
Data Link Control

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Flow Control

Effect of propagation delay, speed, frame size

Error Control

HDLC

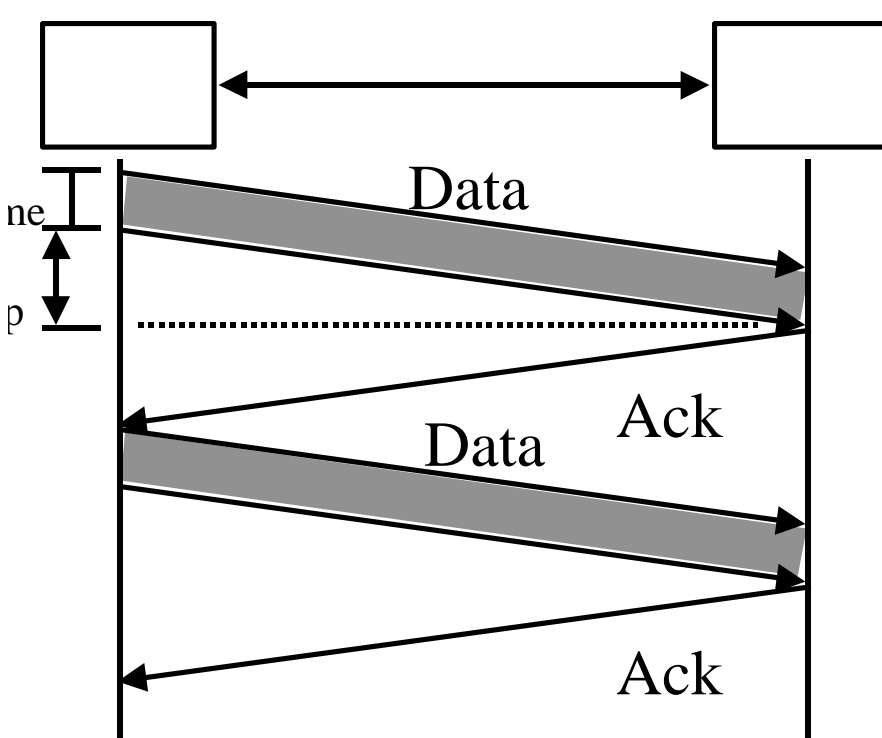
PPP

Flow Control

Flow Control = Sender does not flood the receiver, but maximizes throughput

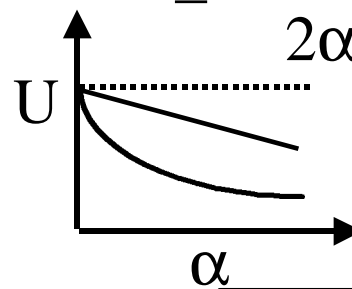
Sender throttled until receiver grants permission

Stop and Wait Flow Control



$$U = \frac{t_{\text{frame}}}{2t_{\text{prop}} + t_{\text{frame}}}$$

$$= \frac{1}{2\alpha + 1}$$



$$\frac{t_{\text{prop}}}{t_{\text{frame}}} = \frac{\text{Distance/Speed of Signal}}{\text{Frame size /Bit rate}}$$

$$= \frac{\text{Distance} \times \text{Bit rate}}{\text{Frame size} \times \text{Speed of Signal}}$$

Light in vacuum
= 300 m/μs
Light in fiber
= 200 m/μs
Electricity
= 250 m/μs

Utilization: Examples

Satellite Link: Propagation Delay $t_{\text{prop}} = 270 \text{ ms}$

Frame Size = 4000 bits = 500 bytes

Data rate = 56 kbps $\Rightarrow t_{\text{frame}} = 4/56 = 71 \text{ ms}$

$\alpha = t_{\text{prop}}/t_{\text{frame}} = 270/71 = 3.8$

$U = 1/(2\alpha+1) = 0.12$

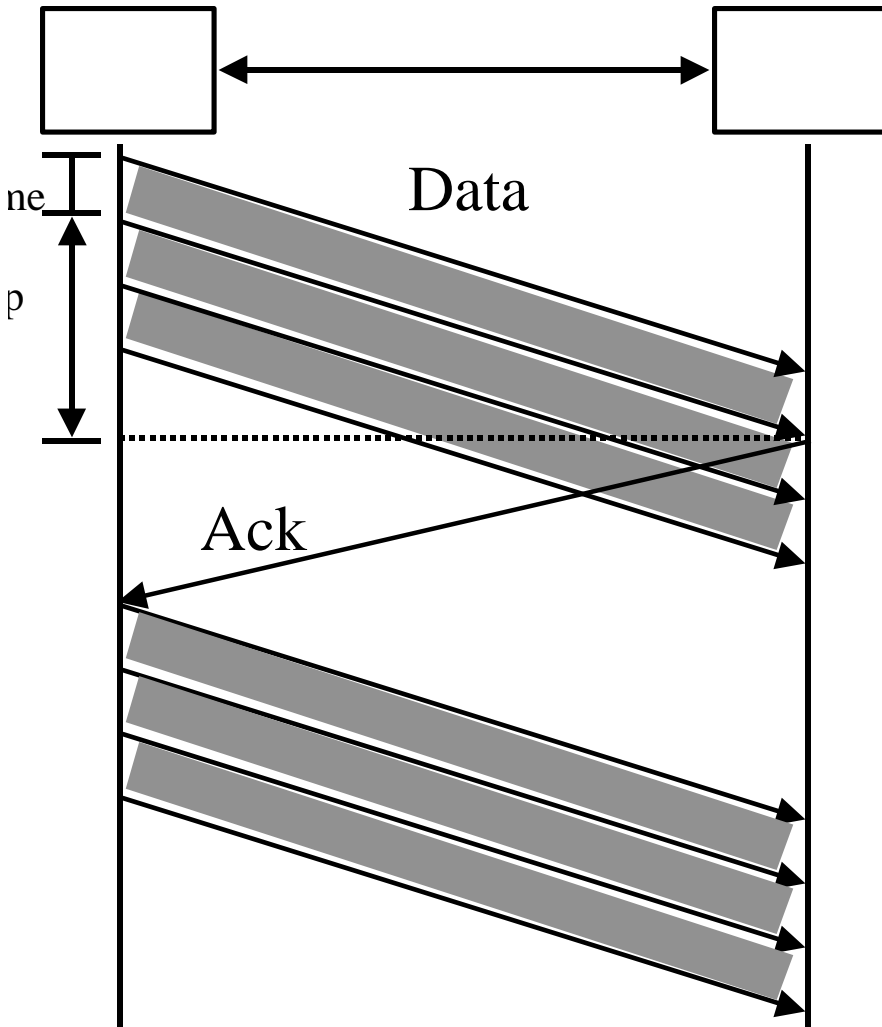
Short Link: 1 km = 5 μs ,

Rate=10 Mbps,

Frame=500 bytes $\Rightarrow t_{\text{frame}} = 4\text{k}/10\text{M} = 400 \mu\text{s}$

$\alpha = t_{\text{prop}}/t_{\text{frame}} = 5/400 = 0.012 \Rightarrow U = 1/(2\alpha+1) = 0.98$

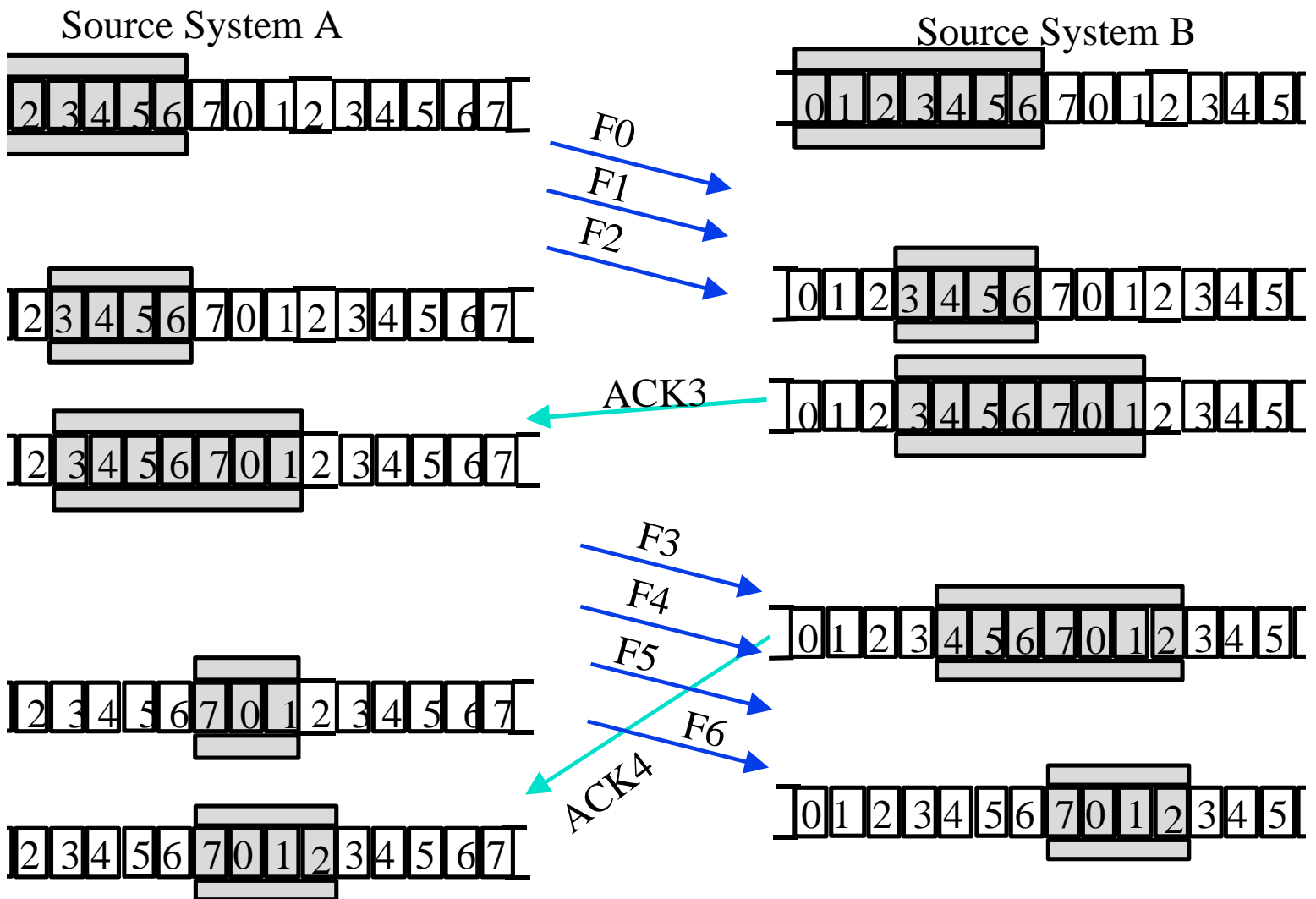
Sliding Window Protocol



$$U = \frac{Nt_{\text{frame}}}{2t_{\text{prop}} + t_{\text{frame}}}$$

$$= \begin{cases} \frac{N}{2\alpha + 1} \\ 1 \text{ if } N > 2\alpha + 1 \end{cases}$$

Sliding Window: Example



Effect of Window Size

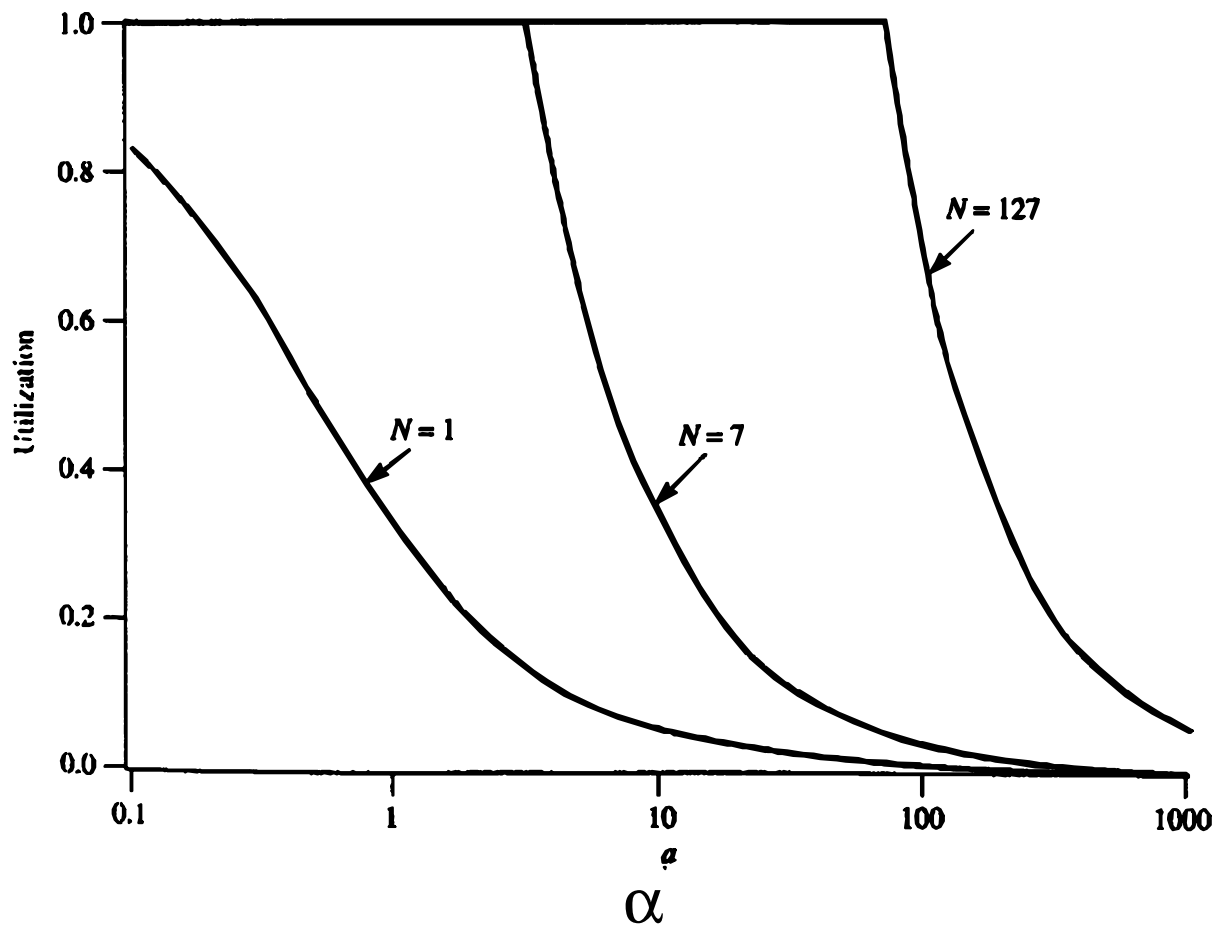
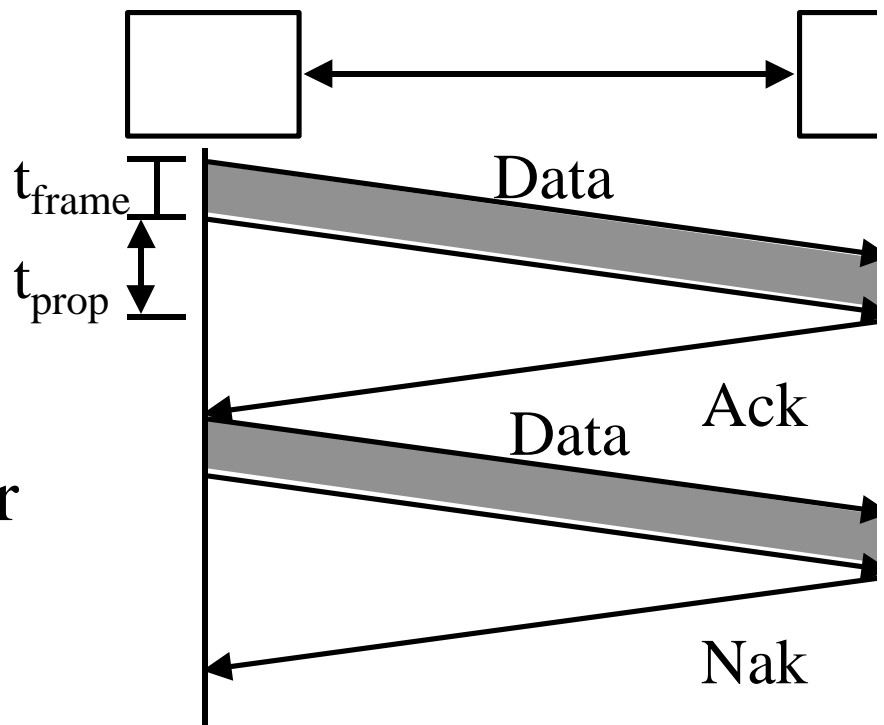


Fig 6.16 Stallings

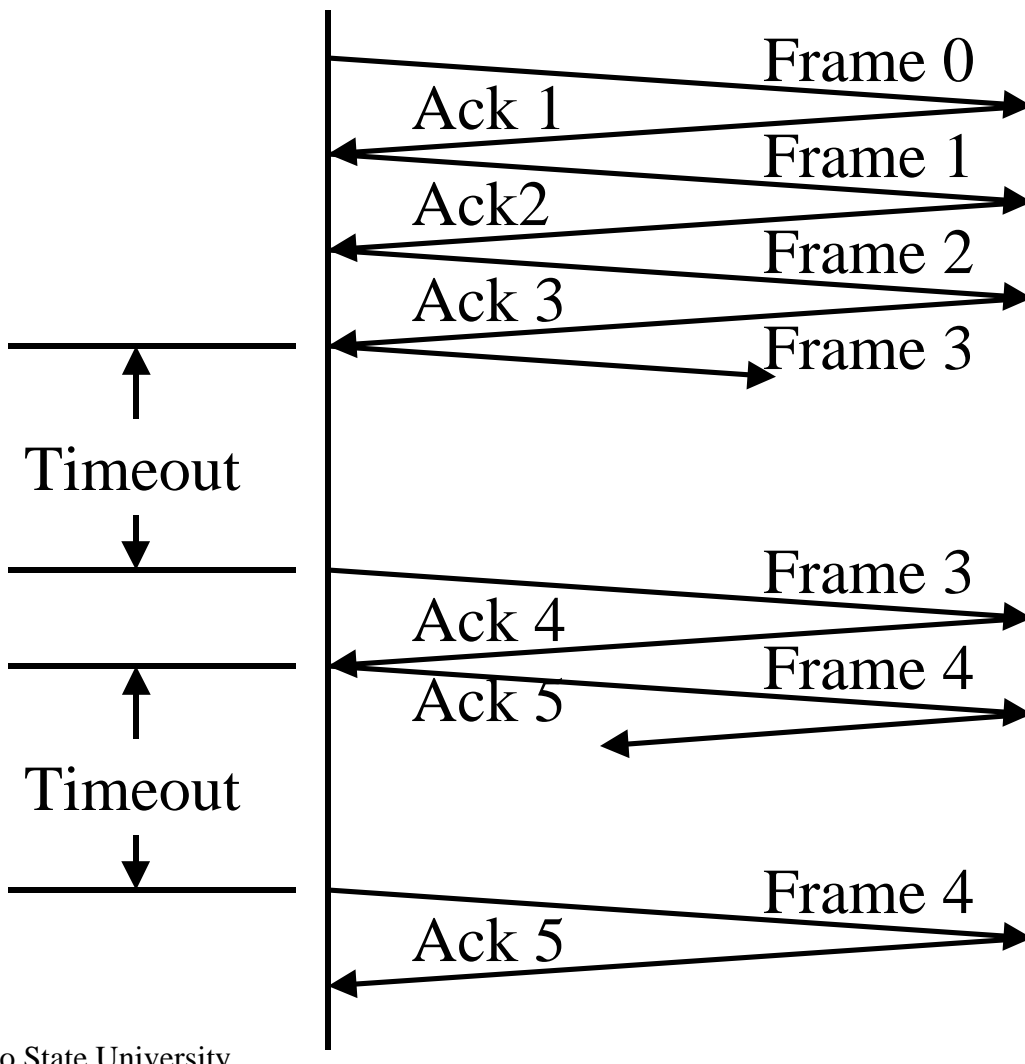
Error Control

Automatic Repeat Request (ARQ)

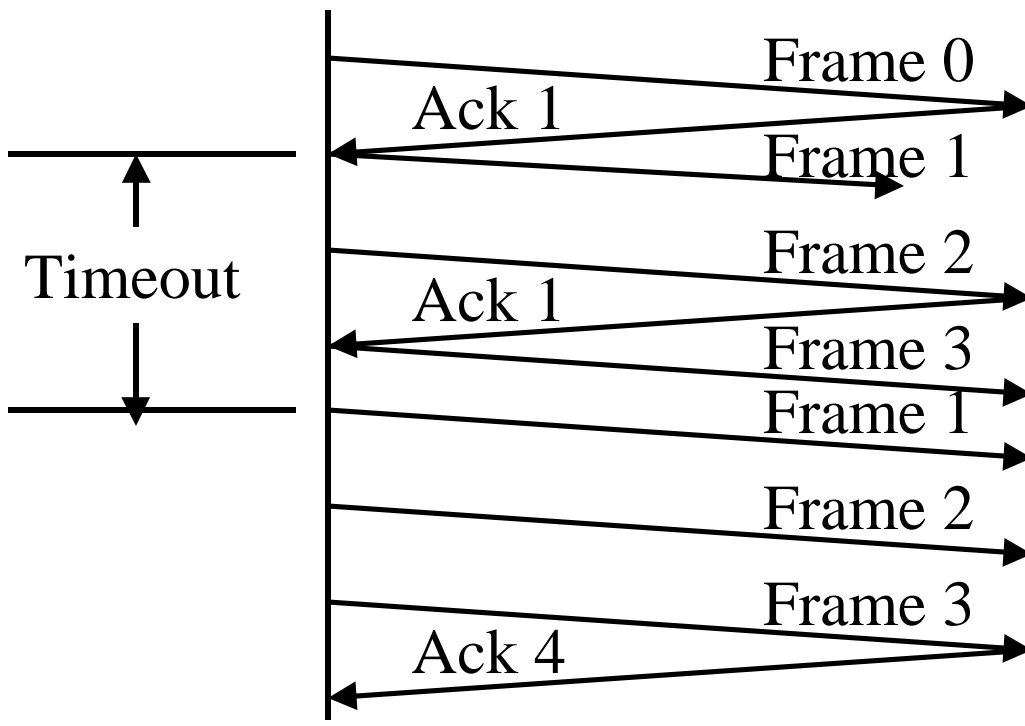
- Error detection
- Acknowledgment
- Retransmission after timeout
- Negative Acknowledgment



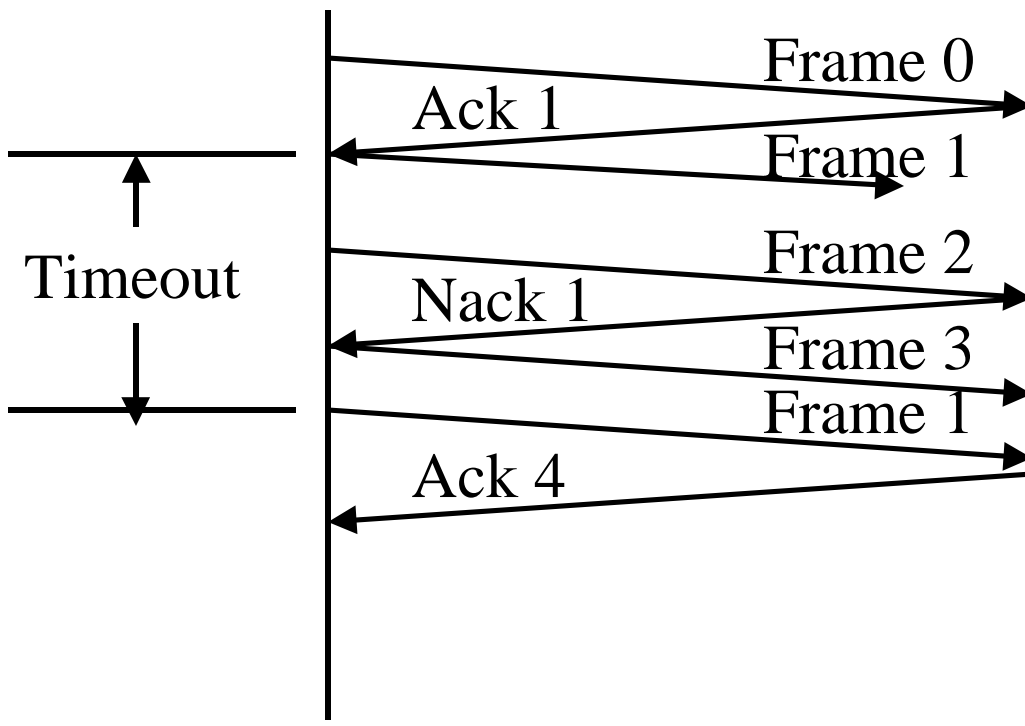
Stop and Wait ARQ



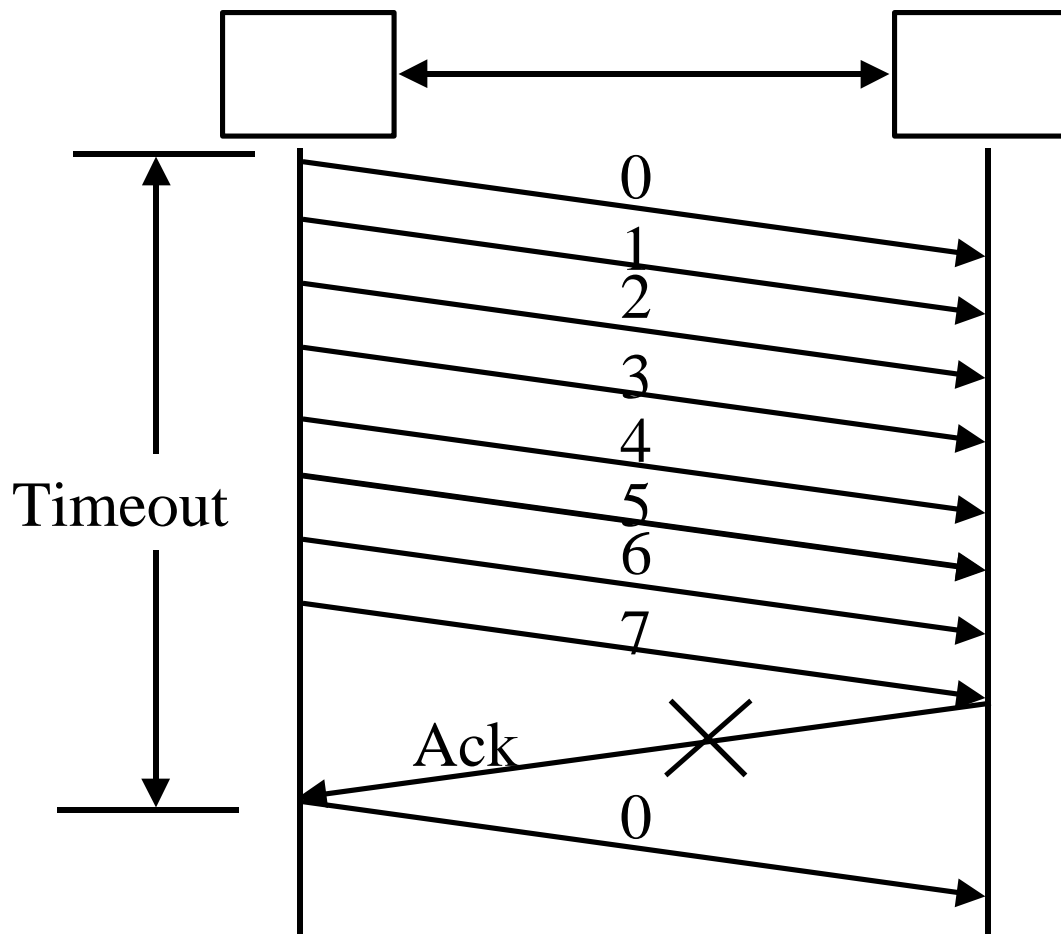
Go-back-n ARQ



Selective Reject ARQ



Selective Reject: Window Size



Sequence number space ≥ 2 window size

HDLC Family

Synchronous Data Link Control (SDLC): IBM

High-Level Data Link Control (HDLC): ISO

Link Access Procedure-Balanced (LAPB): X.25

Link Access Procedure for the D channel (LAPD): ISDN

Link Access Procedure for modems (LAPM): V.42

Link Access Procedure for half-duplex links (LAPX): Teletype

Point-to-Point Protocol (PPP): Internet

Logical Link Control (LLC): IEEE

Advanced Data Communications Control Procedures

(ADCCP): ANSI

V.120 and Frame relay also use HDLC

HDLC



Primary station: Issue commands

Secondary Station: Issue responses

Combined Station: Both primary and secondary

Inbalanced Configuration: One or more secondary

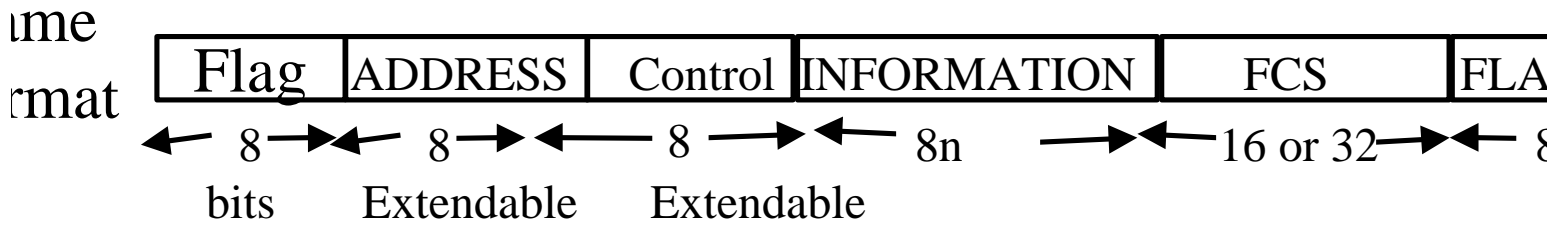
Balanced Configuration: Two combined station

Normal Response Mode (NRM): Response from secondary

Asynchronous Balanced Mode (ABM): Combined Station

Asynchronous Response Mode (ARM): Secondary may respond before command

HDLC Frame Structure

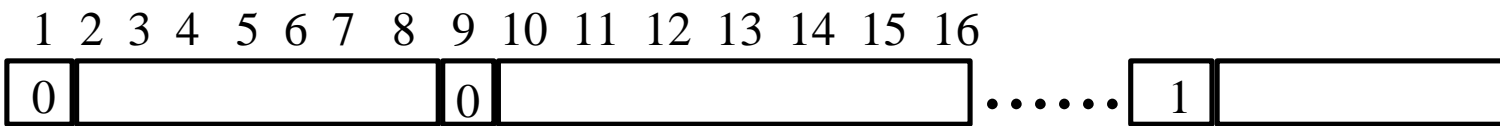


Control Field Format

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

N(S)= Send sequence number N(R)= Recieve sequence number
 S= Supervisory function bits M= Unnumbered bits P/F= Poll/finish

Extended Address Field



Extended Control Field

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Information	0	N(S)						P/F	N(R)							
Supervisory	1	0	S	0	0	0	0	P/F	N(R)							

Fig 6.10 Stallings

Bit Stuffing

Original Pattern

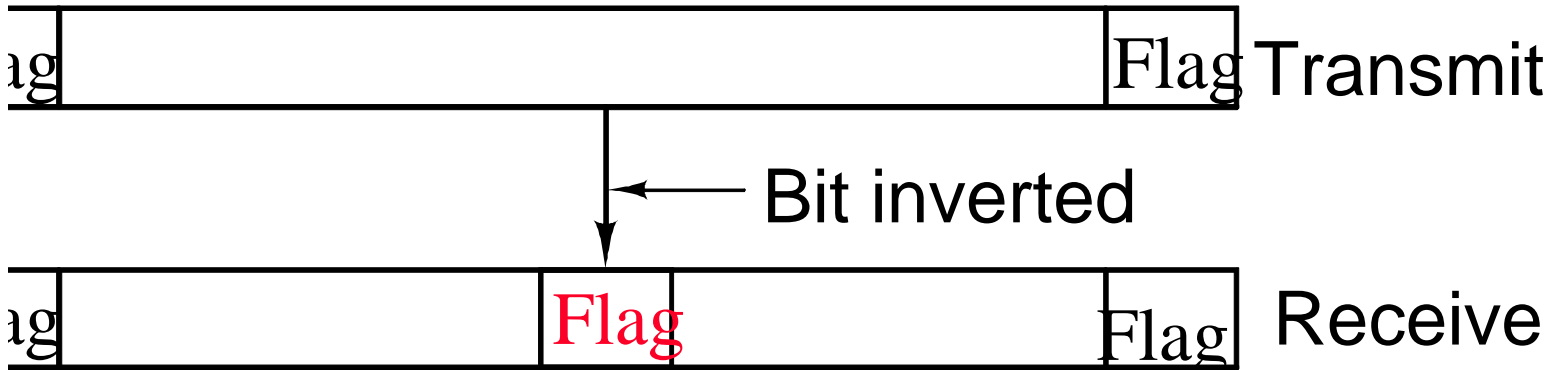
1111111111111011111101111110

After bit-stuffing

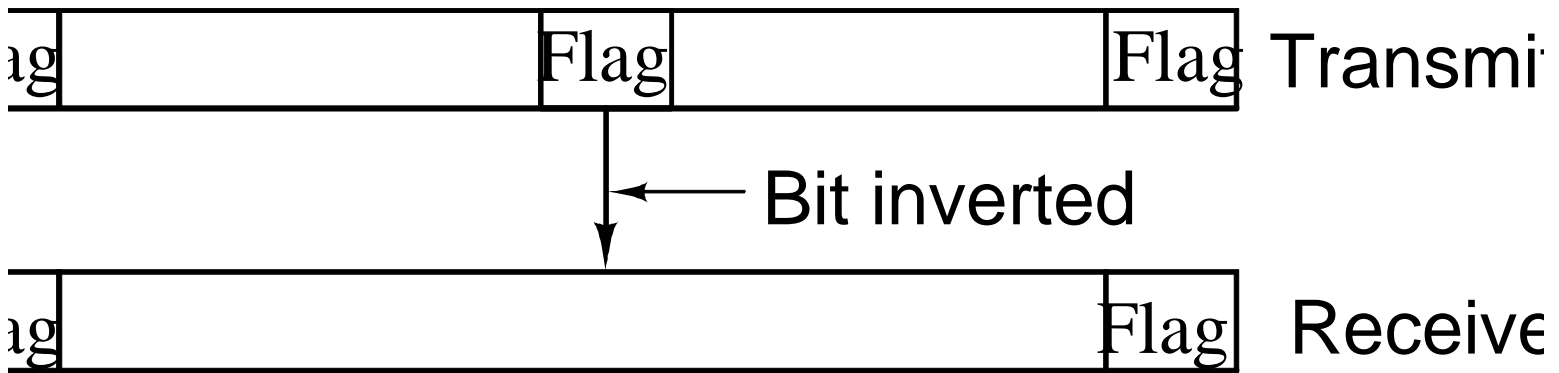
1111101111101101111101011111010



Bit Stuffing (Cont)



(b) An inverted bit splits a frame in two



(c) An inverted bit merges two frames

HDLC Frames

Information Frames: User data

- Piggybacked Acks: Next frame expected
- Poll/Final = Command/Response

Supervisory Frames: Flow and error control

- Go back N and Selective Reject
- Final  No more data to send

Unnumbered Frames: Control

- Mode setting commands and responses
- Information transfer commands and responses
- Recovery commands and responses
- Miscellaneous commands and responses

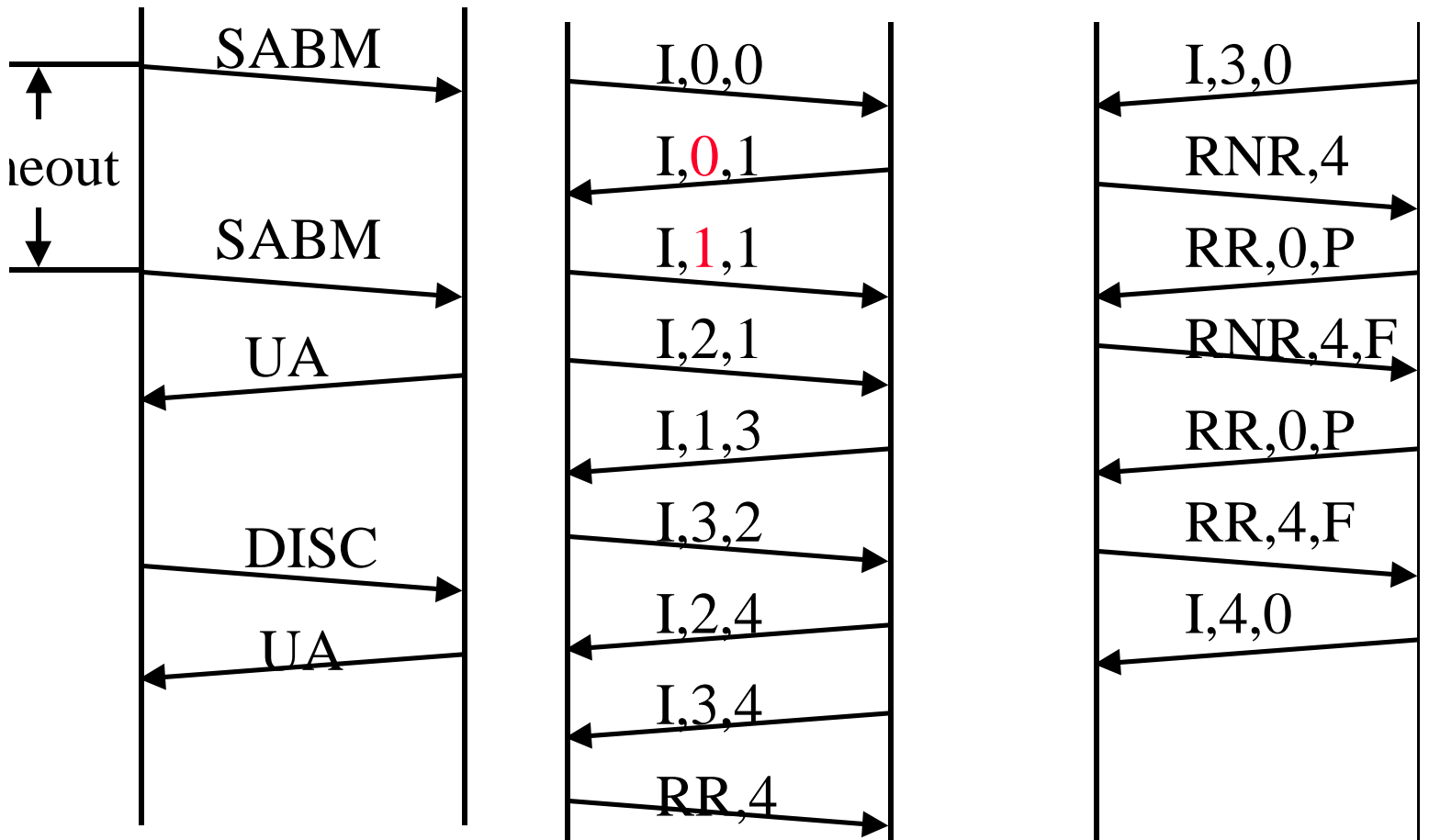
DLC Commands and Responses

Command	Function	Description
Information (I)	C/R	Exchange user data
Supervisory (S)		
Receive Ready (RR)	C/R	Positive Acknowledgement; ready to receive I-frame
Receive Not Ready (RNR)	C/R	Positive acknowledgement; not ready to receive
Reject (REJ)	C/R	Negative acknowledgement; go back N
Selective Reject (SREJ)	C/R	Negative acknowledgement; selective reject
Unnumbered (U)		
Set Normal Response / Extended Mode (SNRM / SNRME)	C	Set mode; extended=two-octet control field
Set Asynchronous Response / Extended Mode (SARM / SARME)	C	Set mode; extended=two-octet control field
Set Asynchronous Balanced / Extended Mode (SABM / SABME)	C	Set mode; extended=two-octet control field
Set Initialization Mode (SIM)	C	Initialize link control functions in addressed station

DLC Commands and Responses (cont)

Command Name	Function	Description
Disconnect (DISC)	C	Terminate logical link connection
Unnumbered Acknowledgement (UA)	R	Acknowledges acceptance of one of the above set-mode commands
Disconnect Mode (DM)	R	Secondary is logically disconnected
Request Disconnect (RD)	R	Request for DISC command
Request Initialization Mode (RIM)	R	Initialization needed; request for SET mode command
Unnumbered Information (UI)	C/R	Used to exchange control information
Unnumbered Poll (UP)	C	Used to solicit control information
Reset (RSET)	C	Used for recovery; resets N(R), N(S)
Exchange Identification (XID)	C/R	Used to request/report identity and status
(TEST)	C/R	Exchange identical information fields for testing
Frame Reject (FRMR)	R	Reports receipt of unacceptable frame

Examples of HDLC Operation



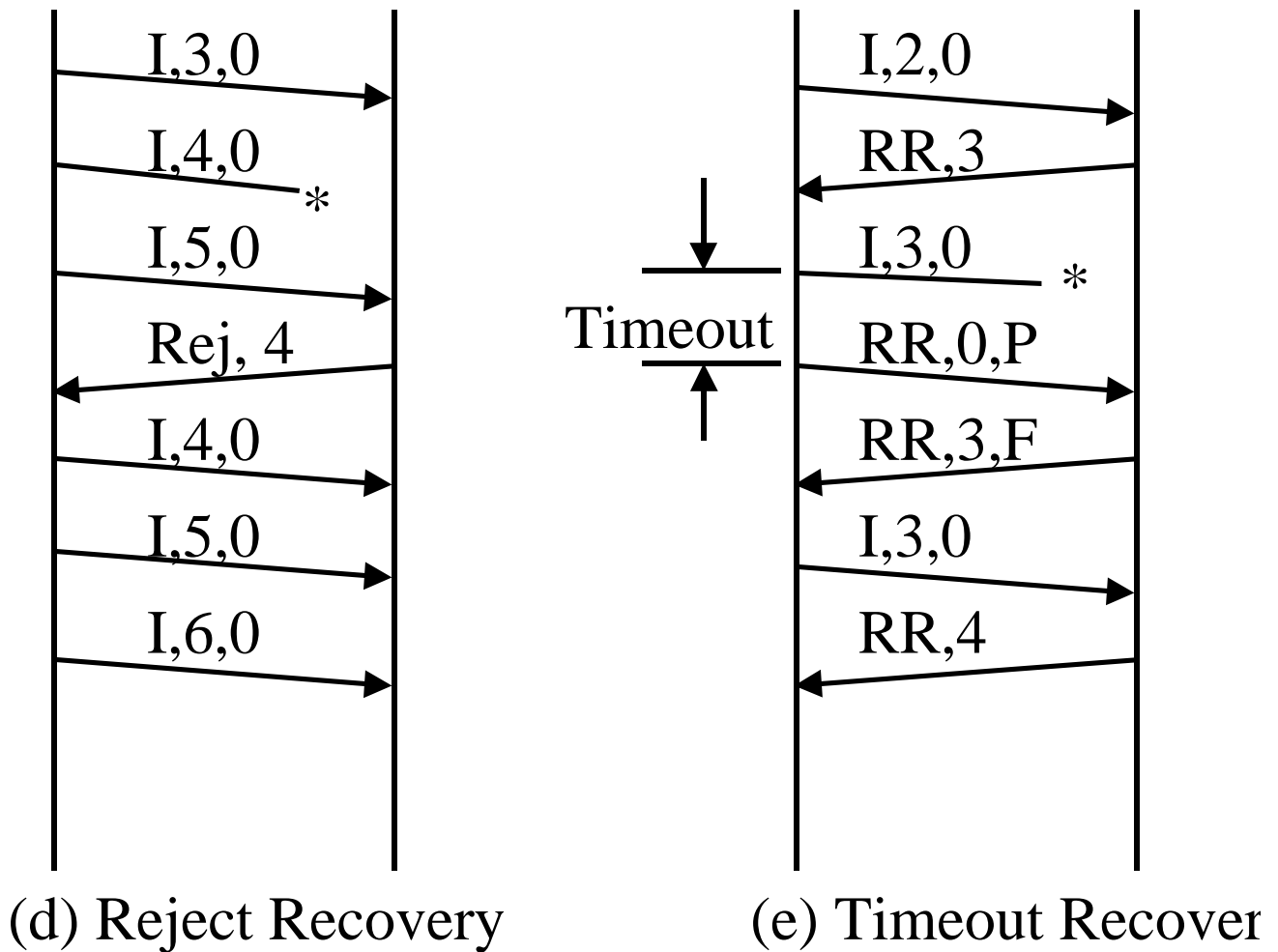
(a) Line setup and disconnect

(b) Two-way data exchange

(c) Busy condition

Fig 6.12 Stallings

Examples of Operation (Cont)



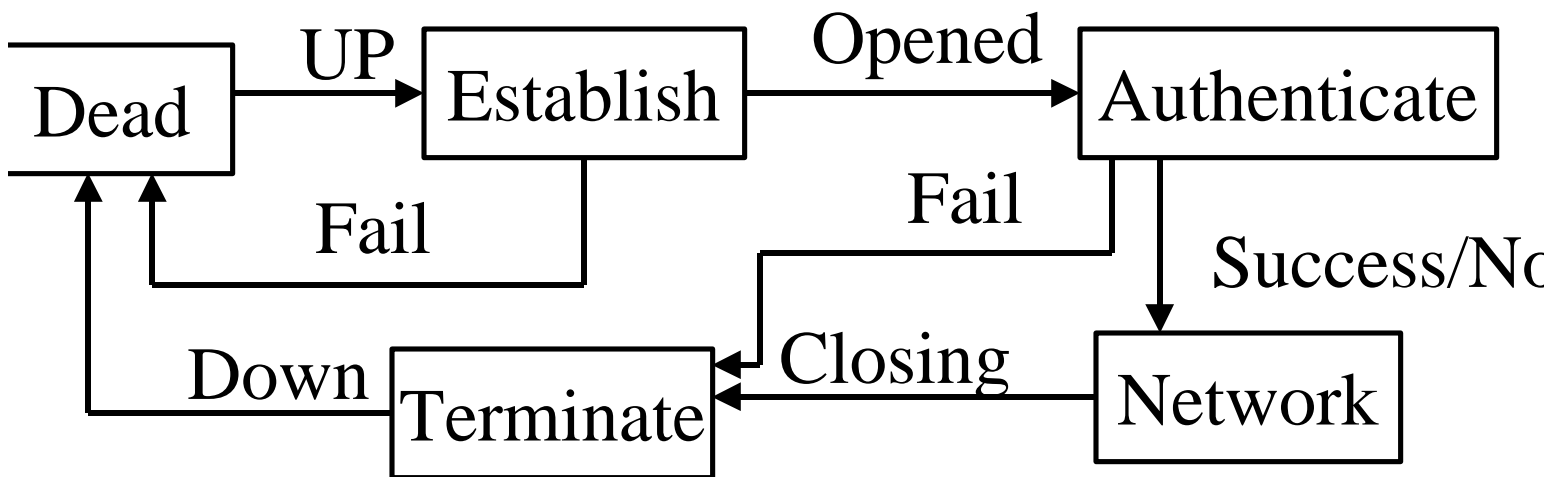
PPP: Introduction

Point-to-point Protocol

Originally for User-network connection

Now being used for router-router connection

Three Components: Data encapsulation, Link Control Protocol (LCP), Network Control Protocols (NCP)



PPP Procedures

Typical connection setup:

- Home PC Modem calls Internet
Provider's router: sets up physical link
- PC sends series of LCP packets
 - + Select PPP (data link) parameters
 - + Authenticate
- PC sends series of NCP packets
 - + Select network parameters
E.g., Get dynamic IP address

Transfer IP packets

PPP in HDLC-Like Framing

Flag	Address	Control	Protocol	
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11110 11111111 00000011

Info	Padding	CRC	Flag
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Flag = 0111 1110 = 7E

Byte Stuffing:

7E \Rightarrow 7D 5E

7D \Rightarrow 7D 5D

Framing (Cont)

Address=FF \Rightarrow All stations

Control=03 \Rightarrow Unnumbered

Poll/final = command/response = 0 \Rightarrow Response

Protocol = 8/16 bits. lsb=1 of LSB \Rightarrow End of address

All protocols are odd and lsb of MSB = 0

Packets may be padded up to MRU.

Maximum receive unit = 1500 default

16-bit FCS default

32-bit FCS can be negotiated using LCP

HDLC Shared zero mode:

01111101111110 = Flag-Flag. Not used in PPP

LCP Config Options

Maximum Receive Unit

Authentication Protocol: C0 23 ⇒ Password

C2 23 ⇒ Challenge Handshake

Quality Protocol: C025 ⇒ Will expect link reports

Magic Number: To related responses with requests

Randomly number in sequence of the request

Helps detect looped back links

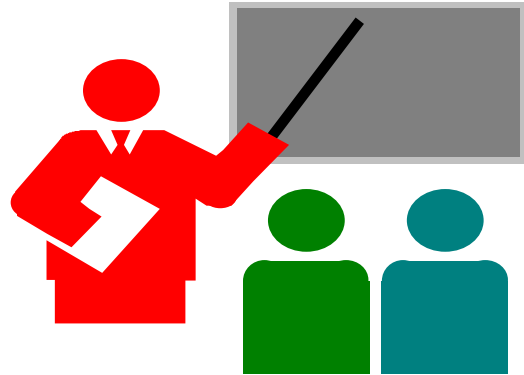
Protocol Field Compression:

Only one byte is used even for 2-byte protocols

Address and Control Field Compression:

F03 is not transmitted. CRC is on compressed frame

Summary



Flow Control: Stop and Wait, Sliding window

Effect of propagation delay, speed, frame size

Error Control: Stop and wait ARQ, Go-back-N, selective Reject

HDLC: Bit stuffing, Flag, I-Frame, RR, RNR