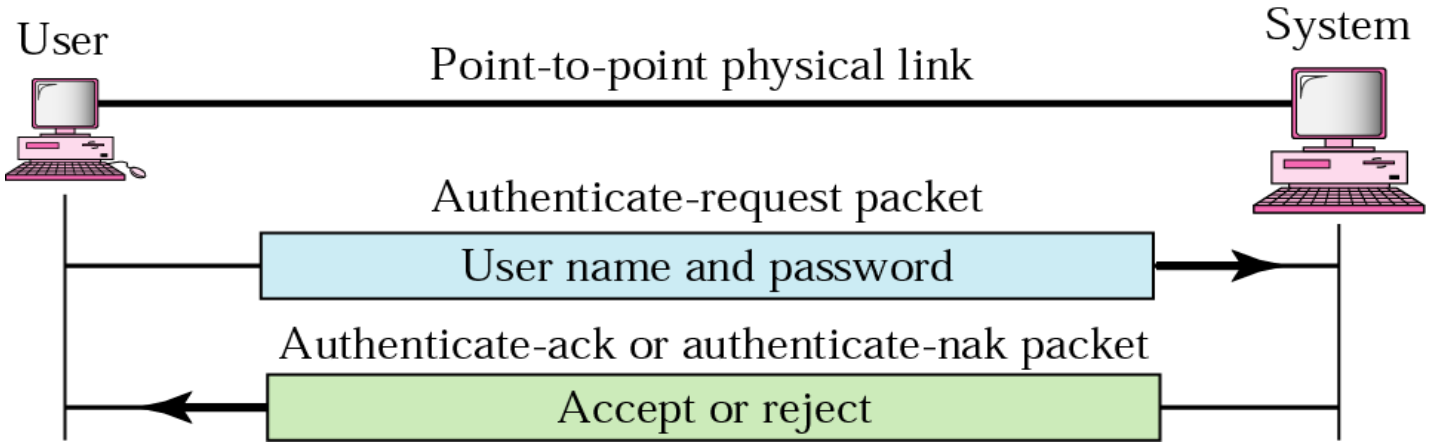
Password Authentication Protocol (PAP)



- 2-Way Handshake
- Password transmitted in clear text

* Figure is courtesy of B. Forouzan

Password Authentication Protocol (PAP)

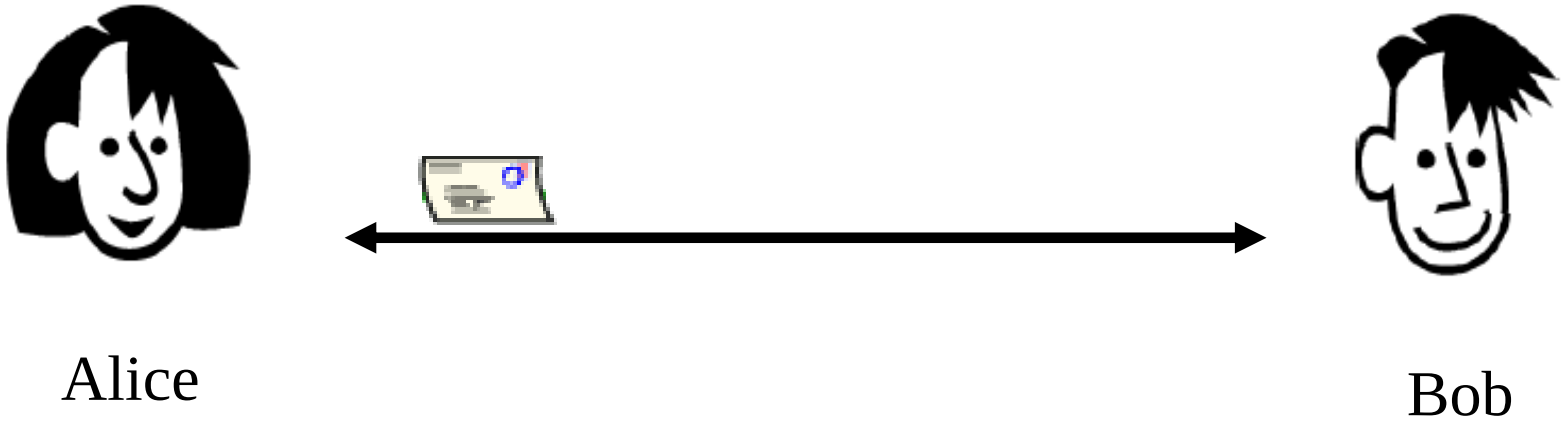


- 2-Way Handshake
- Password transmitted in clear text

...what were they thinking??? **Never** transfer passwords in clear text

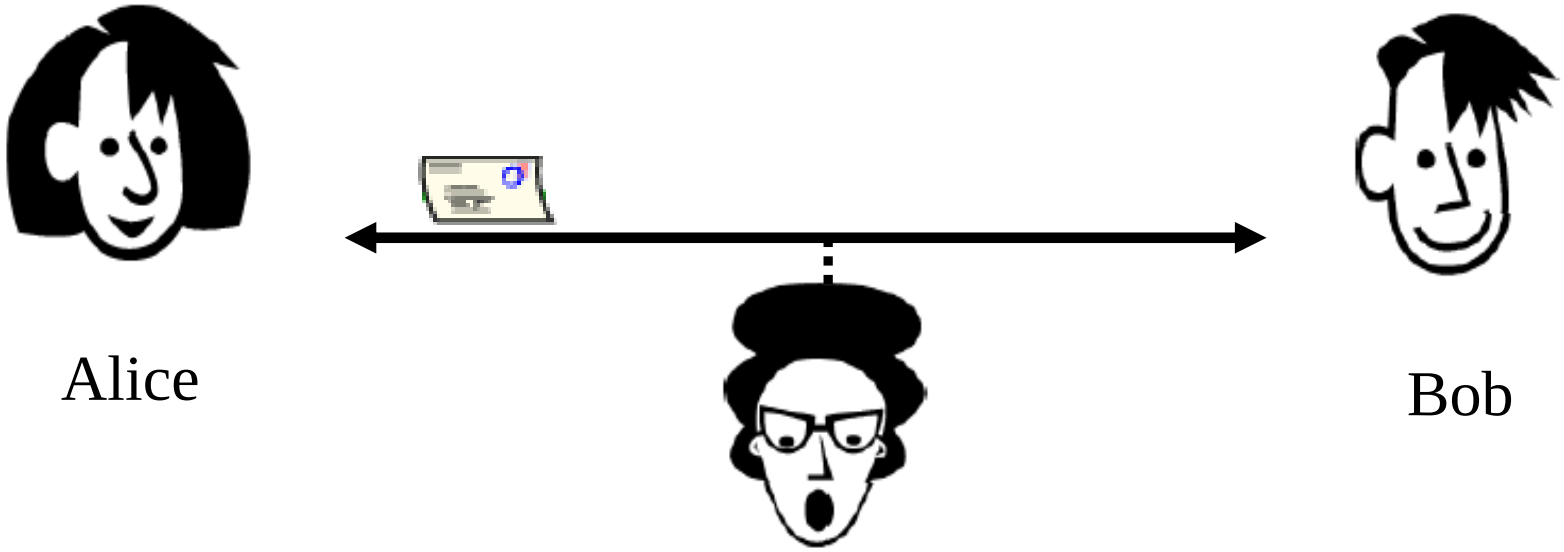
* Figure is courtesy of B. Forouzan

Communication Scenario



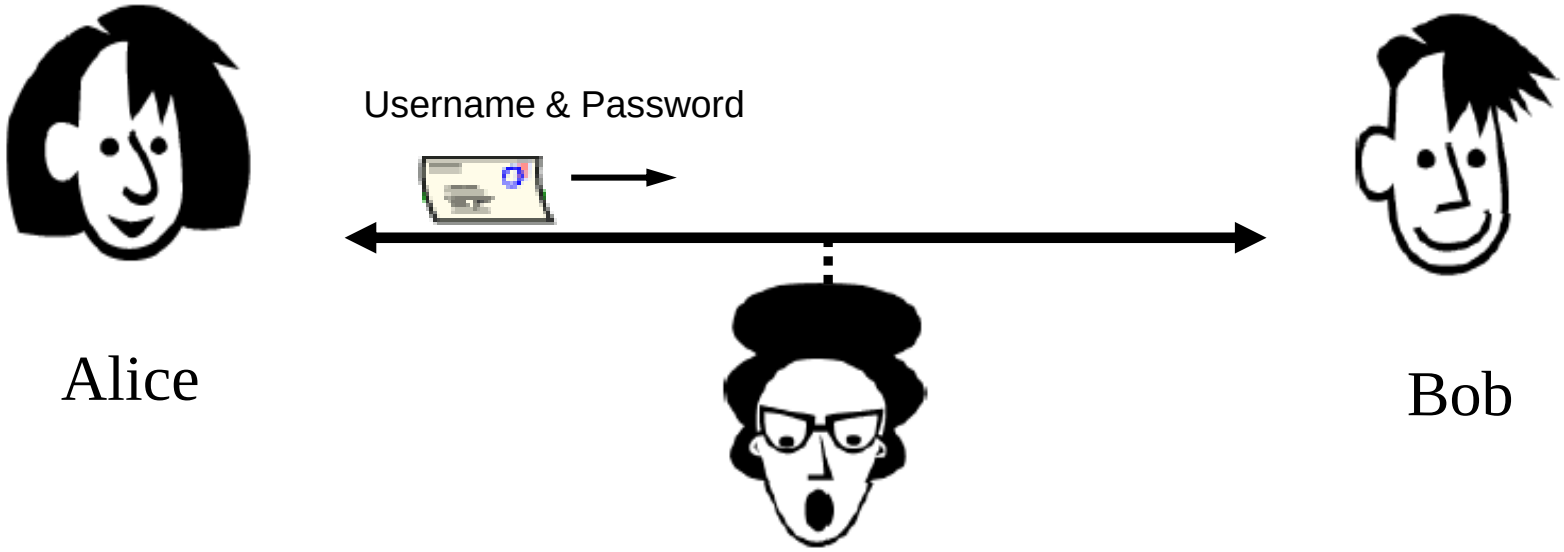
•Alice and Bob want to communicate

Threat: Eavesdropping



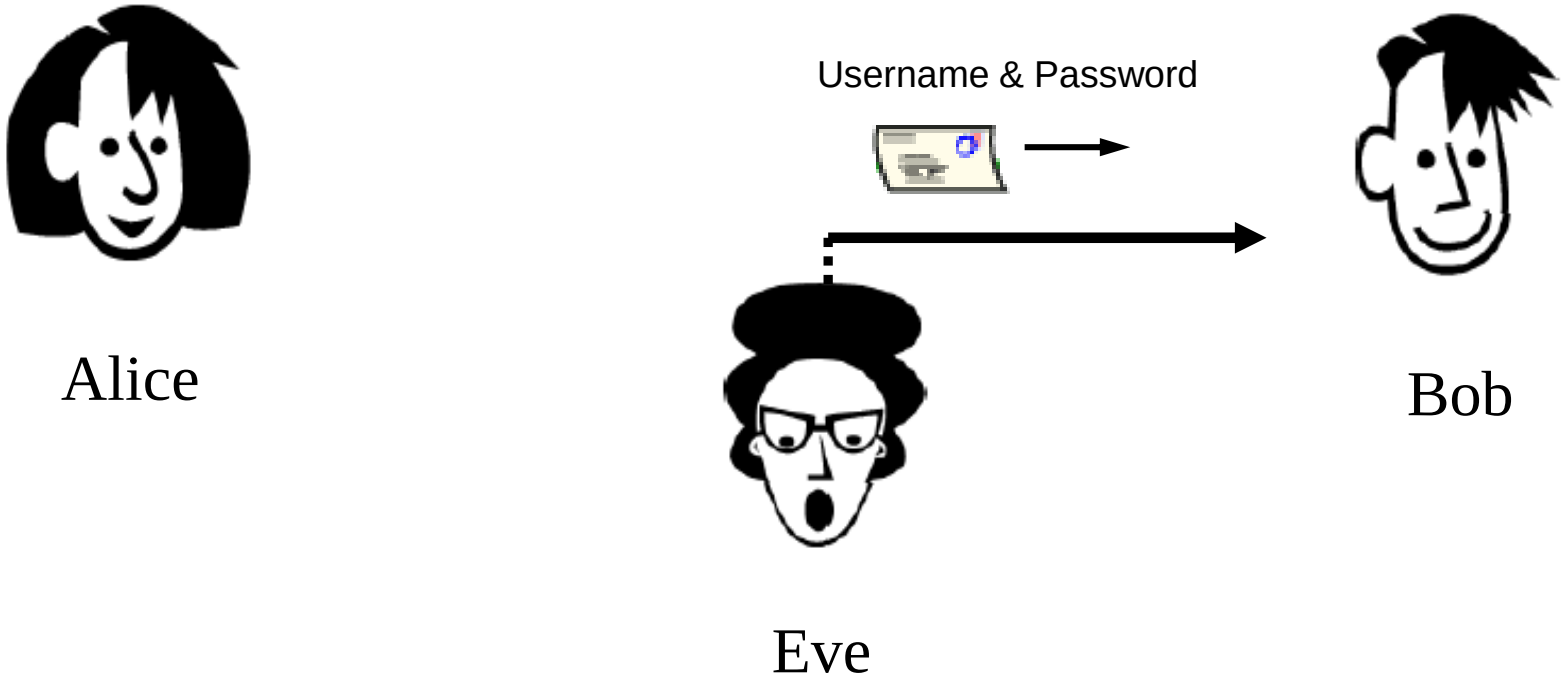
- Alice and Bob want to communicate
- Eve is eavesdropping (intercept, delete, add messages)

PAP Transfer



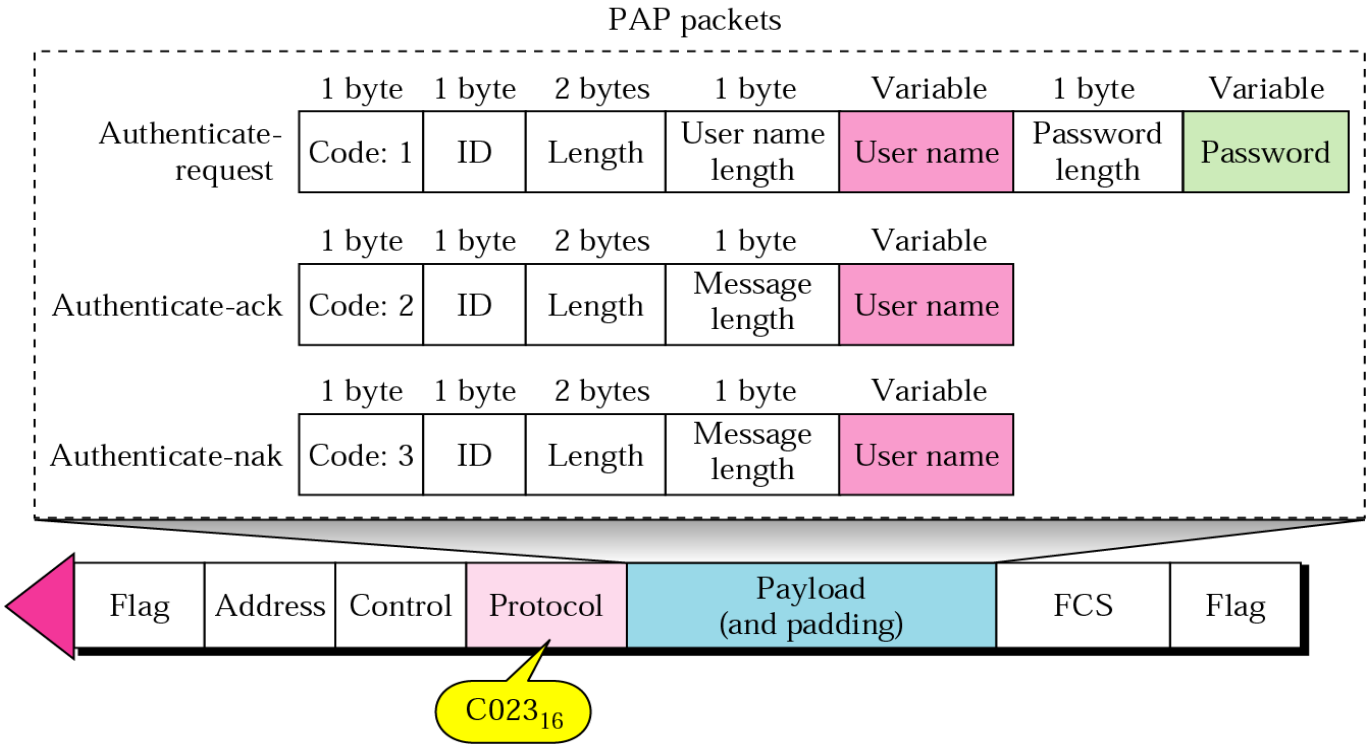
•Eve captures Alice's username & password

Playback Attack



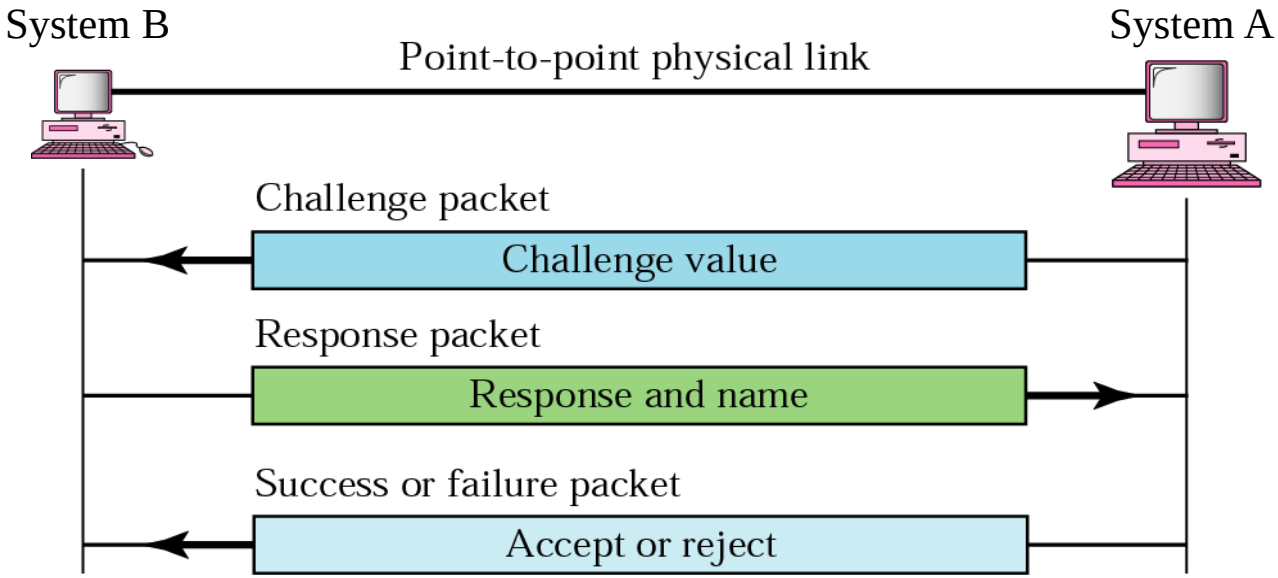
•Eve pretends to be Alice by using sending out the capture message

PAP Packets



* Figure is courtesy of B. Forouzan

CHAP



- **3-Way Handshake**

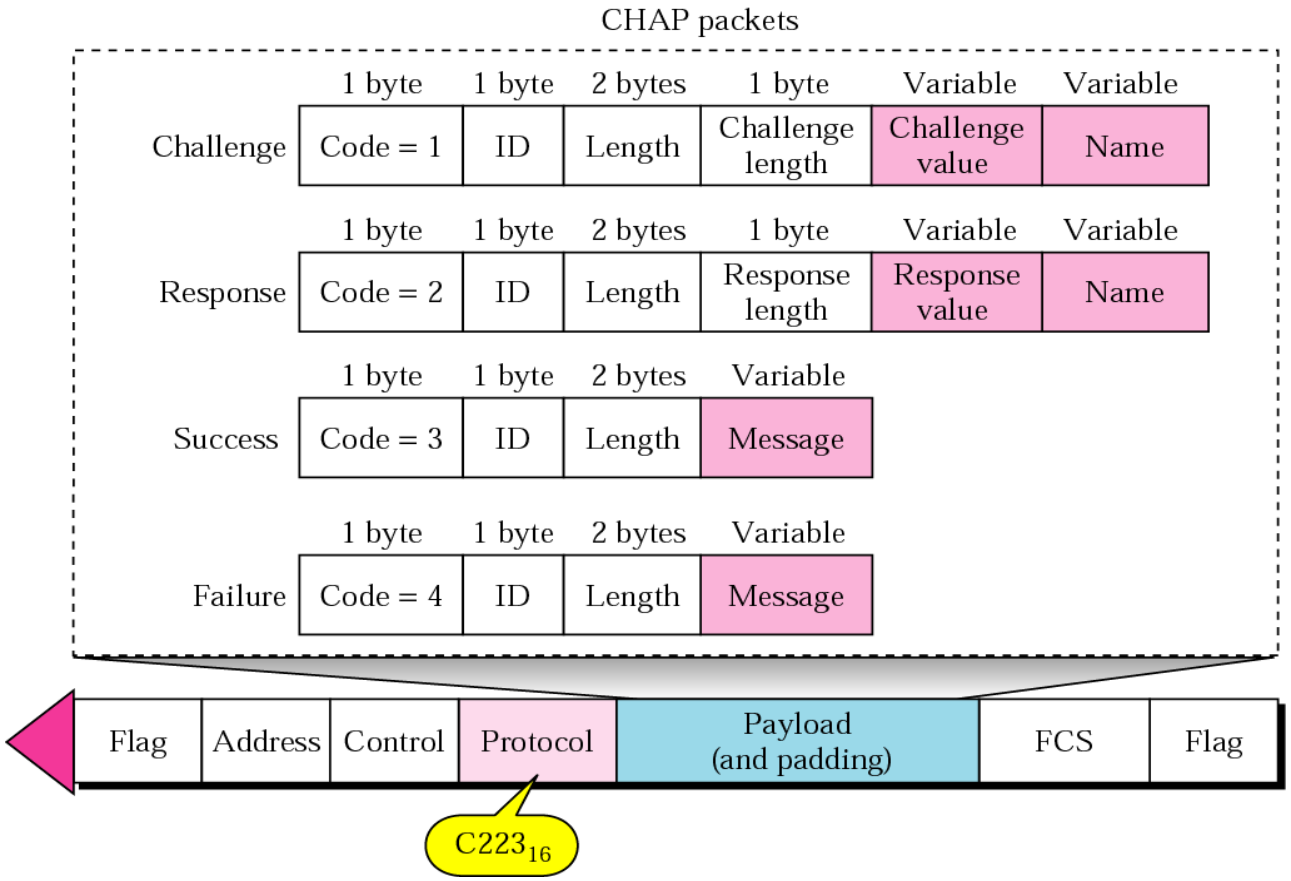
1. A creates challenge ⇨ challenge value

2. B processes challenge value with password ⇨ response

3. A compares response with own calculation ⇨ accepts or rejects response

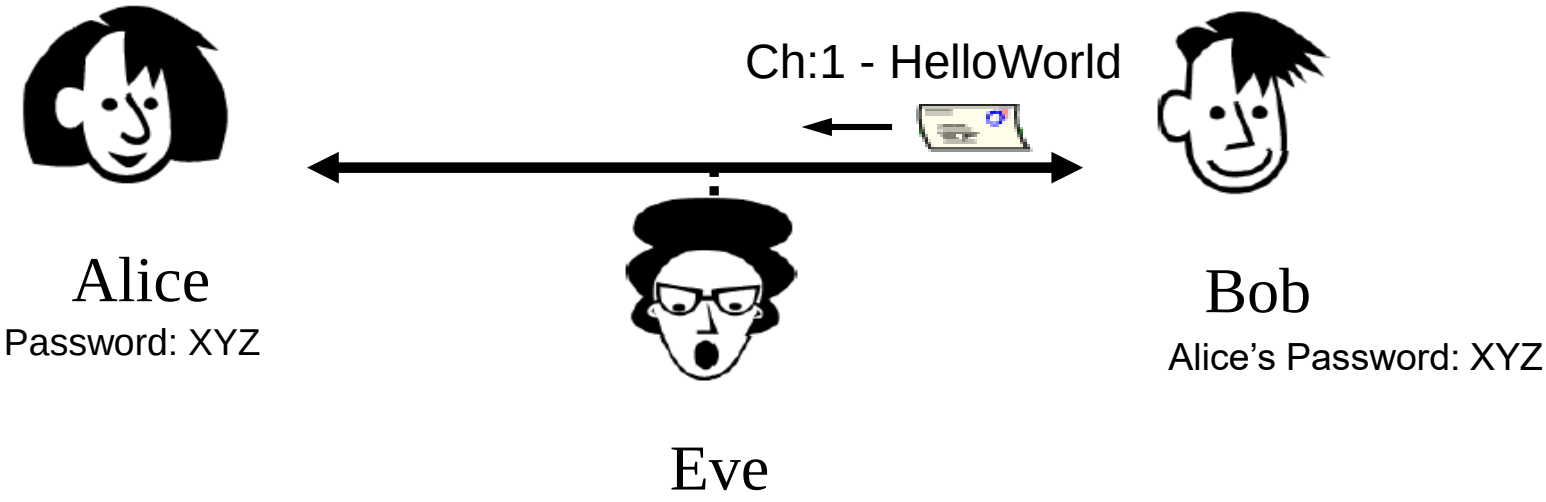
* Figure is courtesy of B. Forouzan

CHAP Packets

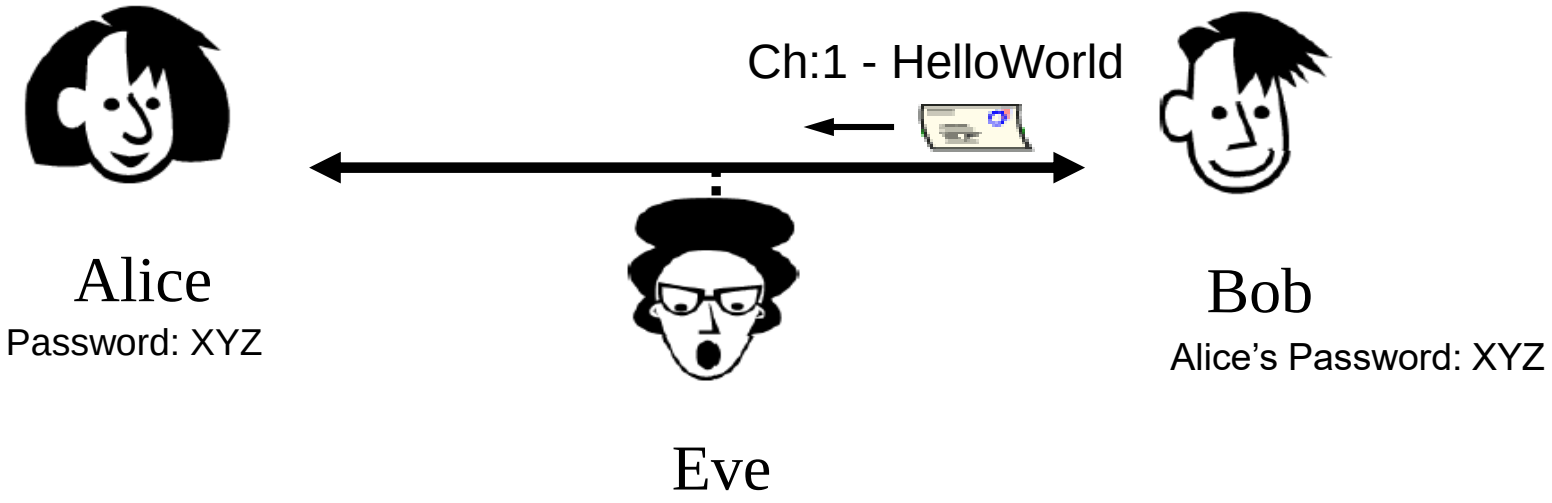


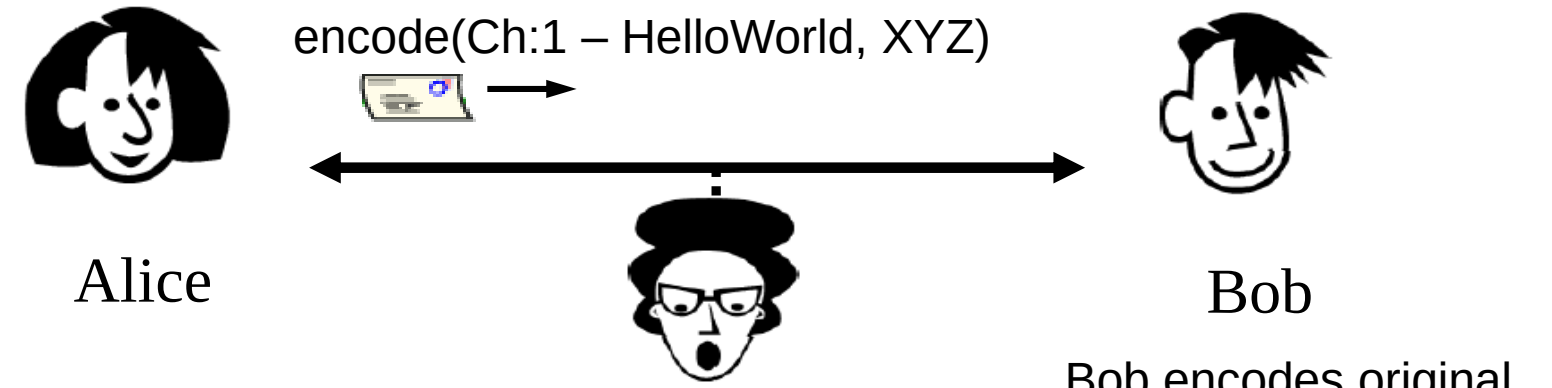
* Figure is courtesy of B. Forouzan

Chap Exchange



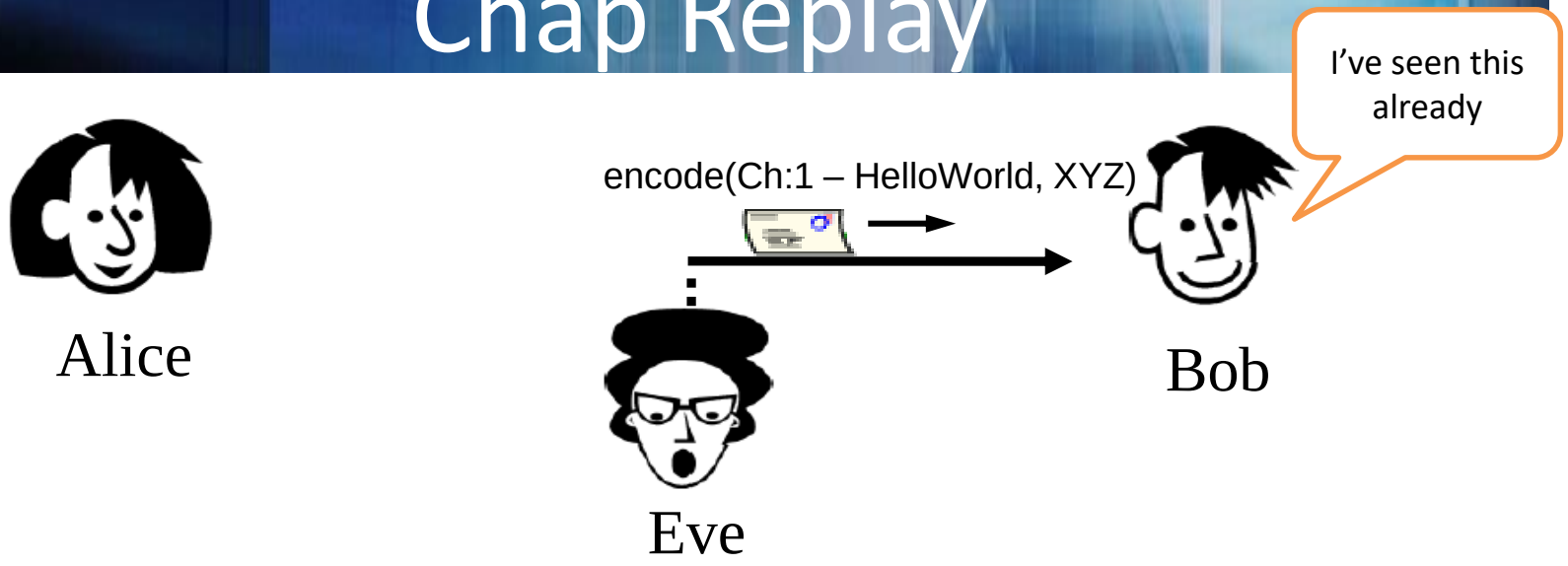
Chap Exchange





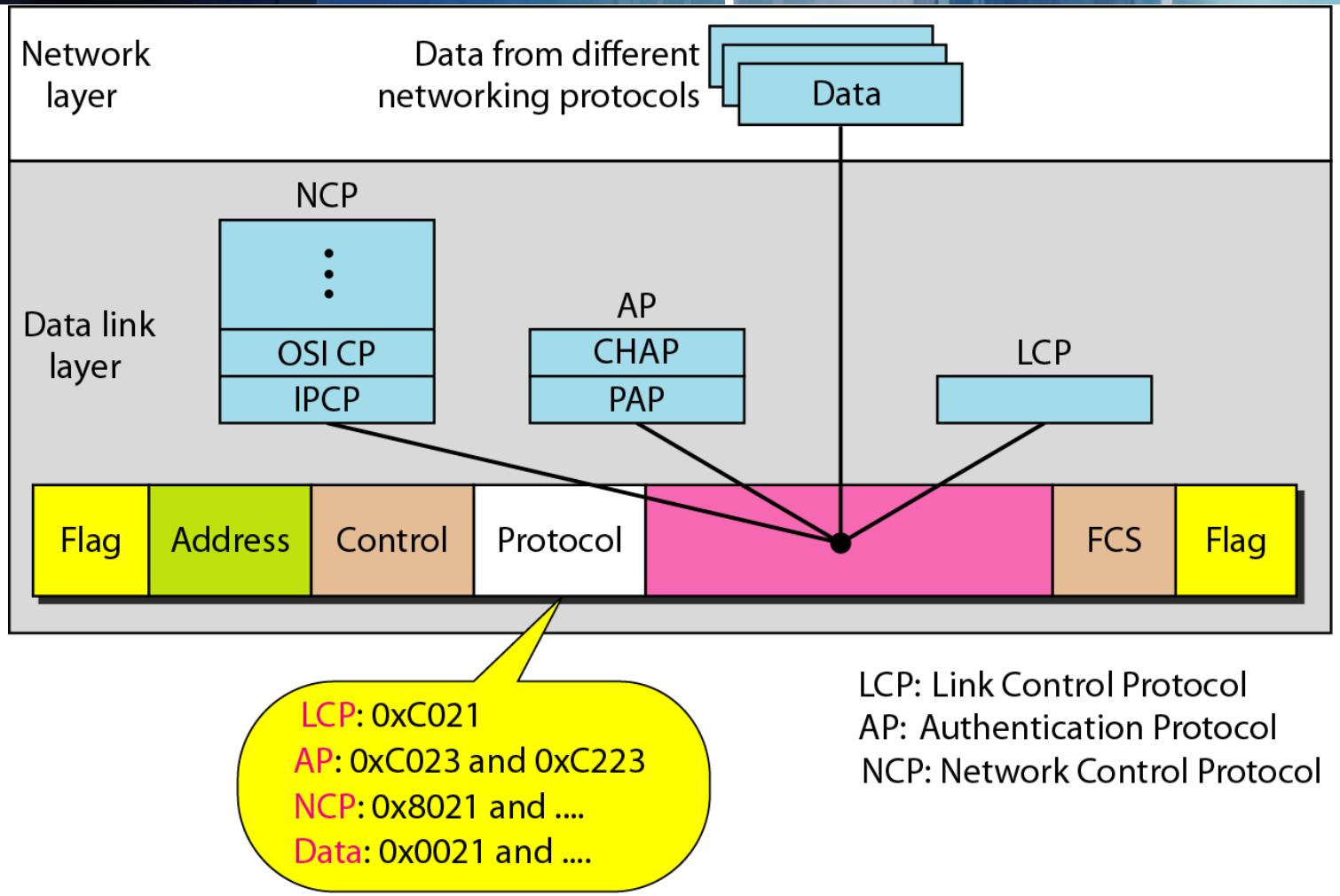
Bob encodes original message with Alice's password & compares

Chap Replay



- Eve can capture both messages
  - but will not see the password
  - or be able to use replay attack

PPP Components



* Figure is courtesy of B. Forouzan

PPP – Encapsulation

flag	addr	ctrl	protocol	data	CRC	flag
7E	FF	03				7E
1	1	1	2	<= 1500	2	1

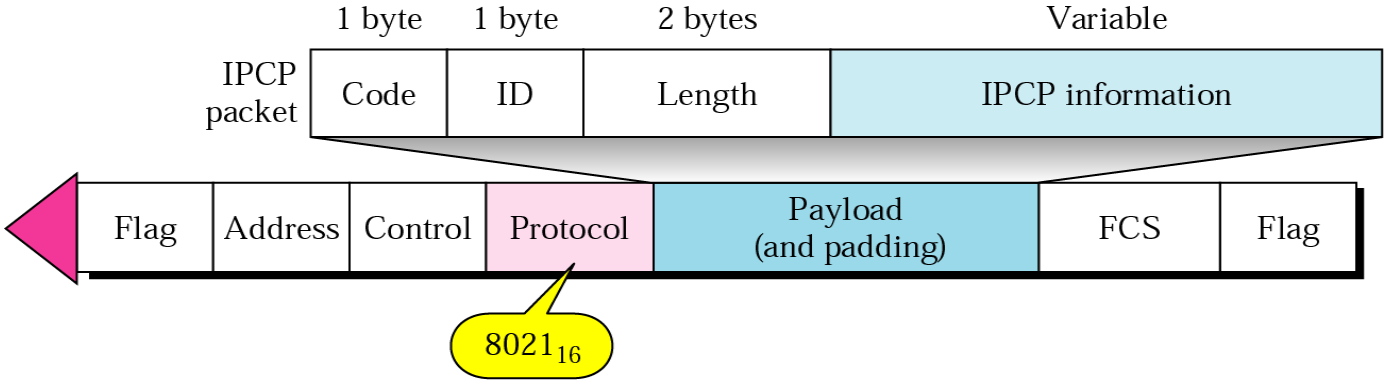
0021	IP datagram
C021	link control data
8021	network control data

* Figure is courtesy of W. Stallings

Network Control Protocol (NCP)

- PPP negotiates Network Layer information
- Consists of specific protocols for network layer protocols
  - IP Control Protocol (IPCP)
  - IPX Control Protocol (IPXCP)
- May include IP Header compression

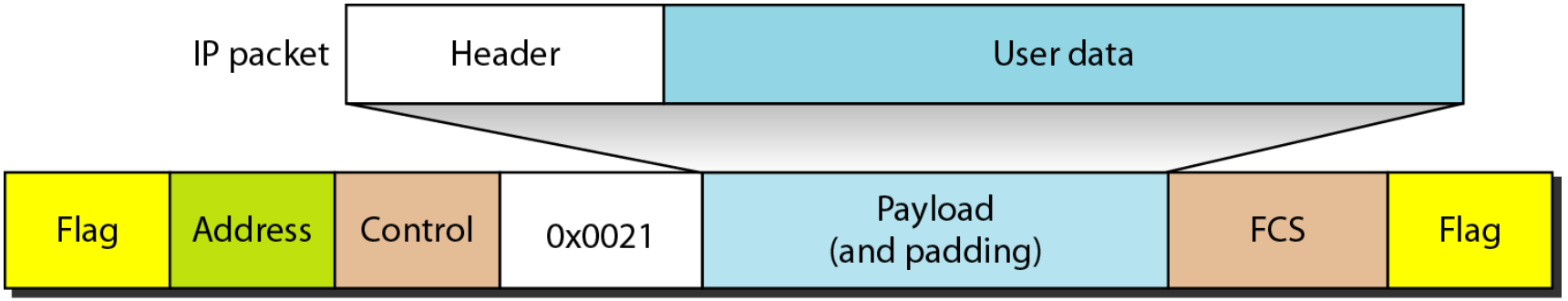
IPCP Packet in PPP Packet



Code	IPCP Packet
01	Configure Request
02	Configure ACK
03	Configure NAK
04	Configure Reject
05	Terminate-request
06	Terminate-ack
07	Code-reject

* Figure is courtesy of B. Forouzan

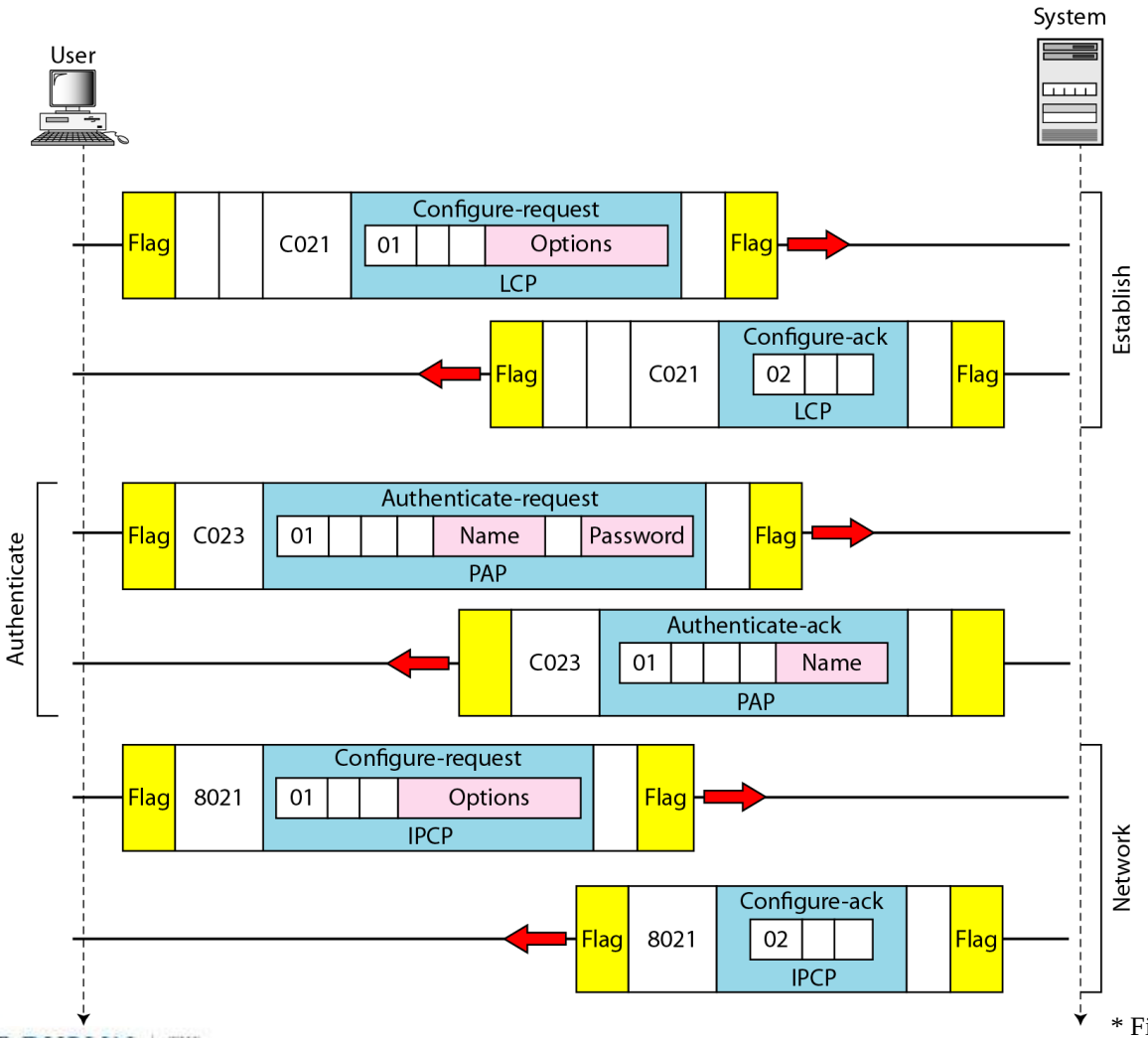
IP Packet Encapsulation



- PPP frame carries IP Packet as payload

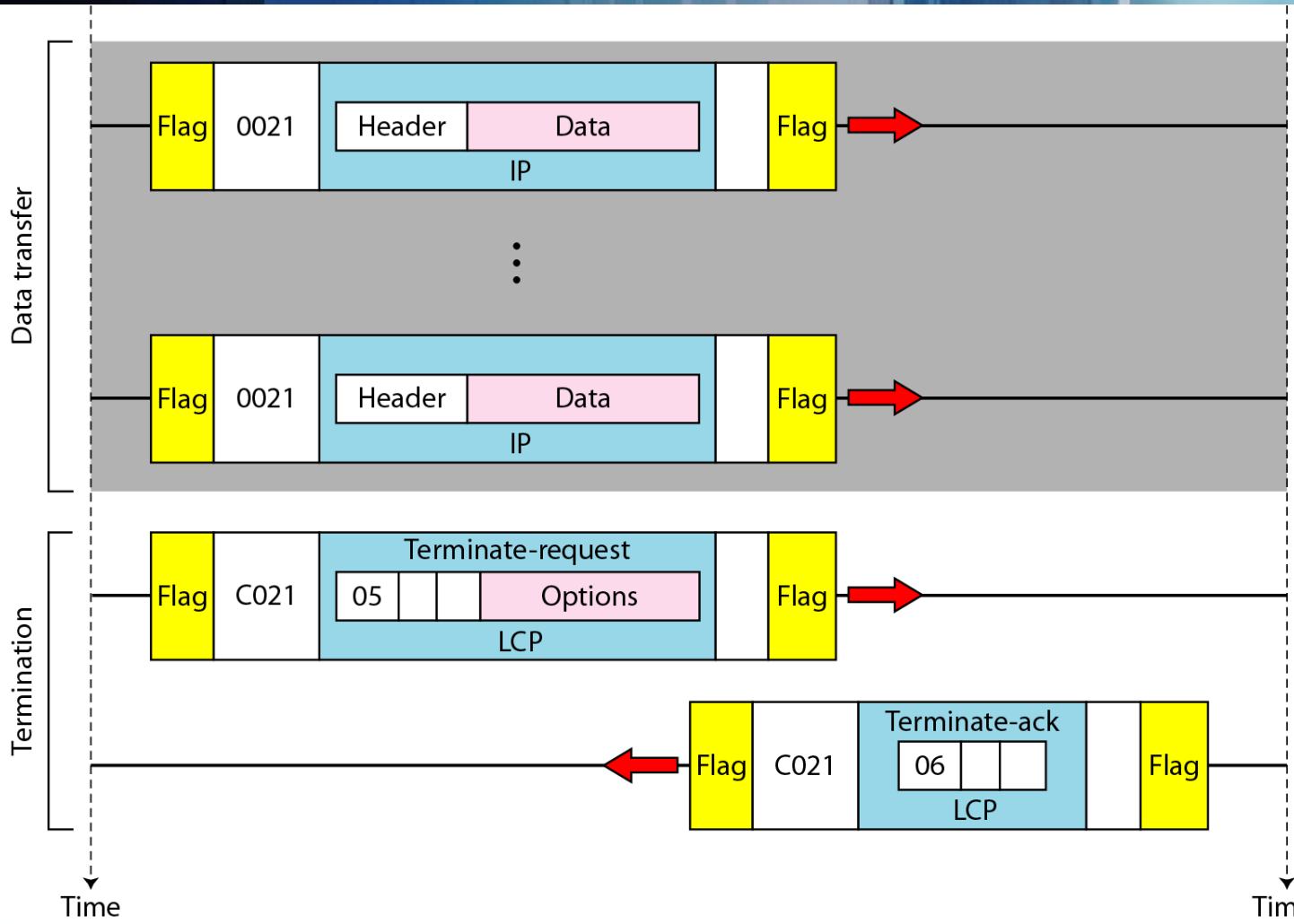
* Figure is courtesy of B. Forouzan

Connection Setup & Authentication



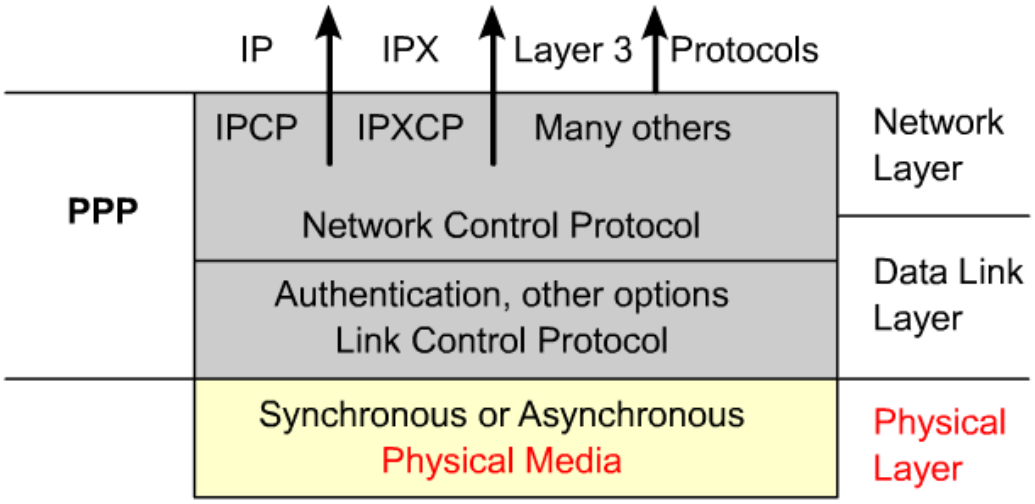
* Figure is courtesy of B. Forouzan

Data Transfer & Termination



* Figure is courtesy of B. Forouzan

PPP in OSI Stack



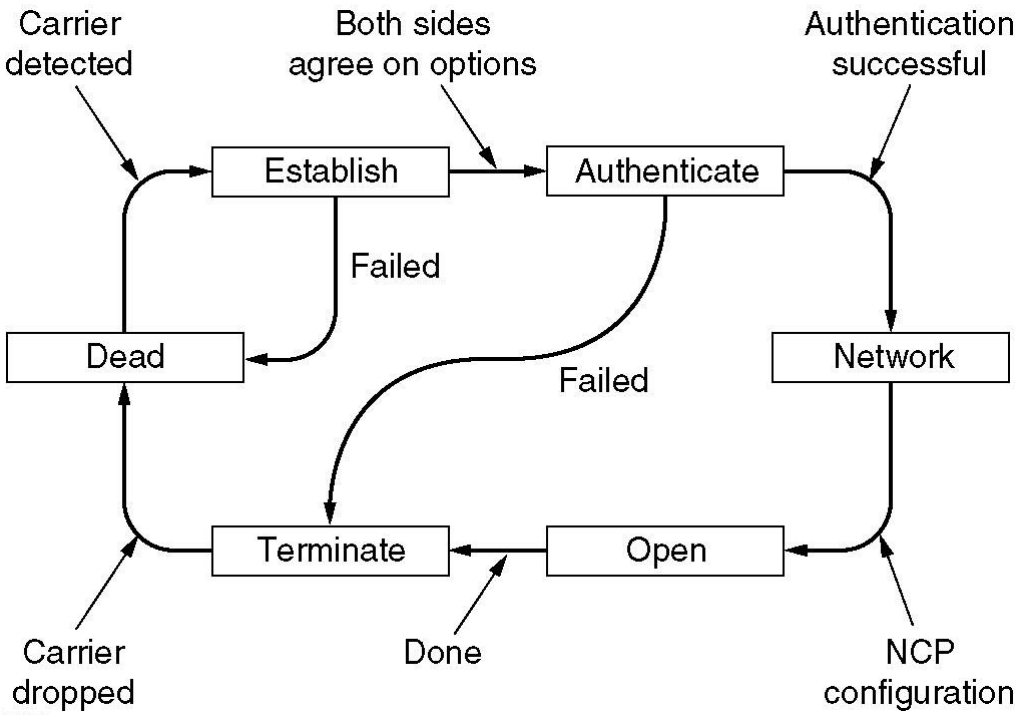
- PPP doesn't implement:
  - error correction/recovery (but error detection)
  - flow control
  - ordered delivery
  - multipoint links

  ⇨ all relegated to higher layers!

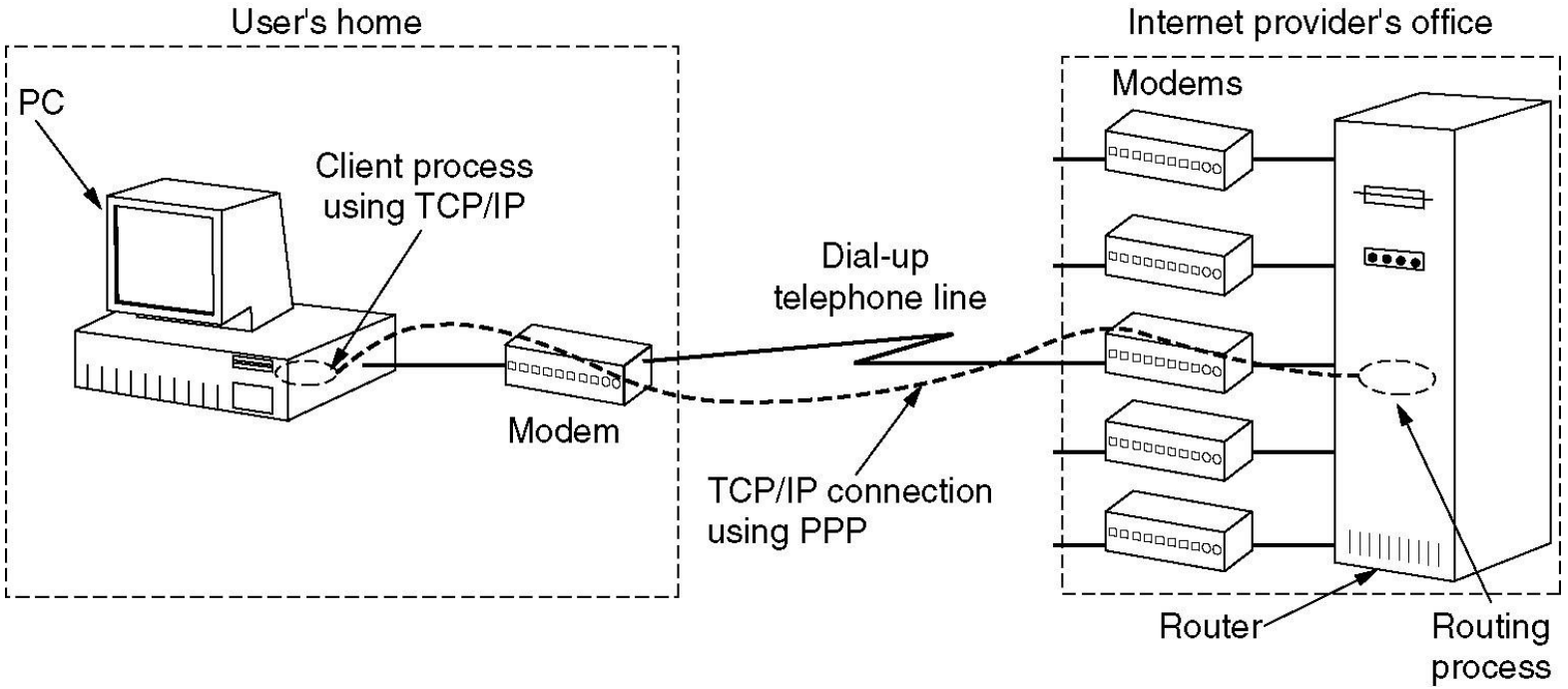
* Figure is courtesy of Cisco Corp.

PPP

- Connection Establishment & Termination
- Format Negotiation
- Authentication

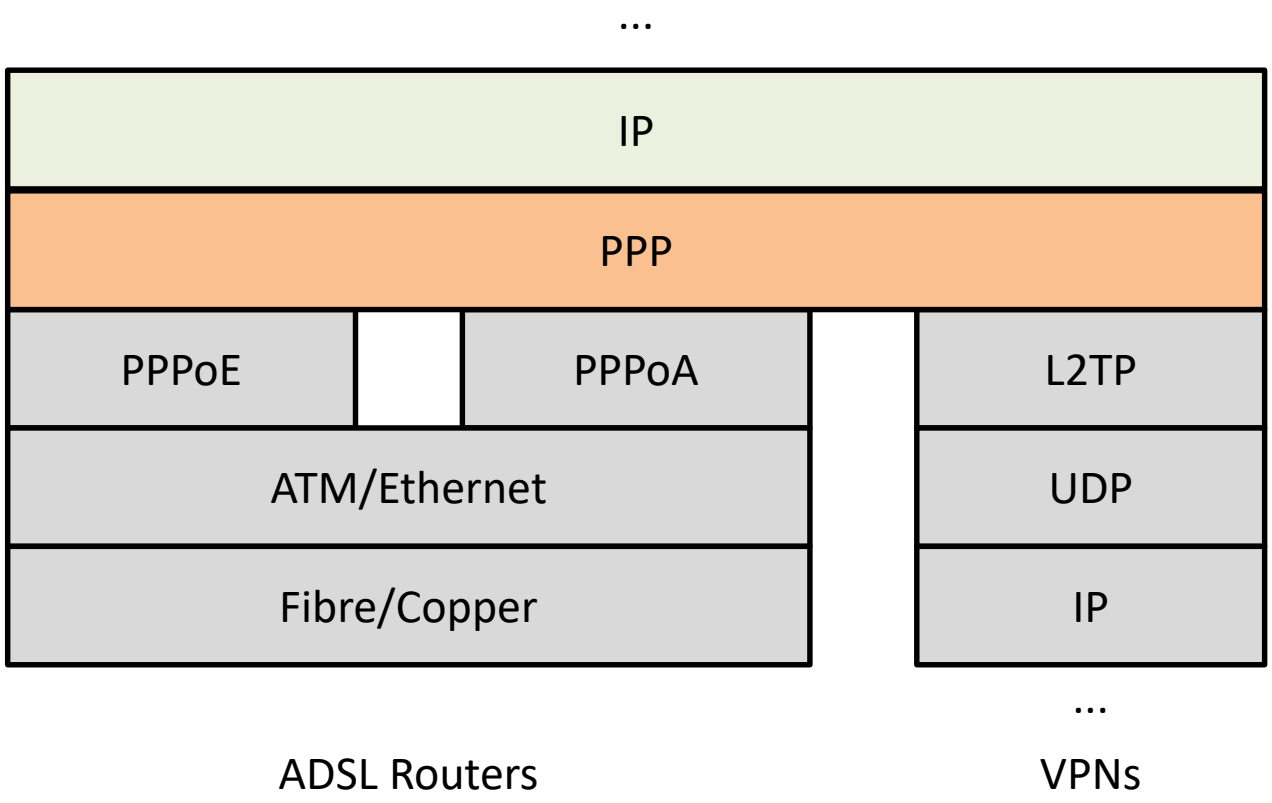


PPP – Why???

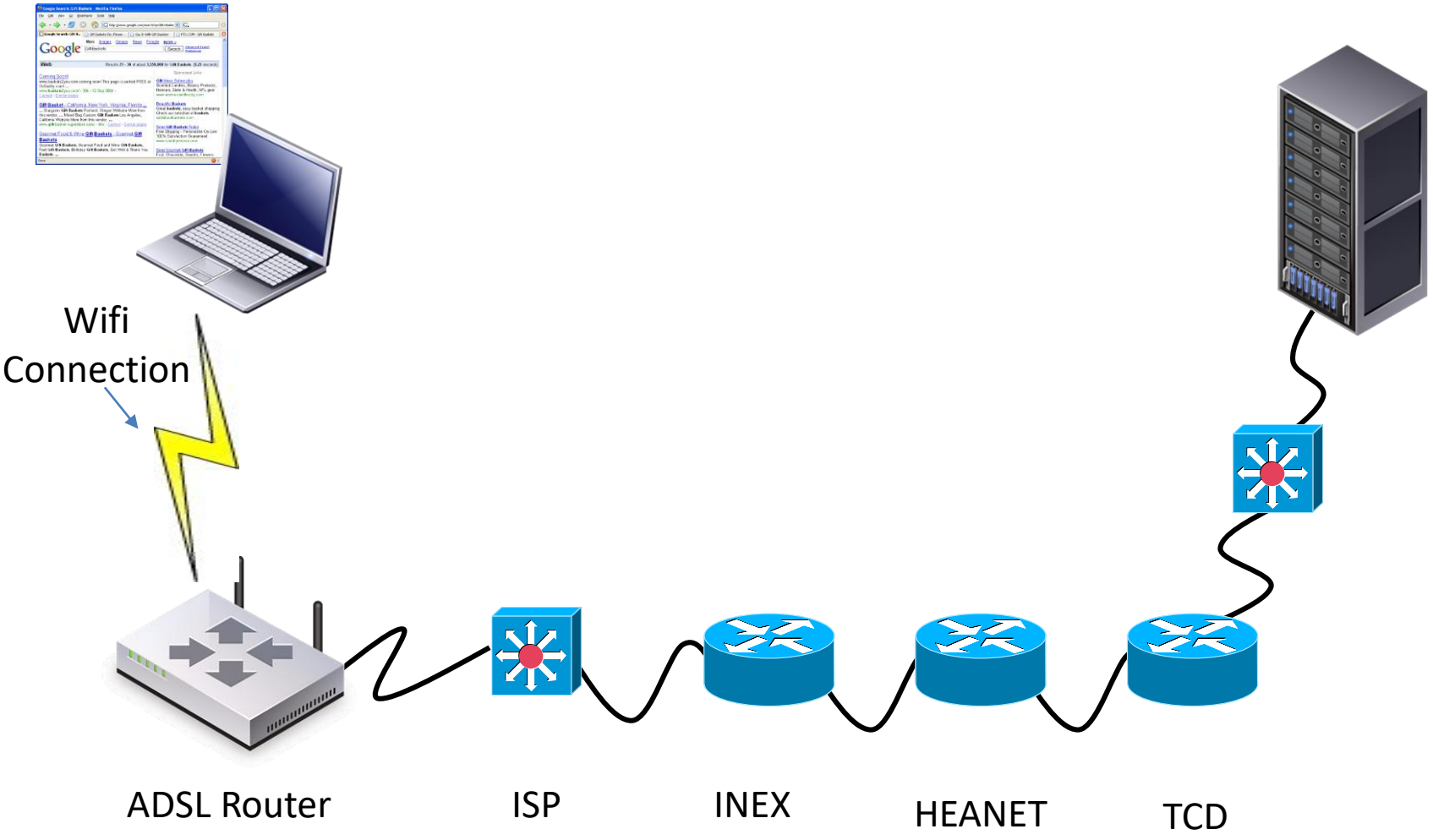


* Figure is courtesy of A. Tanenbaum

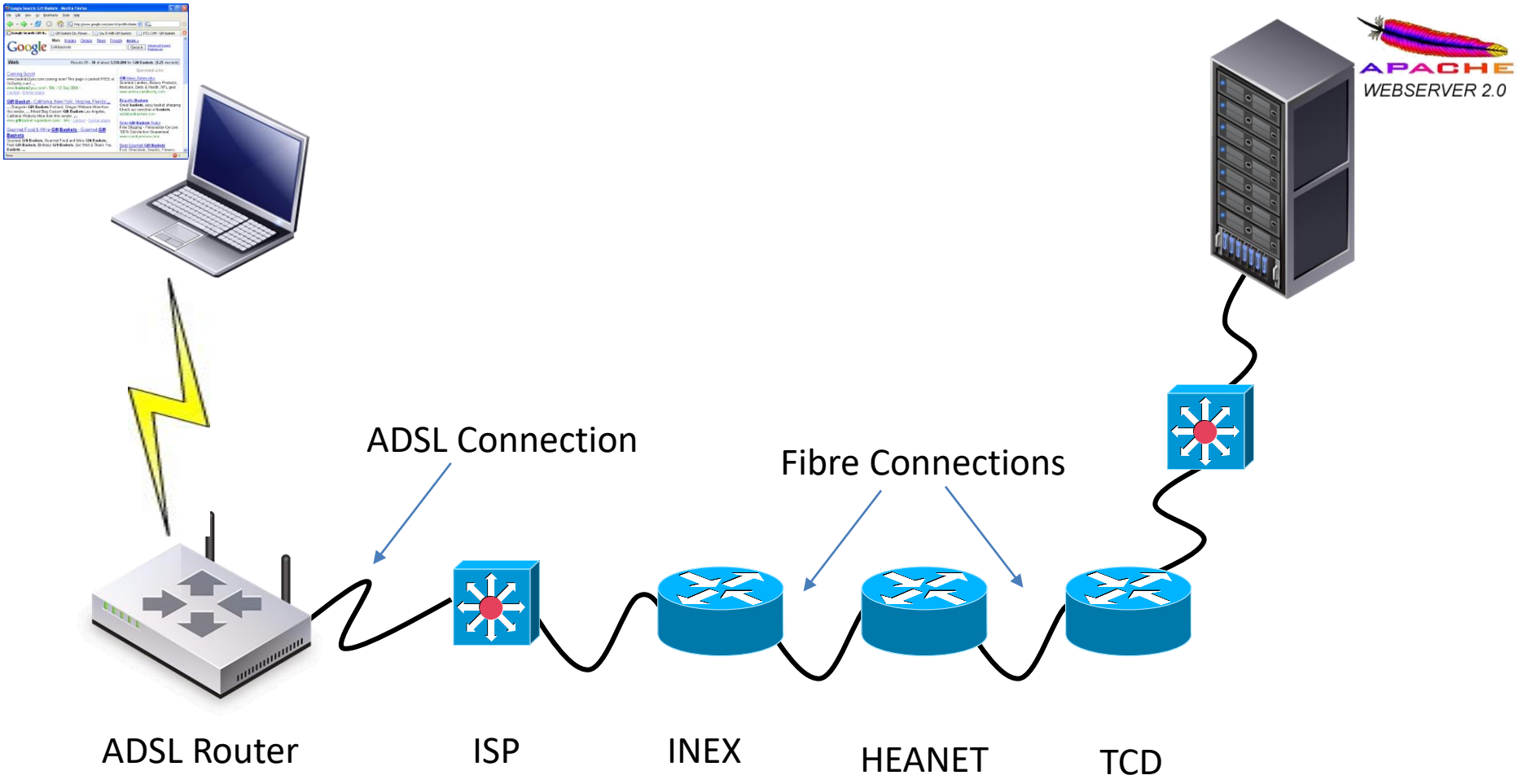
PPP – As Foundation for IP

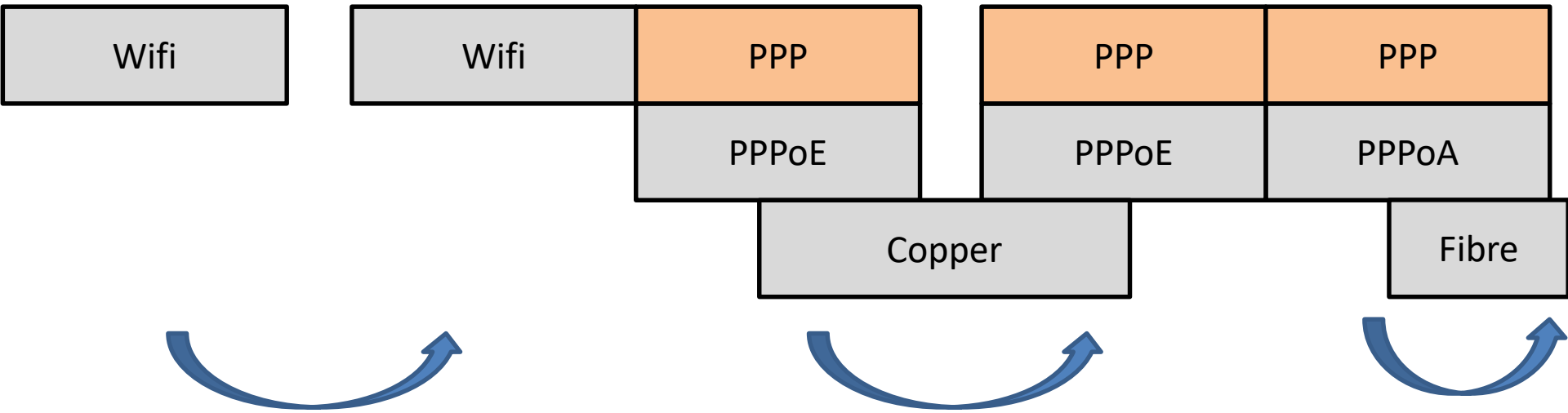


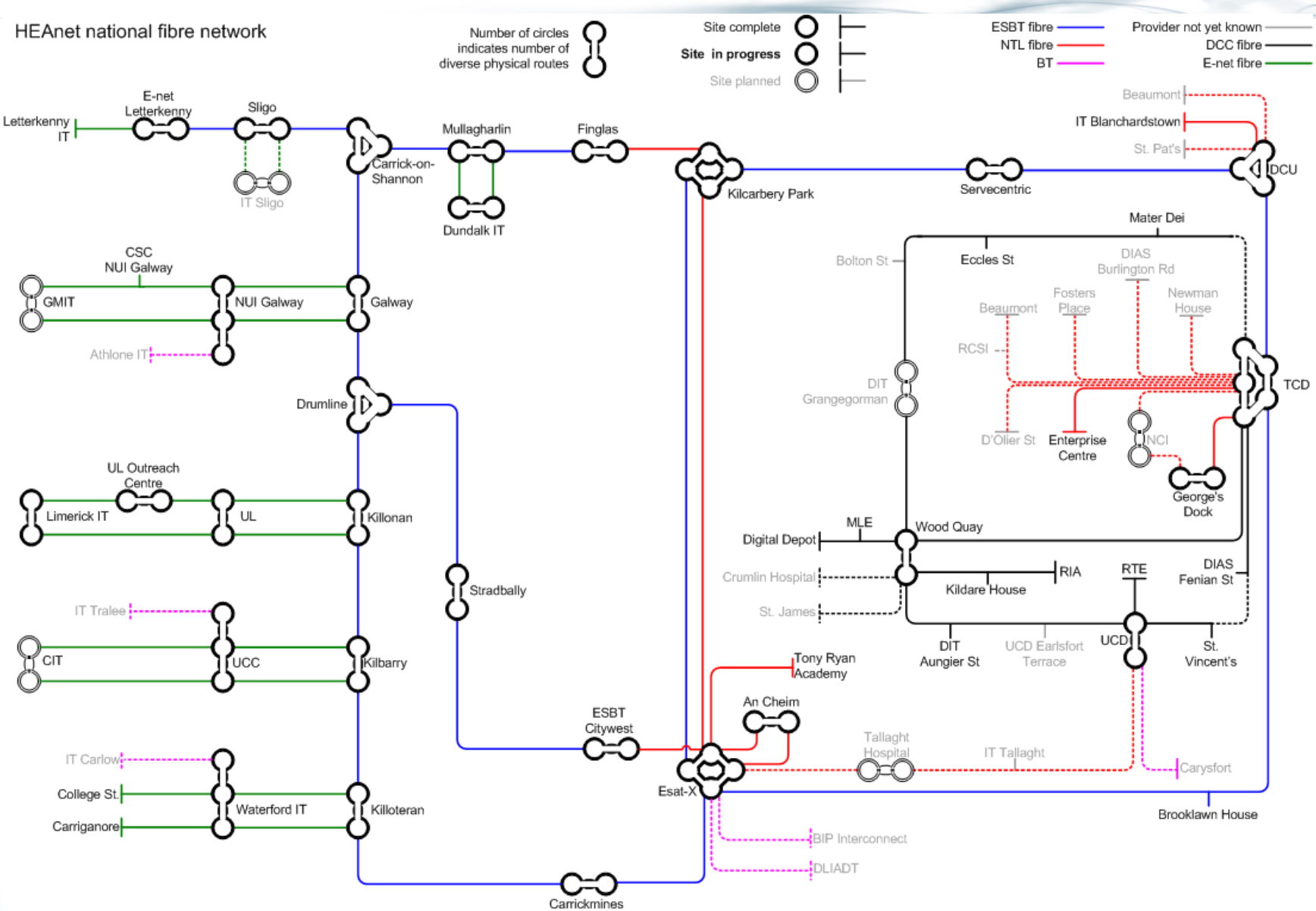
HTML Use Case



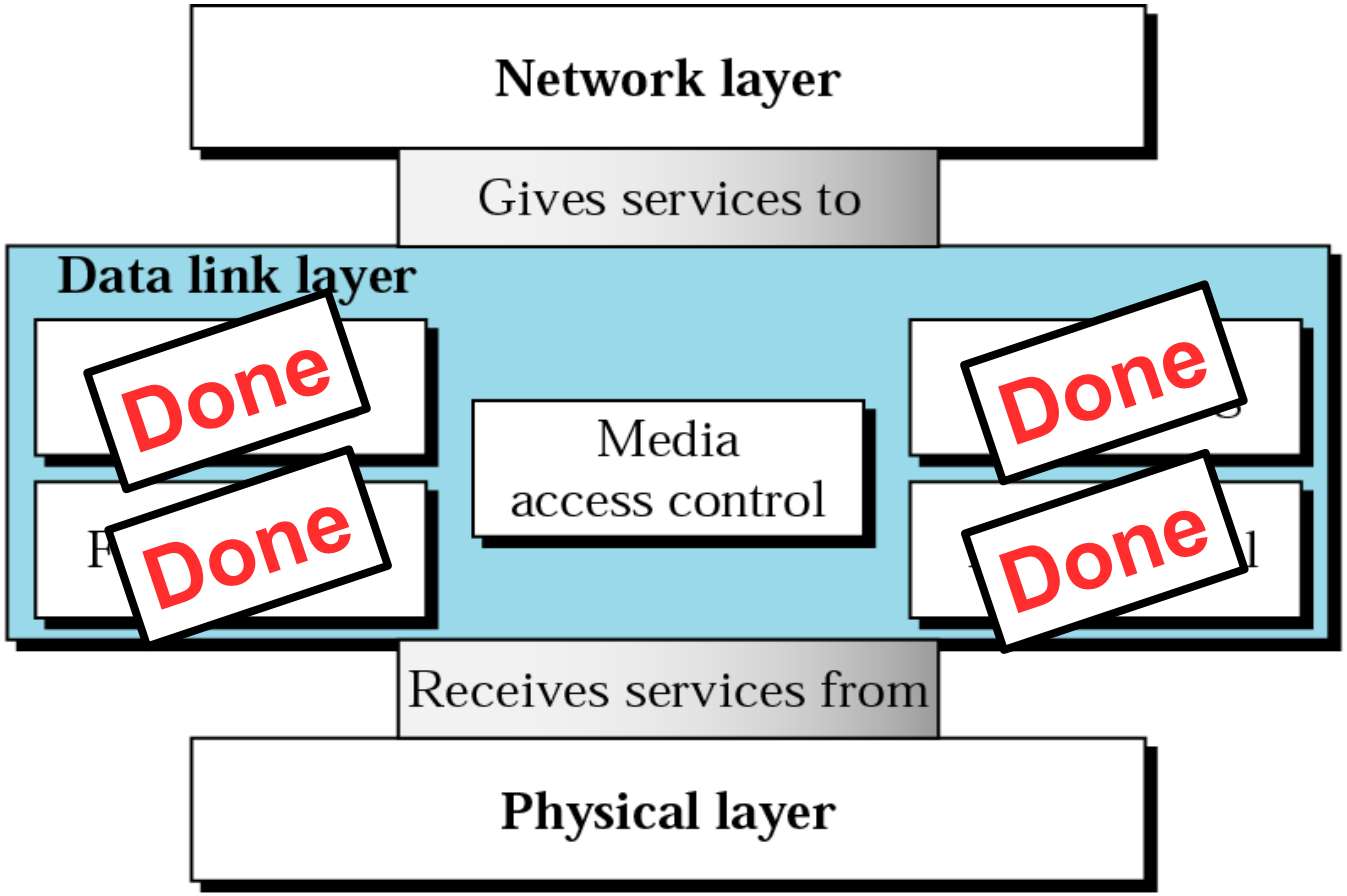
PPP in the HTML Use Case




Wifi
Wifi
PPP
PPP
PPP
PPPoE
PPPoE
PPPoA
Copper
Fibre


HEAnet national fibre network
Number of circles indicates number of diverse physical routes
Site complete
Site in progress
Site planned
ESBT fibre
NTL fibre
BT
Provider not yet known
DCC fibre
E-net fibre
Letterkenny IT
E-net Letterkenny
Sligo
IT Sligo
Carrick-on-Shannon
Mullagharlin
Dundalk IT
Finglas
Kilcarbery Park
Servecentric
DCU
Beaumont
IT Blanchardstown
St. Pat's
Mater Dei
Bolton St
Eccles St
DIAS Burlington Rd
Fosters Place
Newman House
Beaumont
RCSI
DIT Grangegorman
TCD
D'Olier St
Enterprise Centre
NCI
George's Dock
CSC NUI Galway
GMIT
NUI Galway
Galway
Athlone IT
Drumline
UL Outreach Centre
Limerick IT
UL
Killonan
Stradbally
MLE
Digital Depot
Wood Quay
Crumlin Hospital
RIA
Kildare House
RTE
DIAS Fenian St
St. James
DIT Aungier St
UCD Earlsfort Terrace
UCD
St. Vincent's
IT Tralee
CIT
UCC
Kilbarry
Tony Ryan Academy
An Cheim
ESBT Citywest
Tallaght Hospital
IT Tallaght
Carysfort
IT Carlow
College St.
Carriganore
Waterford IT
Killoteran
Esat-X
Brooklawn House
BIP Interconnect
DLIADT
Carrickmines

Link Layer



* Figure is courtesy of B. Forouzan

Assignment Clarifications

- Implement 2 out of 3 approaches; either
  - Stop&Wait and Go-Back-N

  or
  - Stop&Wait and Selective Repeat

- Receivers are reactive
  - ACKs are never retransmitted


That's all folks
Telecomms II