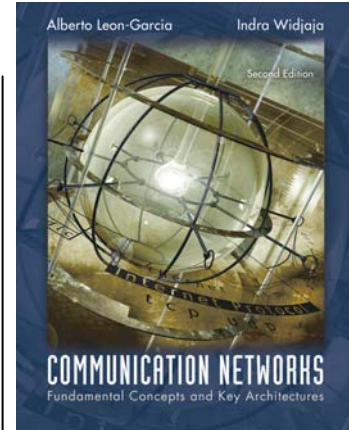
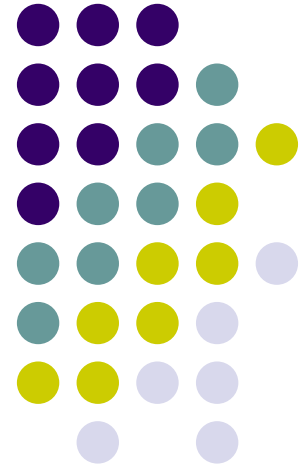


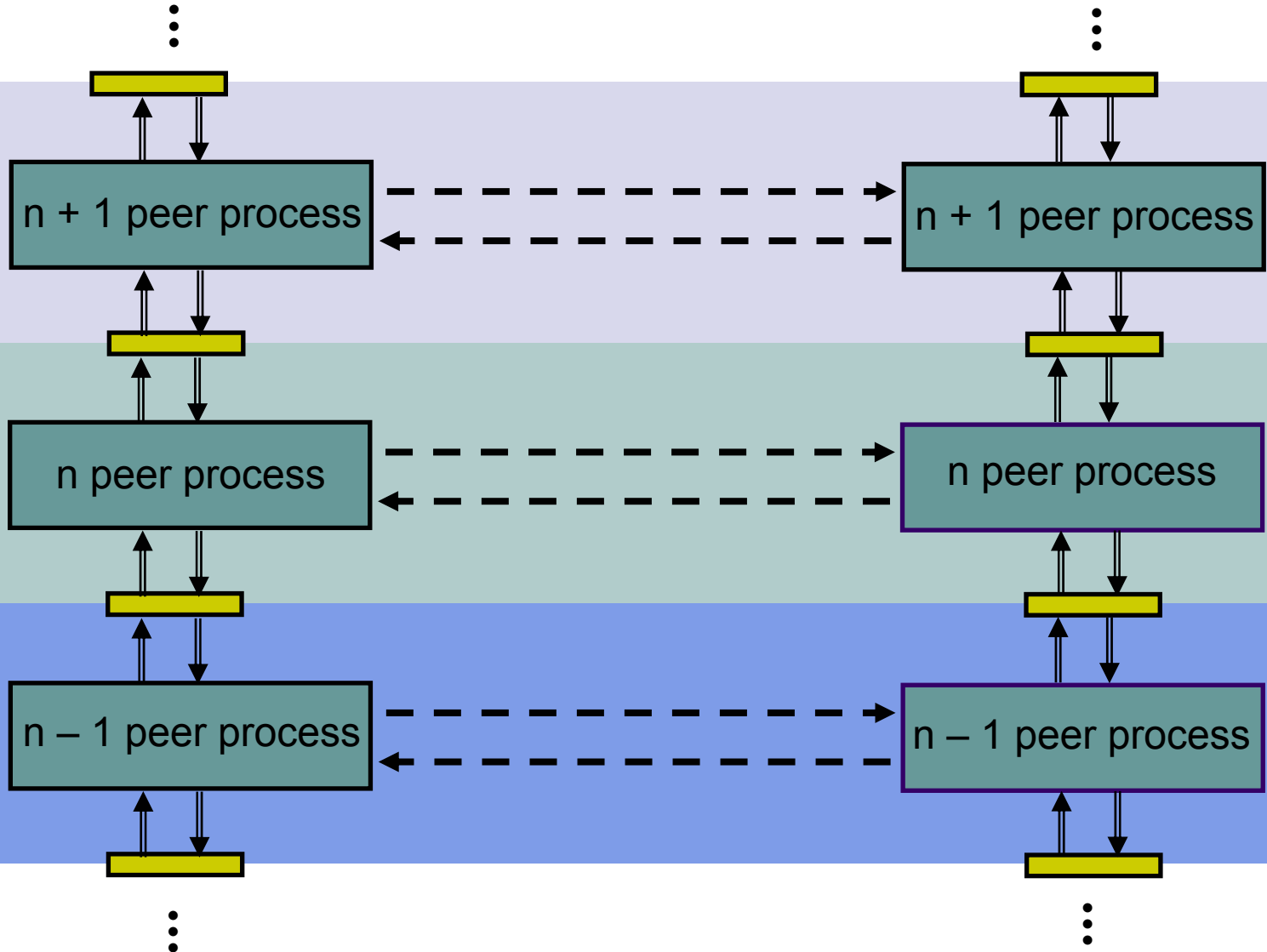
Chapter 5

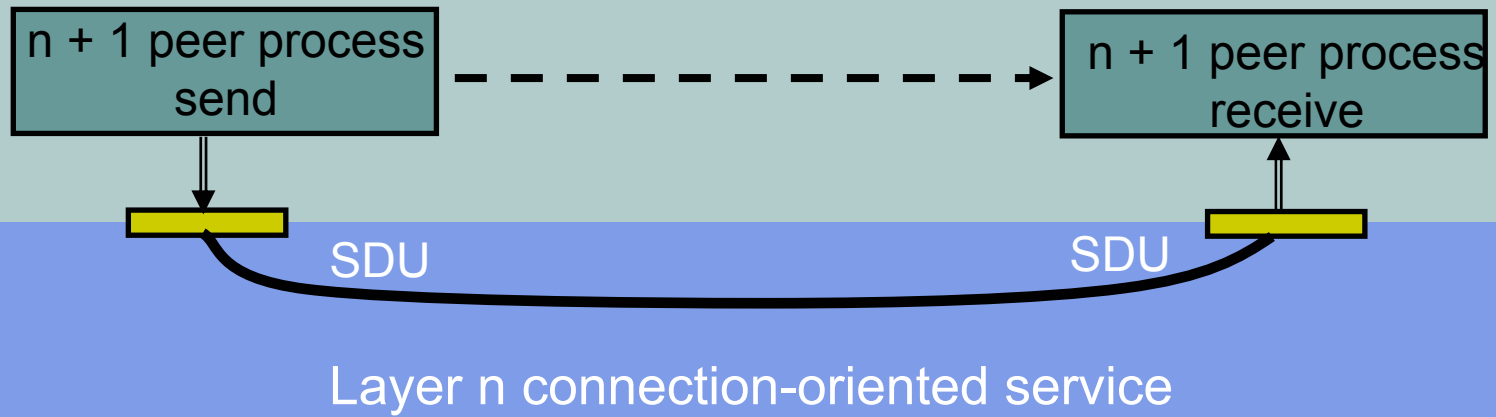
Peer-to-Peer Protocols and Data Link Layer

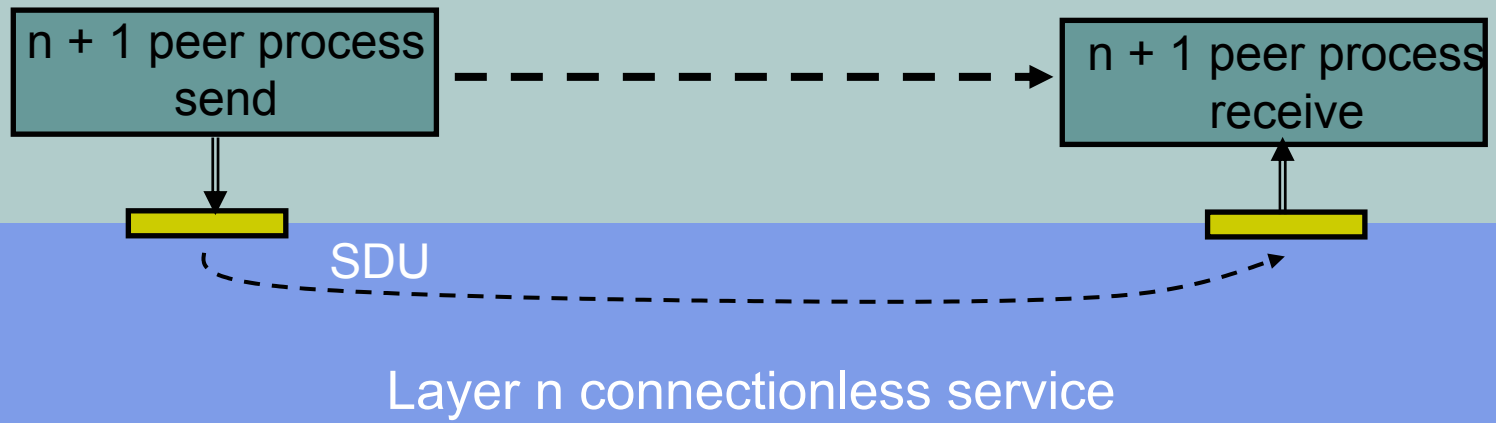


Chapter Figures





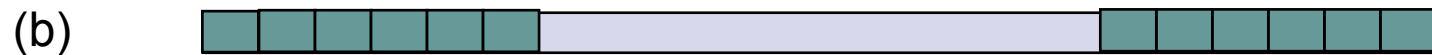




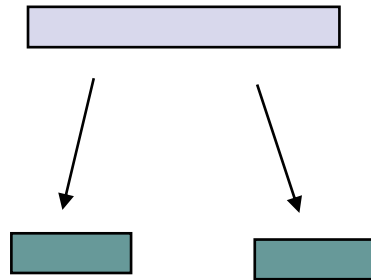
1 call = 1 message = entire sequence of speech samples



1 call = sequence of 1-byte messages

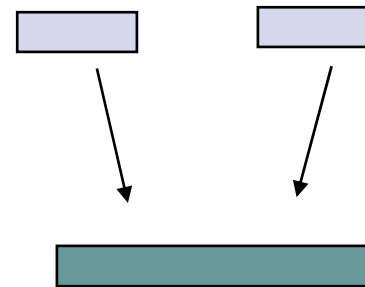


1 long message

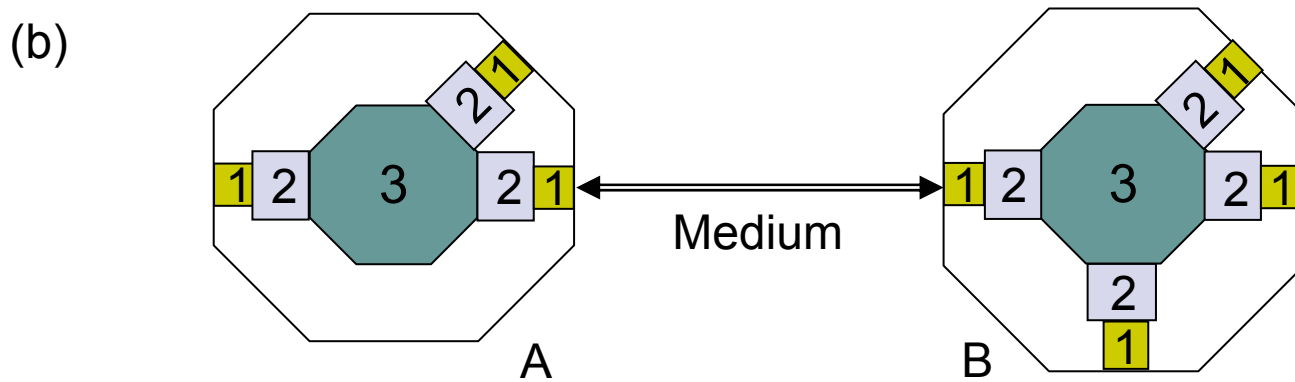
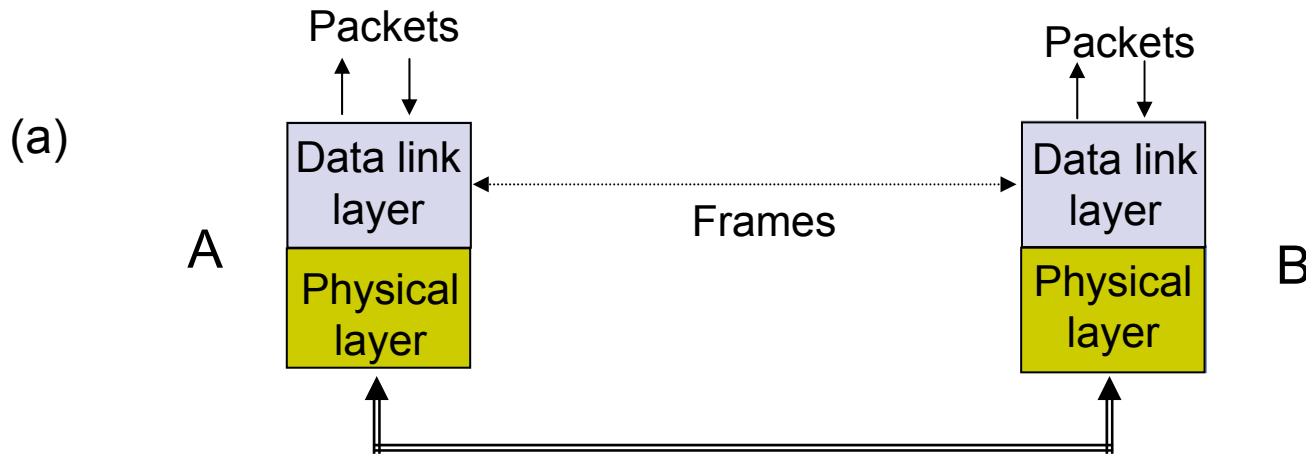


2 or more blocks

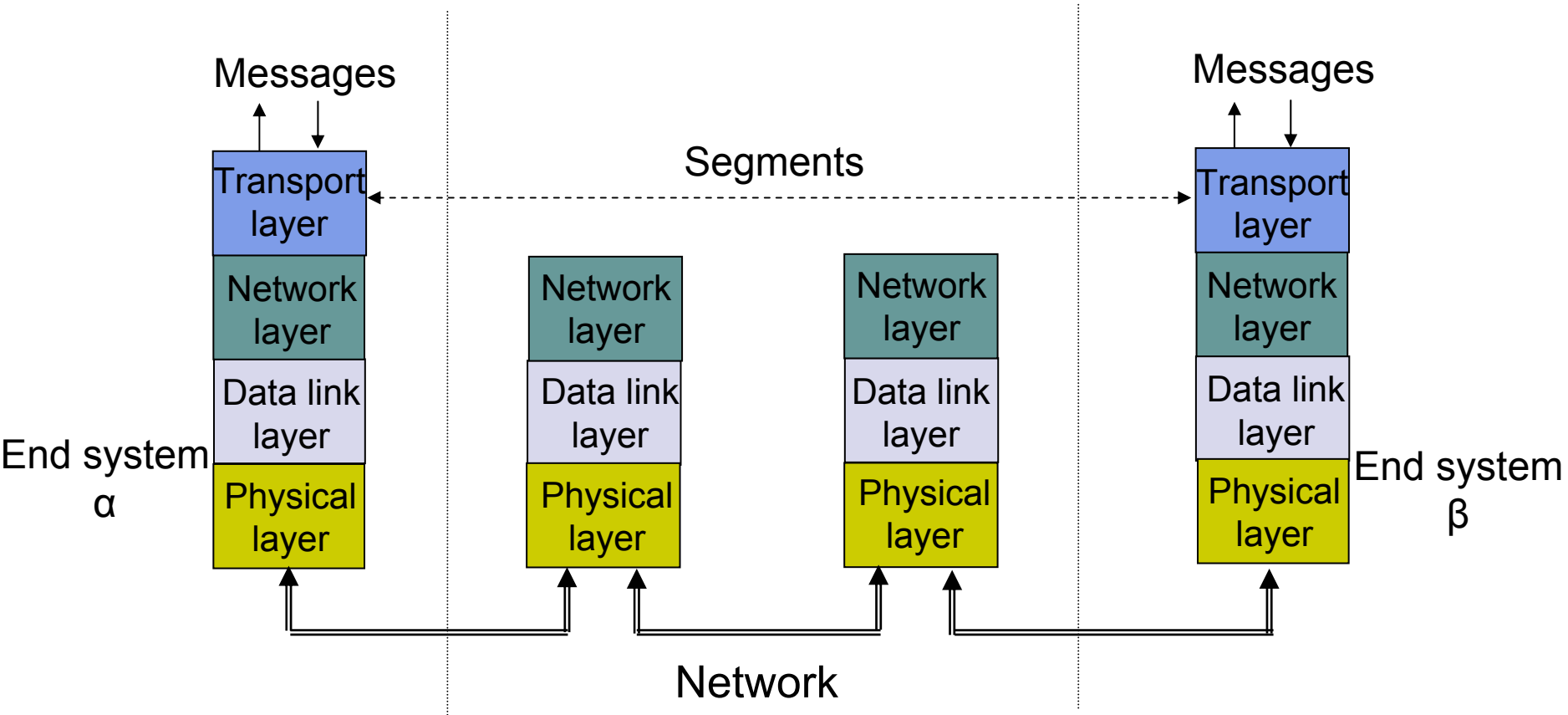
2 or more short messages

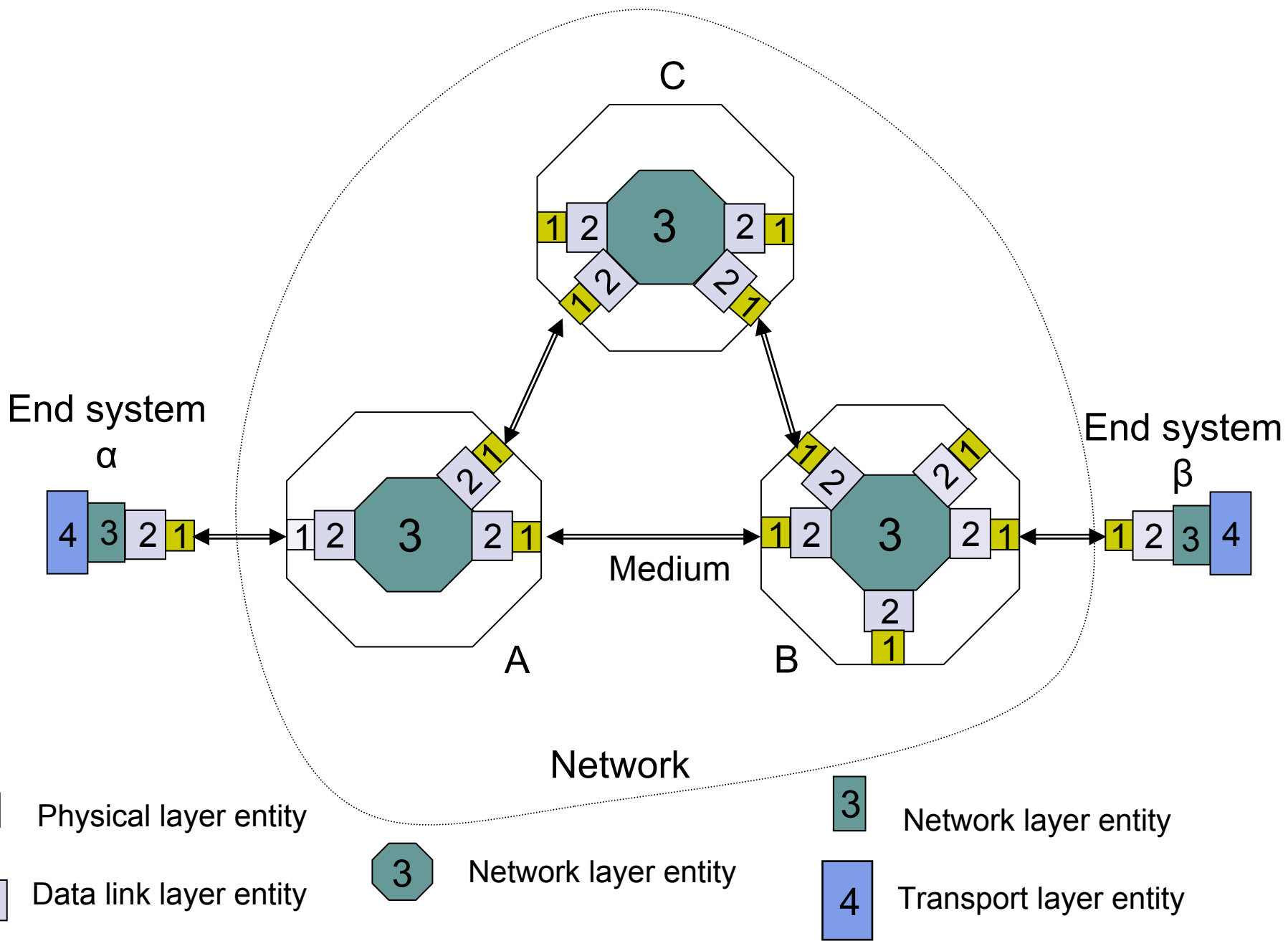


1 block

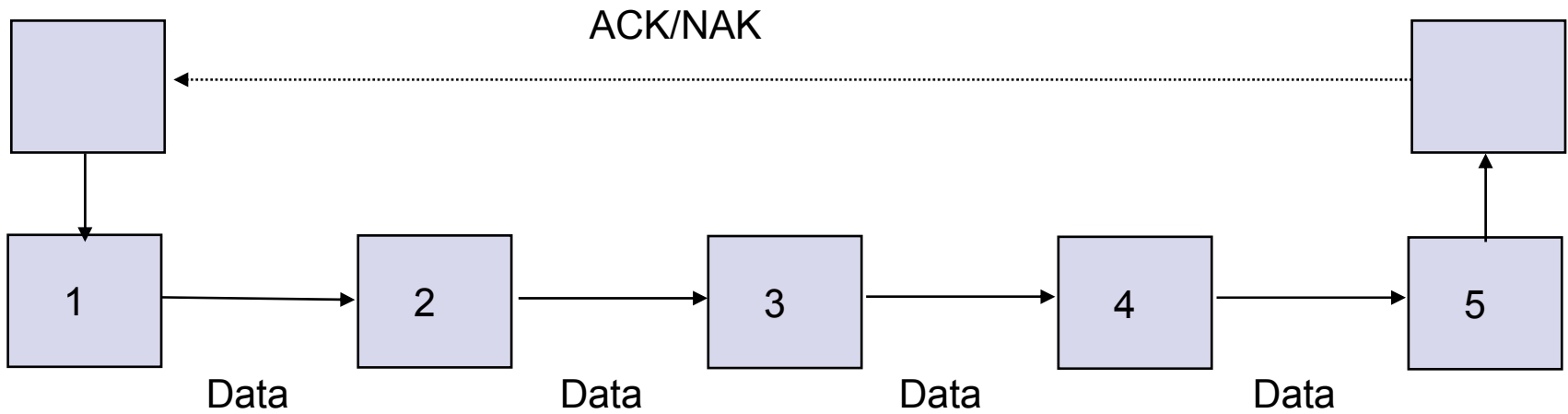


- 1 Physical layer entity
- 2 Data link layer entity
- 3 Network layer entity

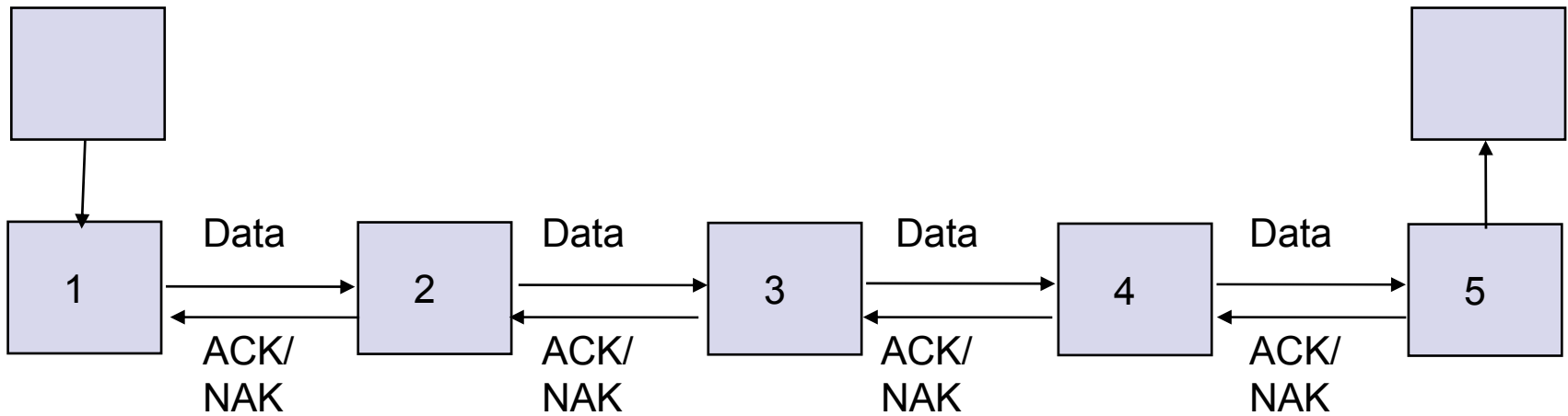


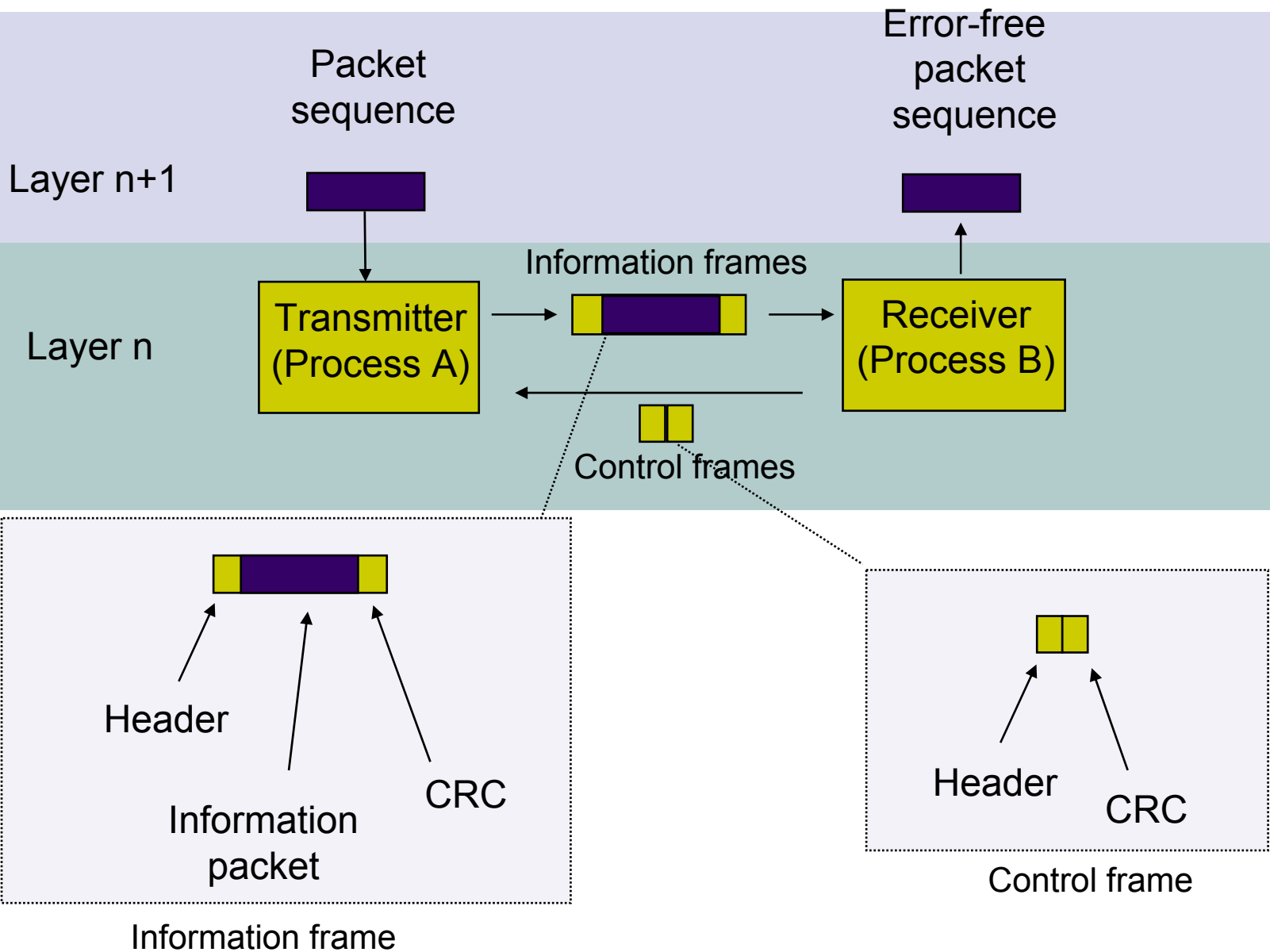


End-to-end

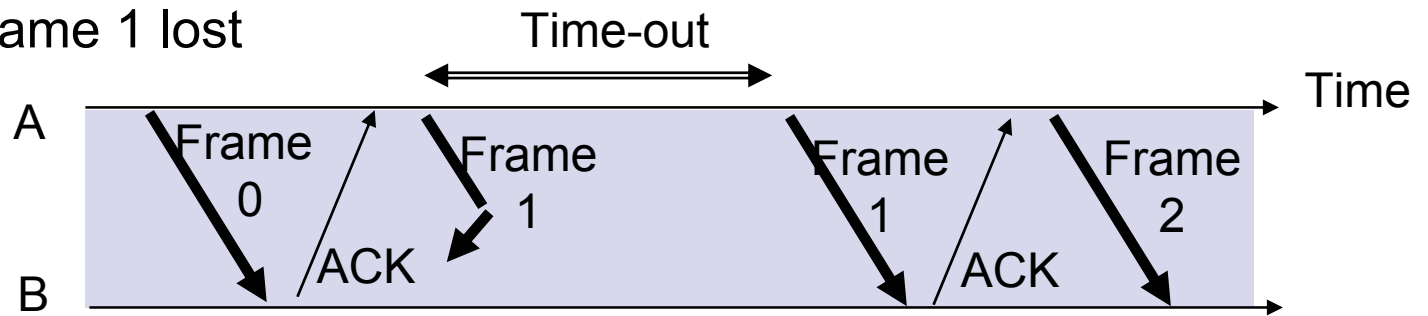


Hop-by-hop

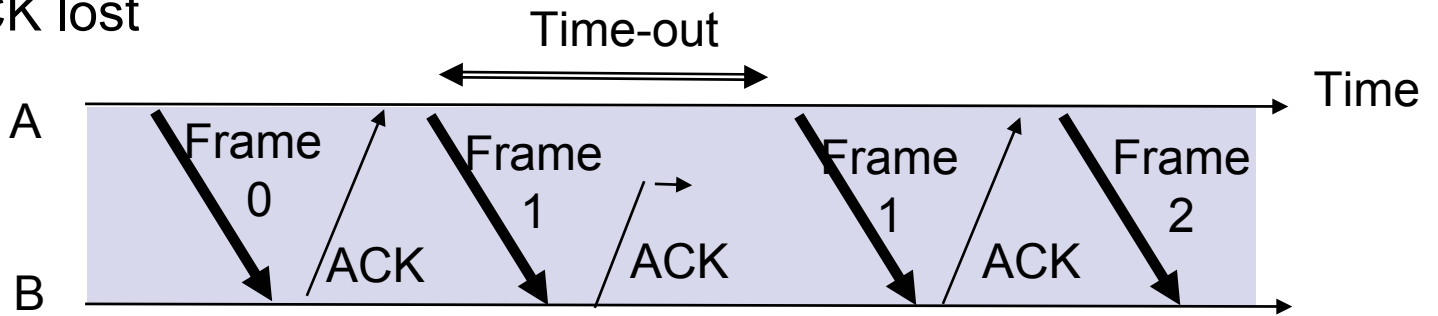


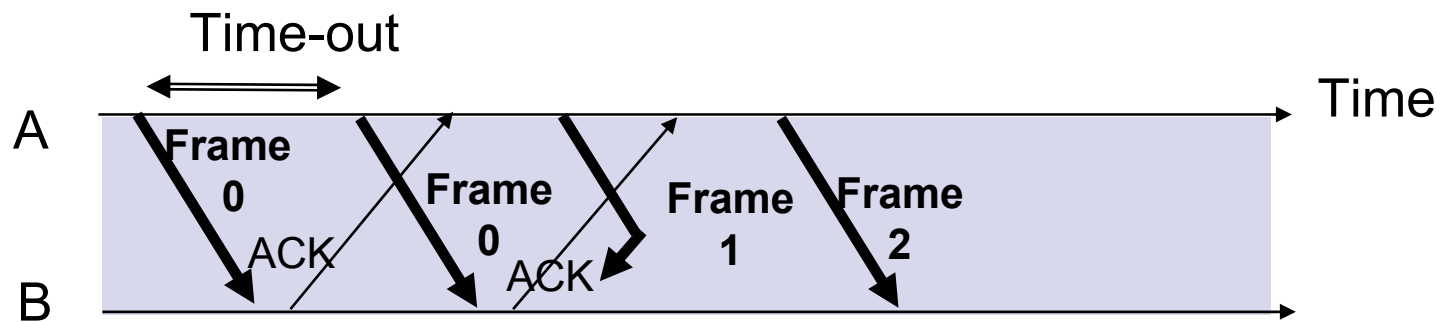


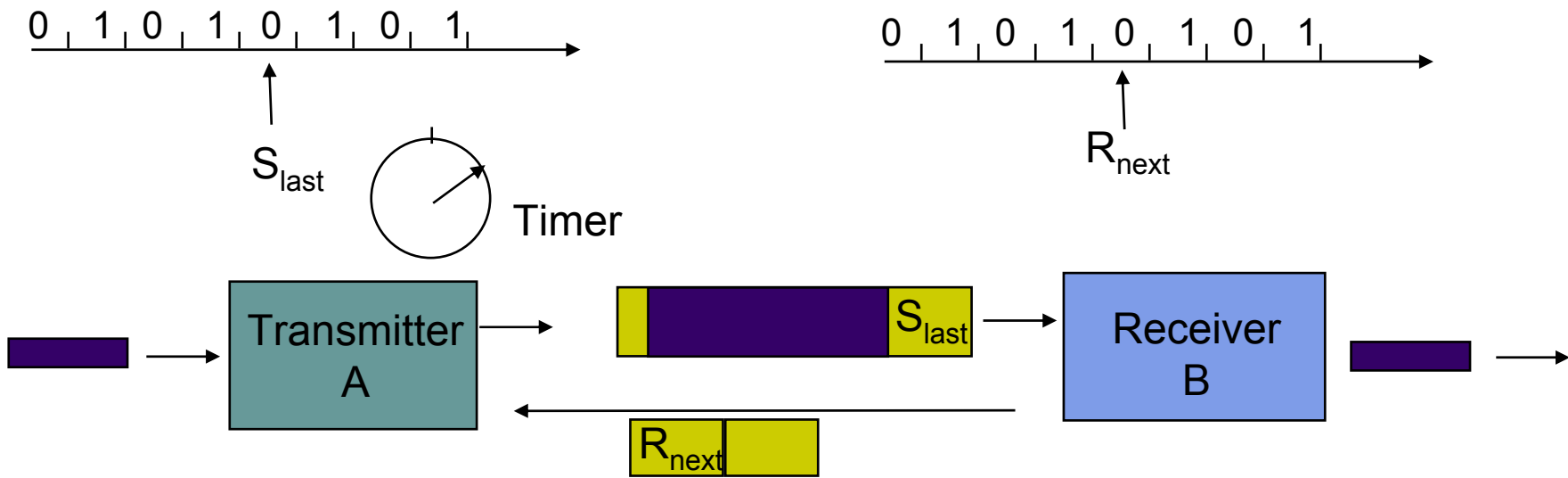
(a) Frame 1 lost



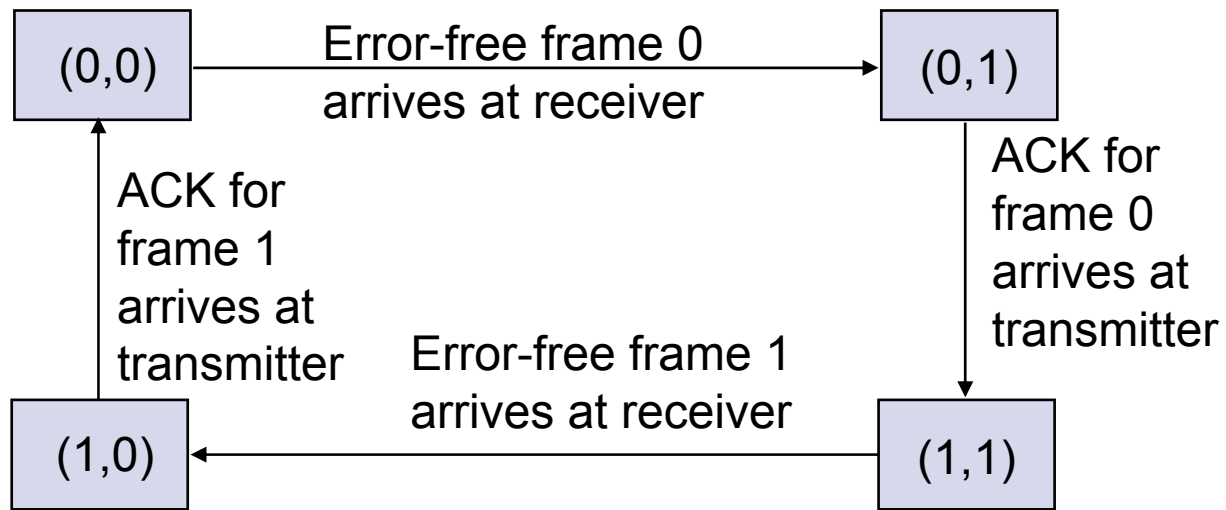
(b) ACK lost

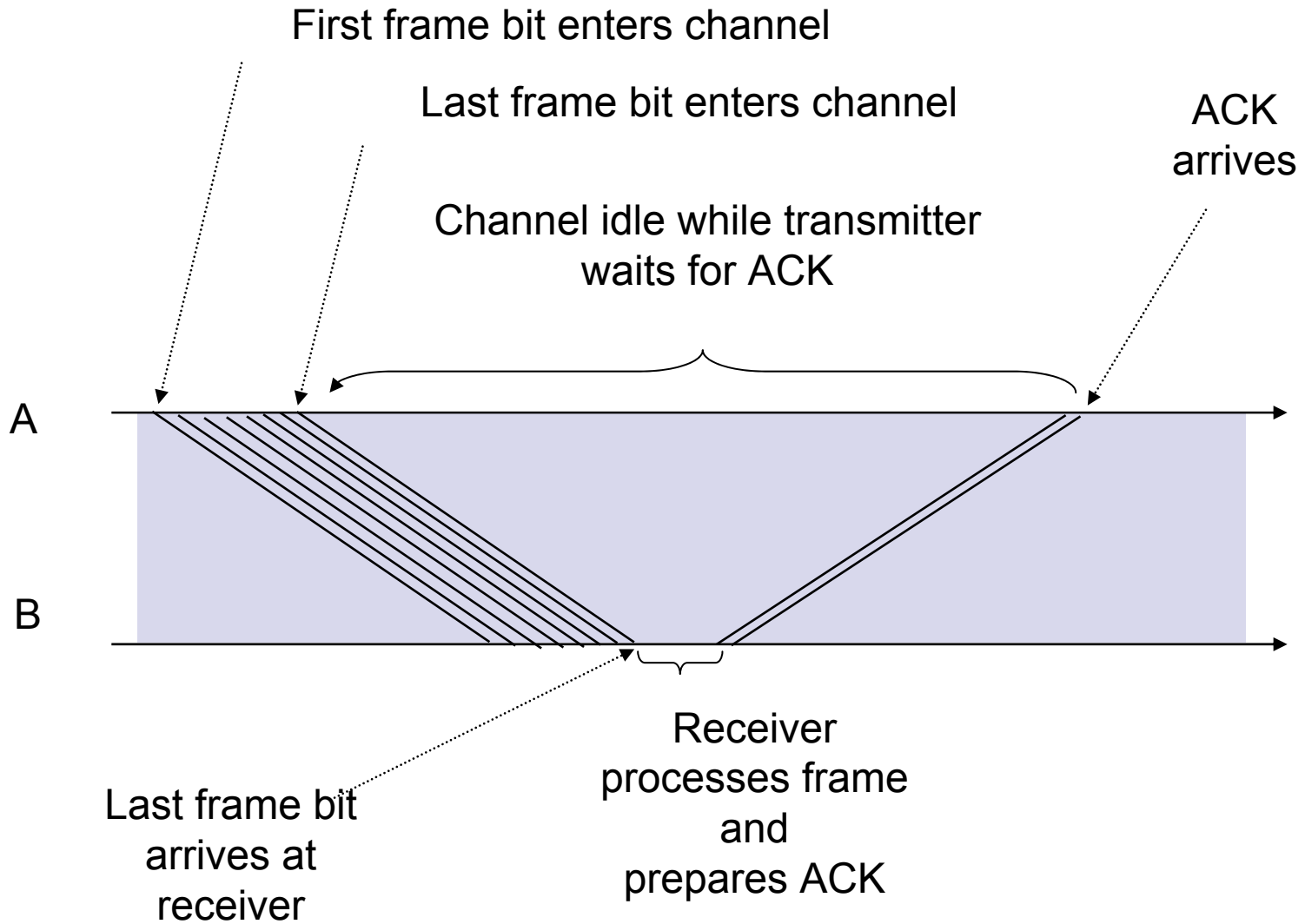


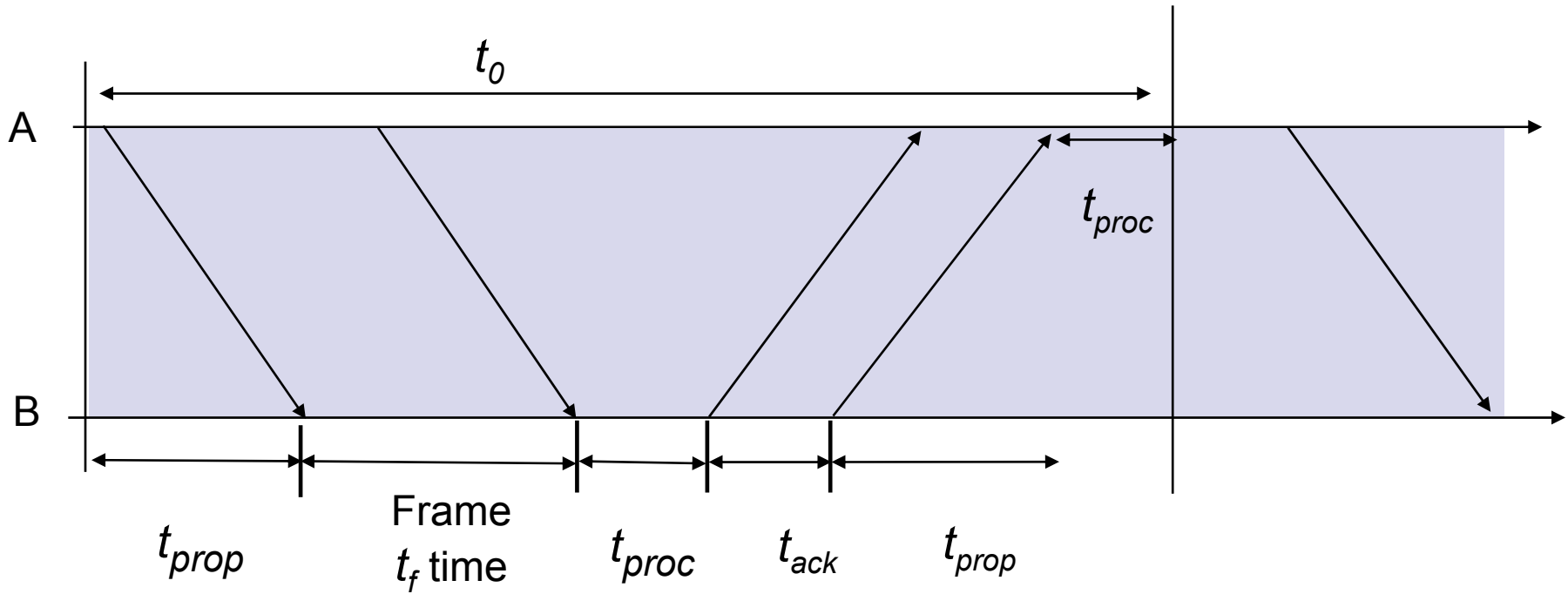




Global State:
 (S_{last}, R_{next})

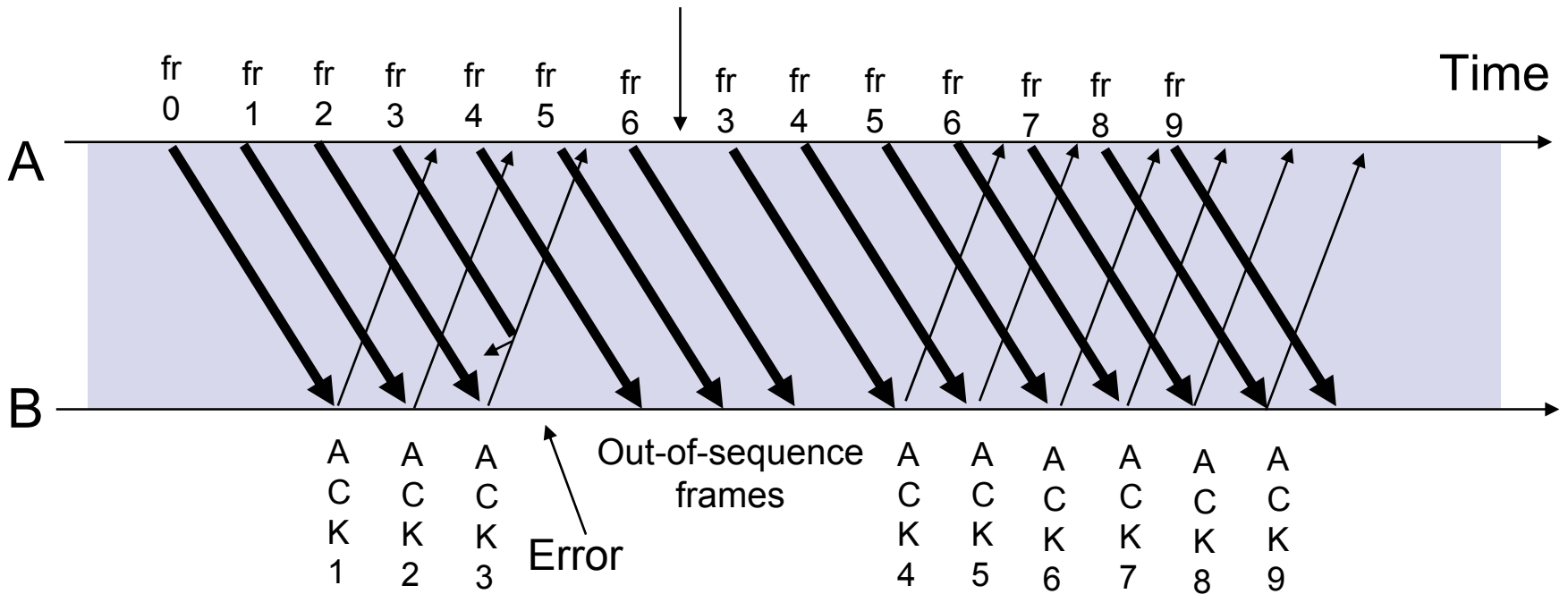


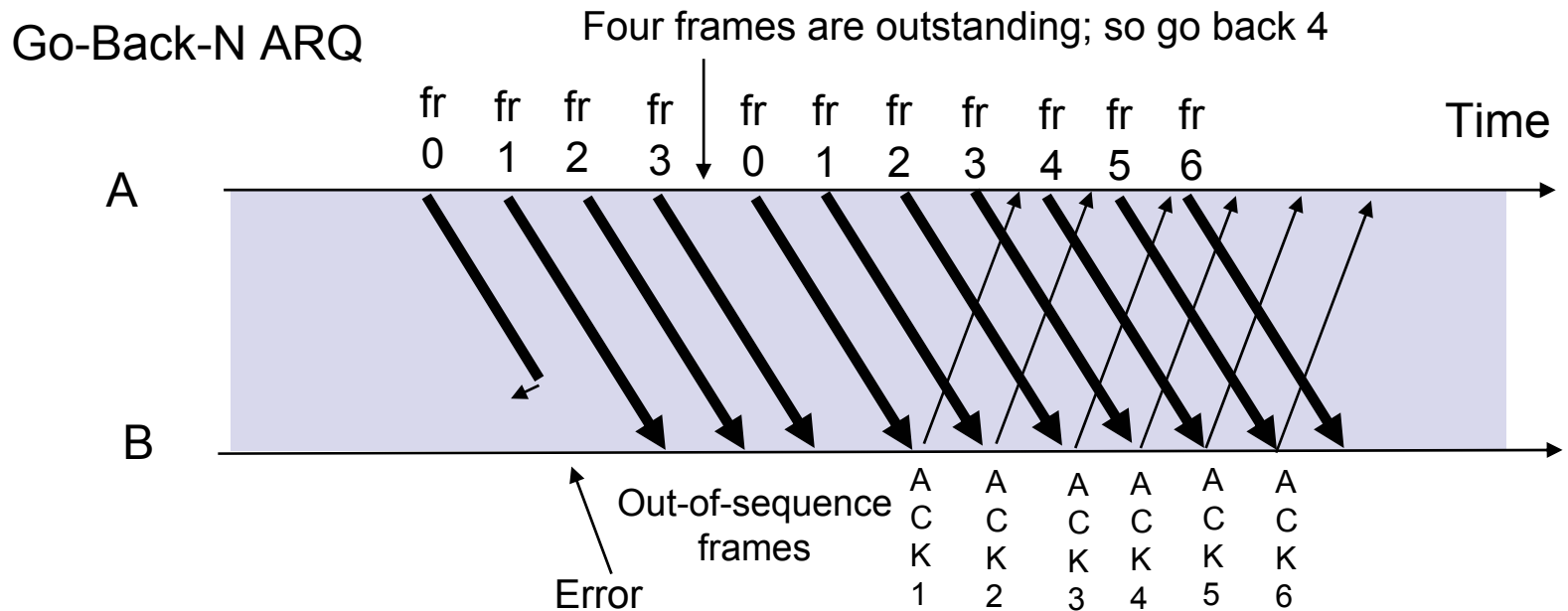
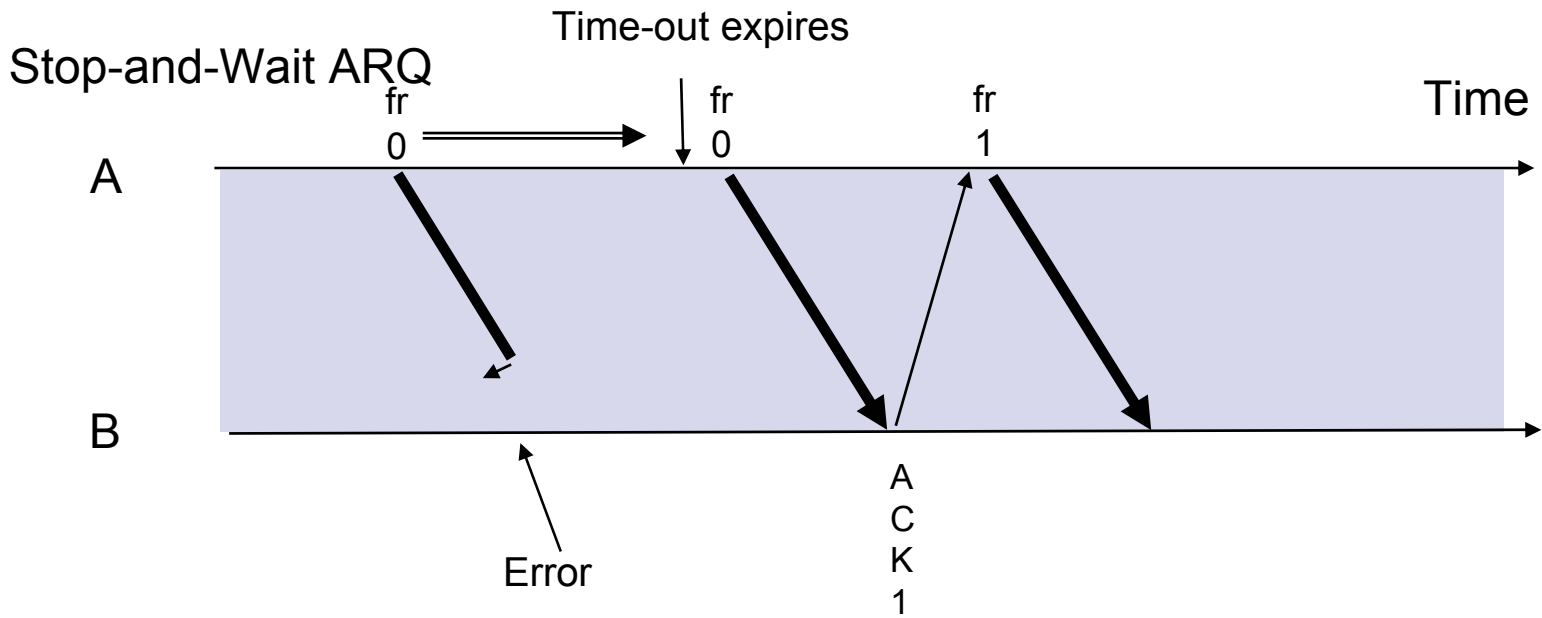


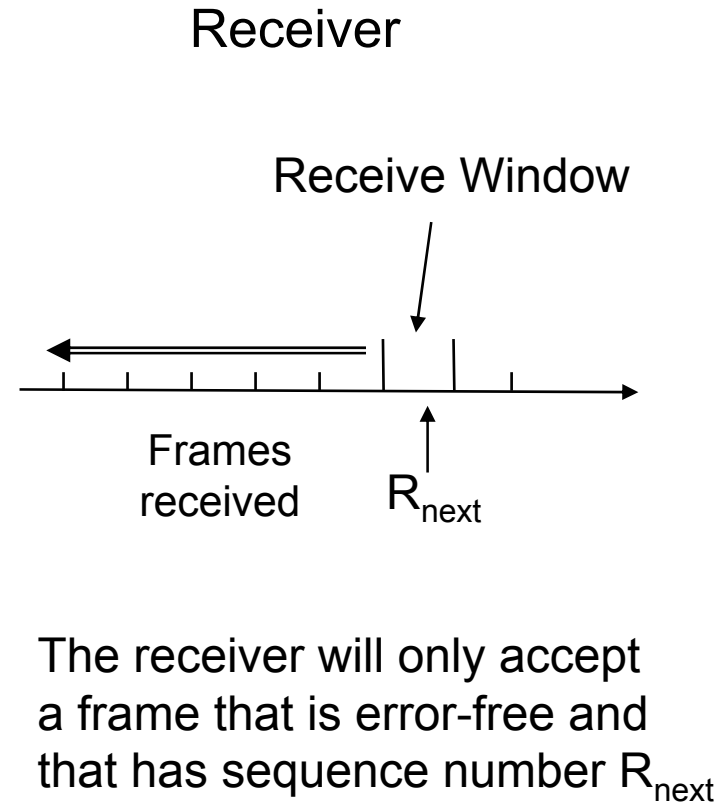
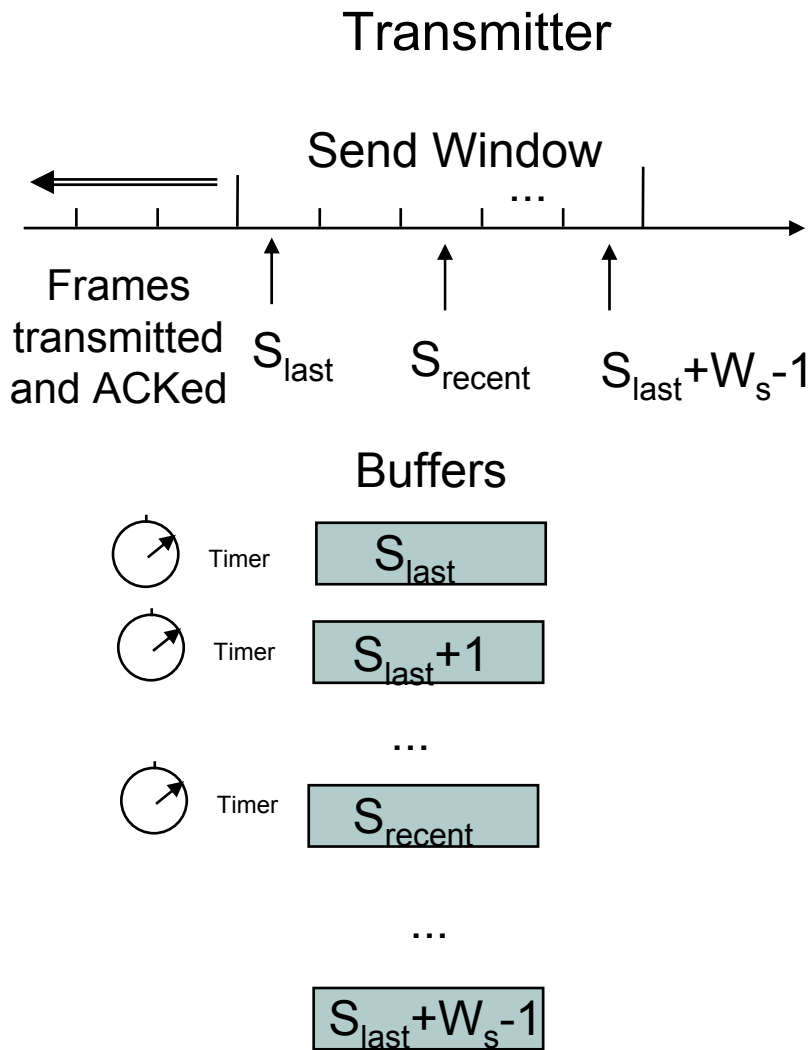


Go-Back-4:

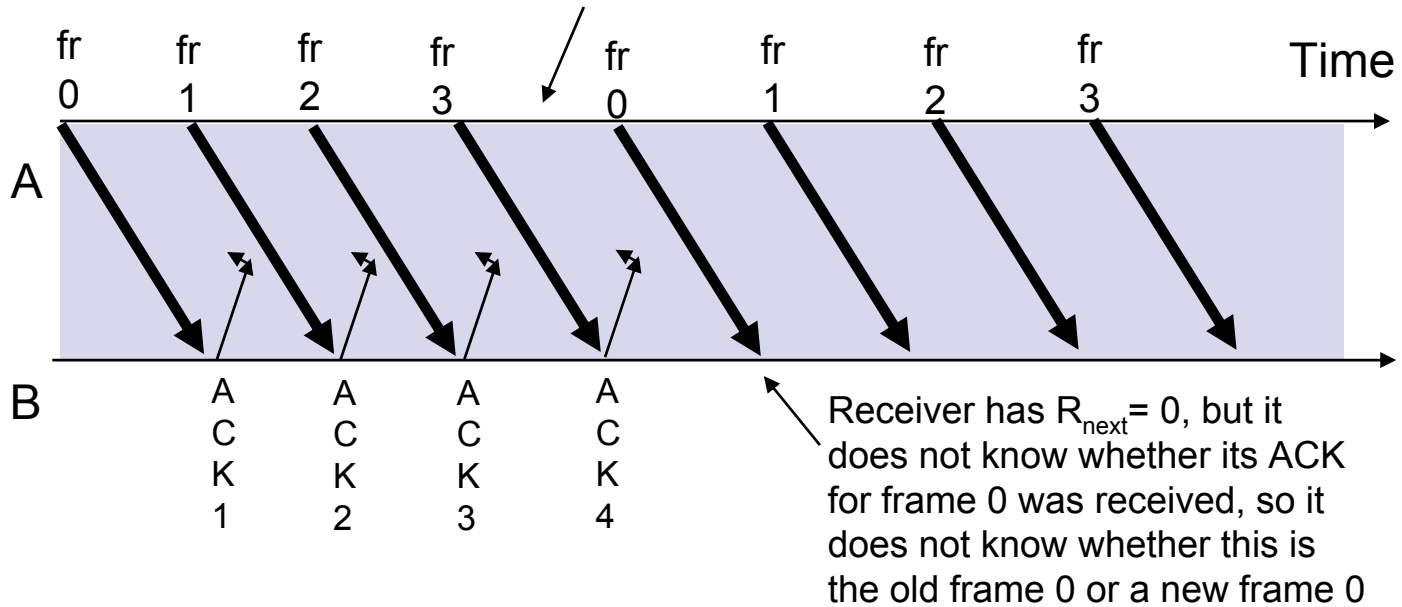
Four frames are outstanding; so go back 4



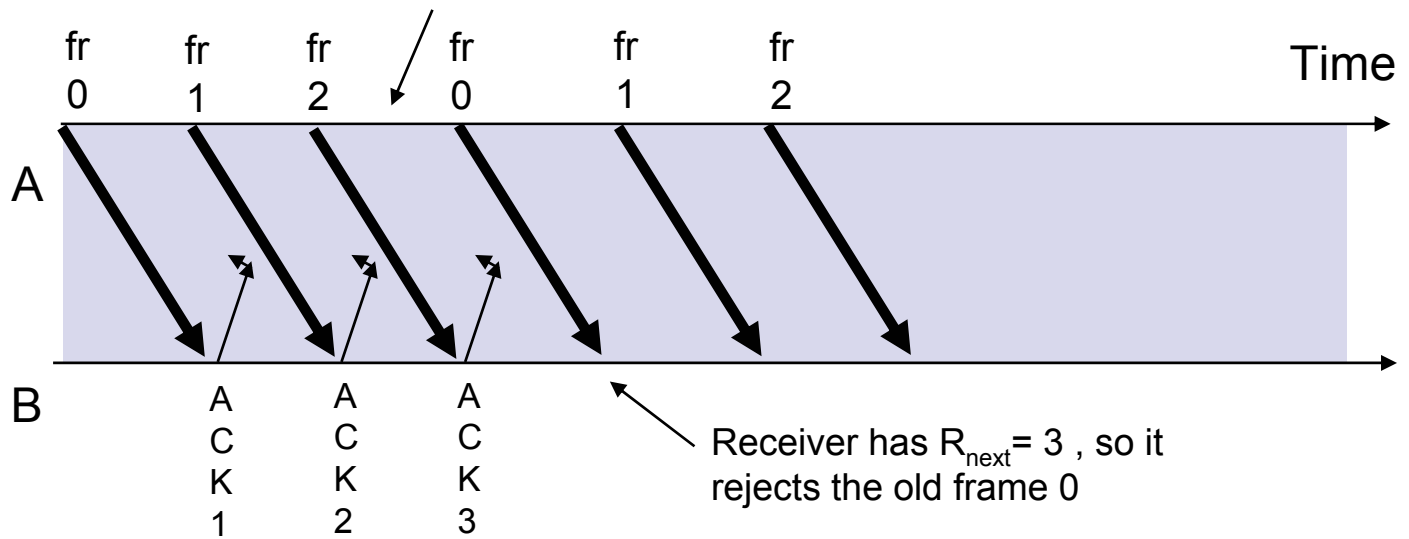


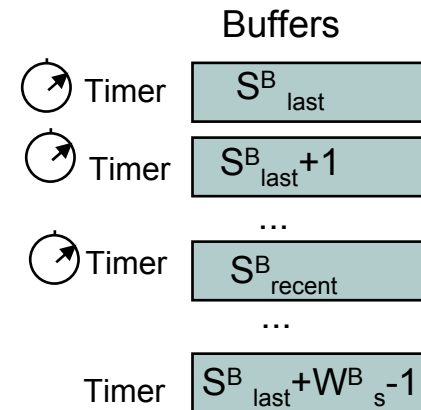
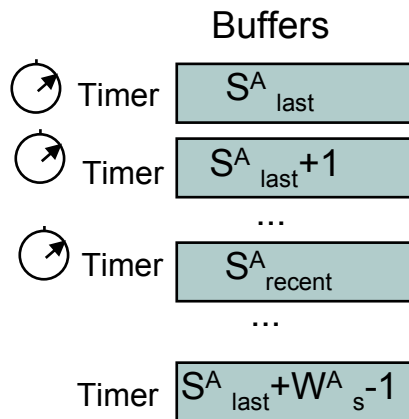
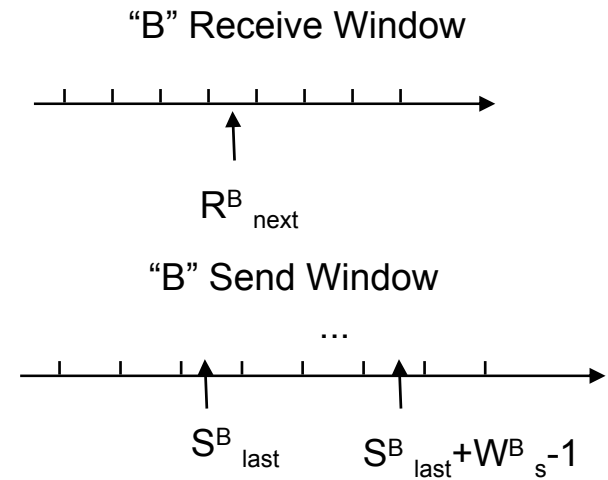
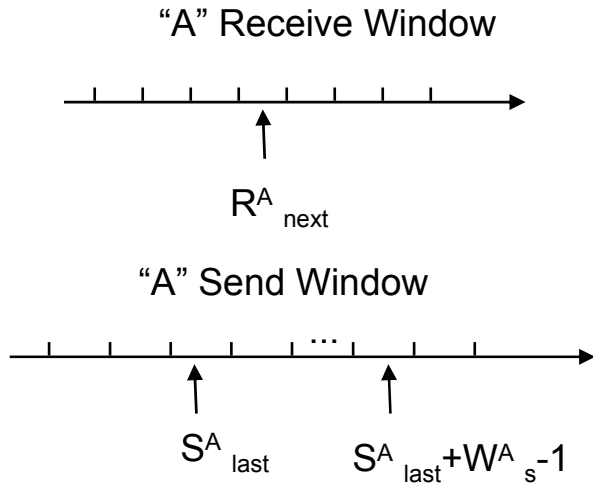
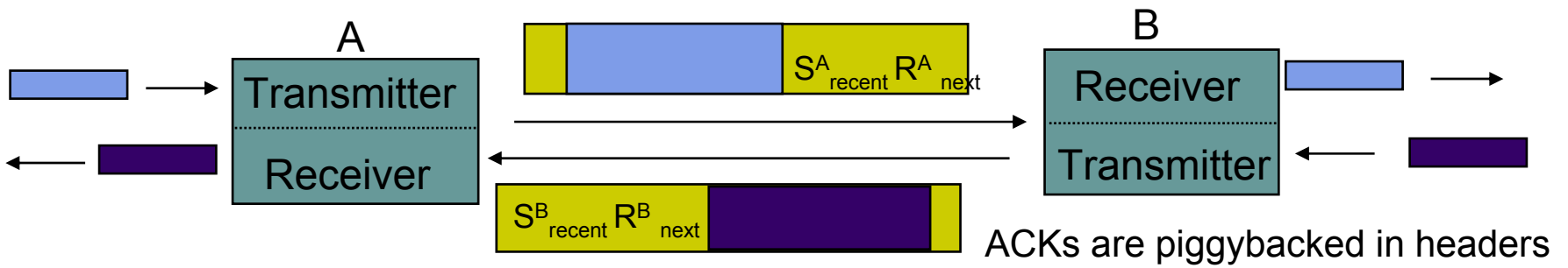


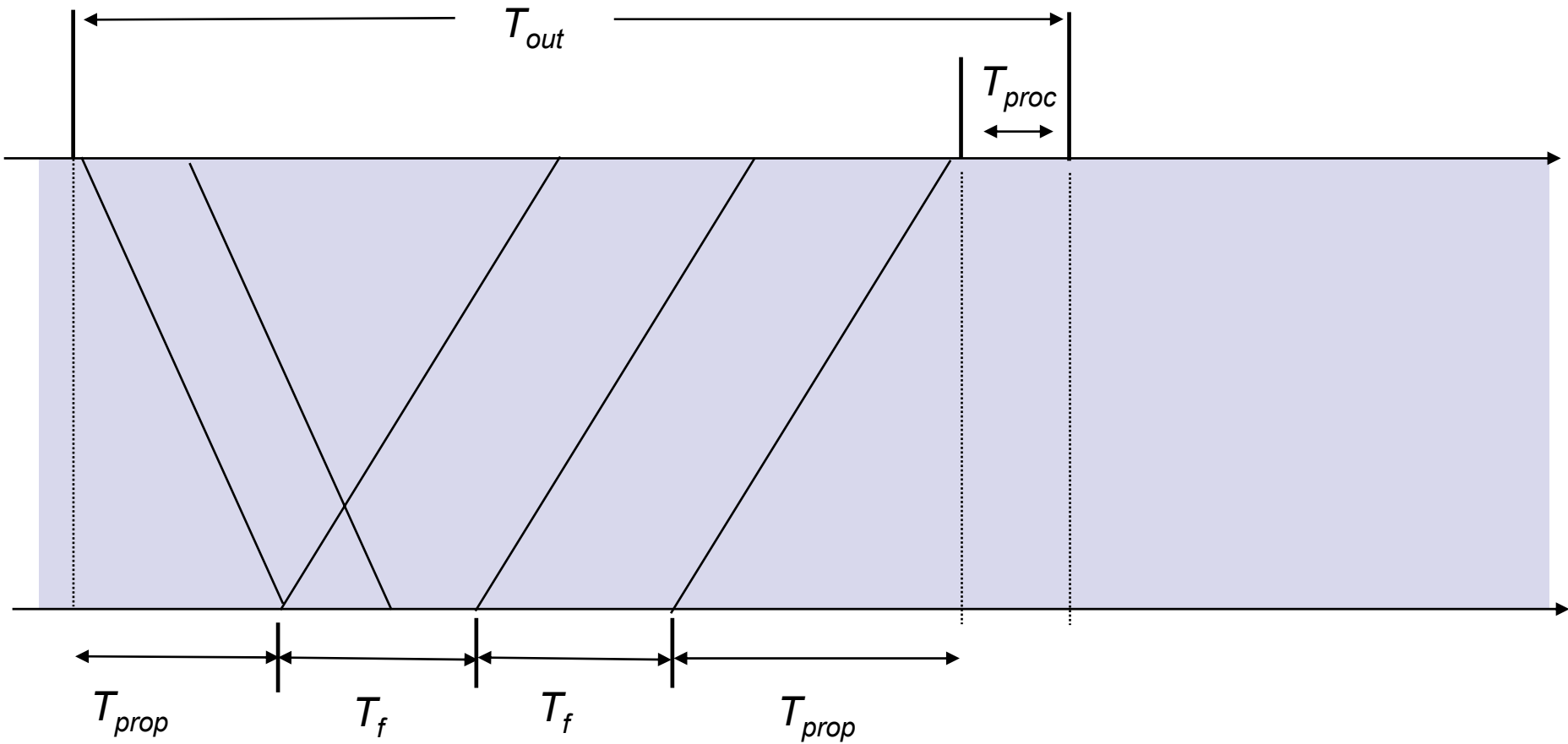
$M = 2^2 = 4$, Go-Back - 4: Transmitter goes back 4



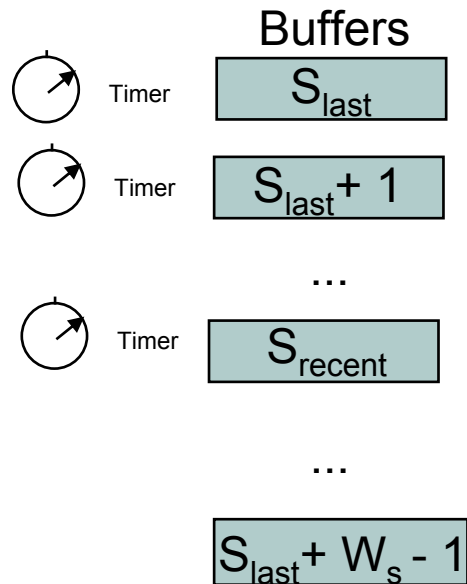
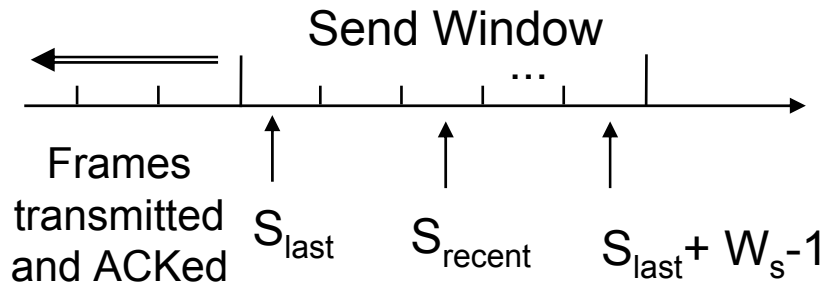
$M = 2^2 = 4$, Go-Back-3: Transmitter goes back 3



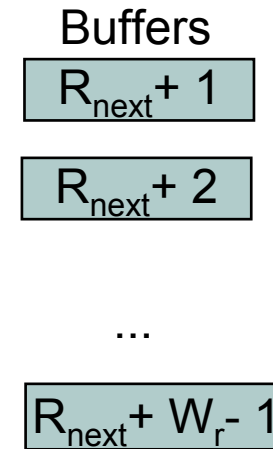
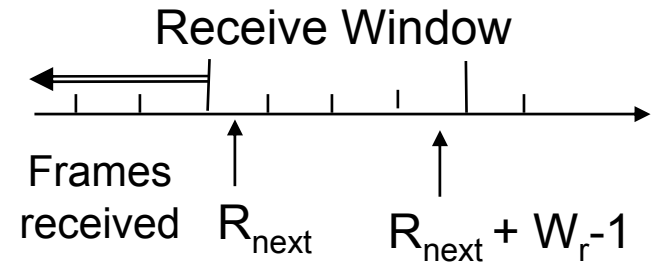


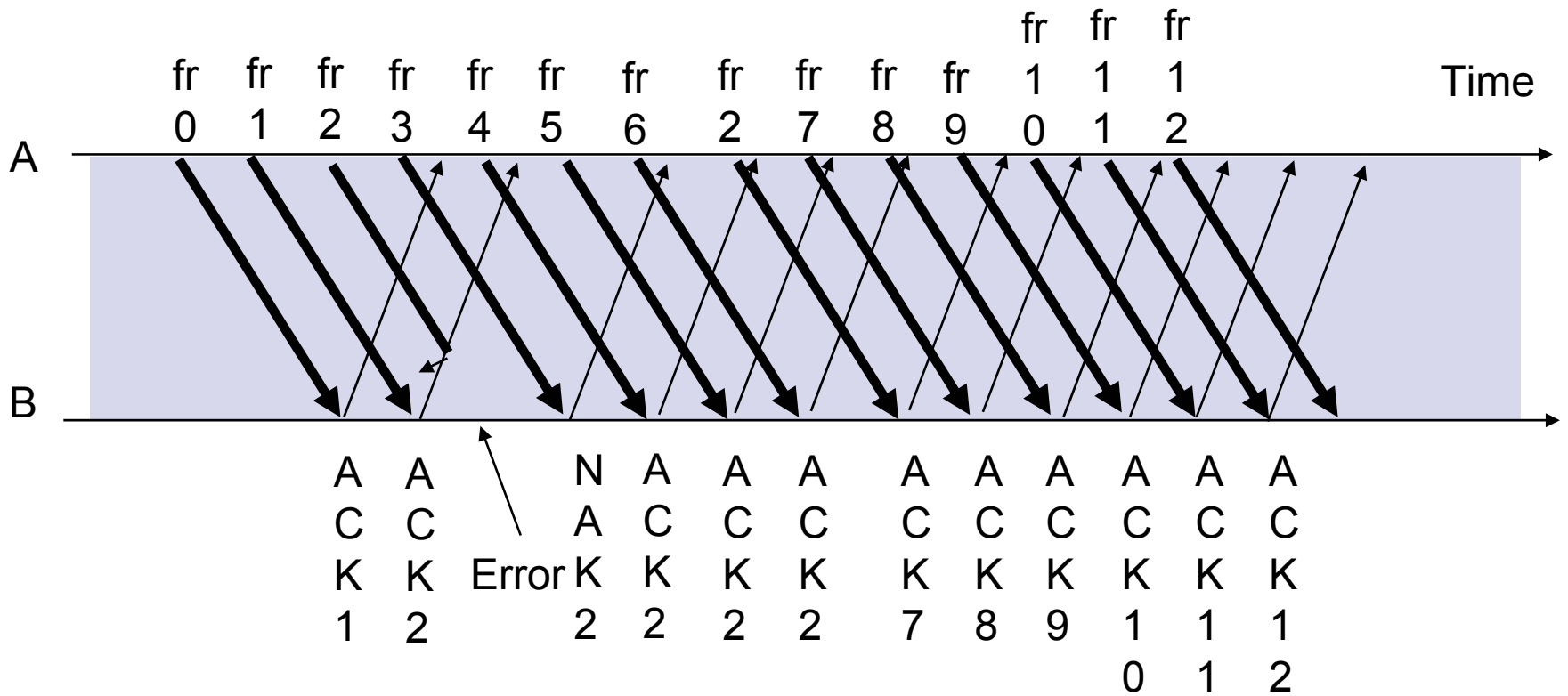


Transmitter

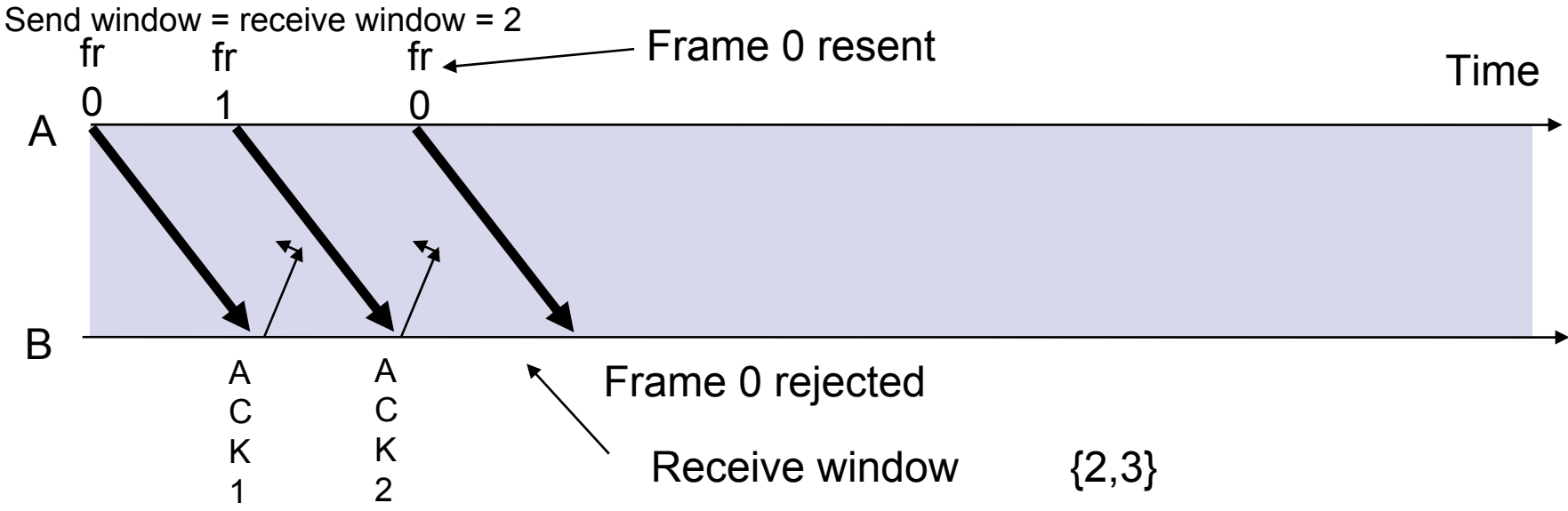
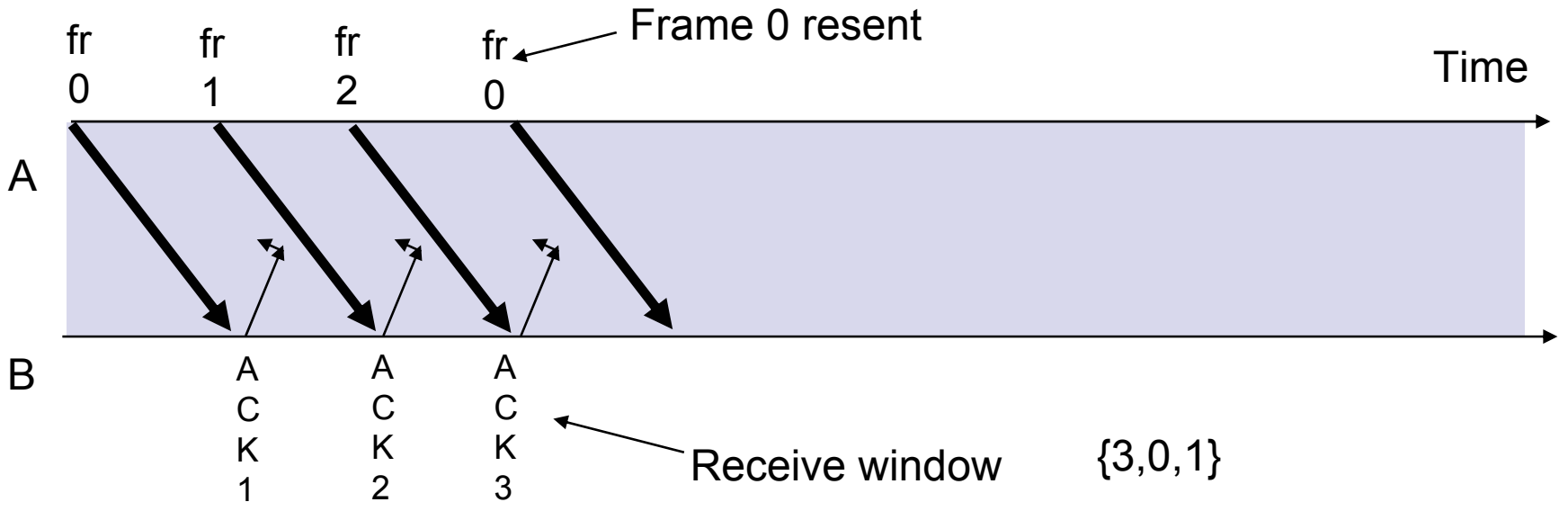


Receiver

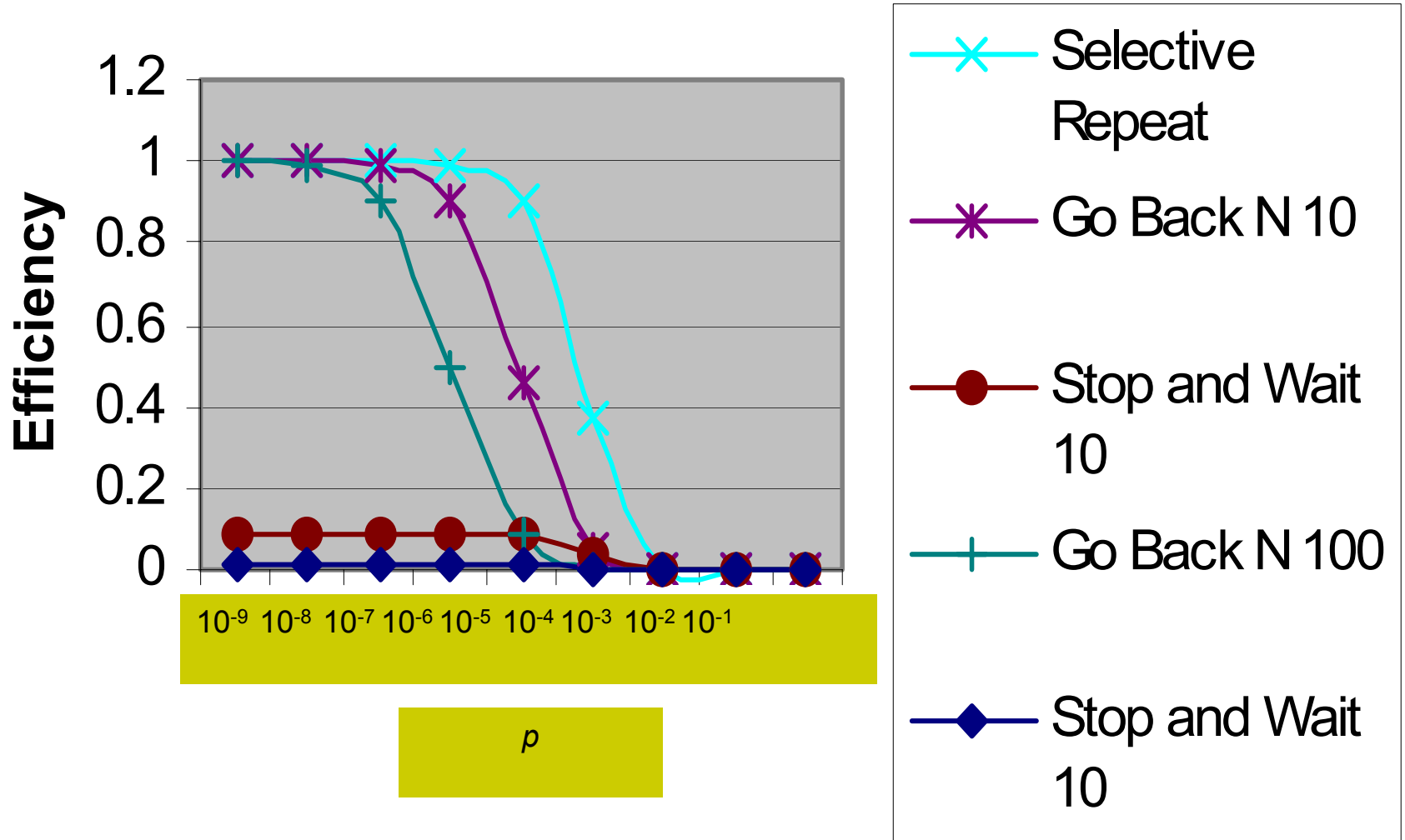


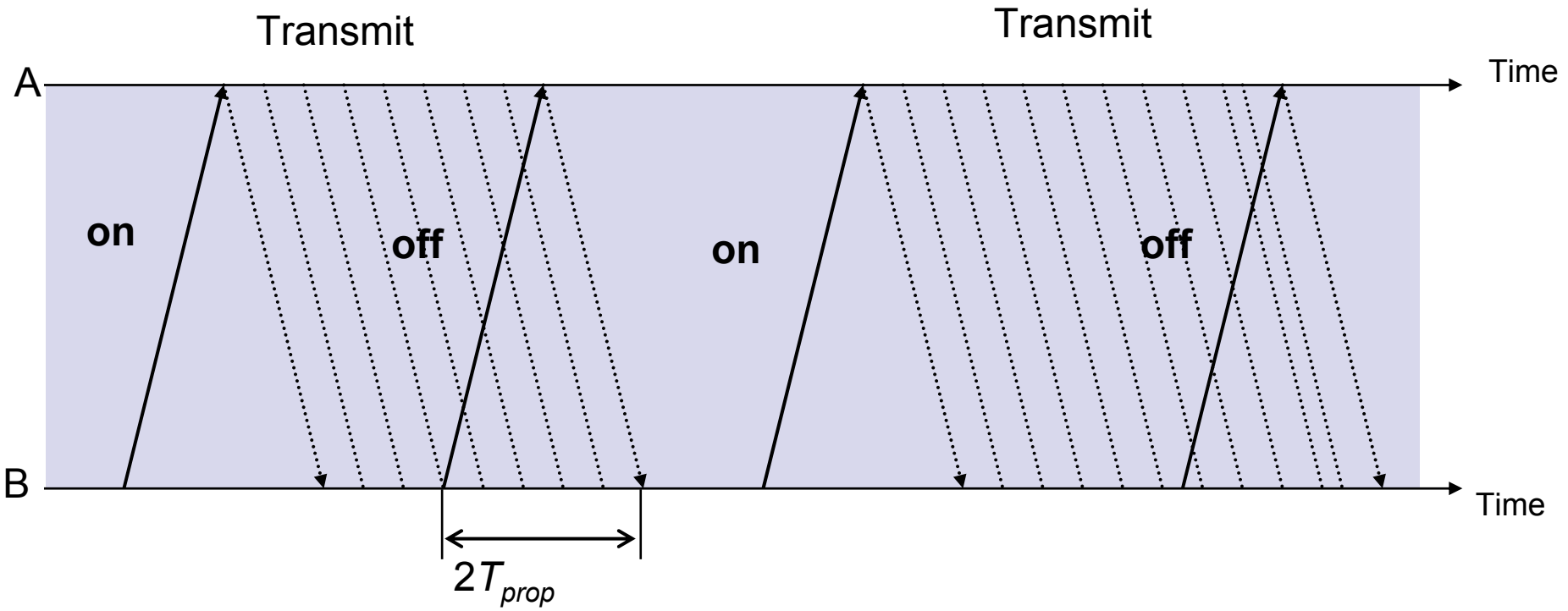


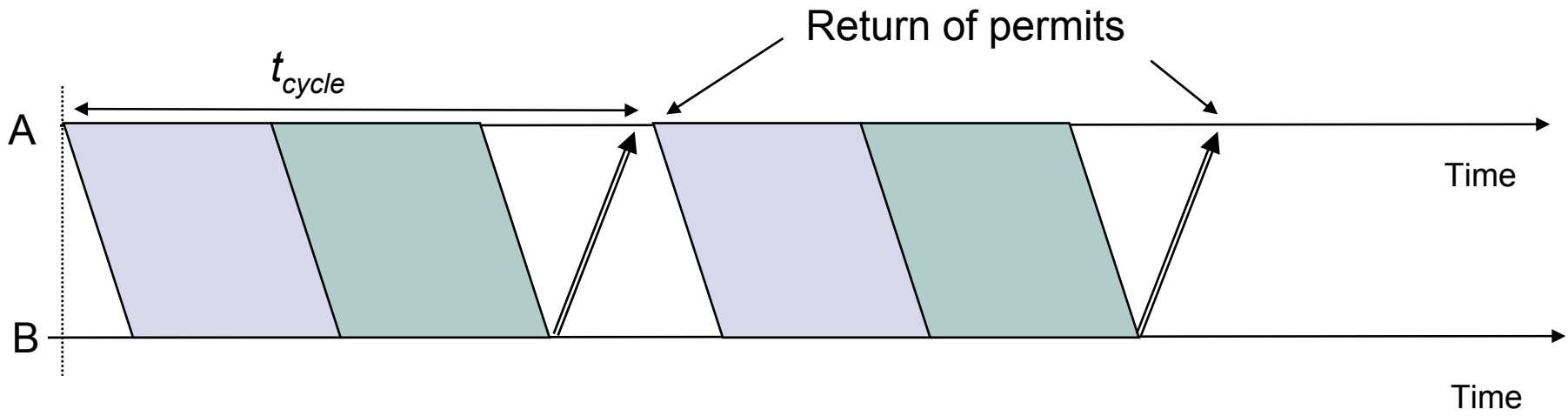
$M = 2^2 = 4$, Selective Repeat: Send window = Receive window = 3



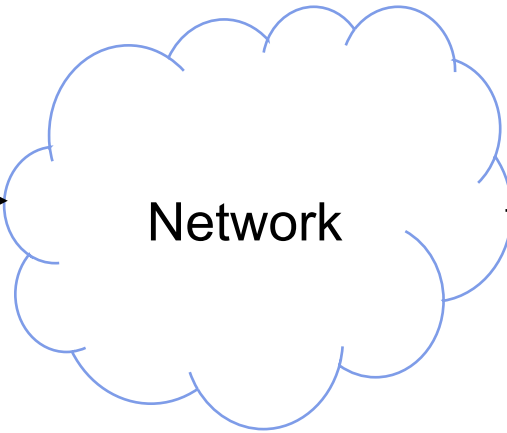
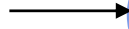
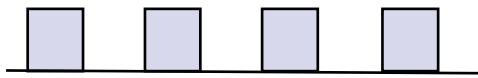
ARQ Efficiency Comparison





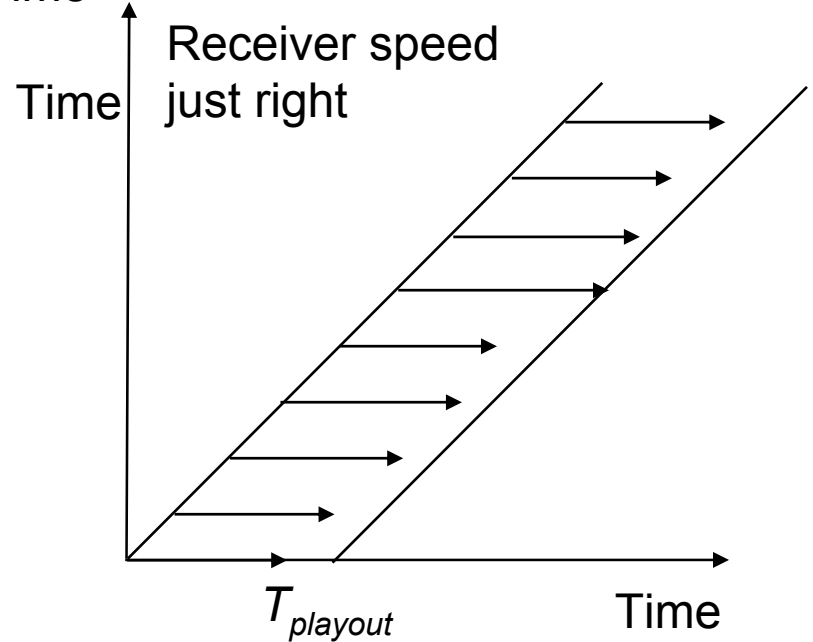
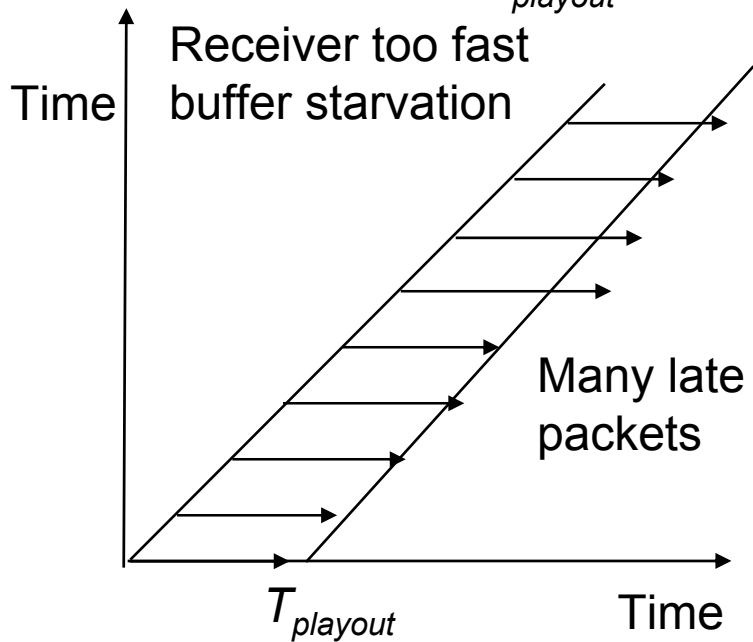
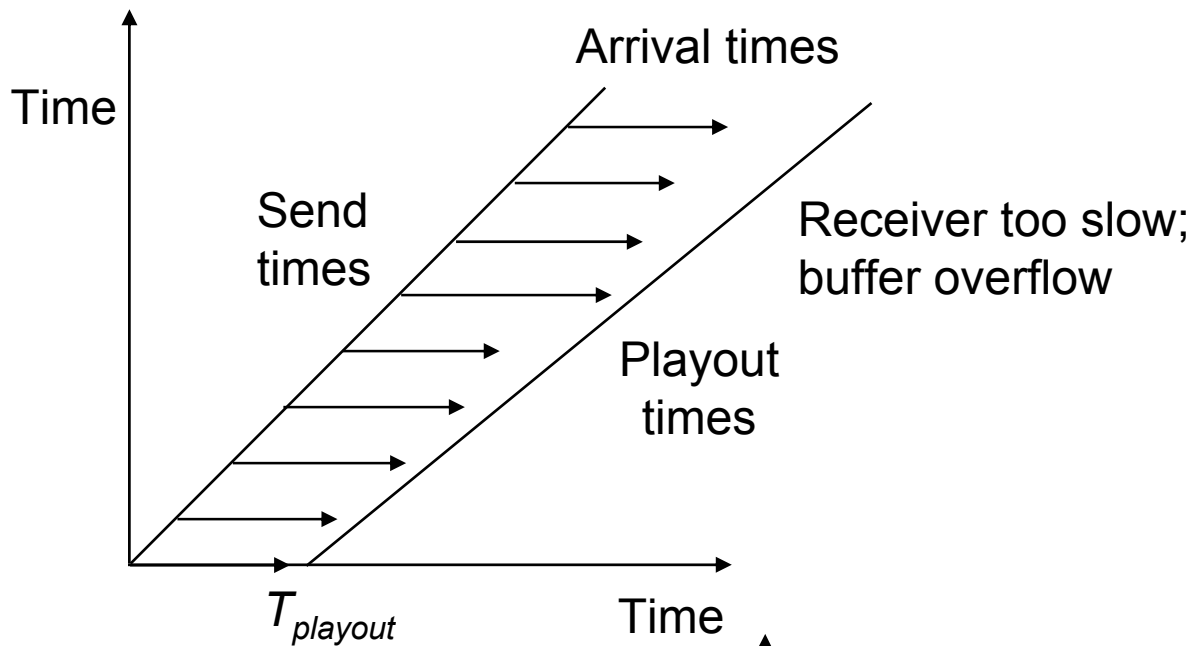


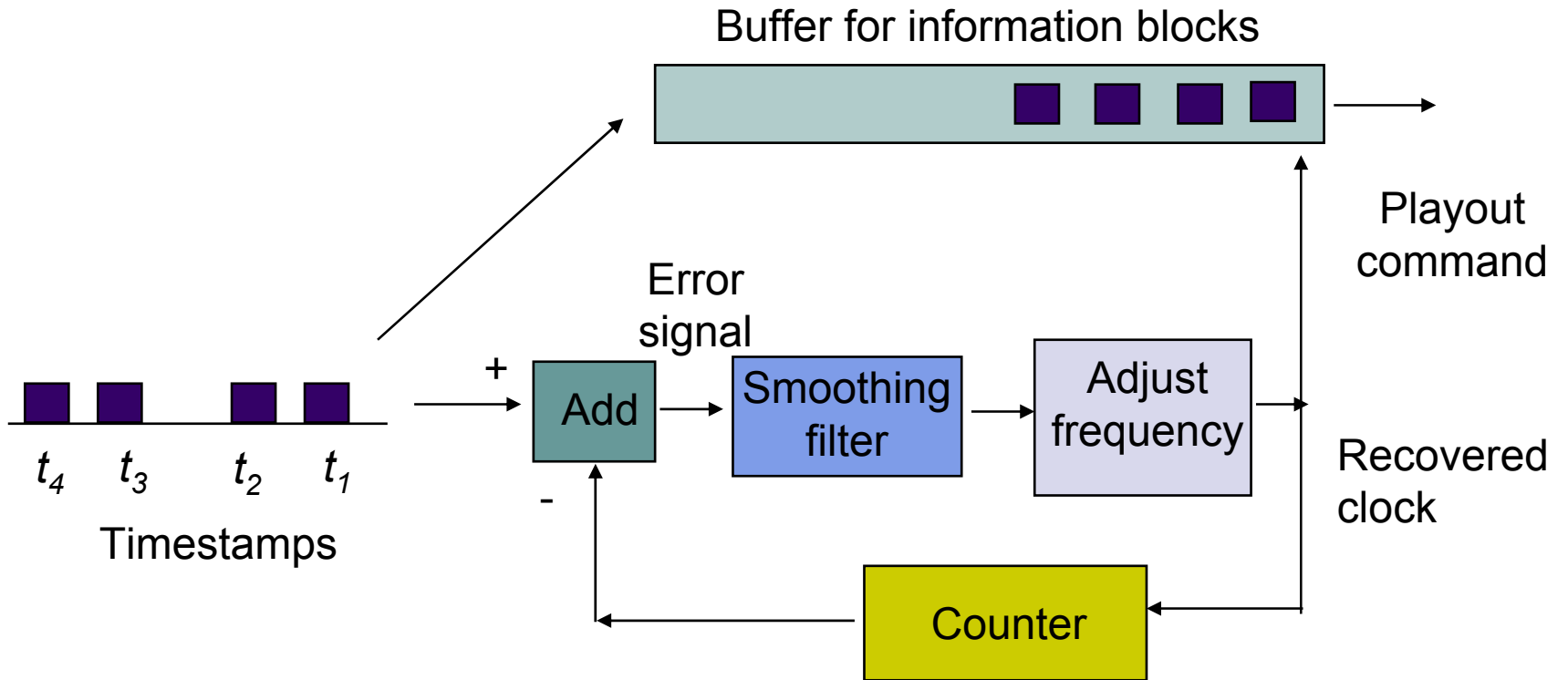
Synchronous source
sends periodic
information blocks

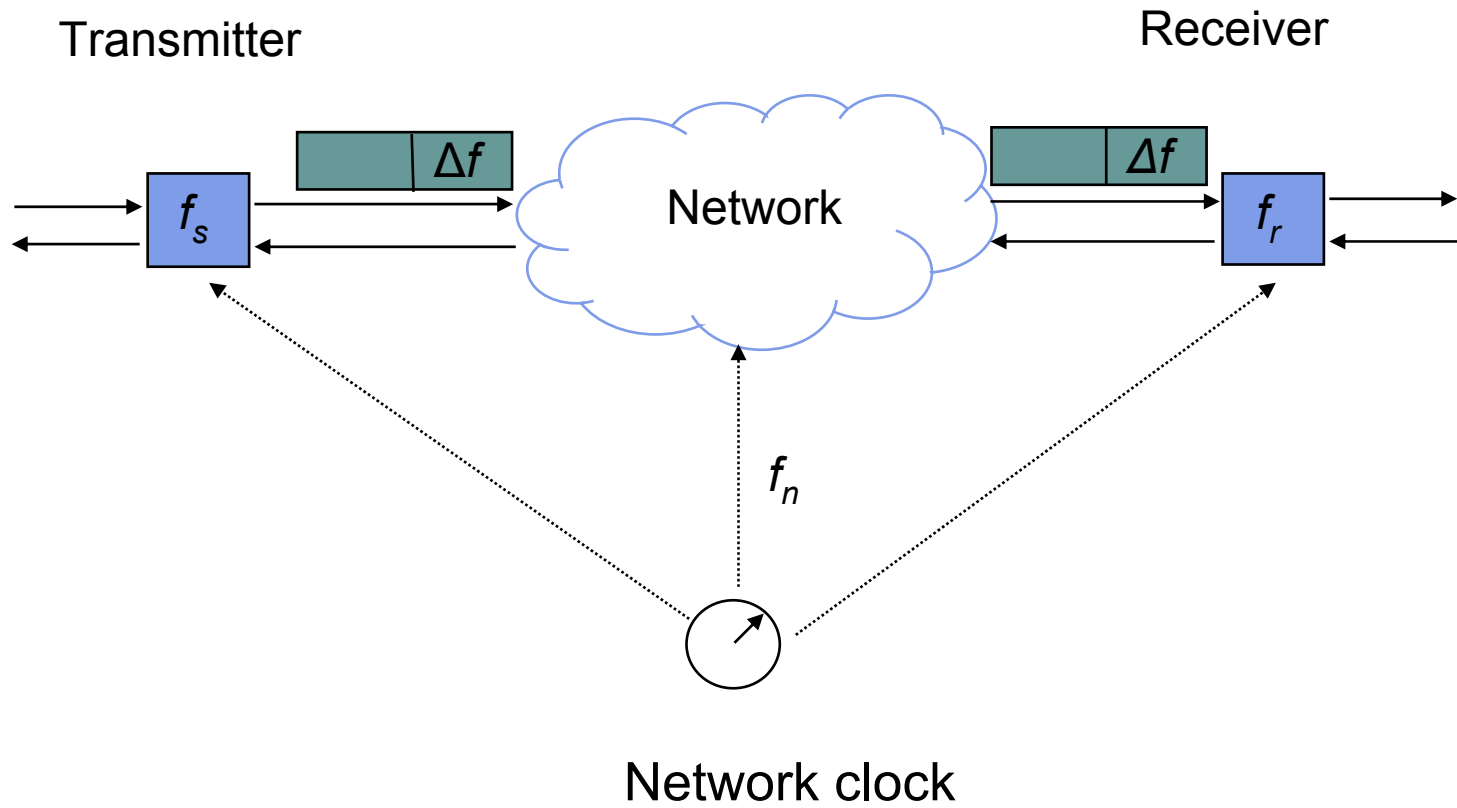


Network output
not periodic









Application

Byte stream



Transmitter



Send buffer

Segments



ACKs

Application

Byte stream



Receiver



Receive buffer



TCP Telnet Capture - Ethereal

File Edit Capture Display Tools Help

No.	Time	Source	Destination	Protocol	Info
1	0.000000	65.95.113.77	128.113.26.22	TCP	2743 > 23 [SYN] Seq=1839733355 Ack=0 win=31988 Len=0
2	0.144934	128.113.26.22	65.95.113.77	TCP	23 > 2743 [SYN, ACK] Seq=1877388864 Ack=1839733356 win=49152 Len=0
3	0.145270	65.95.113.77	128.113.26.22	TCP	2743 > 23 [ACK] Seq=1839733356 Ack=1877388865 win=31988 Len=0
4	0.322432	128.113.26.22	65.95.113.77	TCP	23 > 2743 [PSH, ACK] Seq=1877388865 Ack=1839733356 win=49152 Len=12
5	0.323617	65.95.113.77	128.113.26.22	TCP	2743 > 23 [PSH, ACK] Seq=1839733356 Ack=1877388877 win=31976 Len=3
6	21.606250	65.95.113.77	128.113.26.22	TCP	2743 > 23 [FIN, ACK] Seq=1839733427 Ack=1877389120 win=31733 Len=0
7	21.751944	128.113.26.22	65.95.113.77	TCP	23 > 2743 [ACK] Seq=1877389120 Ack=1839733428 win=49152 Len=0
8	21.757136	128.113.26.22	65.95.113.77	TCP	23 > 2743 [FIN, ACK] Seq=1877389120 Ack=1839733428 win=49152 Len=0
9	21.757468	65.95.113.77	128.113.26.22	TCP	2743 > 23 [ACK] Seq=1839733428 Ack=1877389121 win=31733 Len=0

.....

- Frame 1 (70 bytes on wire, 70 bytes captured)
- Ethernet II, Src: 00:80:c6:e9:fe:08, Dst: 00:90:1a:40:1d:17
- PPP-over-Ethernet Session
- Point-to-Point Protocol
- Internet Protocol, Src Addr: 65.95.113.77 (65.95.113.77), Dst Addr: 128.113.26.22 (128.113.26.22)
- Transmission Control Protocol, Src Port: 2743 (2743), Dst Port: 23 (23), Seq: 1839733355, Ack: 0, Len: 0
 - Source port: 2743 (2743)
 - Destination port: 23 (23)
 - Sequence number: 1839733355
 - Header length: 28 bytes
 - Flags: 0x0002 (SYN)
 - window size: 31988
 - checksum: 0x2644 (correct)
 - options: (8 bytes)

.....

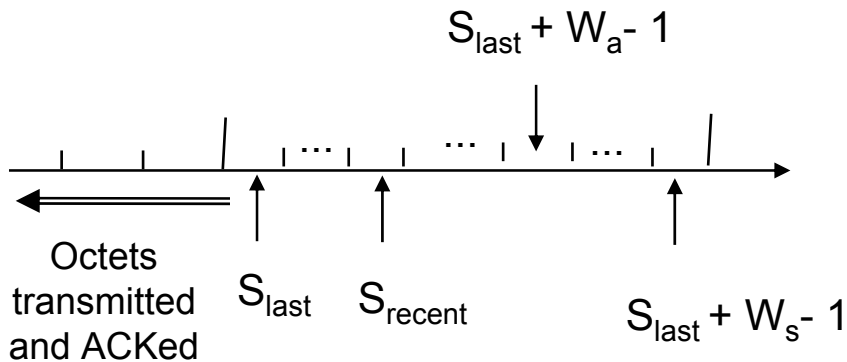
```

0000  00 90 1a 40 1d 17 00 80 c6 e9 fe 08 88 64 11 00  ...@.... .....d..
0010  15 97 00 32 00 21 45 00 00 30 4e 2f 40 00 80 06  ...2.!E. .0N/@...
0020  5f 65 41 5f 71 4d 80 71 1a 16 0a b7 00 17 6d a8  _eA_qM.q .....m.
0030  1a 6b 00 00 00 00 70 02 7c f4 26 44 00 00 02 04  .k....p. |.&D....
0040  05 86 01 01 04 02  .....
  
```

Filter: / Reset Apply File: TCP Telnet Capture

Transmitter

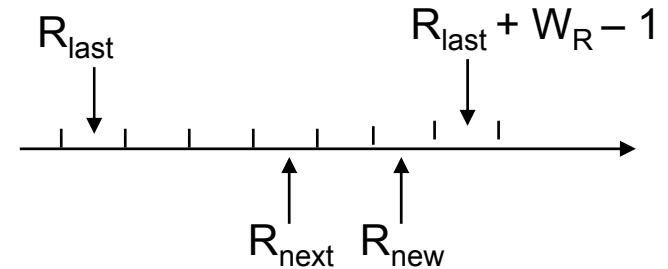
Send Window



- S_{last} = oldest unacknowledged octet
- S_{recent} = highest-numbered transmitted octet
- $S_{last} + W_a - 1$ = highest-numbered octet that can be transmitted
- $S_{last} + W_s - 1$ = highest-numbered octet that can be accepted from the application

Receiver

Receive Window



- R_{last} = highest-numbered octet not yet read by the application
- R_{next} = next expected octet
- R_{new} = highest numbered octet received correctly
- $R_{last} + W_R - 1$ = highest-numbered octet that can be accommodated in receive buffer

Data to be sent



After stuffing and framing





(a)

Data to be sent

011011111111100

After stuffing and framing

011111100110111110111111000001111110

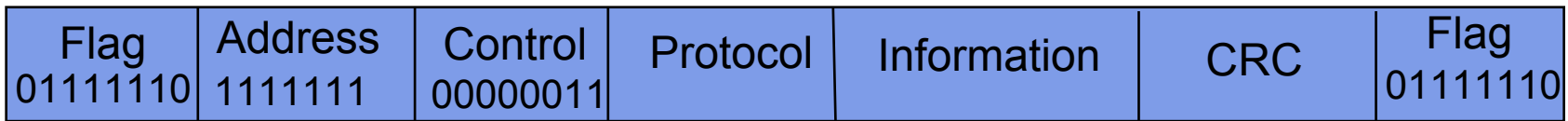
(b)

Data received

01111110000111011111011111011001111110

After destuffing and deframing

000111011111-11111-110



All stations are to accept the frame

Unnumbered frame

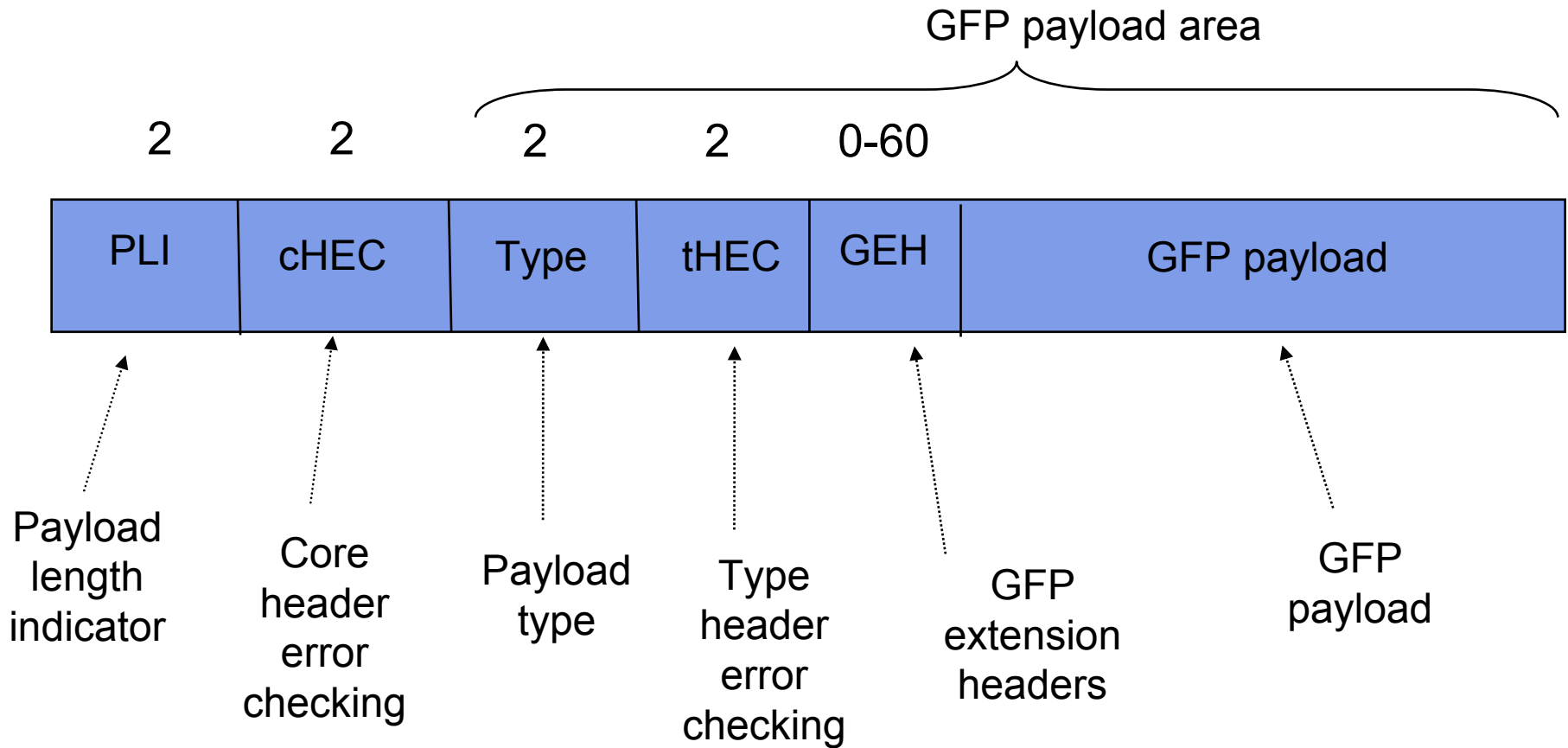
Specifies what kind of packet is contained in the payload, e.g., LCP, NCP, IP, OSI CLNP, IPX

Data to be sent

41	7D	42	7E	50	70	46
----	----	----	----	----	----	----

After stuffing and framing

7E	41	7D	5D	42	7D	5E	50	70	46	7E
----	----	----	----	----	----	----	----	----	----	----



PPP.htm - Ethereal

File Edit Capture Display Tools Help

No.	Time	Source	Destination	Protocol	Info
1	0.000000	10.0.0.6	207.38.64.53	HTTP	GET /taisnpd/ HTTP/1.0
2	0.000000	10.0.0.6	207.38.64.53	TCP	1245 > 80 [FIN, ACK] Seq=778940233 Ack
3	0.000000	10.0.0.6	207.38.64.53	TCP	1249 > 80 [SYN] Seq=1032757018 Ack=0 w
4	0.000000	207.193.25.12	207.38.64.53	HTTP	GET /taisnpd/ HTTP/1.0
5	0.000000	207.193.25.12	207.38.64.53	TCP	1245 > 80 [FIN, ACK] Seq=778940233 Ack
6	0.010000	207.193.25.12	207.38.64.53	TCP	1249 > 80 [SYN] Seq=1032757018 Ack=0 w
7	0.110000	207.38.64.53	207.193.25.12	TCP	80 > 1245 [RST] Seq=4013566122 Ack=0 w
8	0.110000	207.38.64.53	10.0.0.6	TCP	80 > 1245 [RST] Seq=4013566122 Ack=0 w
9	0.110000	207.38.64.53	207.193.25.12	TCP	80 > 1245 [RST] Seq=4013566122 Ack=0 w
10	0.110000	207.38.64.53	10.0.0.6	TCP	80 > 1245 [RST] Seq=4013566122 Ack=0 w

Frame 4 (387 bytes on wire, 387 bytes captured)

- Point-to-Point Protocol
 - Address: 0xff
 - Control: 0x03
 - Protocol: Multilink (0x003d)
- PPP Multilink Protocol
- Point-to-Point Protocol
- Internet Protocol, Src Addr: 207.193.25.12 (207.193.25.12), Dst Addr: 207.38.64.53 (207.38.64.53)
- Transmission Control Protocol, Src Port: 1245 (1245), Dst Port: 80 (80), Seq: 778939907, Ack: 4013566122
- Hypertext Transfer Protocol

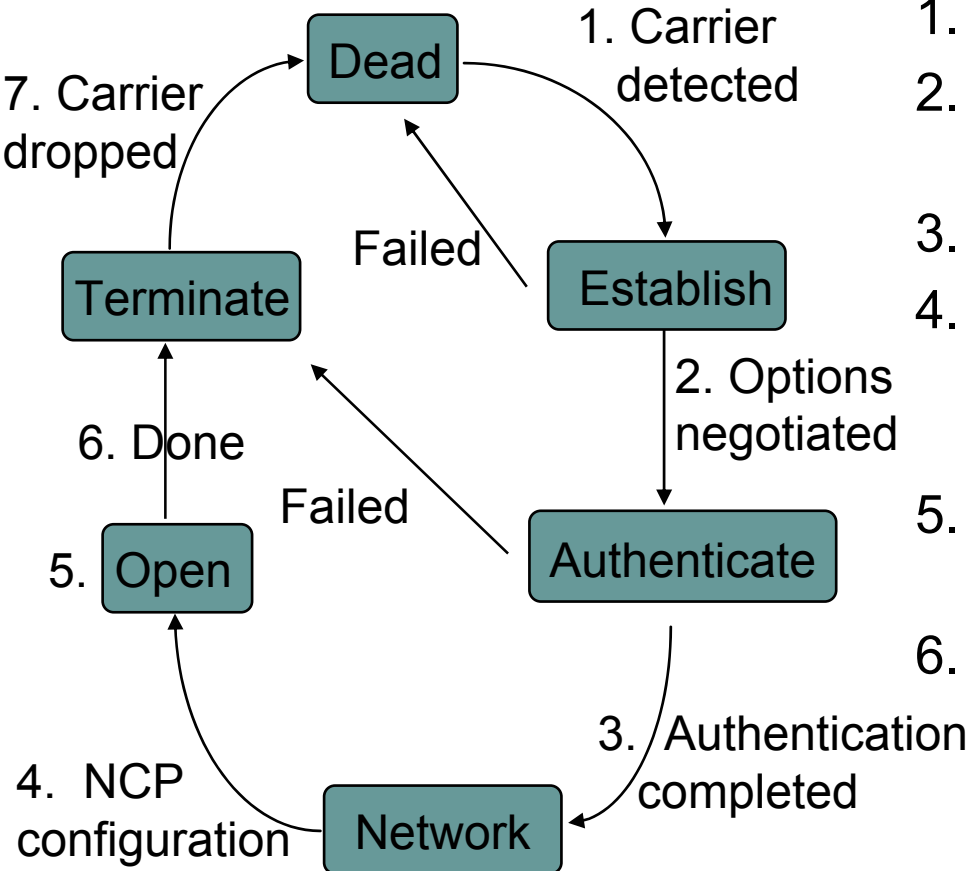
```

0000 ff 03 00 3d c0 00 01 b5 21 45 00 01 7a 39 51 40  ...=.... !E..z9Q@
0010 00 3f 06 09 04 cf c1 19 0c cf 26 40 35 04 dd 00  .?...... ..&@5...
0020 50 2e 6d ae 03 ef 3a 28 aa 80 18 7d 2e 4a f3 00  P.m...:( ...}.J..
0030 00 01 01 08 0a 00 0a e3 80 09 db 5a a8 47 45 54  ..... ..Z.GET
0040 20 2f 74 61 69 73 6e 70 64 2f 20 48 54 54 50 2f  /taisnp d/ HTTP/
0050 31 2e 30 0d 0a 52 65 66 65 72 65 72 3a 20 68 74  1.0..Ref erer: ht

```

Filter: Reset Apply Point-to-Point Protocol (ppp), 4 bytes

A Typical Scenario



Home PC to Internet Service Provider

1. PC calls router via modem.
2. PC and router exchange LCP packets to negotiate PPP parameters.
3. Check on identities.
4. NCP packets exchanged to configure the network layer, e.g., TCP/IP (requires IP address assignment).
5. Data transport, e.g. send/receive IP packets.
6. NCP used to tear down the network layer connection (free up IP address); LCP used to shut down data link layer connection.
7. Modem hangs up.

PPP LCP and NCP Negotiation - Ethereal

File Edit Capture Display Tools Help

No. .	Time	Source	Destination	Protocol	Info
1	0.000000	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP LCP	PPP LCP Configuration Request
2	2.999526	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP LCP	PPP LCP Configuration Request
3	3.130440	20:52:45:43:56:00	20:52:45:43:56:00	PPP LCP	PPP LCP Configuration Reject
4	3.130495	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP LCP	PPP LCP Configuration Request
5	3.243457	20:52:45:43:56:00	20:52:45:43:56:00	PPP LCP	PPP LCP Configuration Ack
6	5.096025	20:52:45:43:56:00	20:52:45:43:56:00	PPP LCP	PPP LCP Configuration Request
7	5.096072	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP LCP	PPP LCP Configuration Reject
8	5.220084	20:52:45:43:56:00	20:52:45:43:56:00	PPP LCP	PPP LCP Configuration Request
9	5.220127	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP LCP	PPP LCP Configuration Ack
10	5.220155	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP PAP	PPP PAP Authenticate-Request
11	5.423283	20:52:45:43:56:00	20:52:45:43:56:00	PPP PAP	PPP PAP Authenticate-Ack
12	5.423367	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP IPCP	PPP IPCP Configuration Request
13	5.423390	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP CCP	PPP CCP Configuration Request
14	5.428998	20:52:45:43:56:00	20:52:45:43:56:00	PPP IPCP	PPP IPCP Configuration Request
15	5.429038	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP IPCP	PPP IPCP Configuration Ack
16	5.558729	20:52:45:43:56:00	20:52:45:43:56:00	PPP IPCP	PPP IPCP Configuration Reject
17	5.558785	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP IPCP	PPP IPCP Configuration Request
18	5.564373	20:52:45:43:56:00	20:52:45:43:56:00	PPP LCP	PPP LCP Protocol Reject
19	5.699896	20:52:45:43:56:00	20:52:45:43:56:00	PPP IPCP	PPP IPCP Configuration Nak
20	5.699938	20:53:45:4e:44:00	20:53:45:4e:44:00	PPP IPCP	PPP IPCP Configuration Request
21	5.846675	20:52:45:43:56:00	20:52:45:43:56:00	PPP IPCP	PPP IPCP Configuration Ack

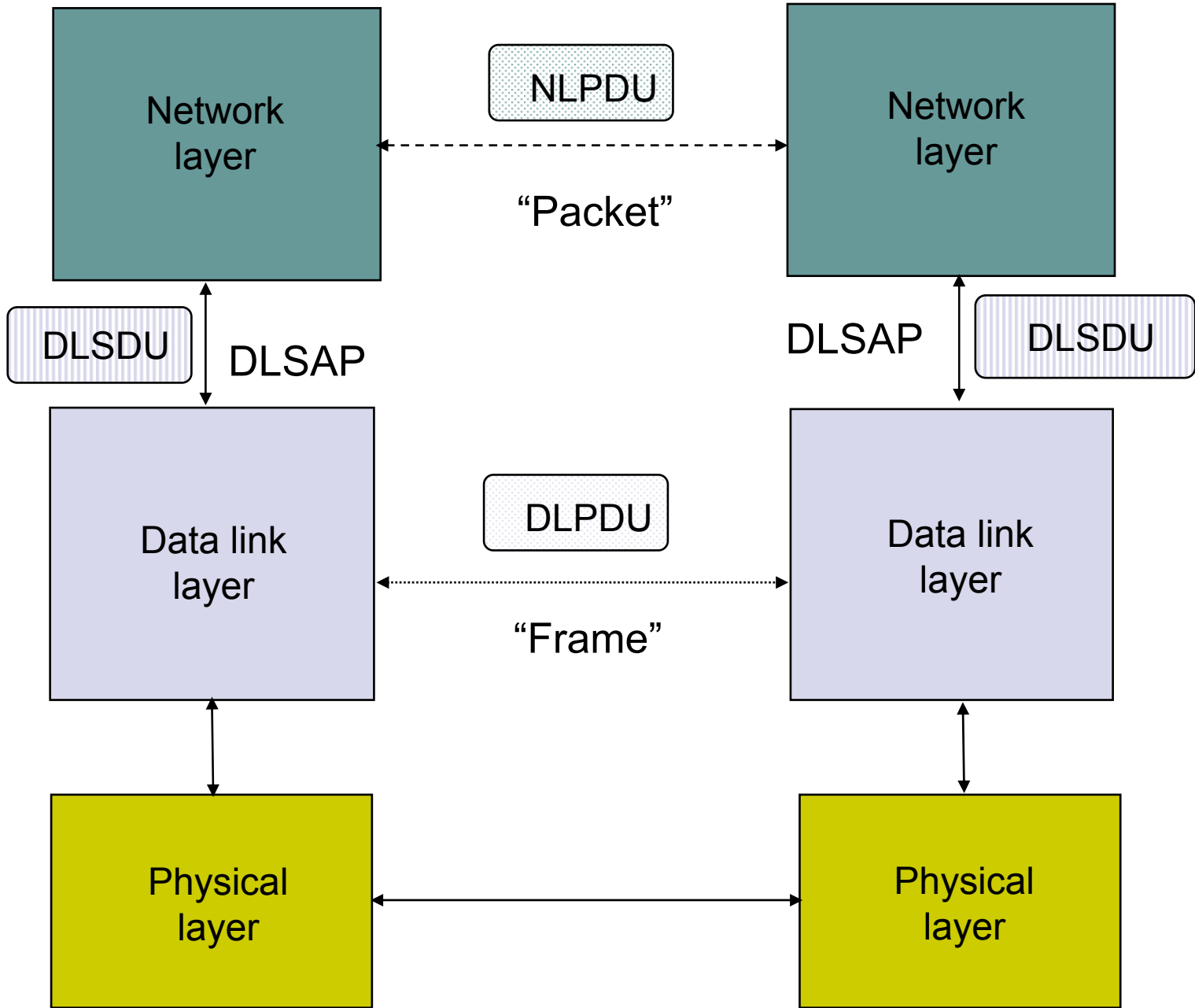
Frame 9 (38 bytes on wire, 38 bytes captured)
Ethernet II, Src: 20:53:45:4e:44:00, Dst: 20:53:45:4e:44:00
PPP Link Control Protocol
Code: Configuration Ack (0x02)
Identifier: 0x83
Length: 24
Options: (20 bytes)
Async Control Character Map: 0x000a0000 (DC1 (XON), DC3 (XOFF))
Authentication protocol: 4 bytes
Magic number: 0x218ad821
Protocol field compression
Address/control field compression

```

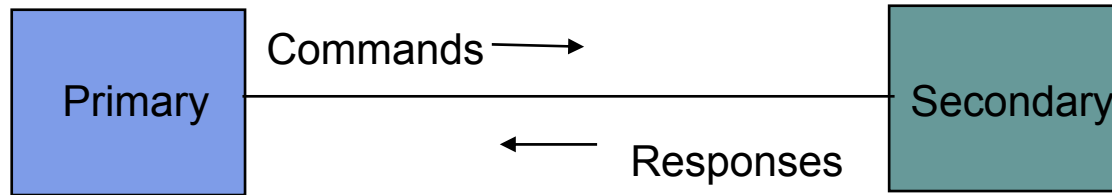
0000  20 53 45 4e 44 00 20 53 45 4e 44 00 c0 21 02 83  SEND. S END...!..
0010  00 18 02 06 00 0a 00 00 03 04 c0 23 05 06 21 8a  .....#...!..
0020  d8 21 07 02 08 02  ..!....

```

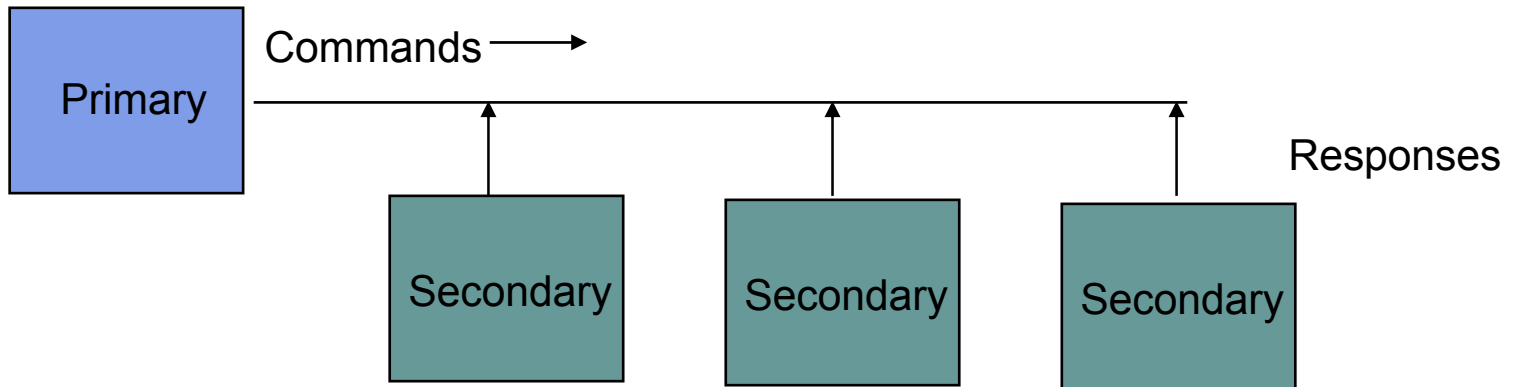
Filter: / Reset Apply File: PPP LCP and NCP Negotiation



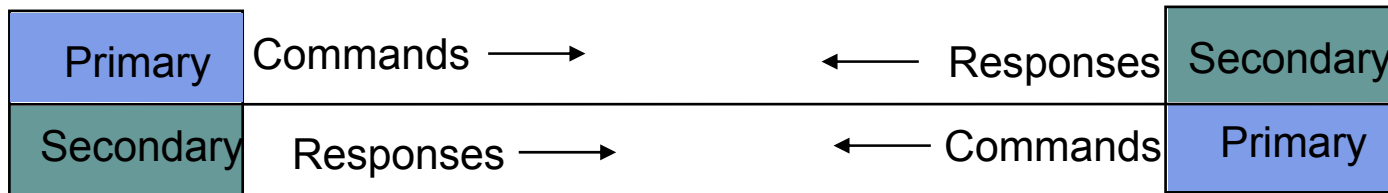
Unbalanced point-to-point link

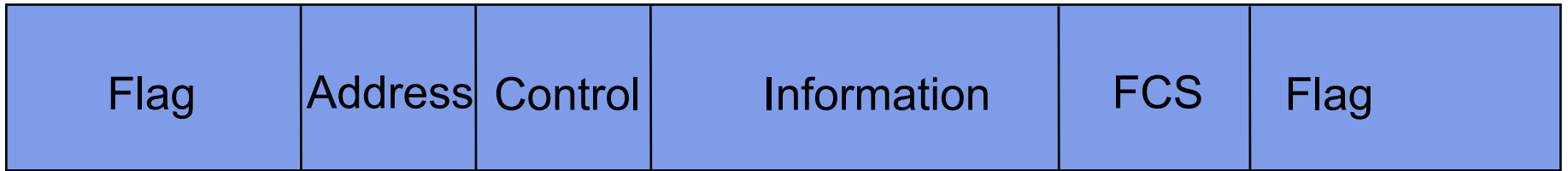


Unbalanced multipoint link

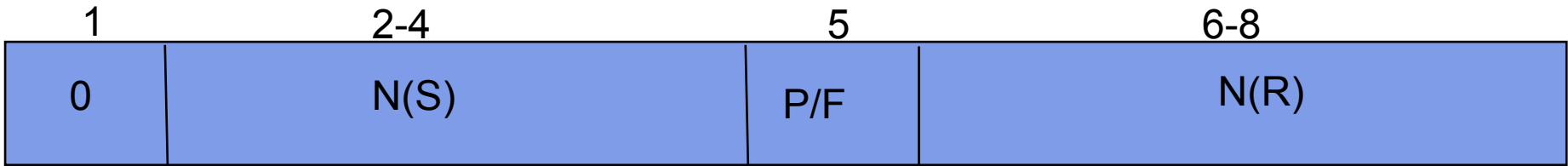


Balanced point-to-point link between combined stations

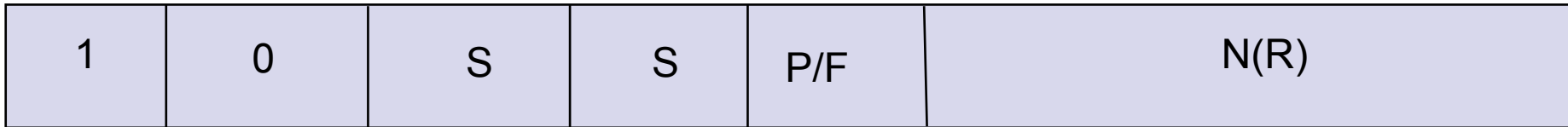




Information Frame

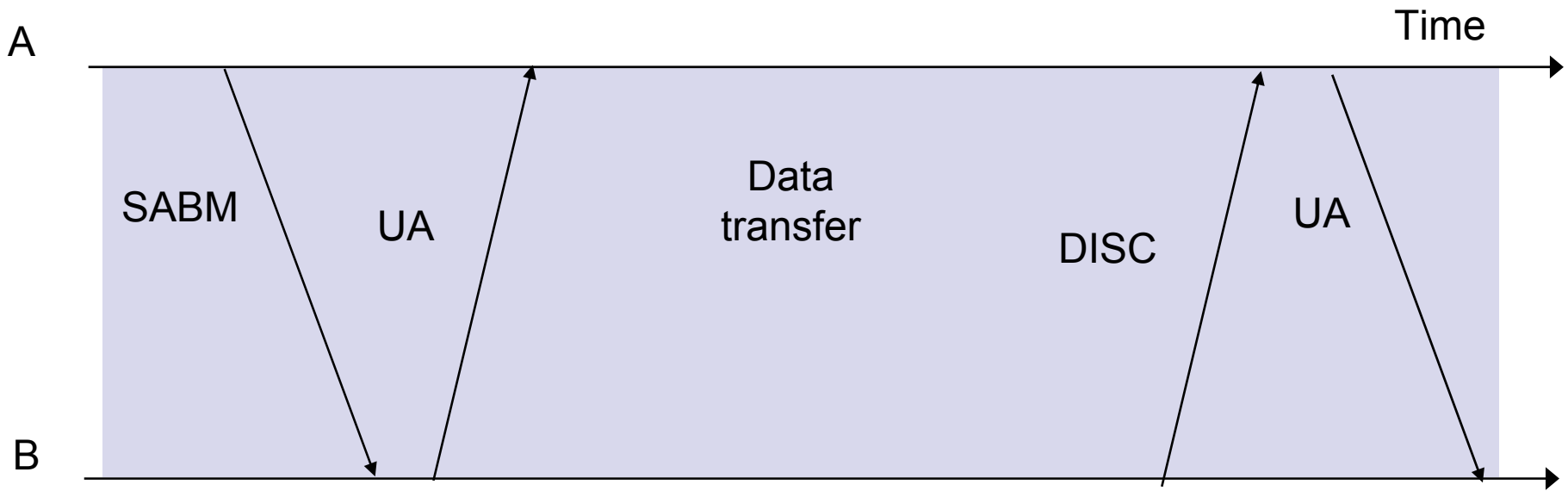


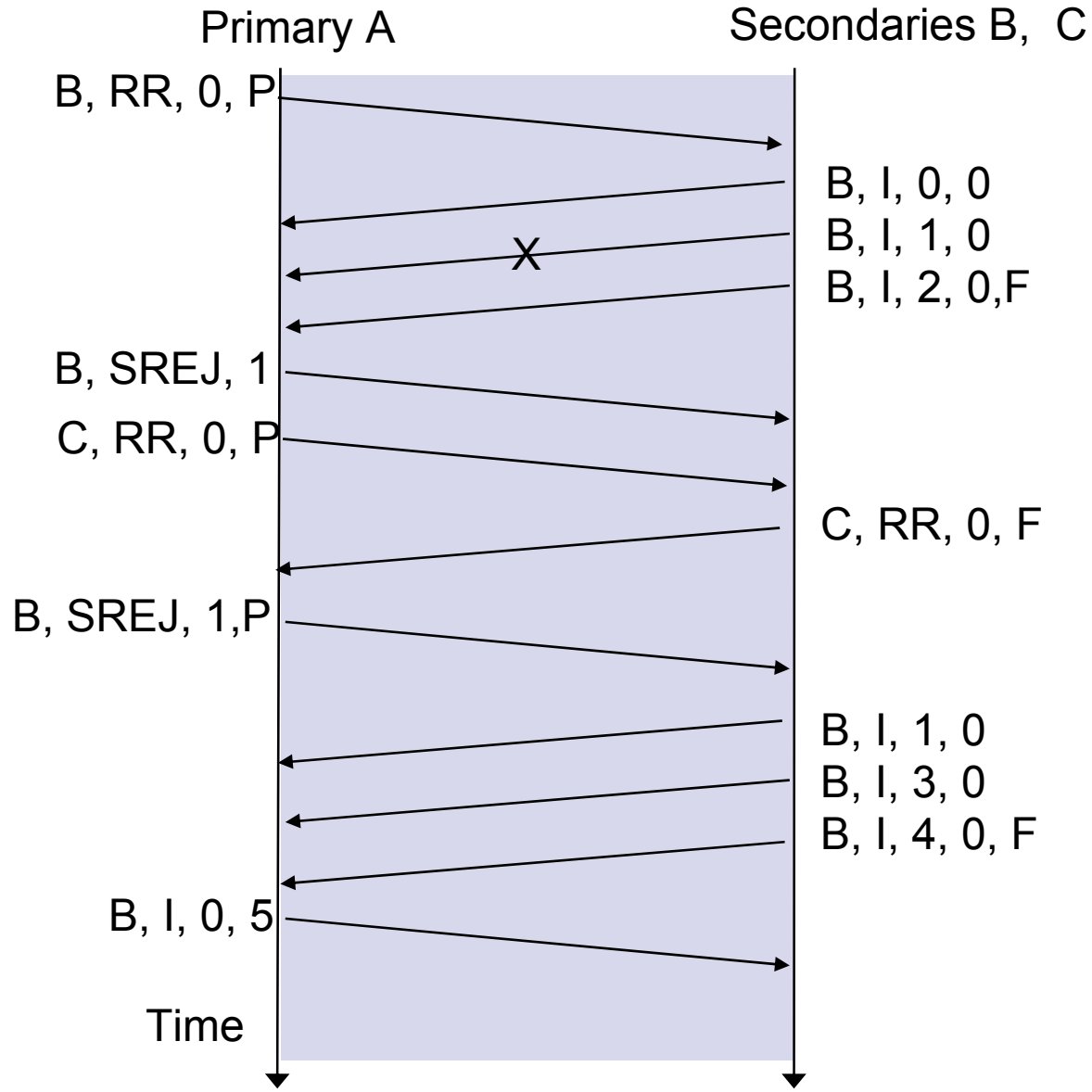
Supervisory Frame

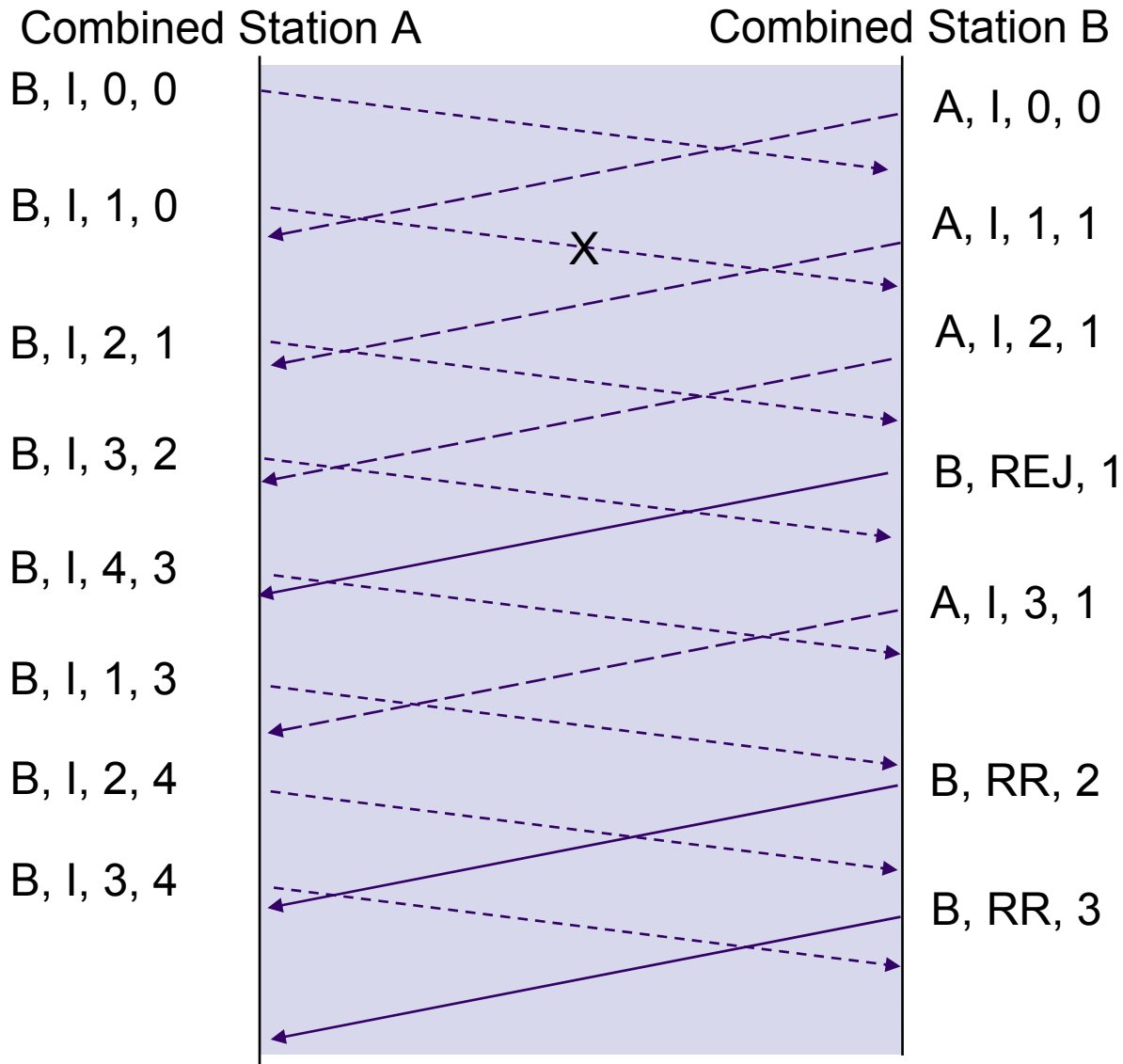


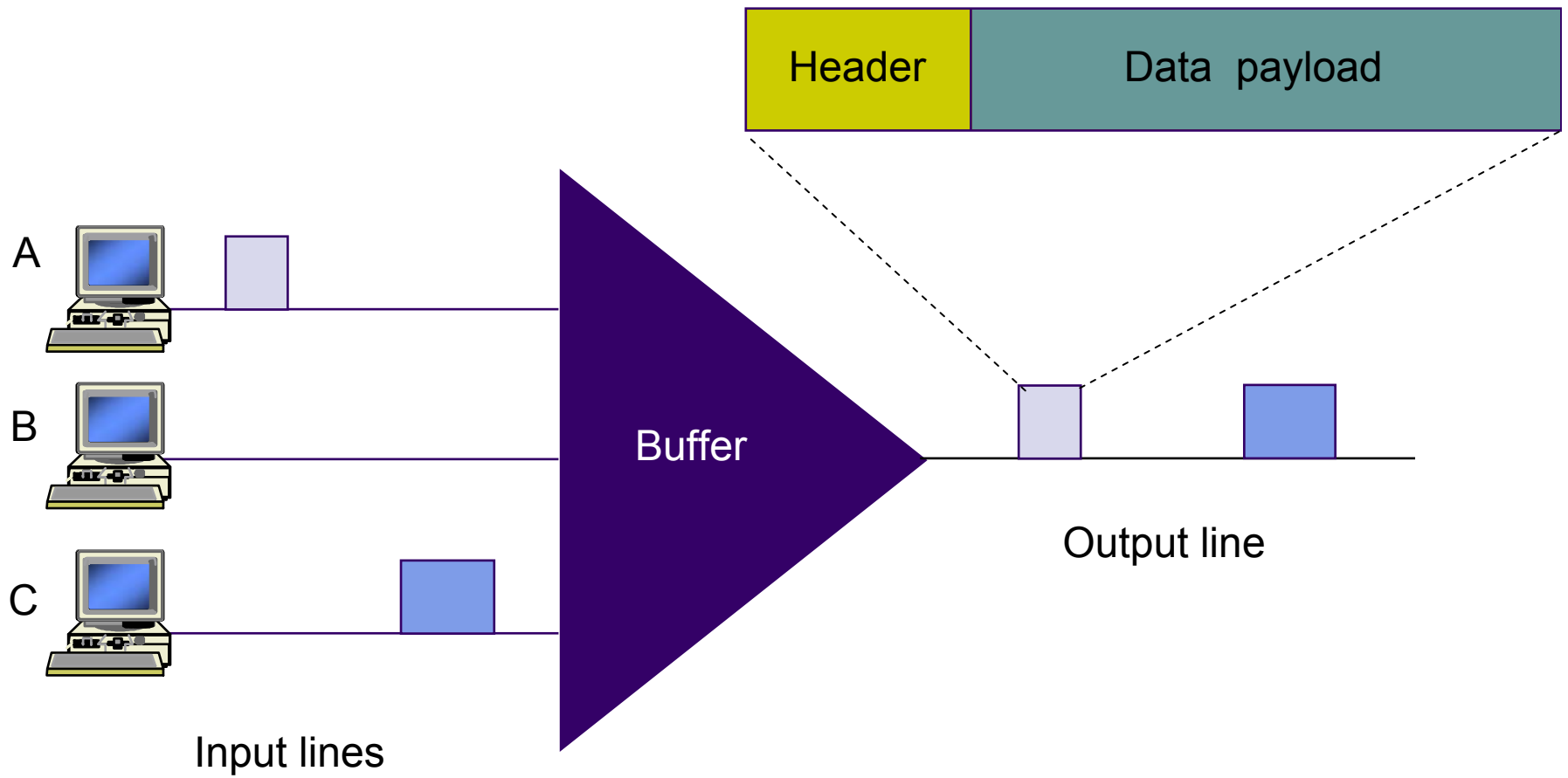
Unnumbered Frame

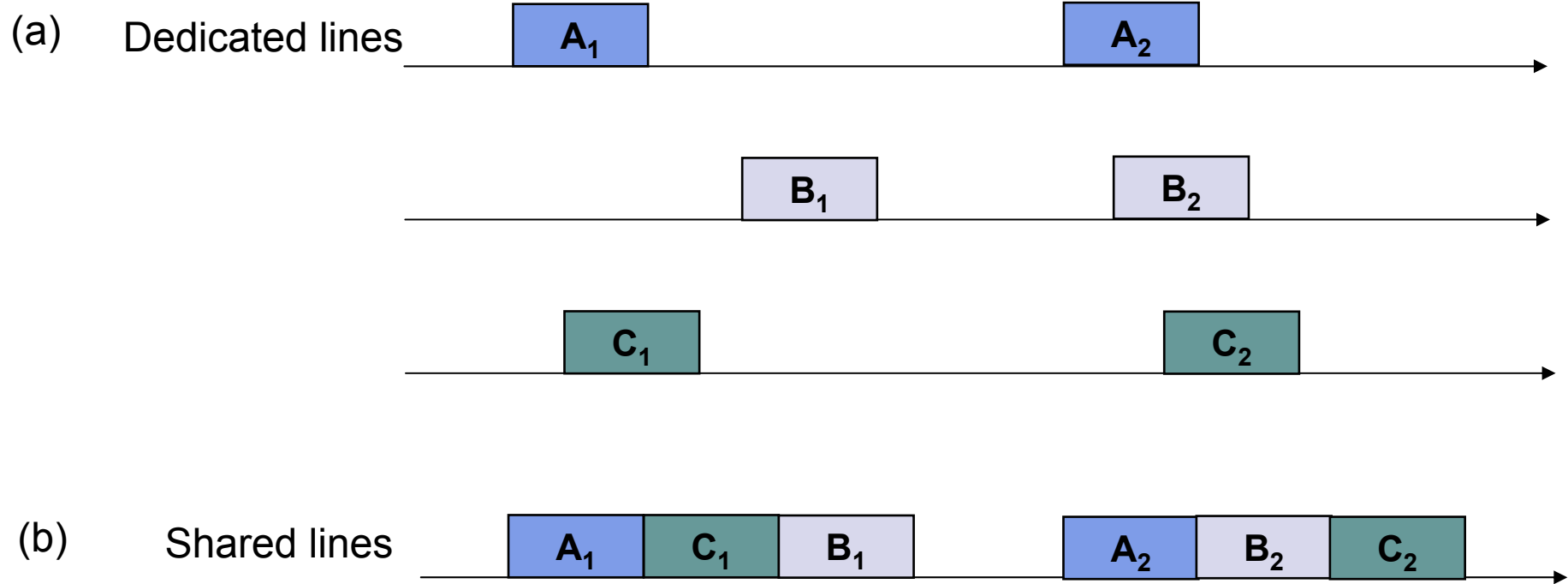


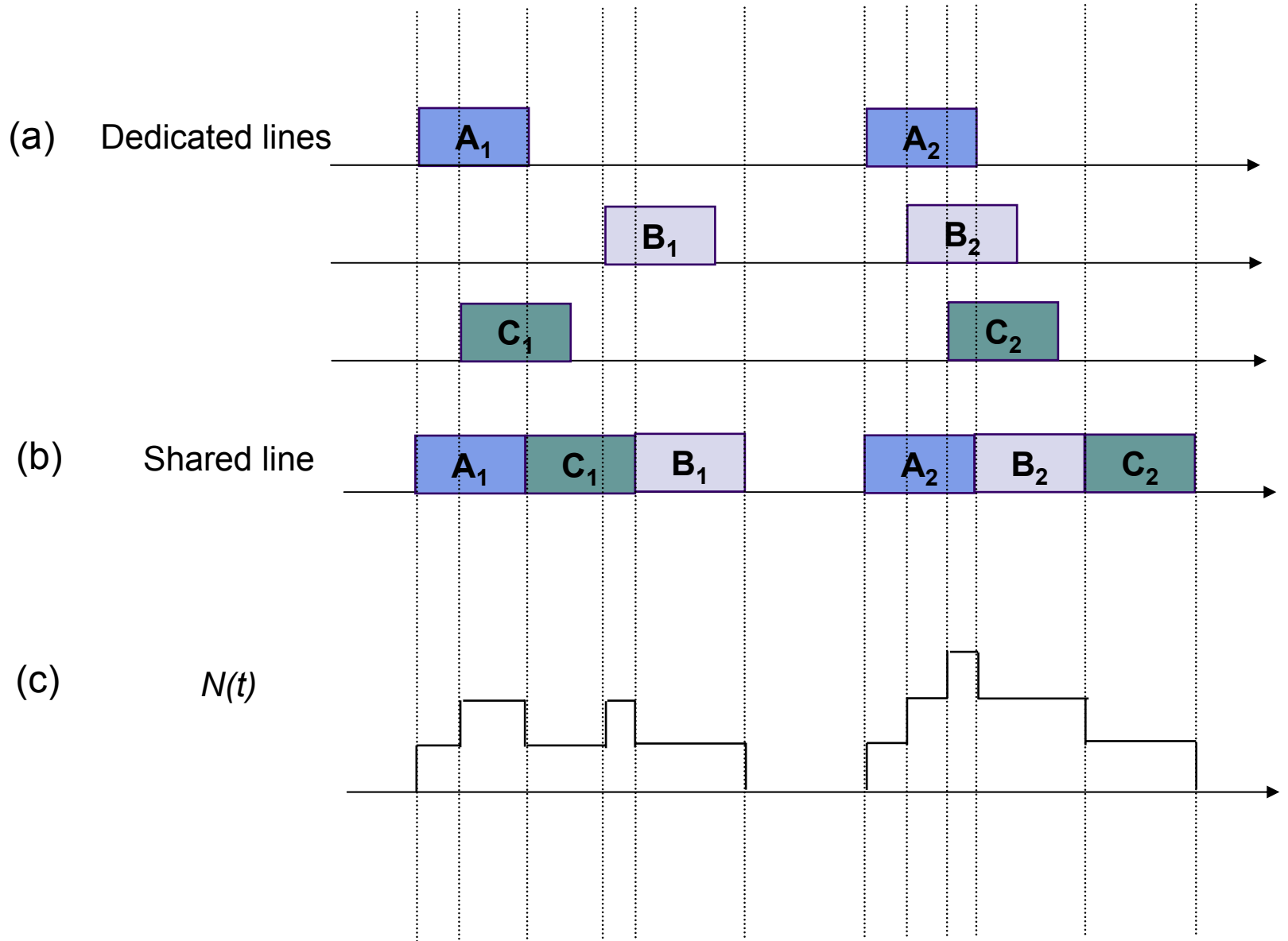


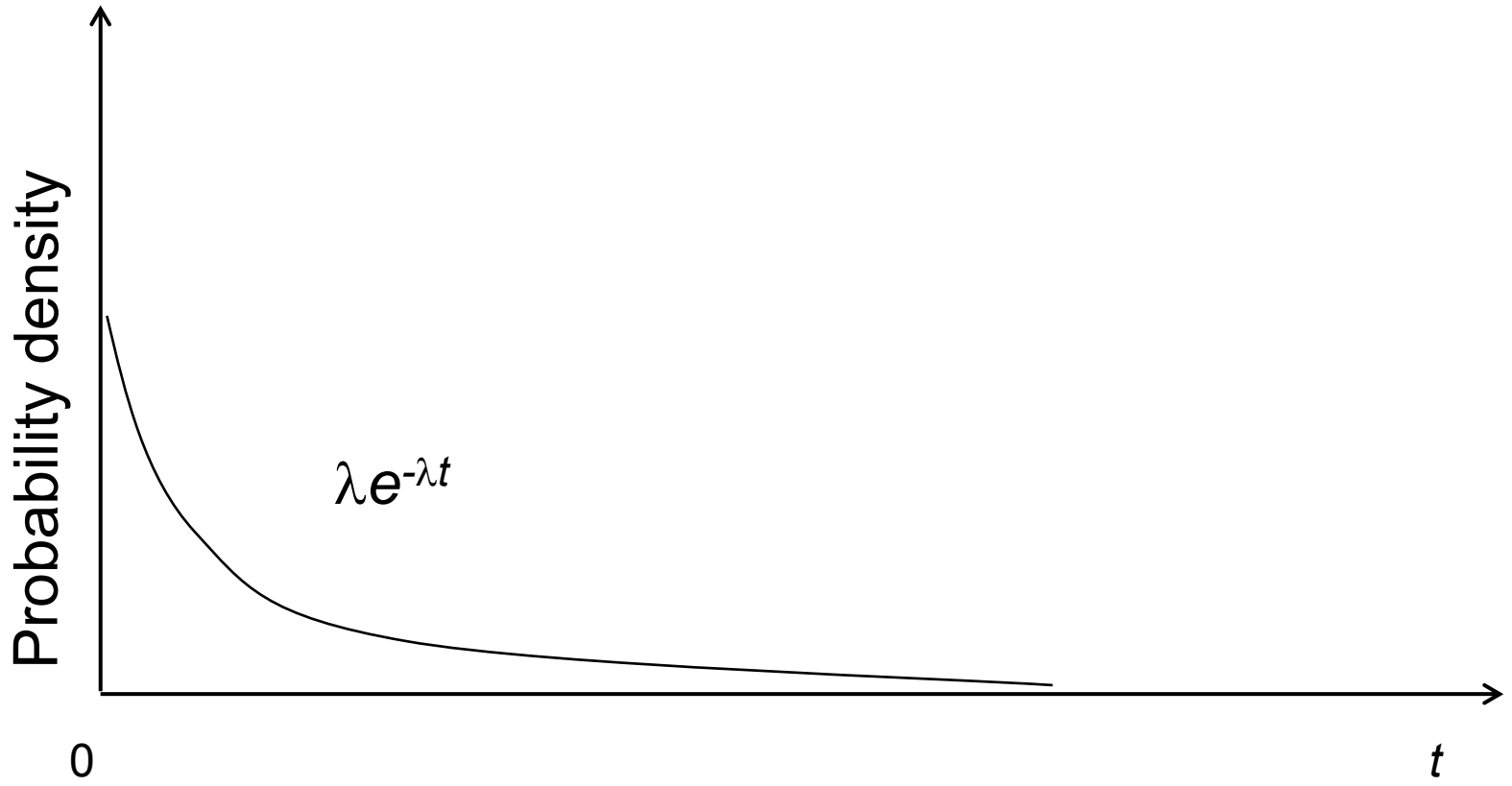




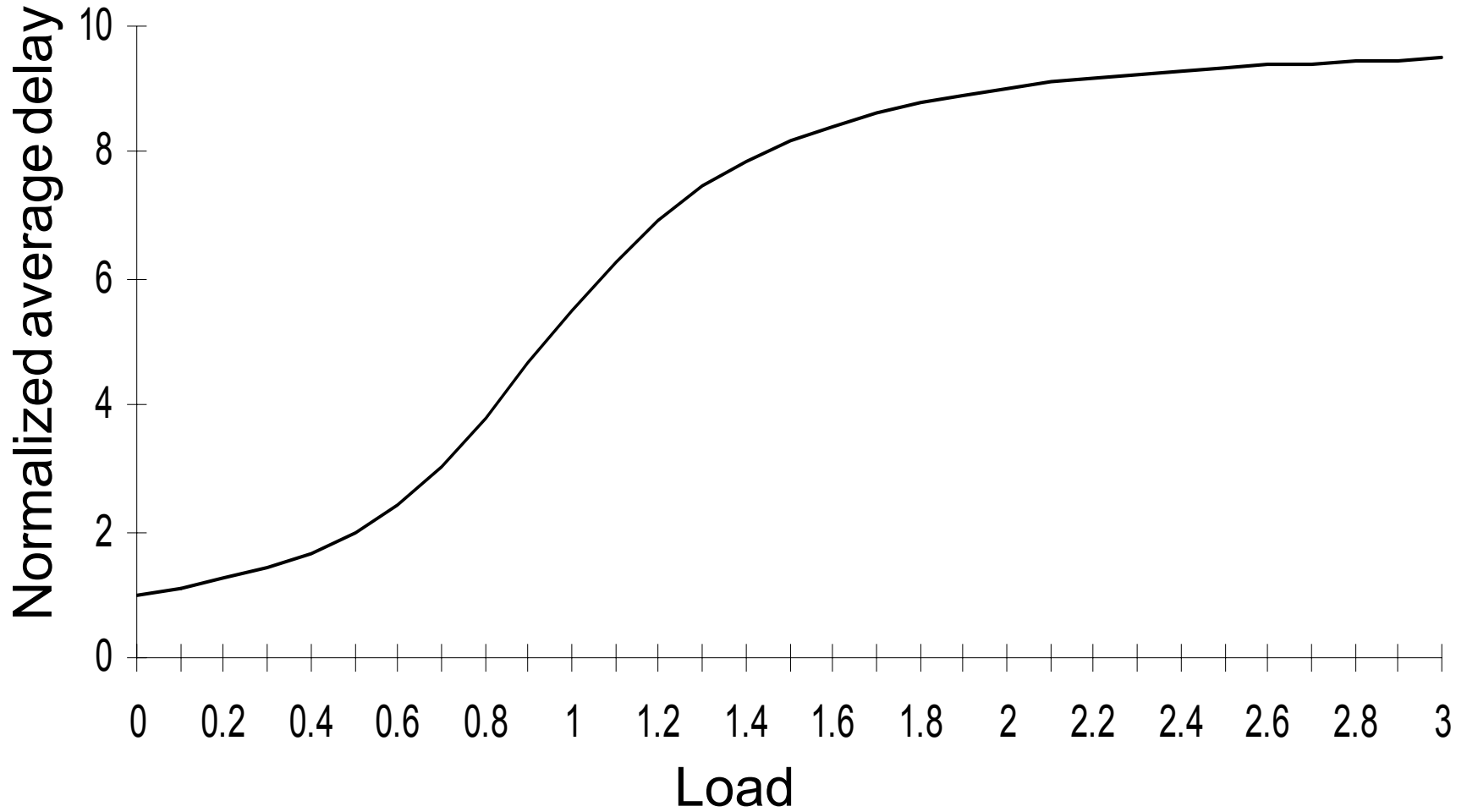


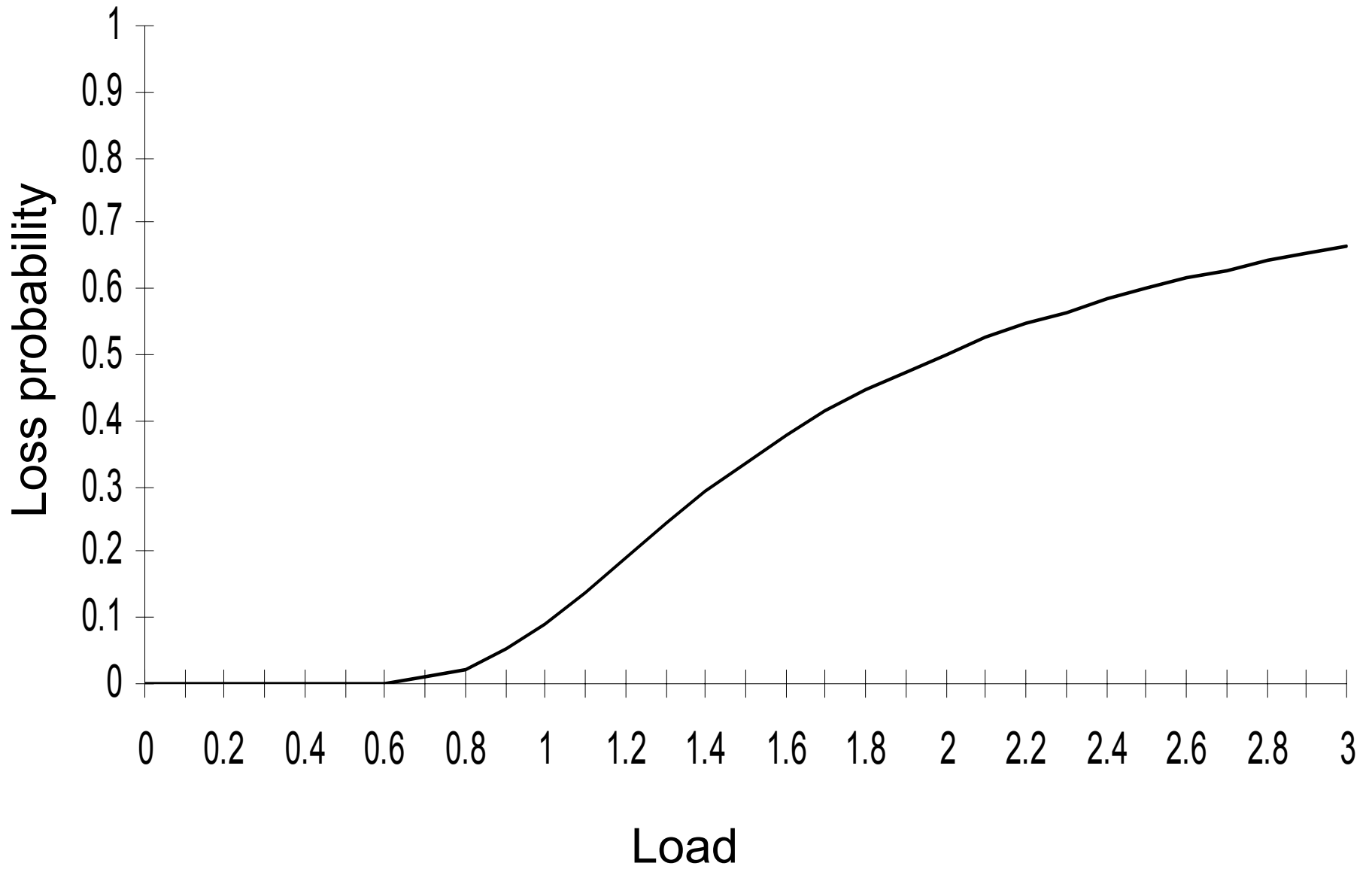


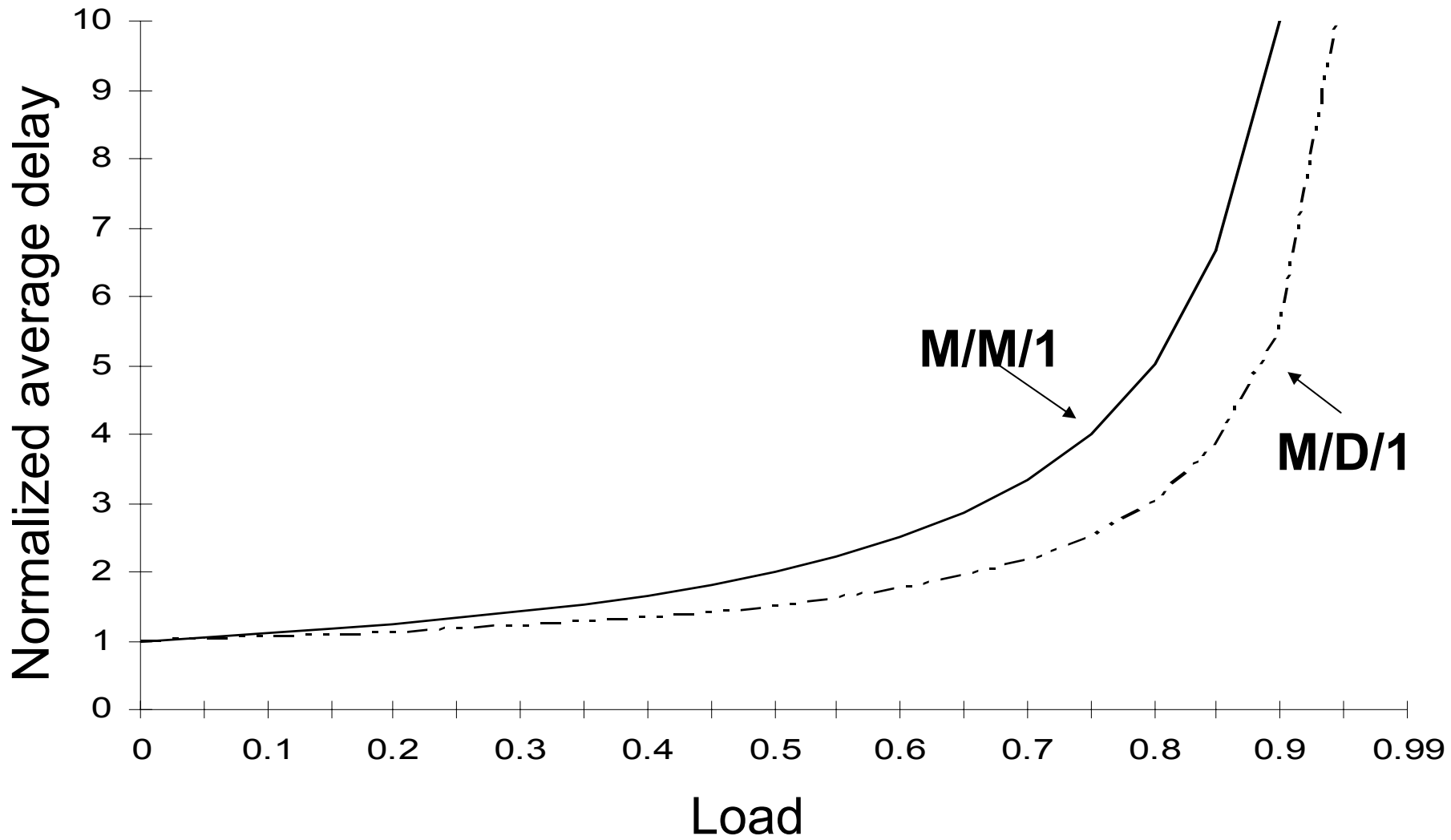


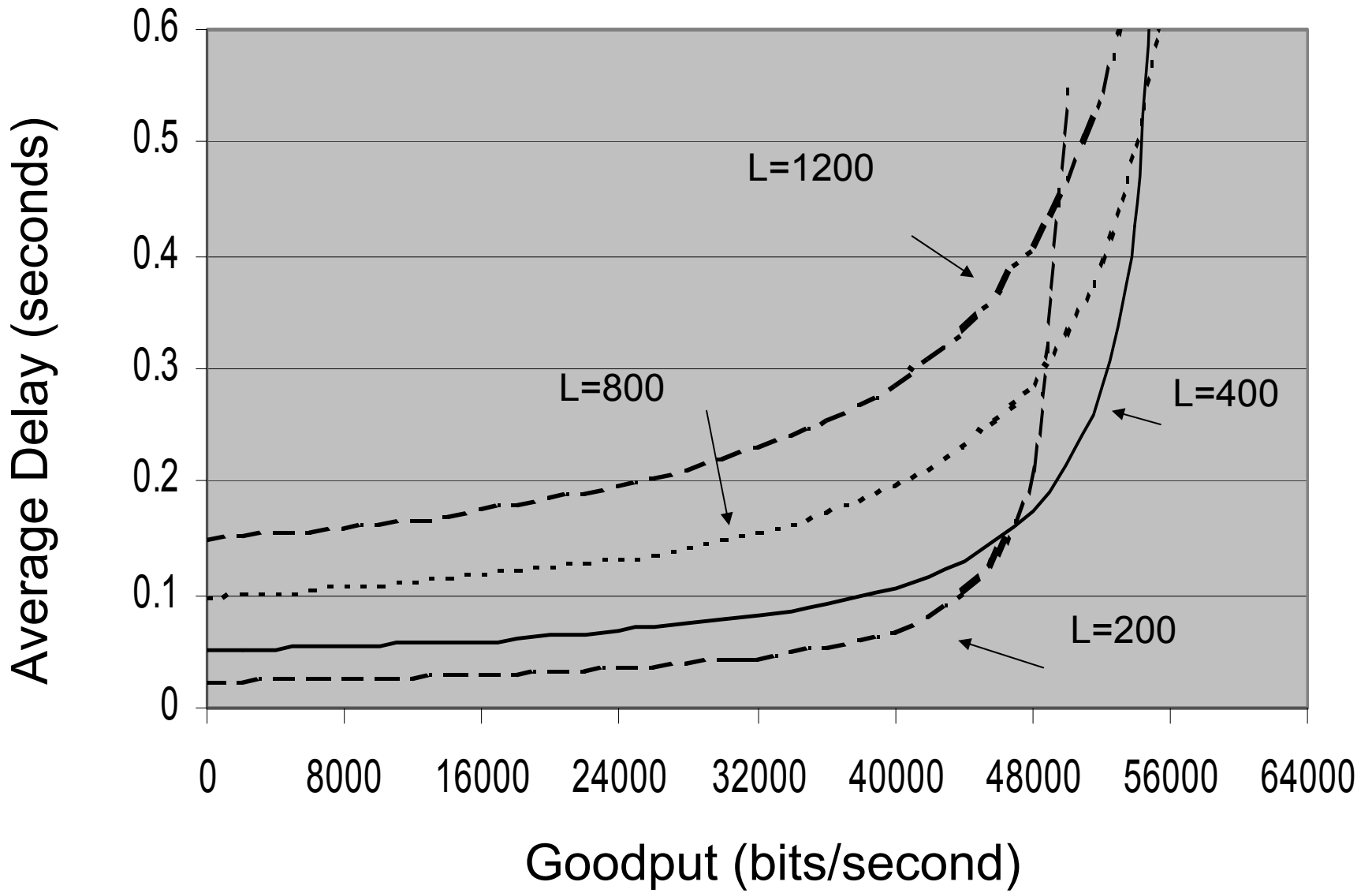


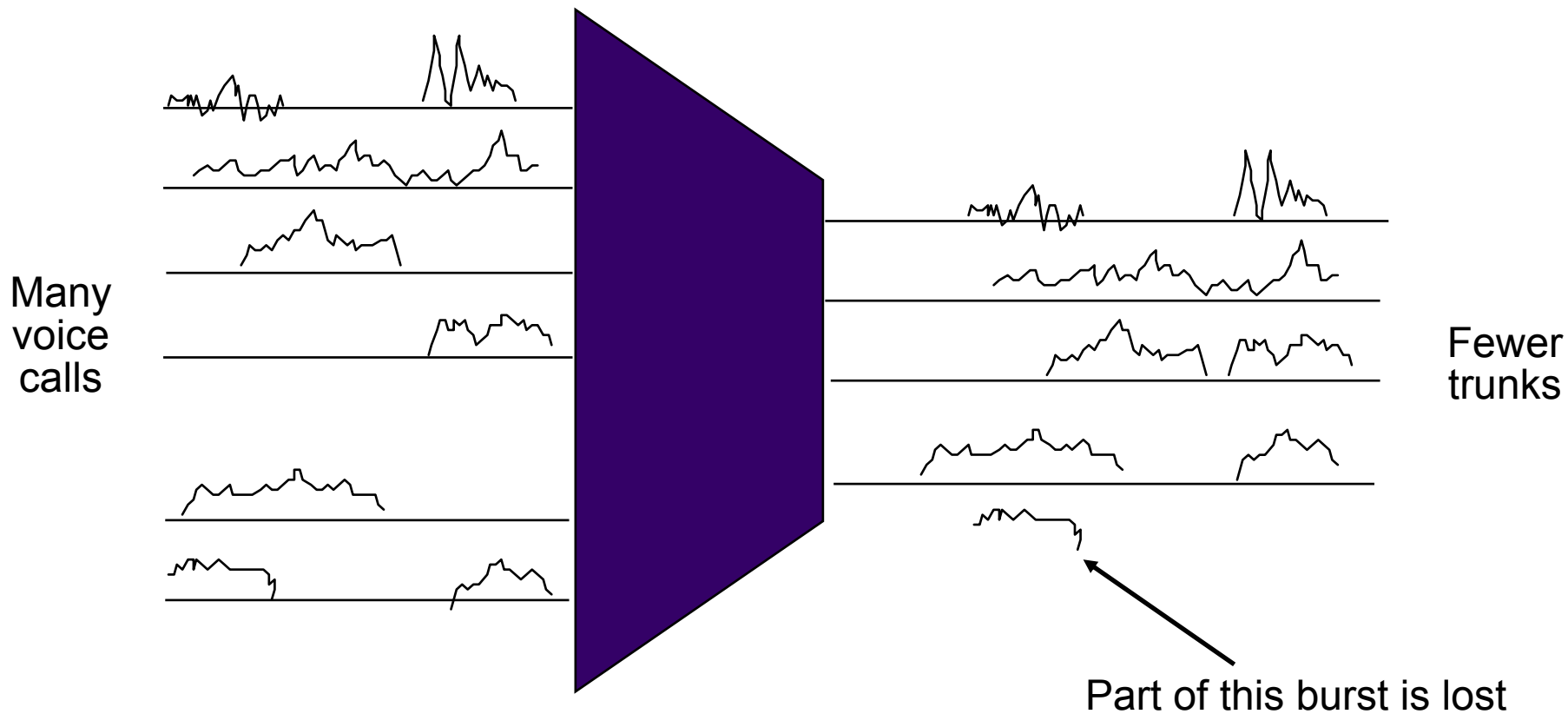
Finite buffer multiplexer



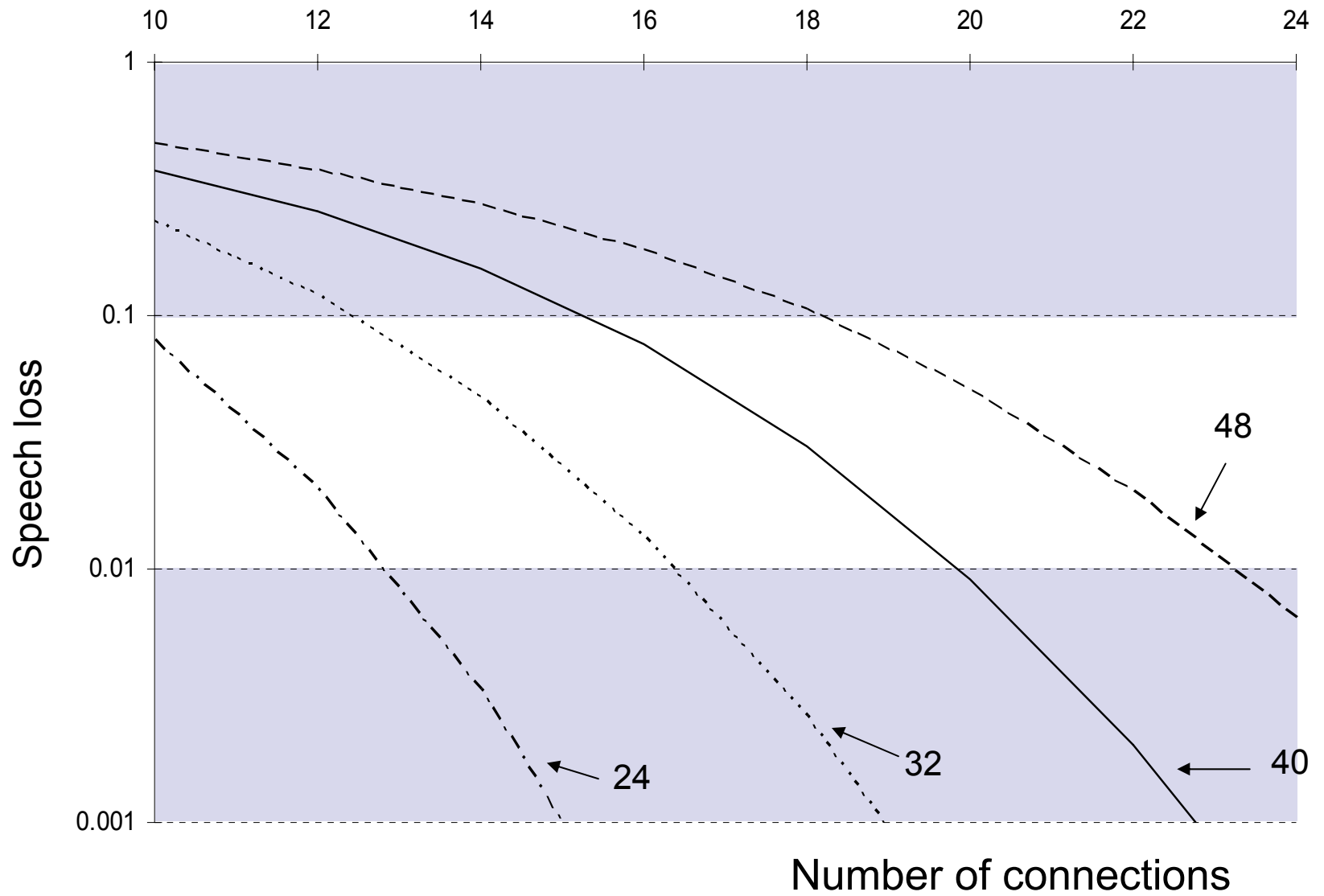








Trunks



Many voice terminals
generating voice packets

