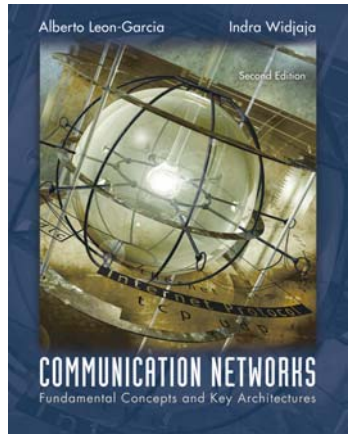
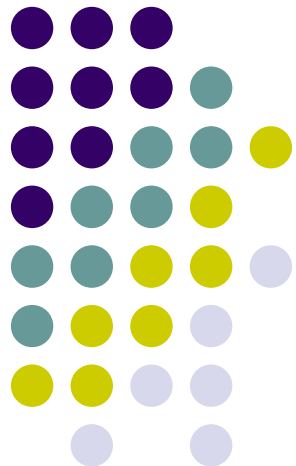
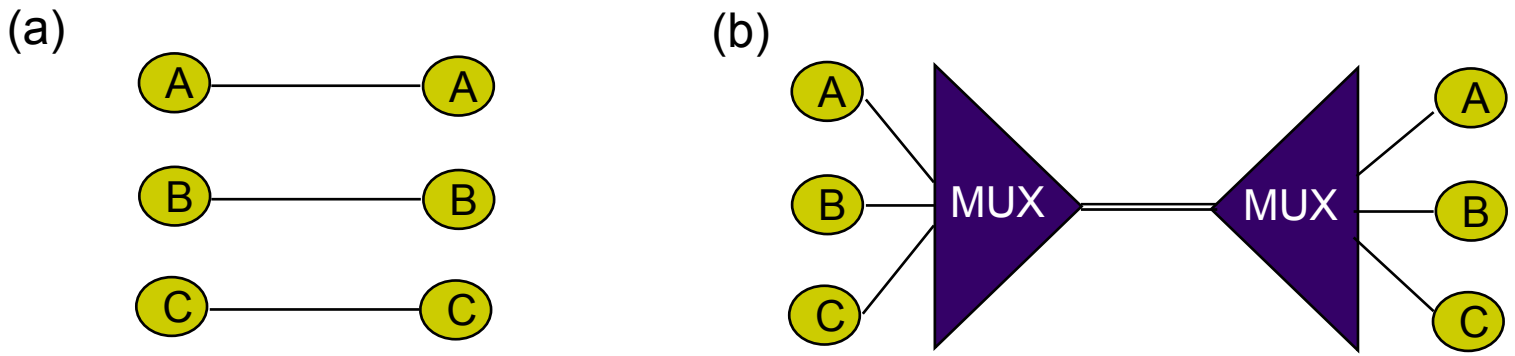
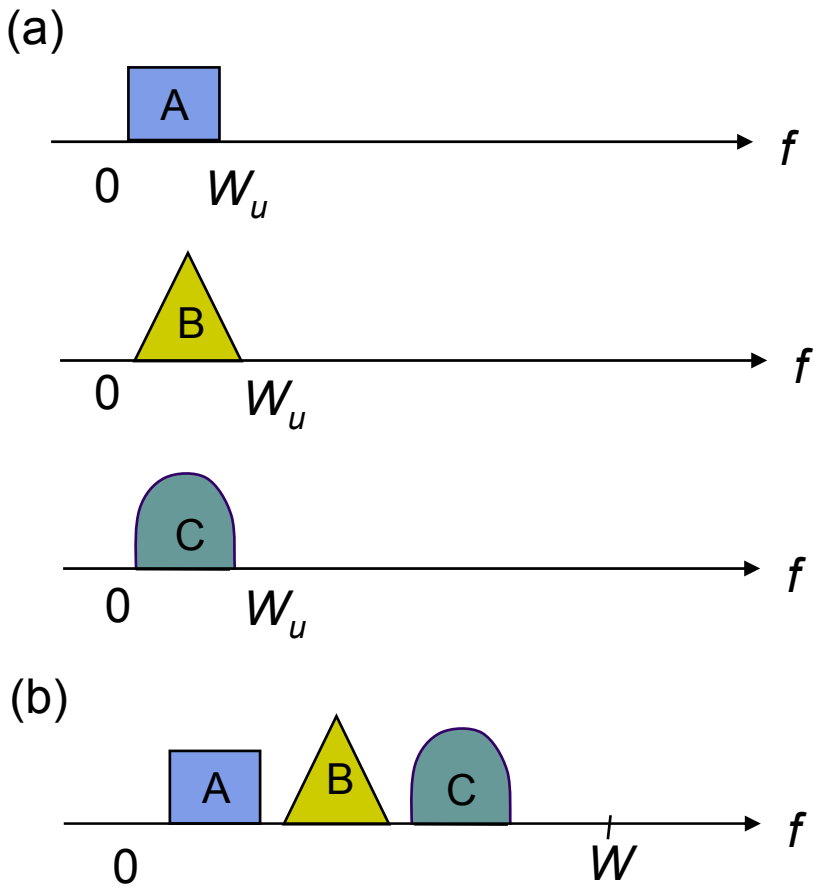
Chapter 4
Circuit-Switching Networks

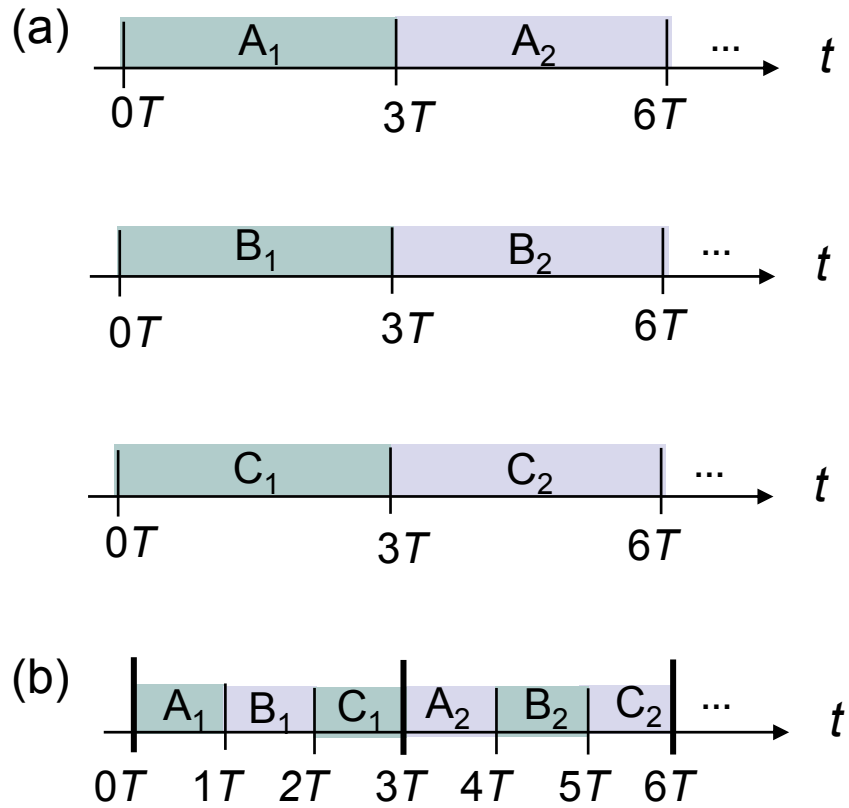


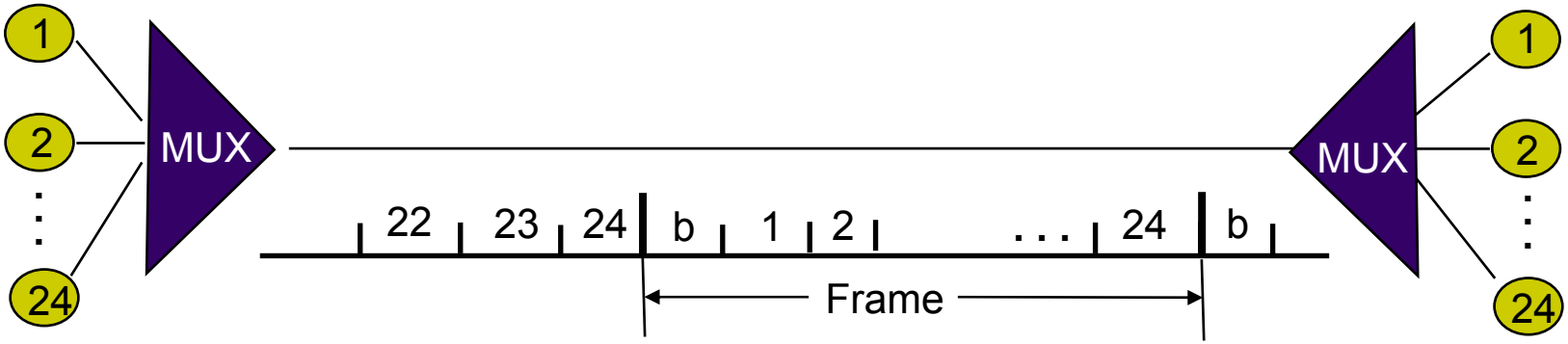


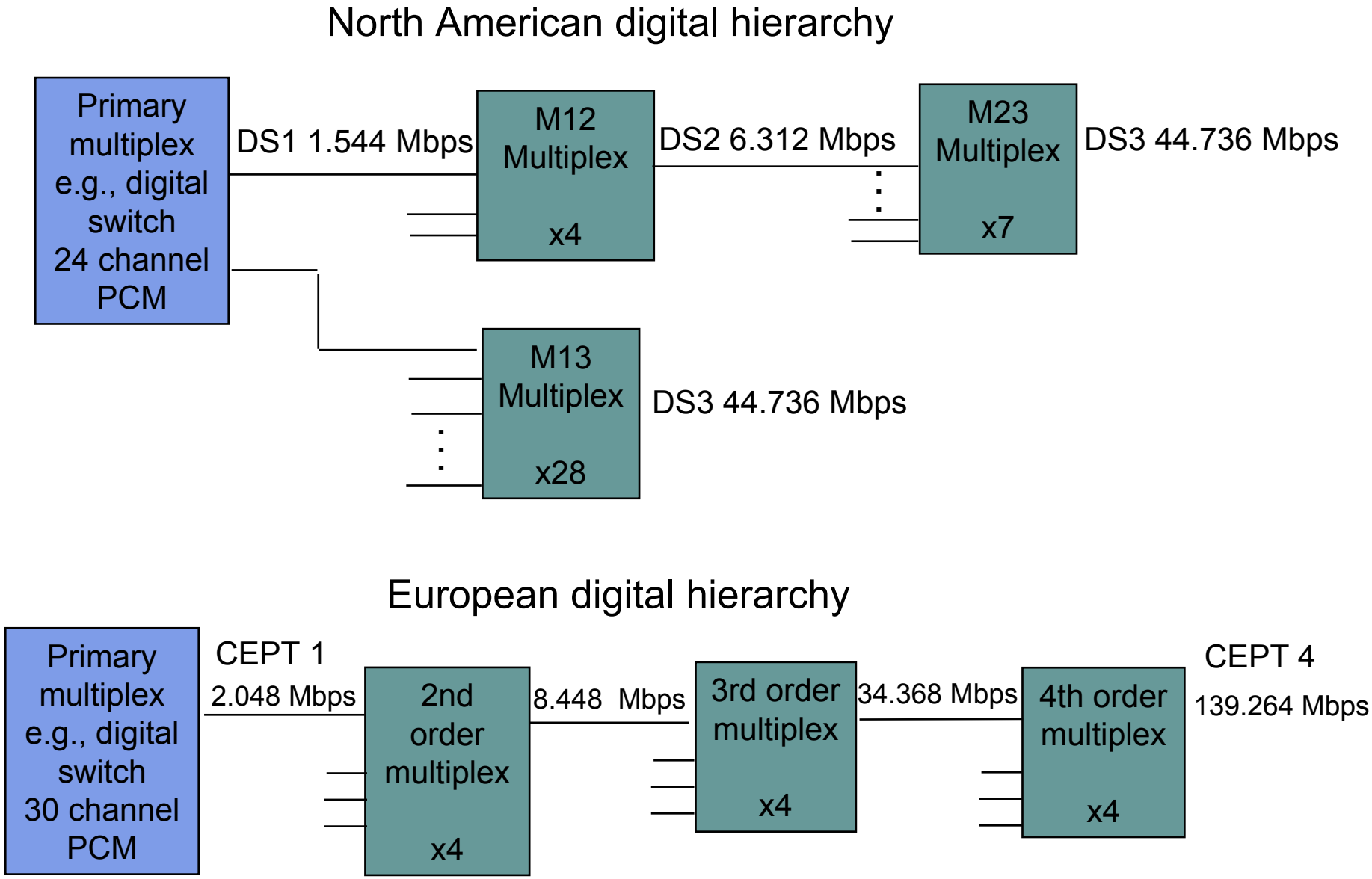
Chapter Figures

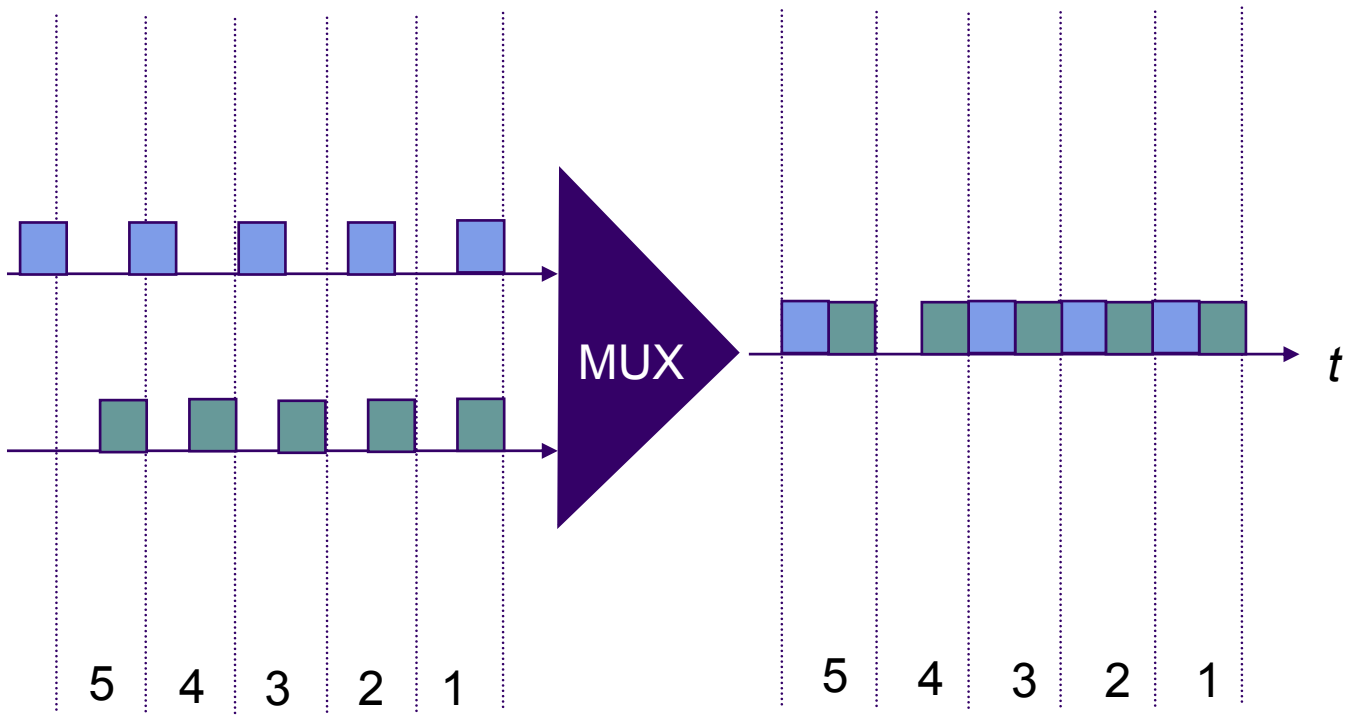

(a)
A
A
B
B
C
C
(b)
A
B
C
MUX
MUX
A
B
C

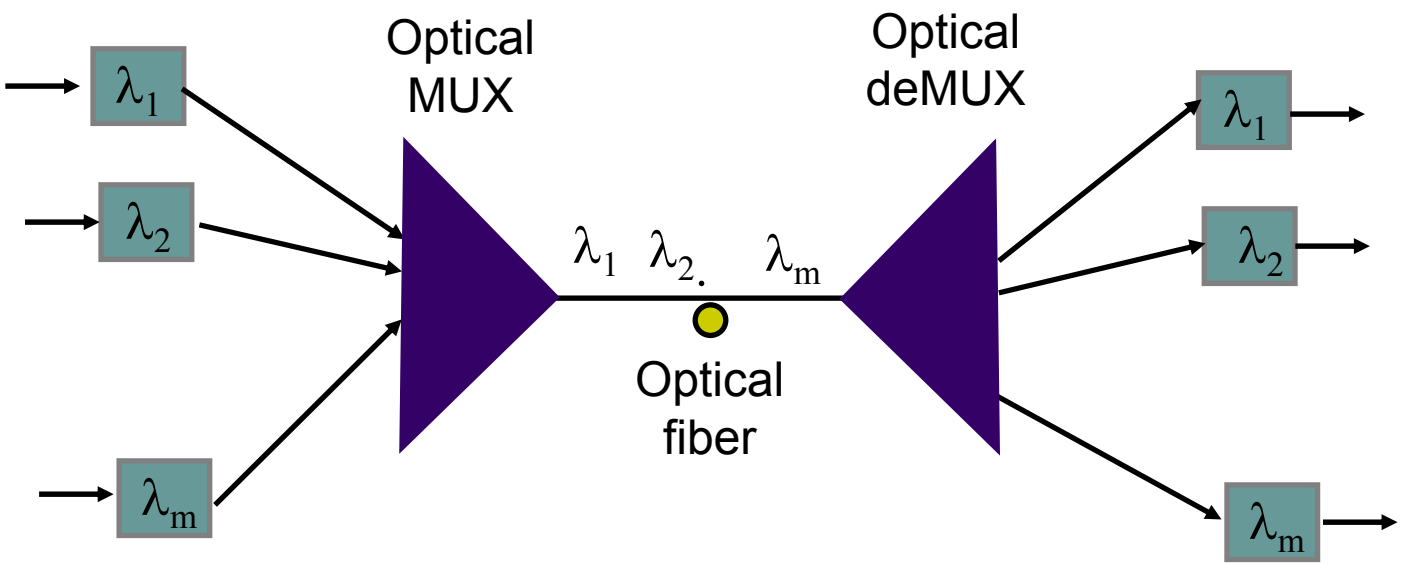

(a)
A
0
W_u
f
B
0
W_u
f
C
0
W_u
f
(b)
A
B
C
0
W
f

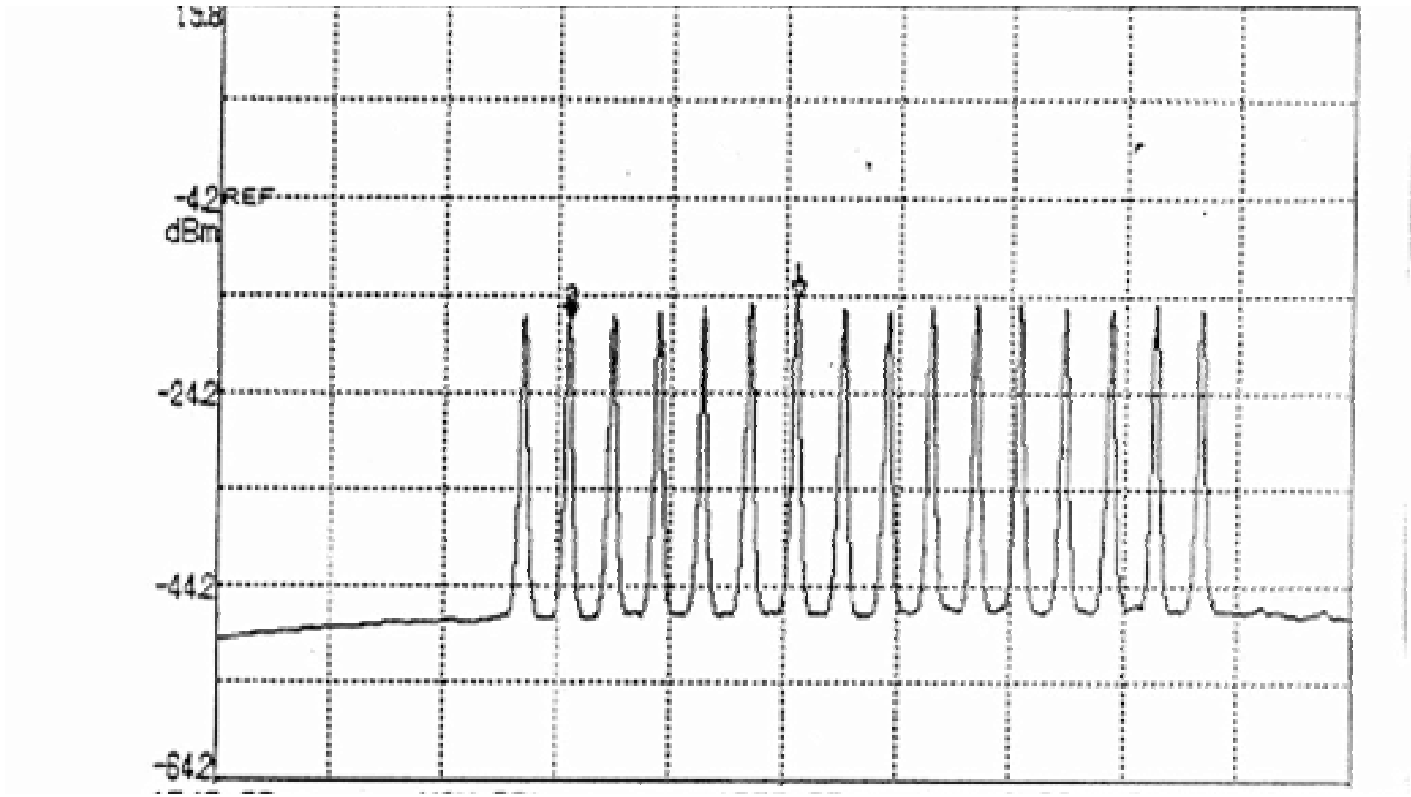

(a)
A1
A2
...
t
0T
3T
6T
B1
B2
...
t
0T
3T
6T
C1
C2
...
t
0T
3T
6T
(b)
A1
B1
C1
A2
B2
C2
...
t
0T
1T
2T
3T
4T
5T
6T

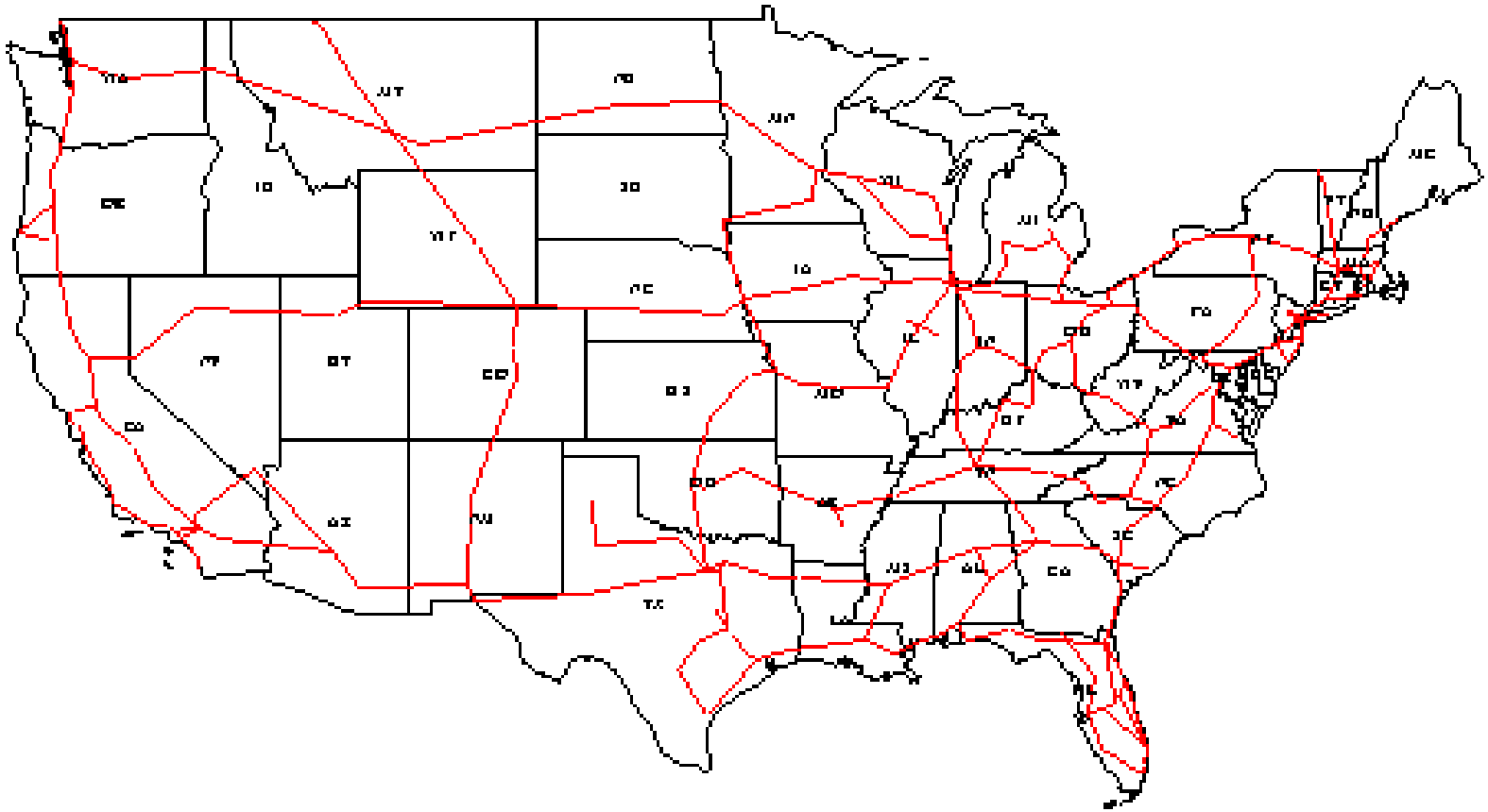

1
2
24
MUX
22
23
24
b
1
2
. . .
24
b
Frame
MUX
1
2
24

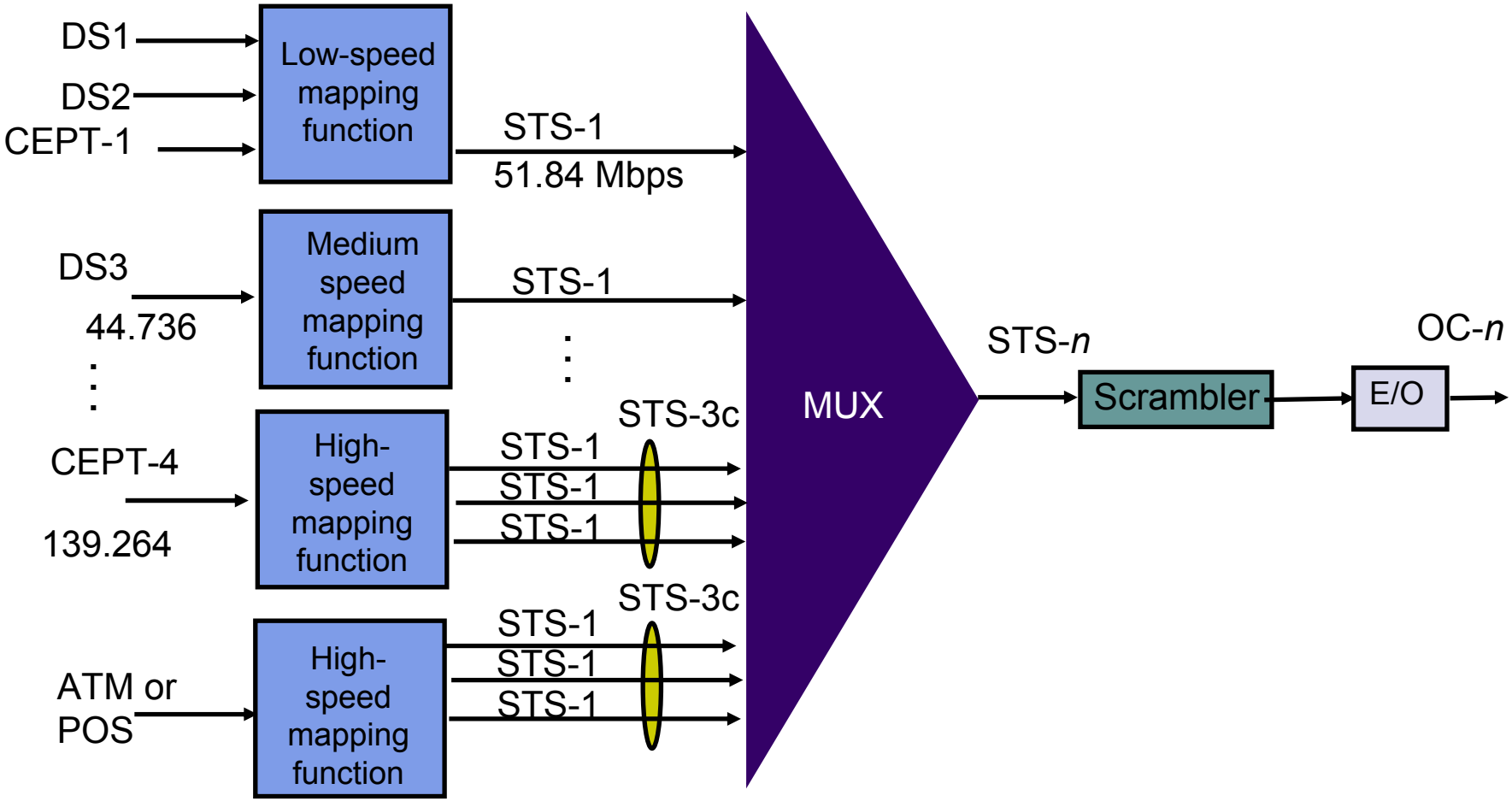

North American digital hierarchy
Primary multiplex e.g., digital switch 24 channel PCM
DS1 1.544 Mbps
M12 Multiplex
x4
DS2 6.312 Mbps
M23 Multiplex
x7
DS3 44.736 Mbps
M13 Multiplex
x28
DS3 44.736 Mbps
European digital hierarchy
Primary multiplex e.g., digital switch 30 channel PCM
CEPT 1
2.048 Mbps
2nd order multiplex
x4
8.448 Mbps
3rd order multiplex
x4
34.368 Mbps
4th order multiplex
x4
CEPT 4
139.264 Mbps


MUX
t
5
4
3
2
1
5
4
3
2
1

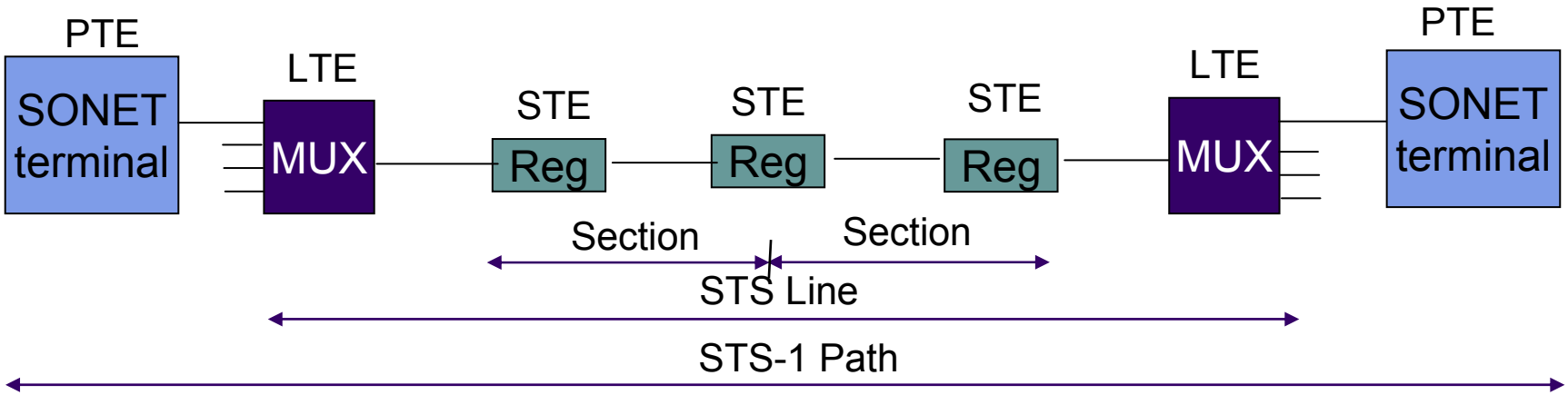

Optical
MUX
Optical
deMUX
λ1
λ2
λm
λ1 λ2. λm
Optical
fiber
λ1
λ2
λm


-42 REF
dBm
-242
-442
-642



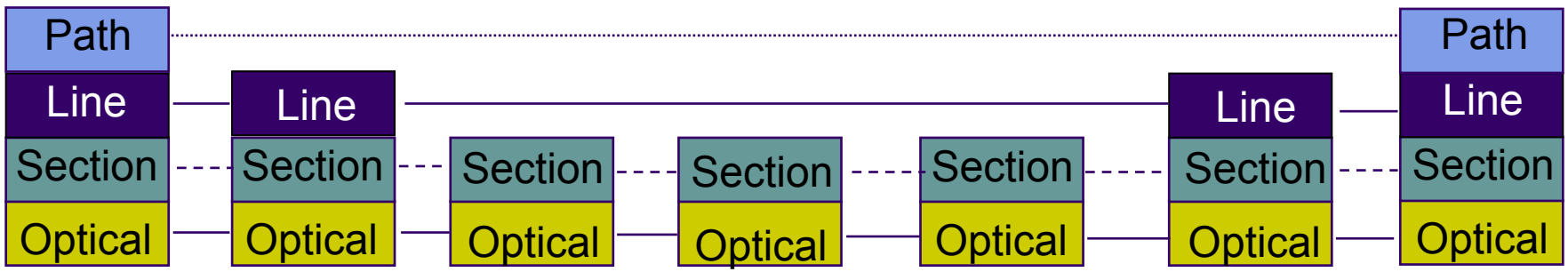

DS1
DS2
CEPT-1
Low-speed mapping function
STS-1
51.84 Mbps
DS3
44.736
Medium speed mapping function
STS-1
CEPT-4
139.264
High-speed mapping function
STS-3c
STS-1
STS-1
STS-1
ATM or POS
High-speed mapping function
STS-3c
STS-1
STS-1
STS-1
MUX
STS-n
Scrambler
E/O
OC-n

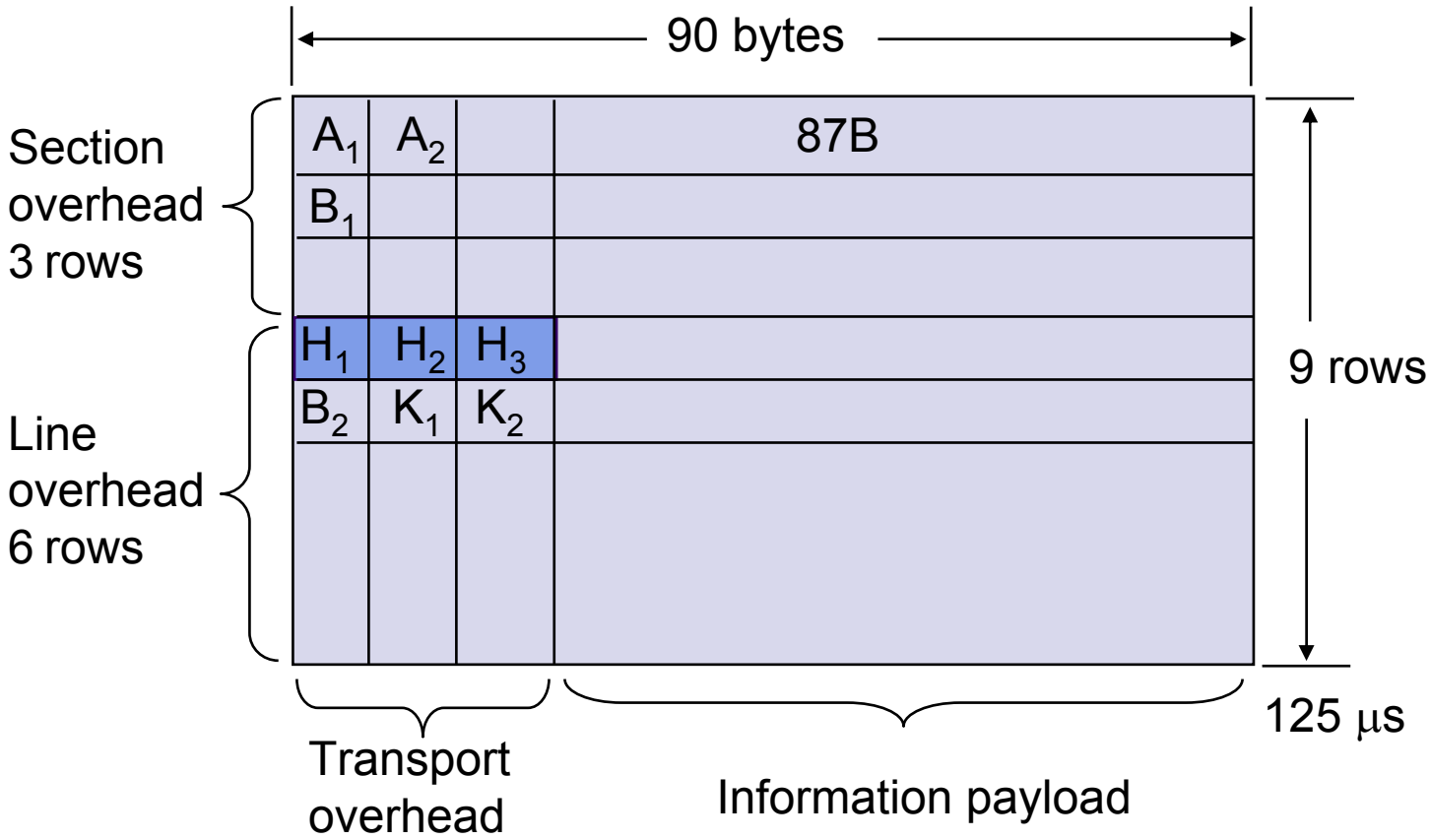
(a)

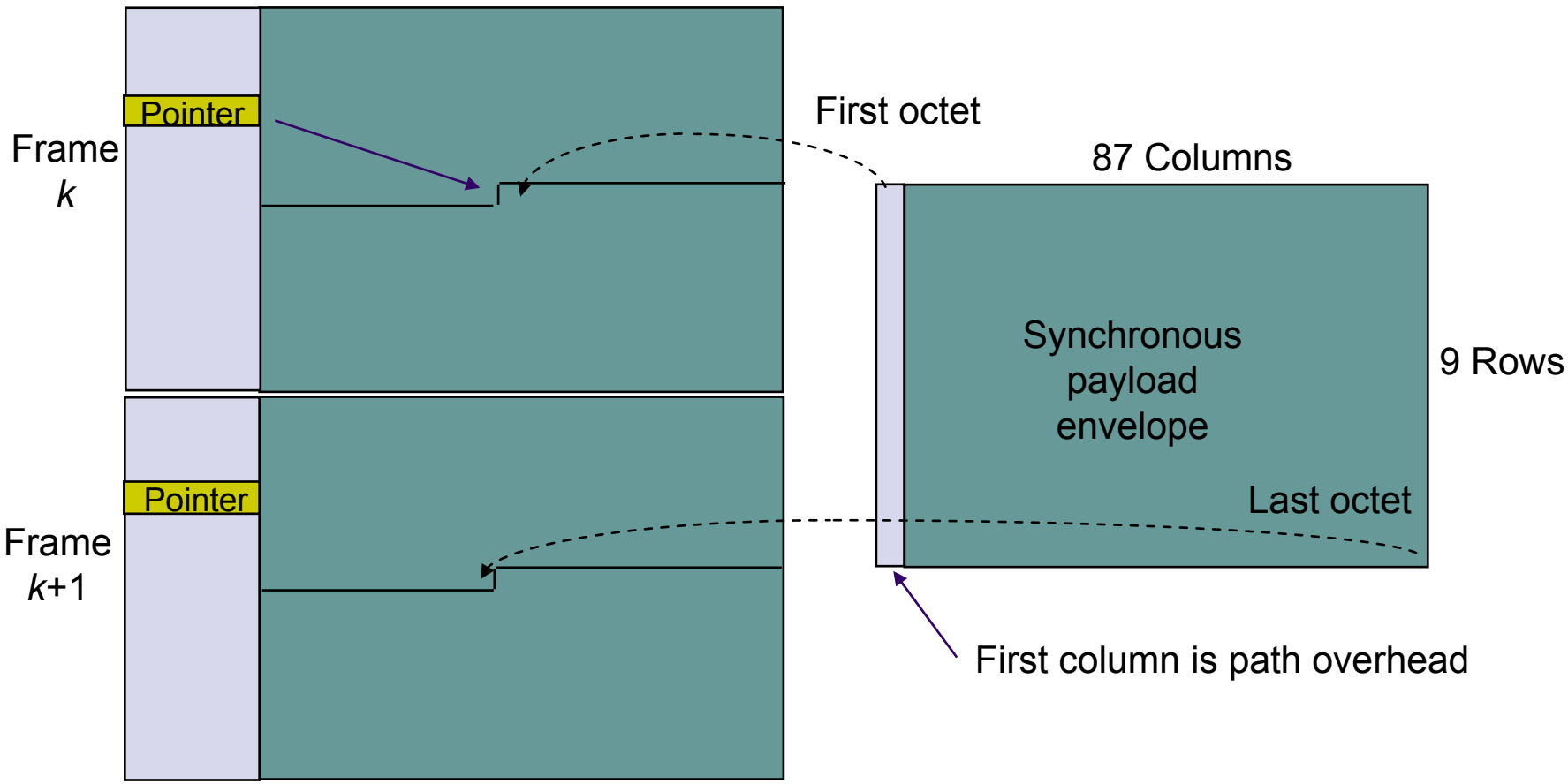


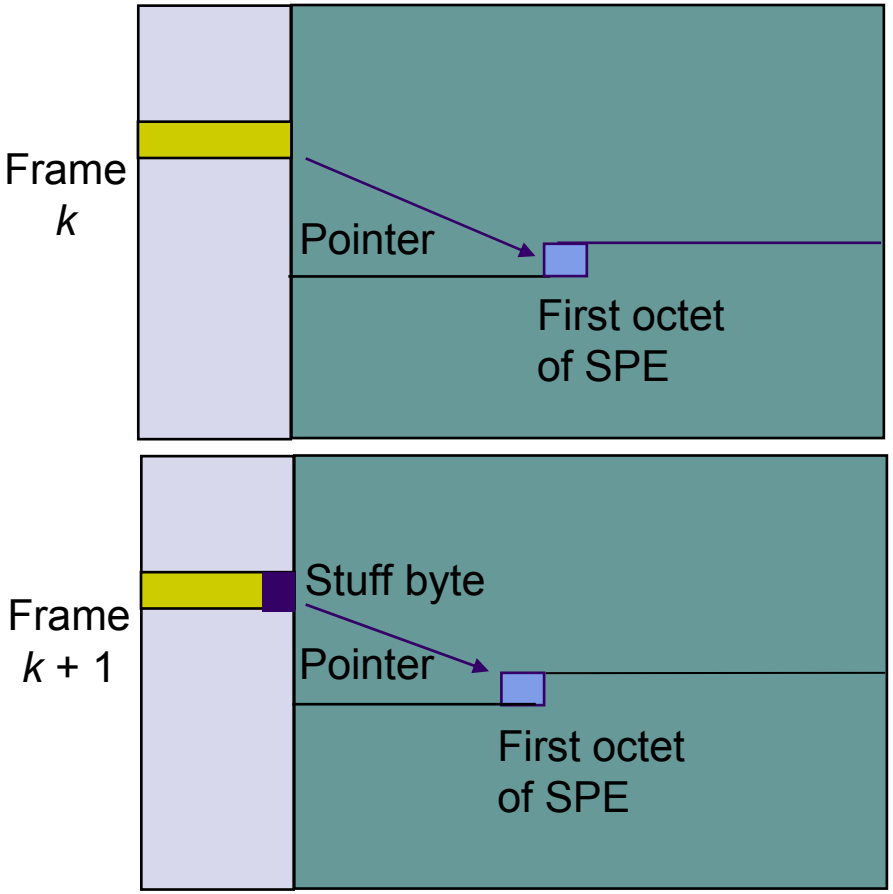
STE = Section Terminating Equipment, for example, a repeater/regenerator
LTE = Line Terminating Equipment, for example, a STS-1 to STS-3 multiplexer
PTE = Path Terminating Equipment, for example, an STS-1 multiplexer

(b)

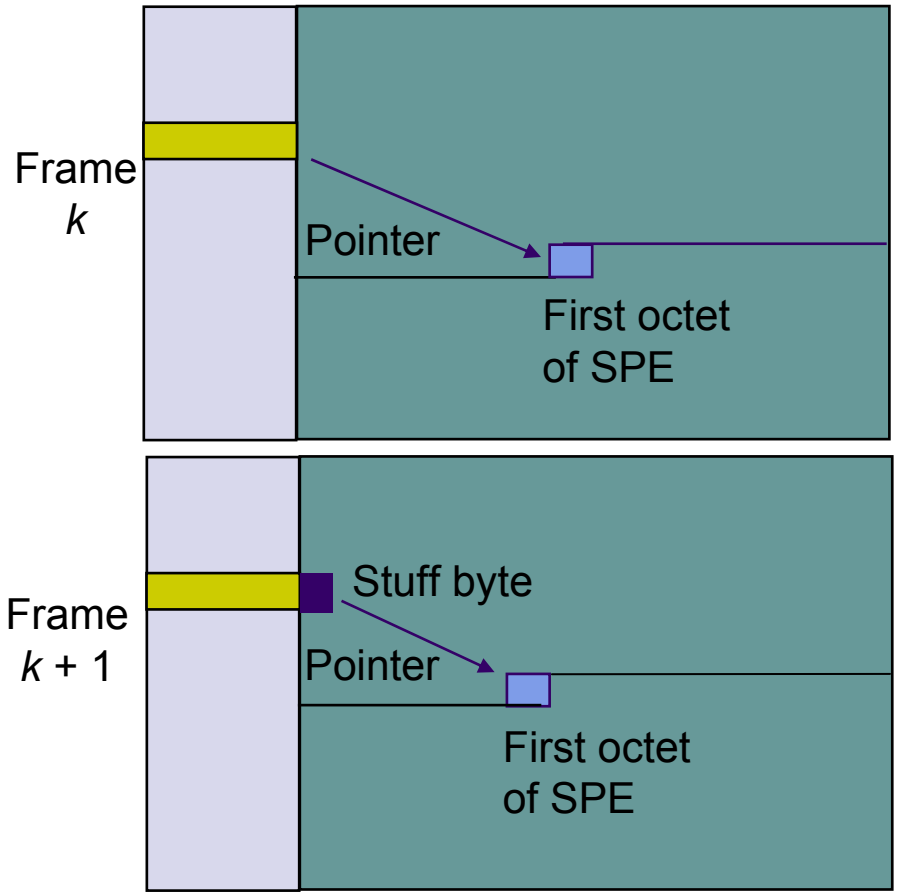



90 bytes
Section overhead 3 rows
Line overhead 6 rows
A1
A2
87B
B1
H1
H2
H3
B2
K1
K2
9 rows
125 μs
Transport overhead
Information payload

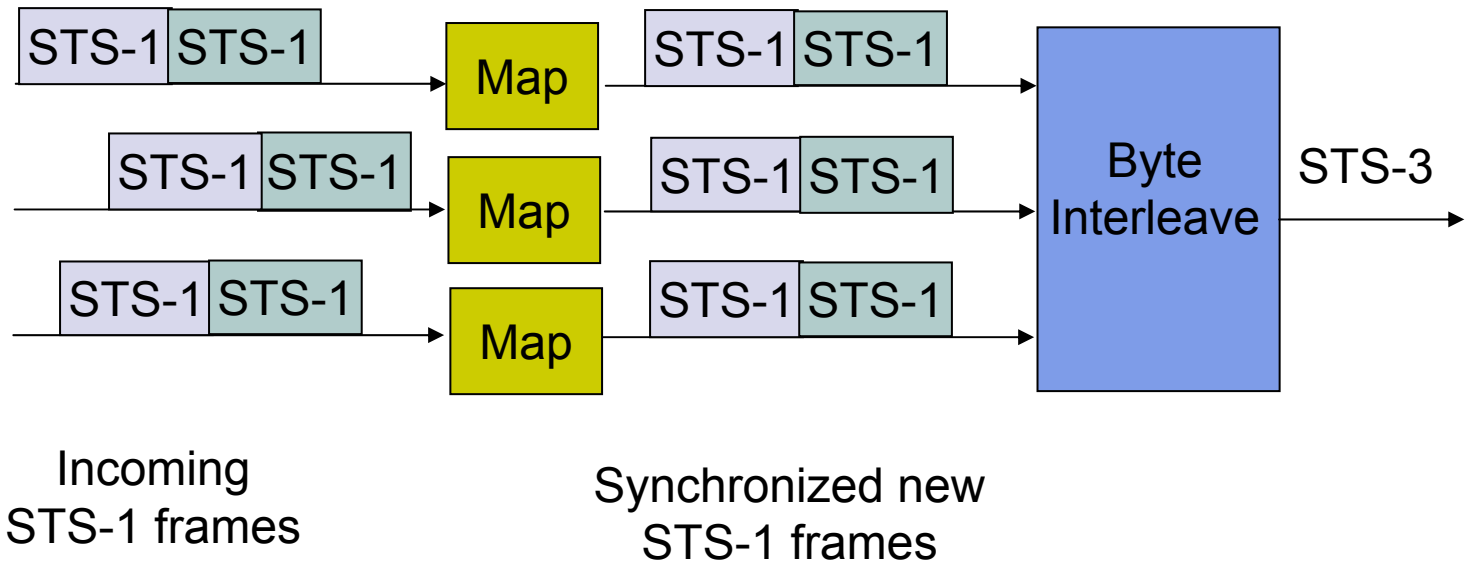

Pointer
Frame
k
First octet
87 Columns
Synchronous
payload
envelope
9 Rows
Last octet
Pointer
Frame
k+1
First column is path overhead

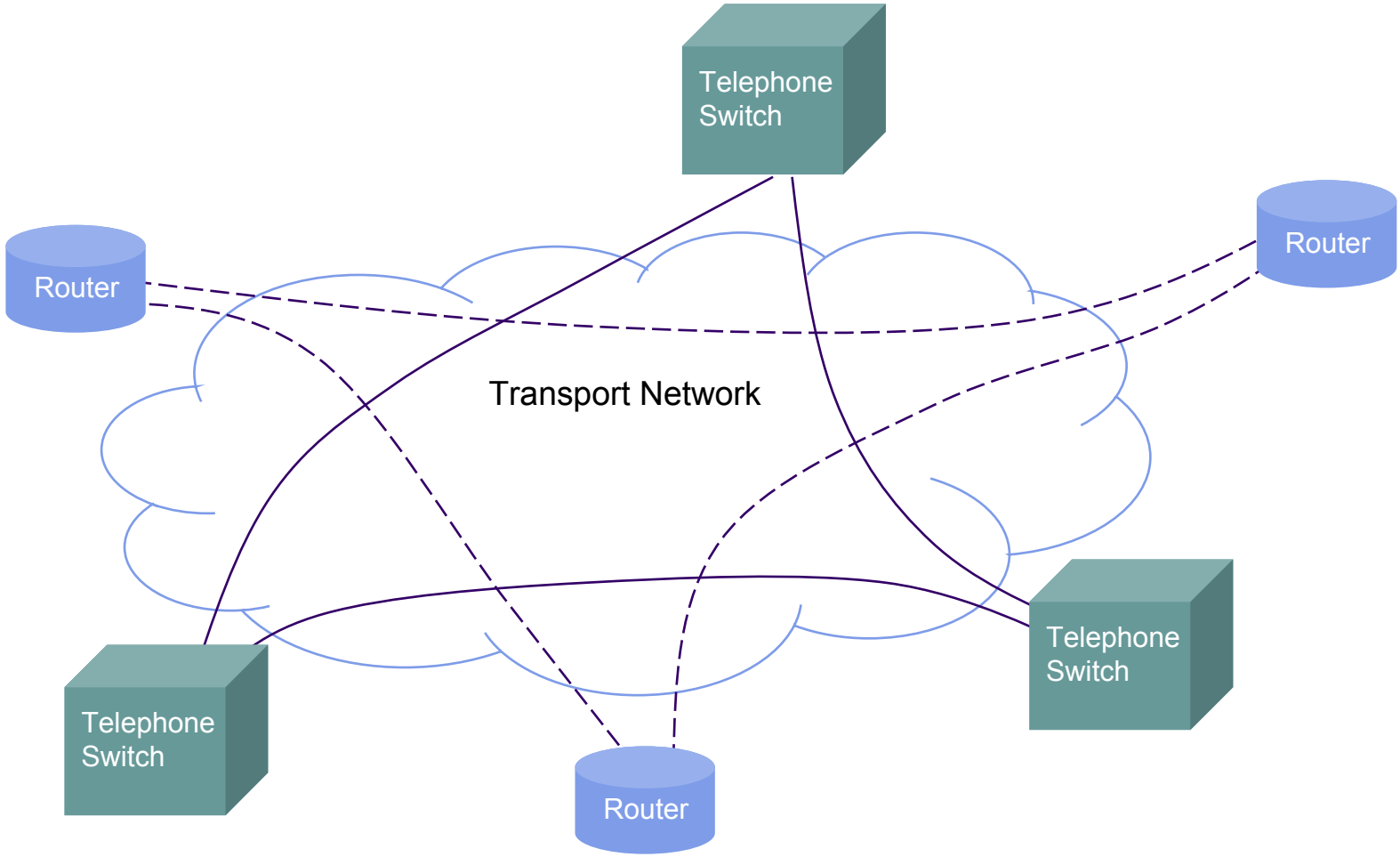


(a) Negative byte stuffing

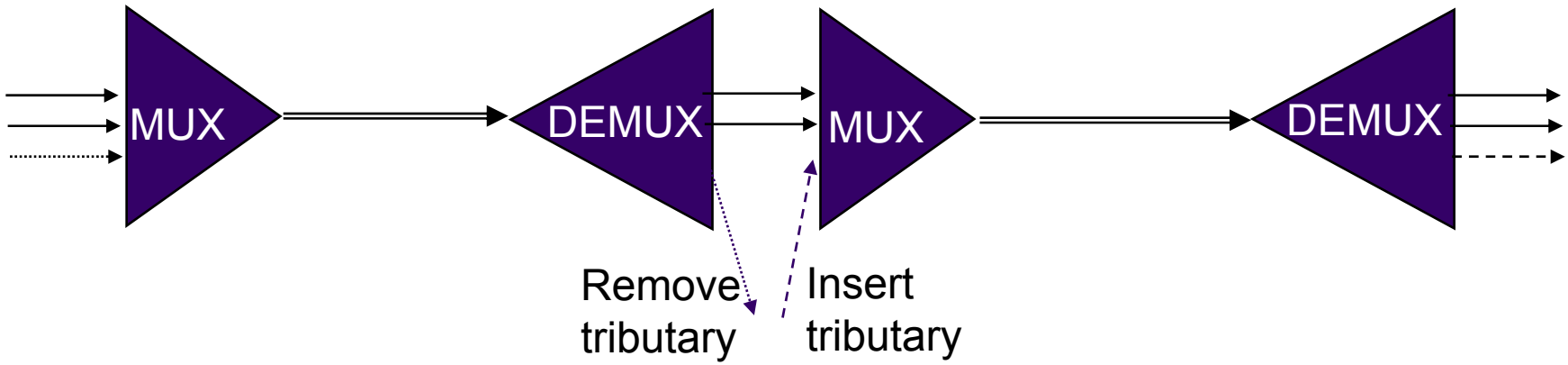


(b) Positive byte stuffing

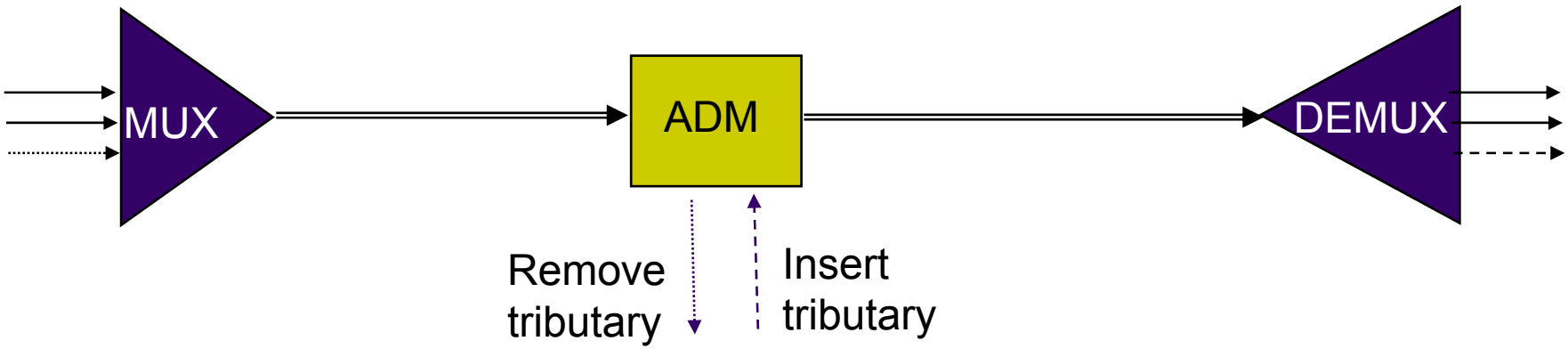

STS-1
STS-1
STS-1
STS-1
STS-1
STS-1
Map
Map
Map
STS-1
STS-1
STS-1
STS-1
STS-1
STS-1
Byte
Interleave
STS-3
Incoming
STS-1 frames
Synchronized new
STS-1 frames

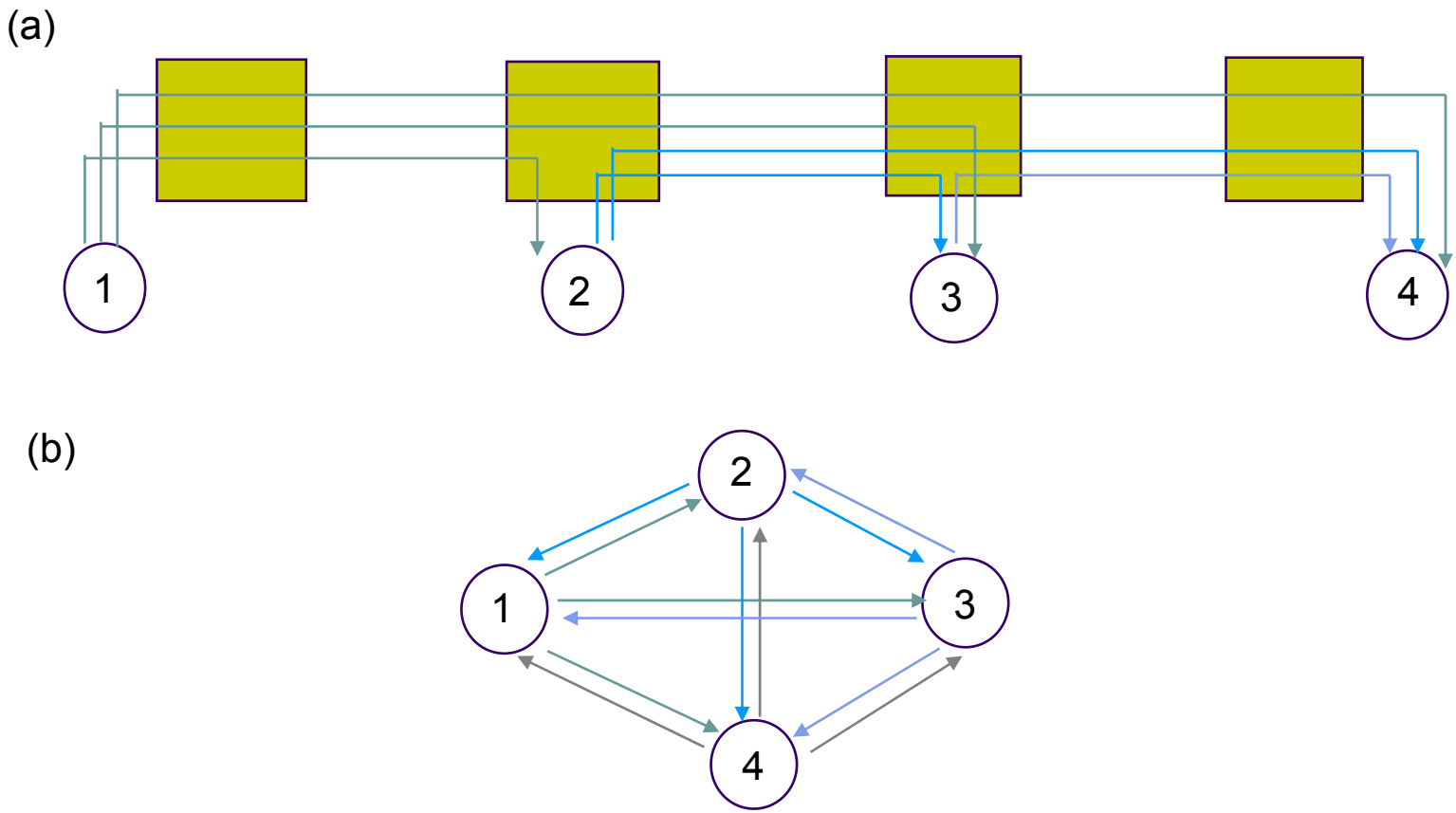

Telephone Switch
Router
Router
Transport Network
Telephone Switch
Telephone Switch
Router

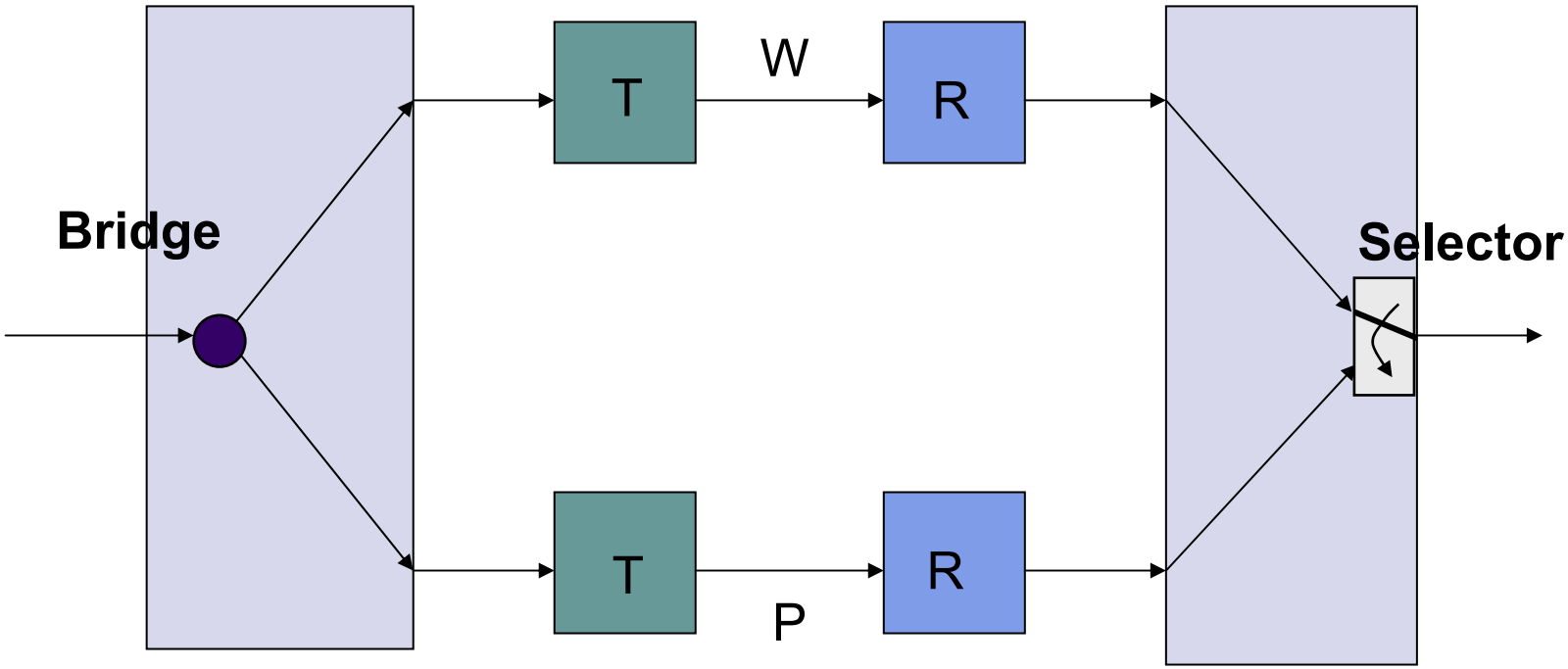
(a) Pre-SONET multiplexing



(b) SONET add-drop multiplexing

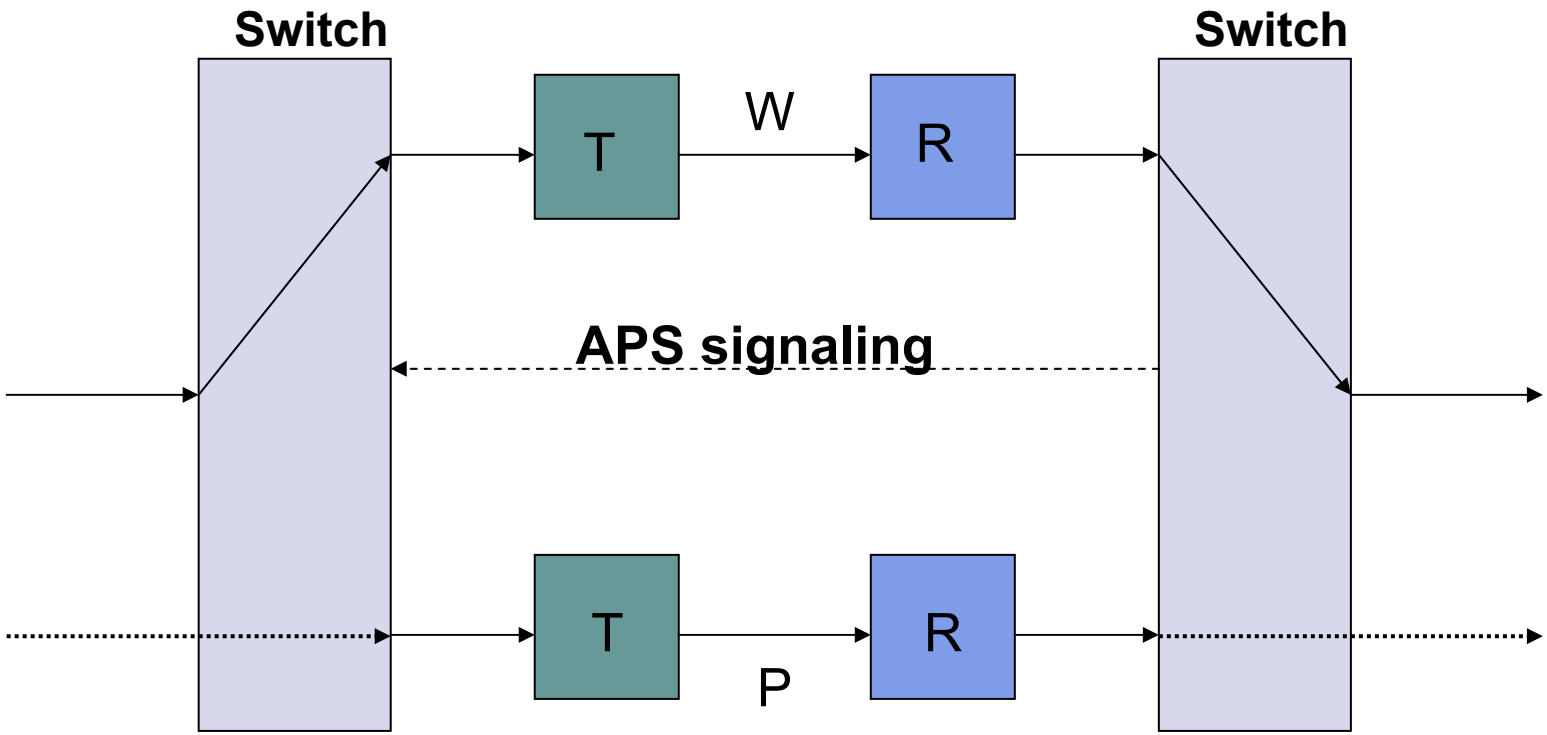


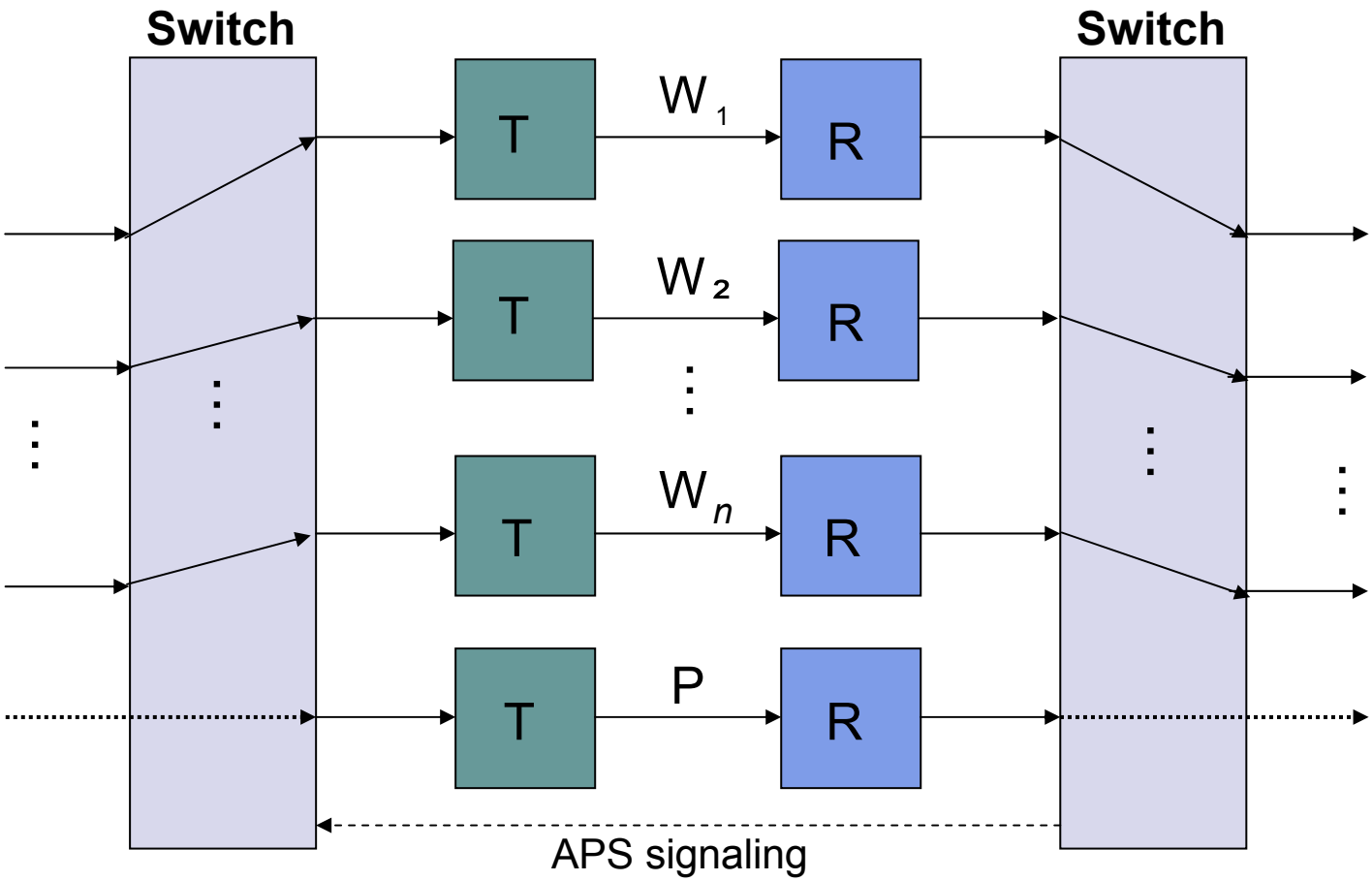

(a)
1
2
3
4
(b)
2
1
3
4



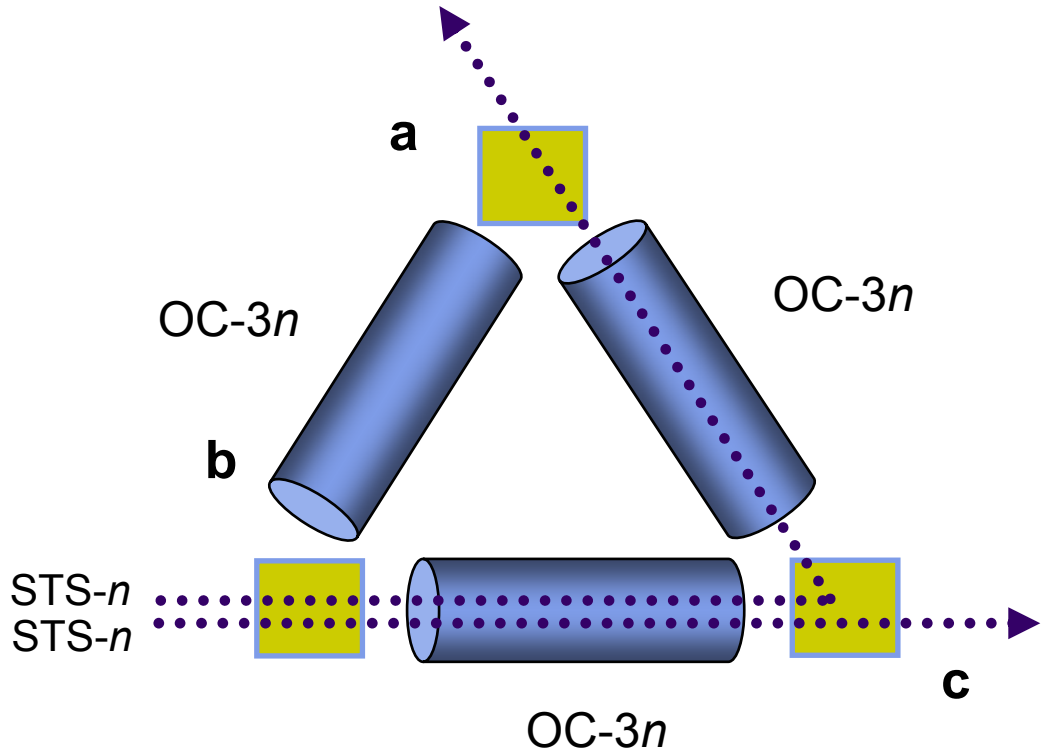
T = Transmitter W = Working line

R = Receiver P = Protection line

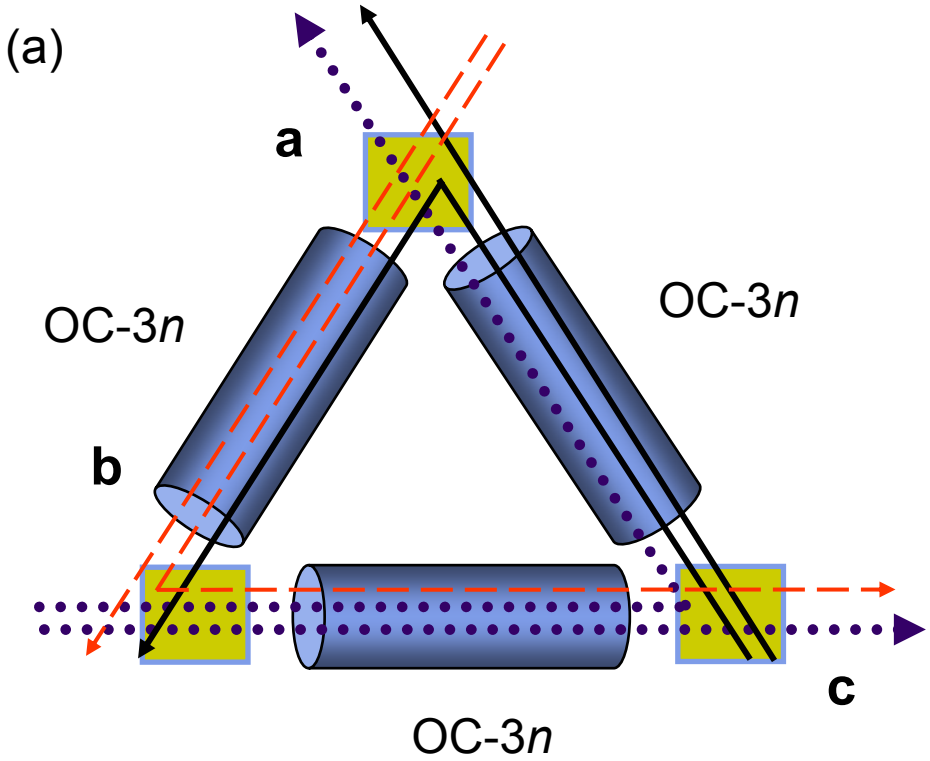

Switch
Switch
T
W
R
APS signaling
T
R
P
T = Transmitter
R = Receiver
W = Working line
P = Protection line



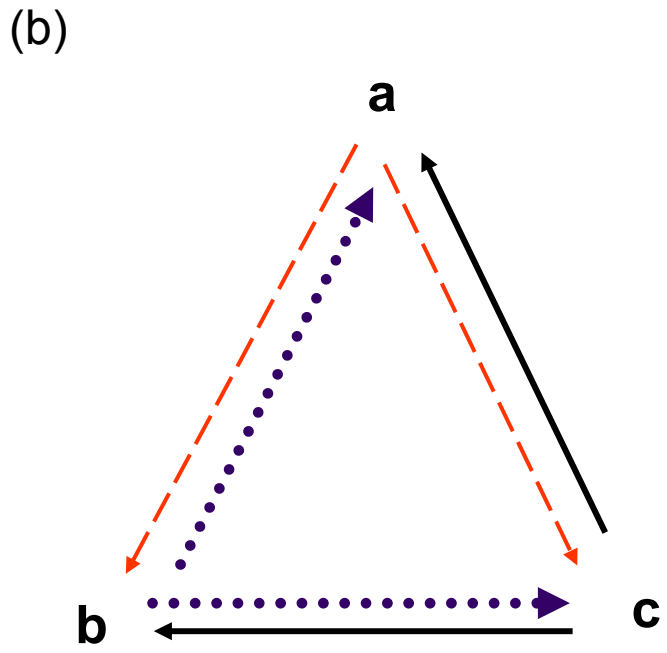
T = Transmitter W = Working line
R = Receiver P = Protection line



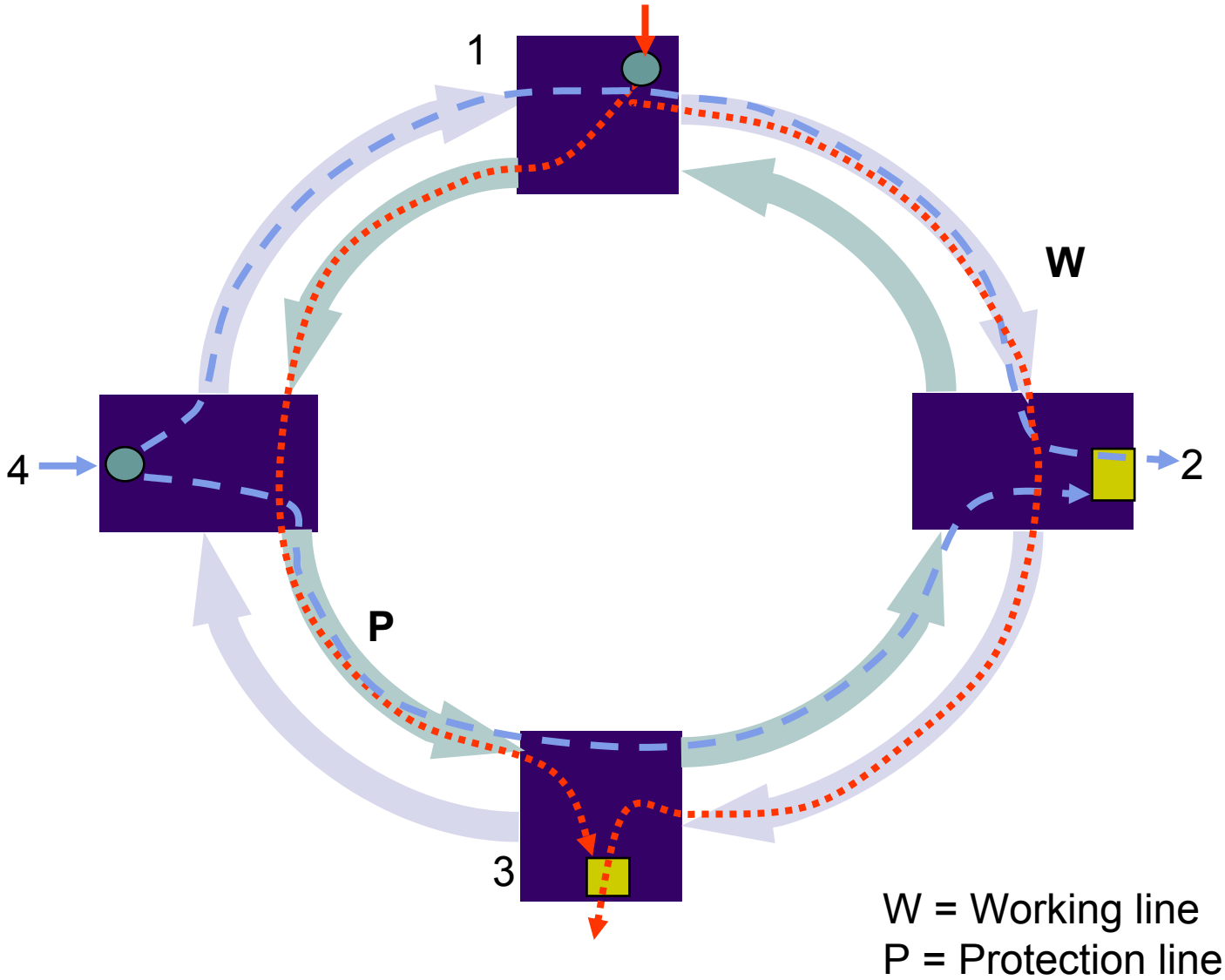
Physical ring topology

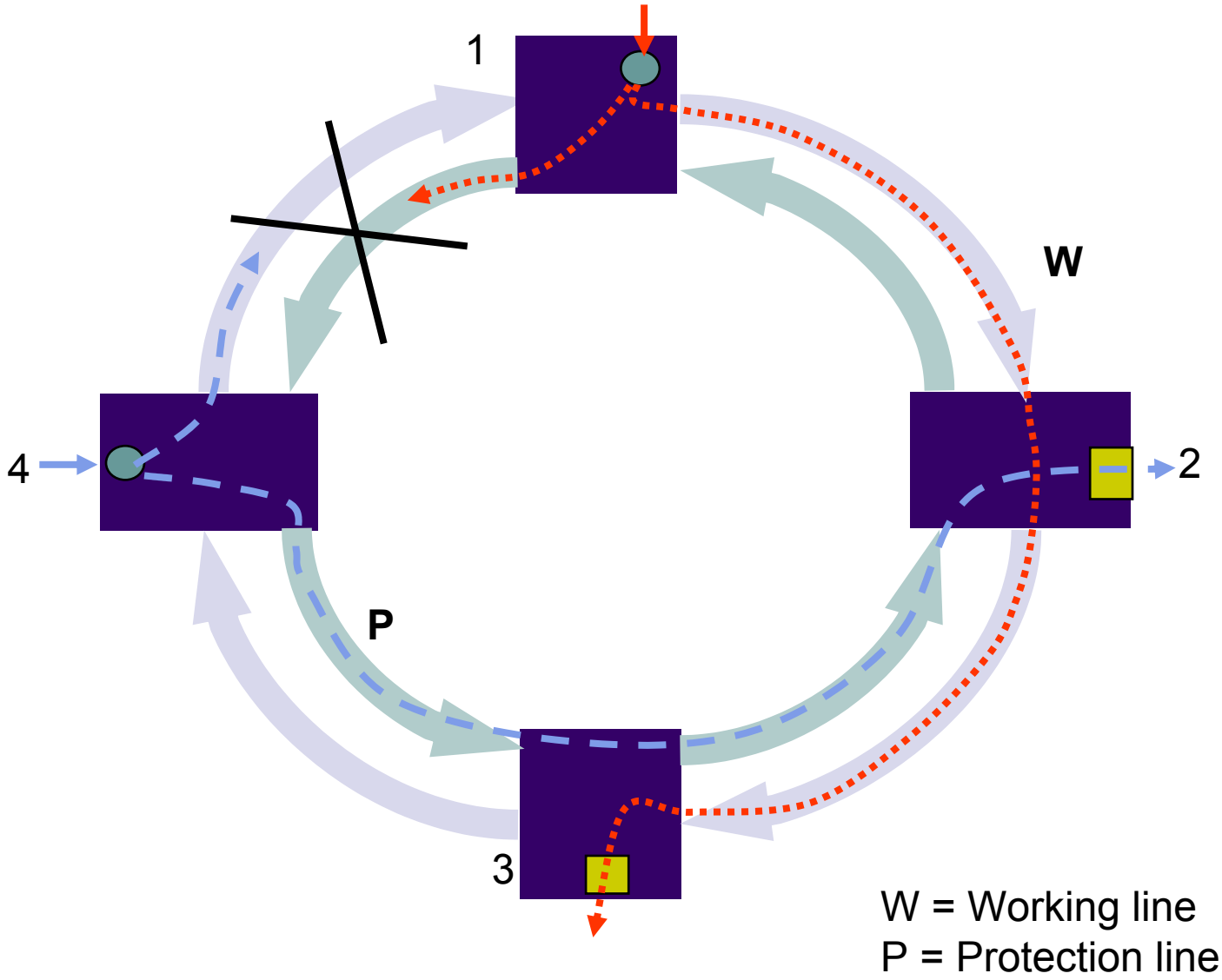


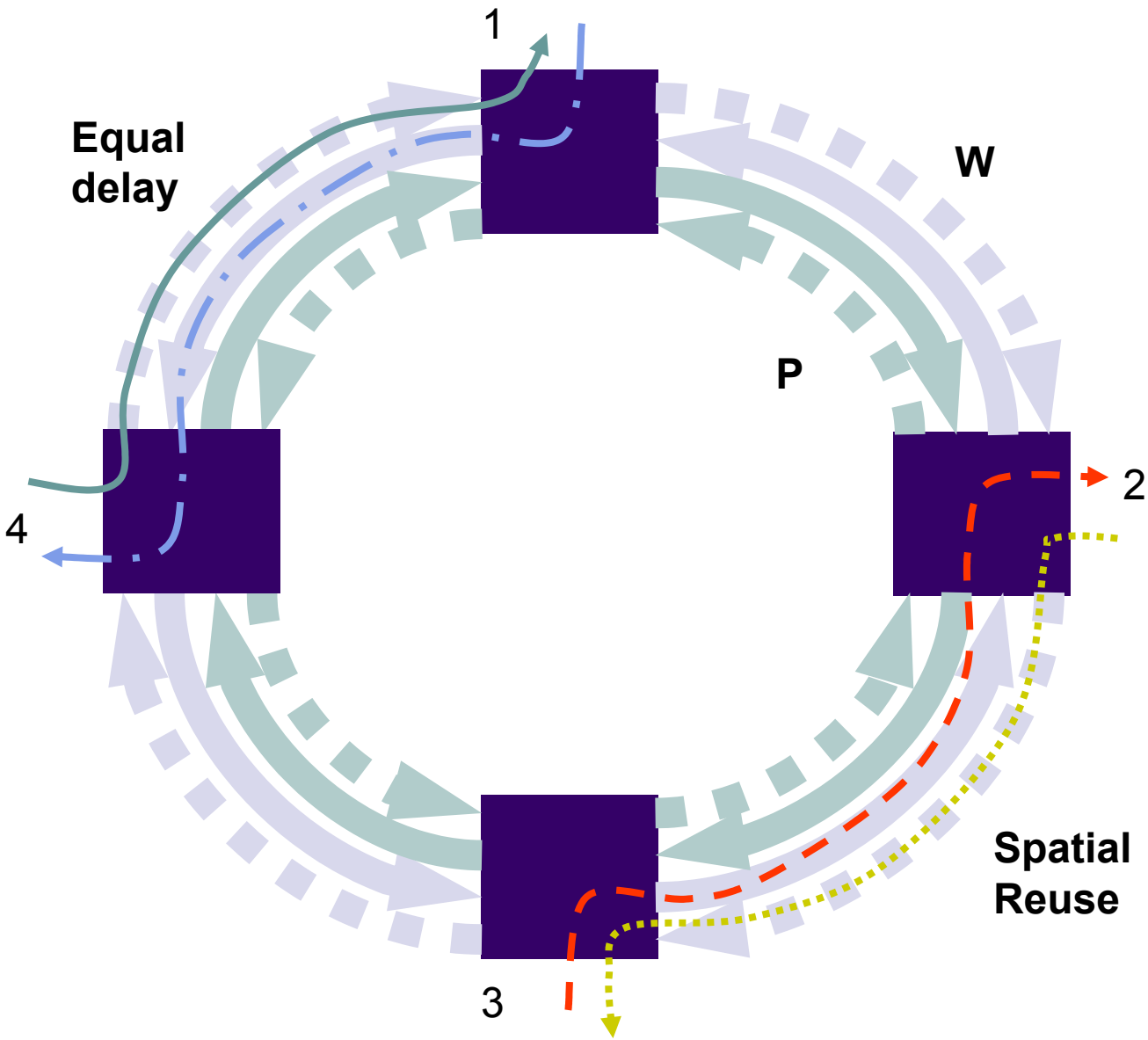
Three ADMs connected in physical ring topology

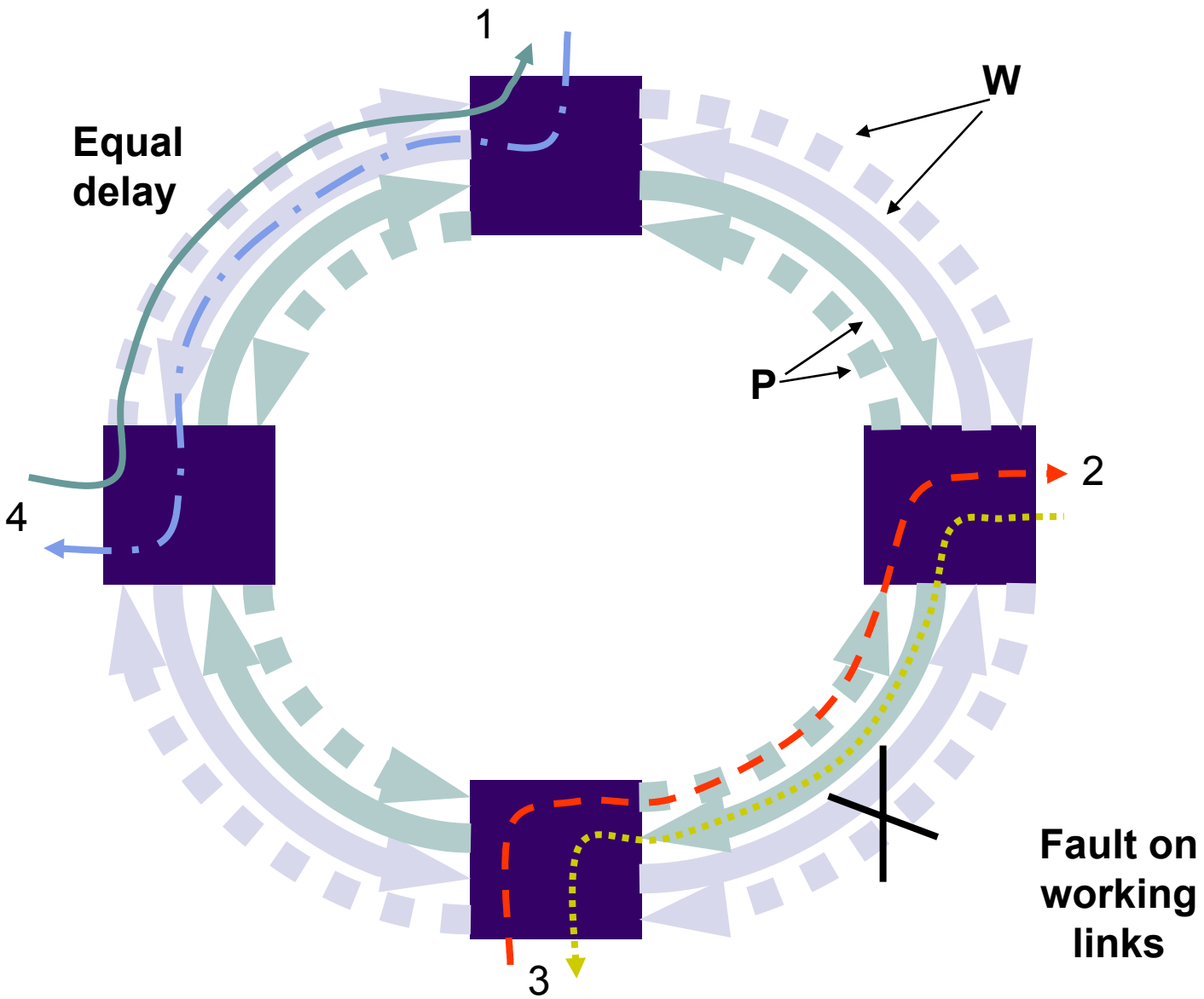


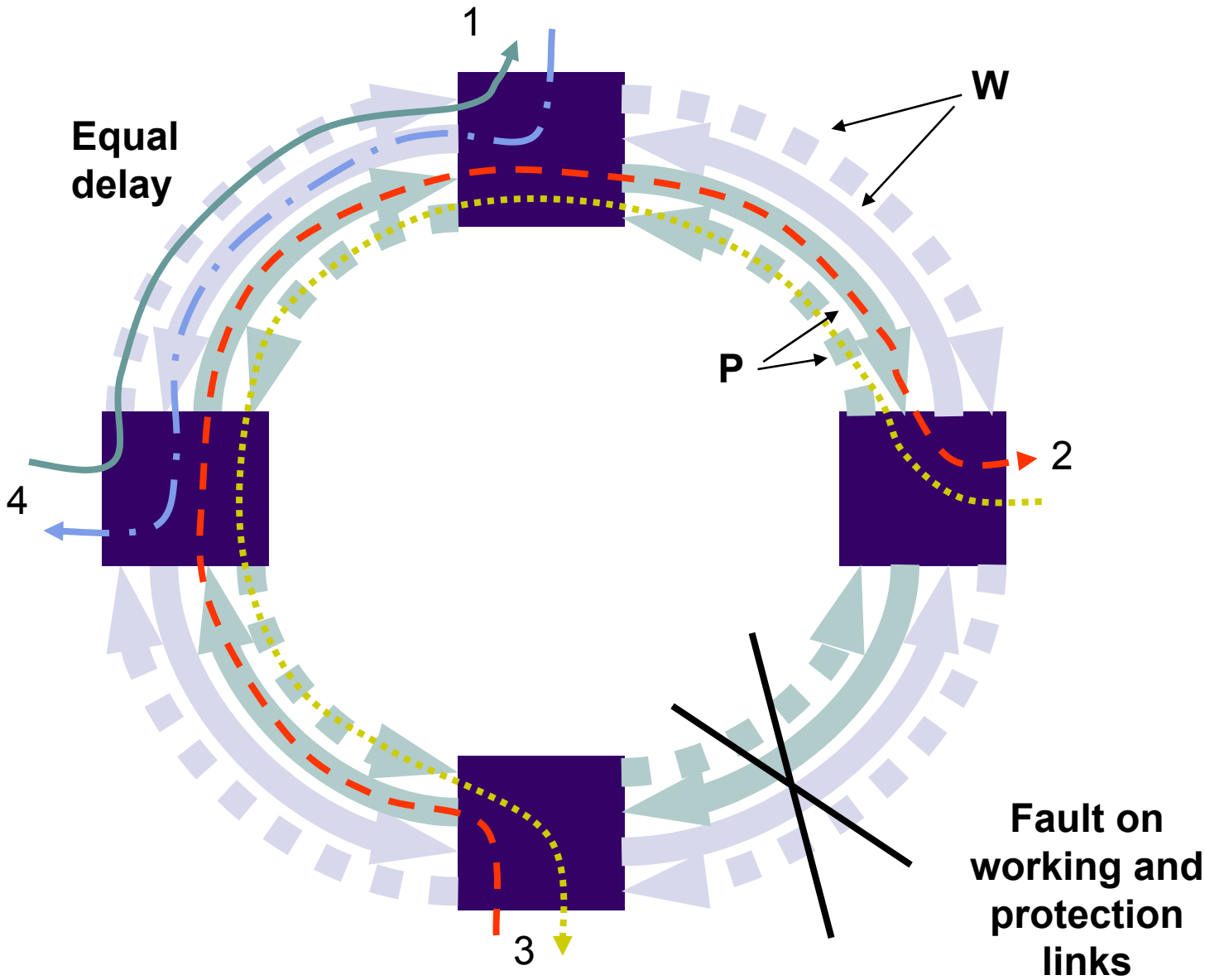
Logical fully connected topology

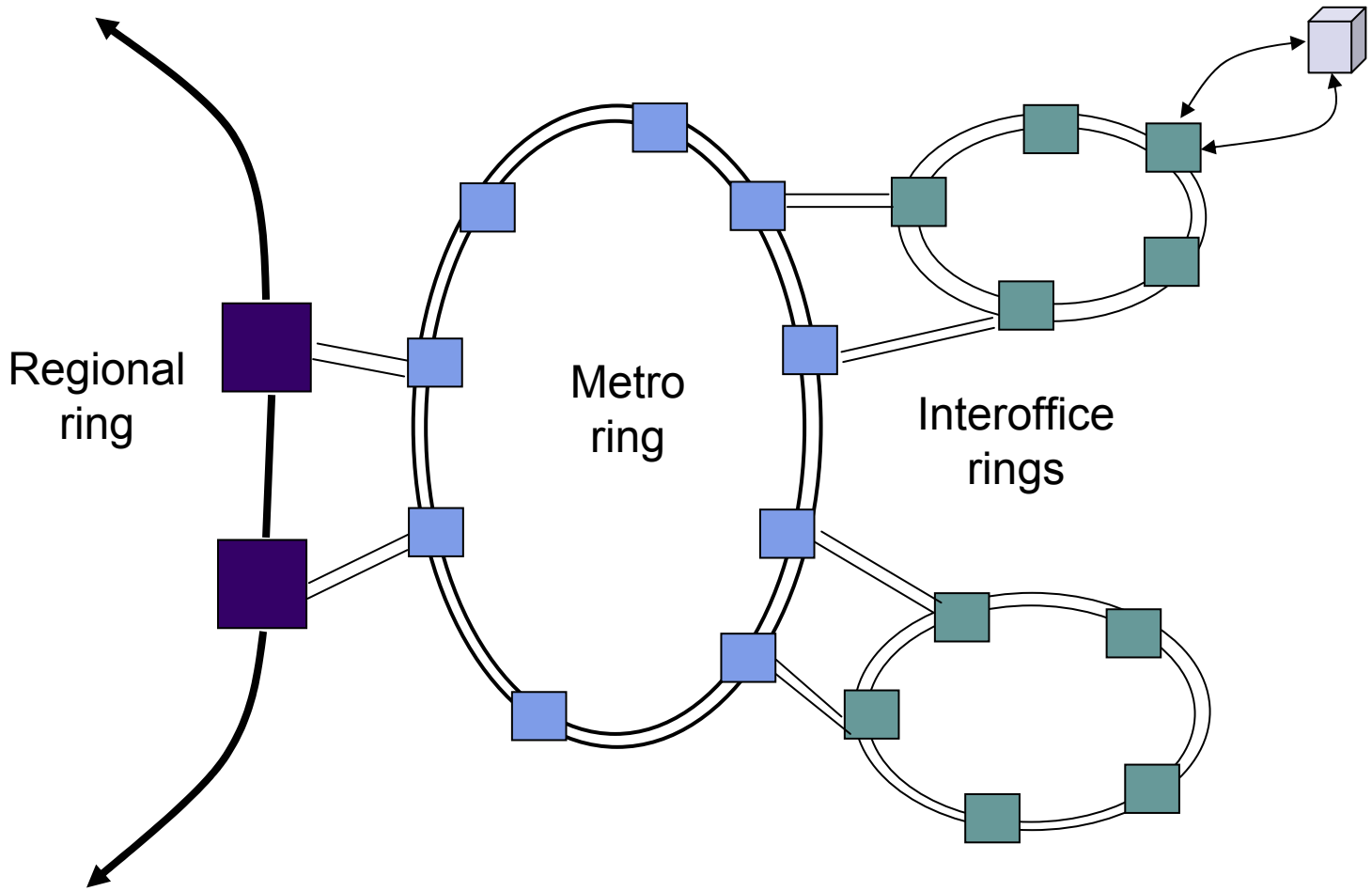

1
2
3
4
W
P
W = Working line
P = Protection line

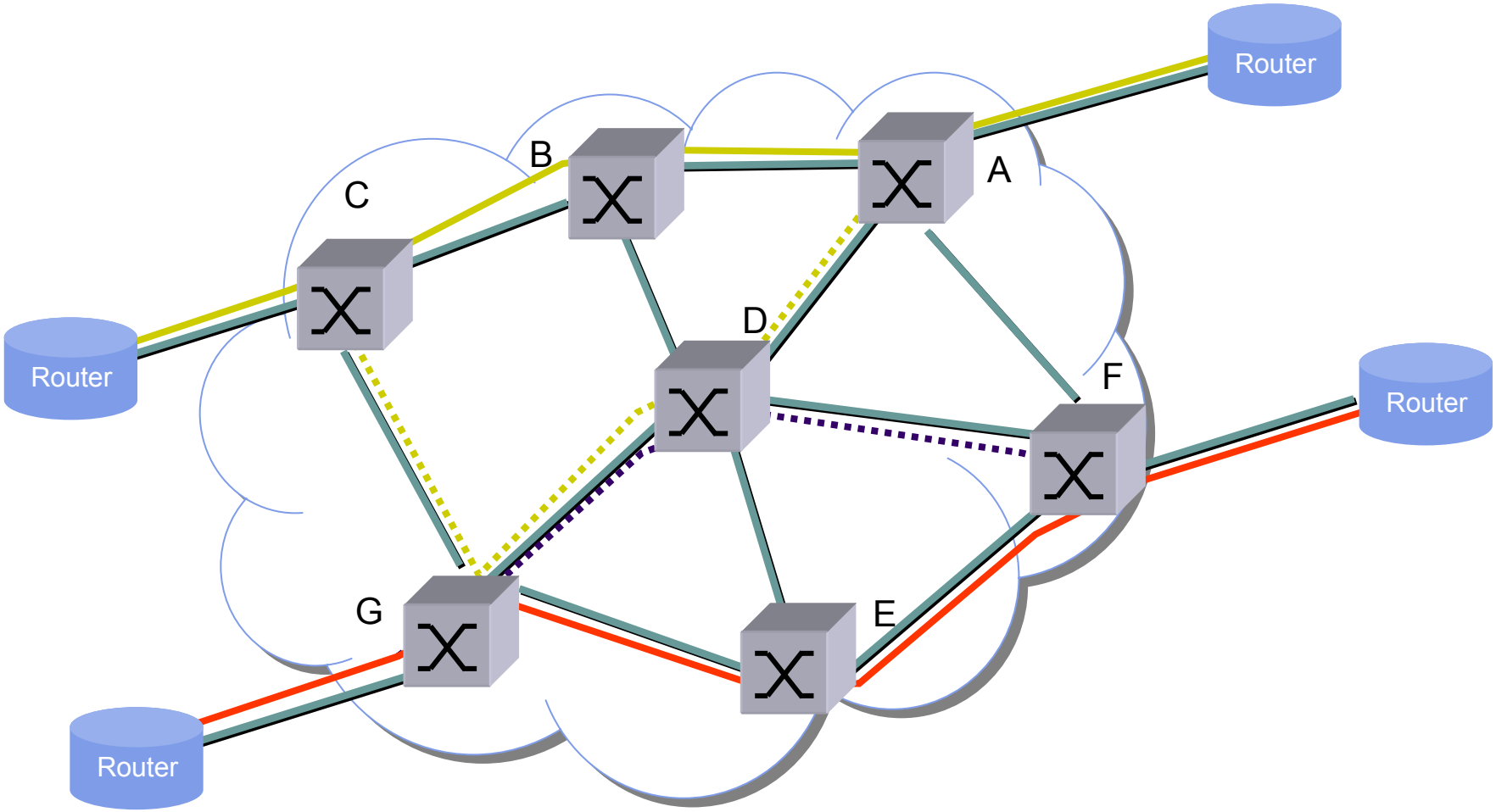

1
2
3
4
W
P
W = Working line
P = Protection line


1
Equal
delay
W
P
2
4
3
Spatial
Reuse

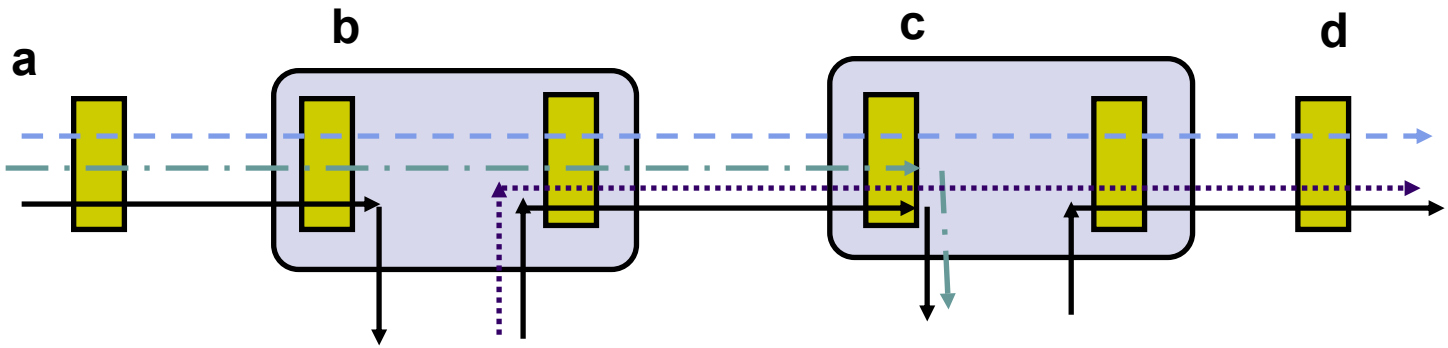

1
W
Equal
delay
P
2
4
3
Fault on
working
links


1
Equal
delay
W
P
2
4
3
Fault on
working and
protection
links

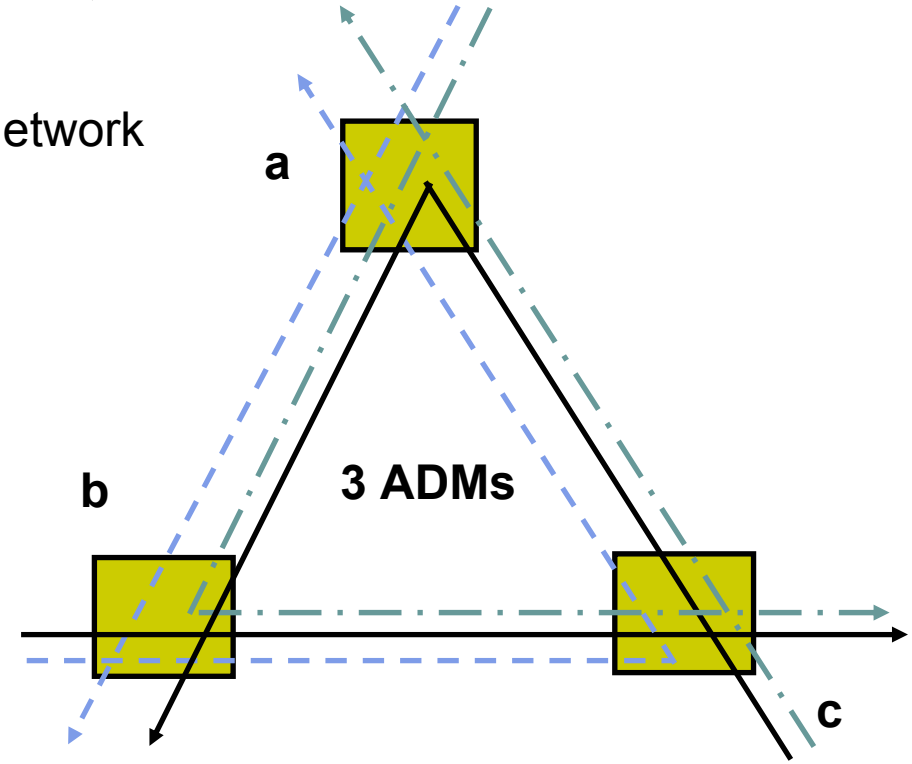

Regional ring
Metro ring
Interoffice rings

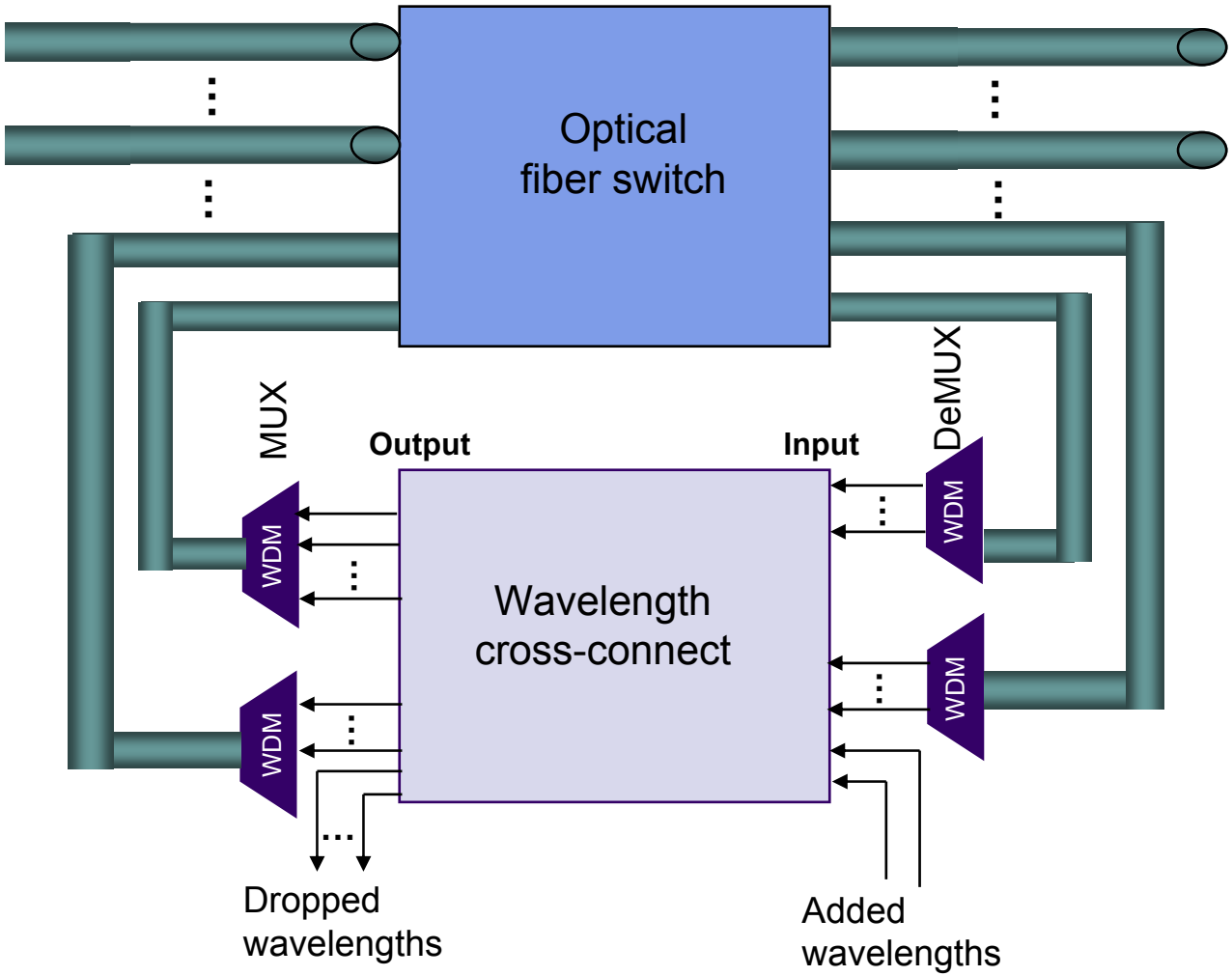

Router
Router
Router
Router
A
B
C
D
E
F
G

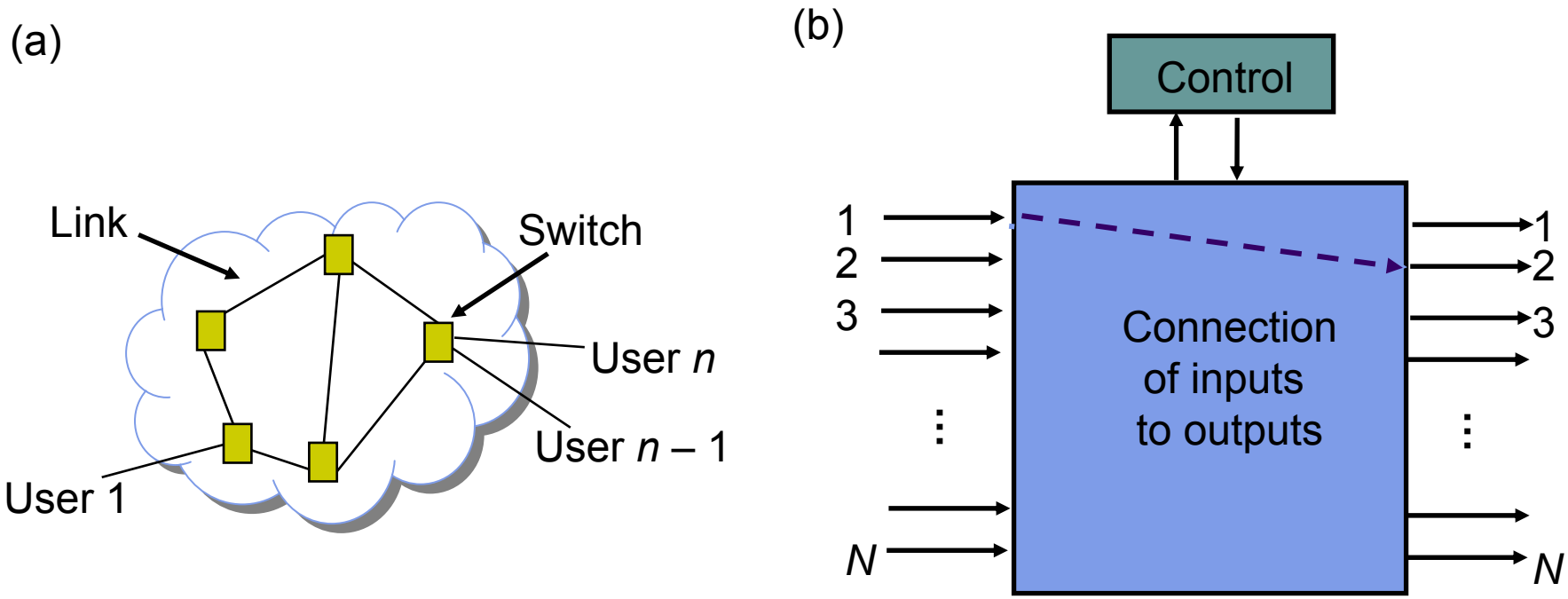
(a) WDM chain network

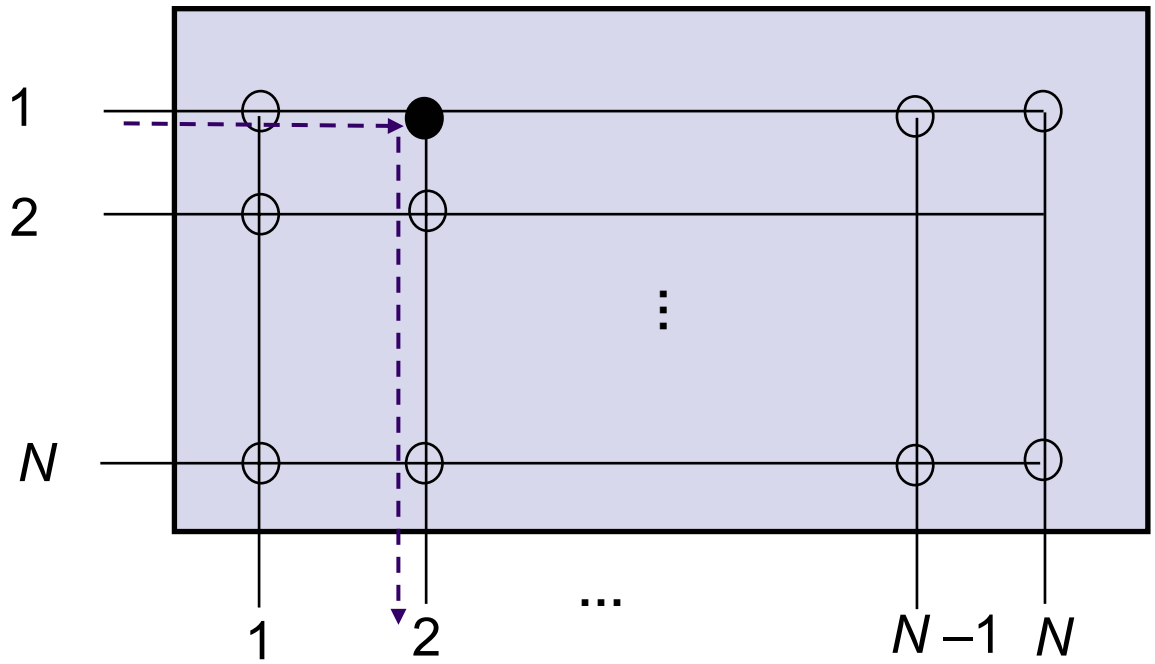


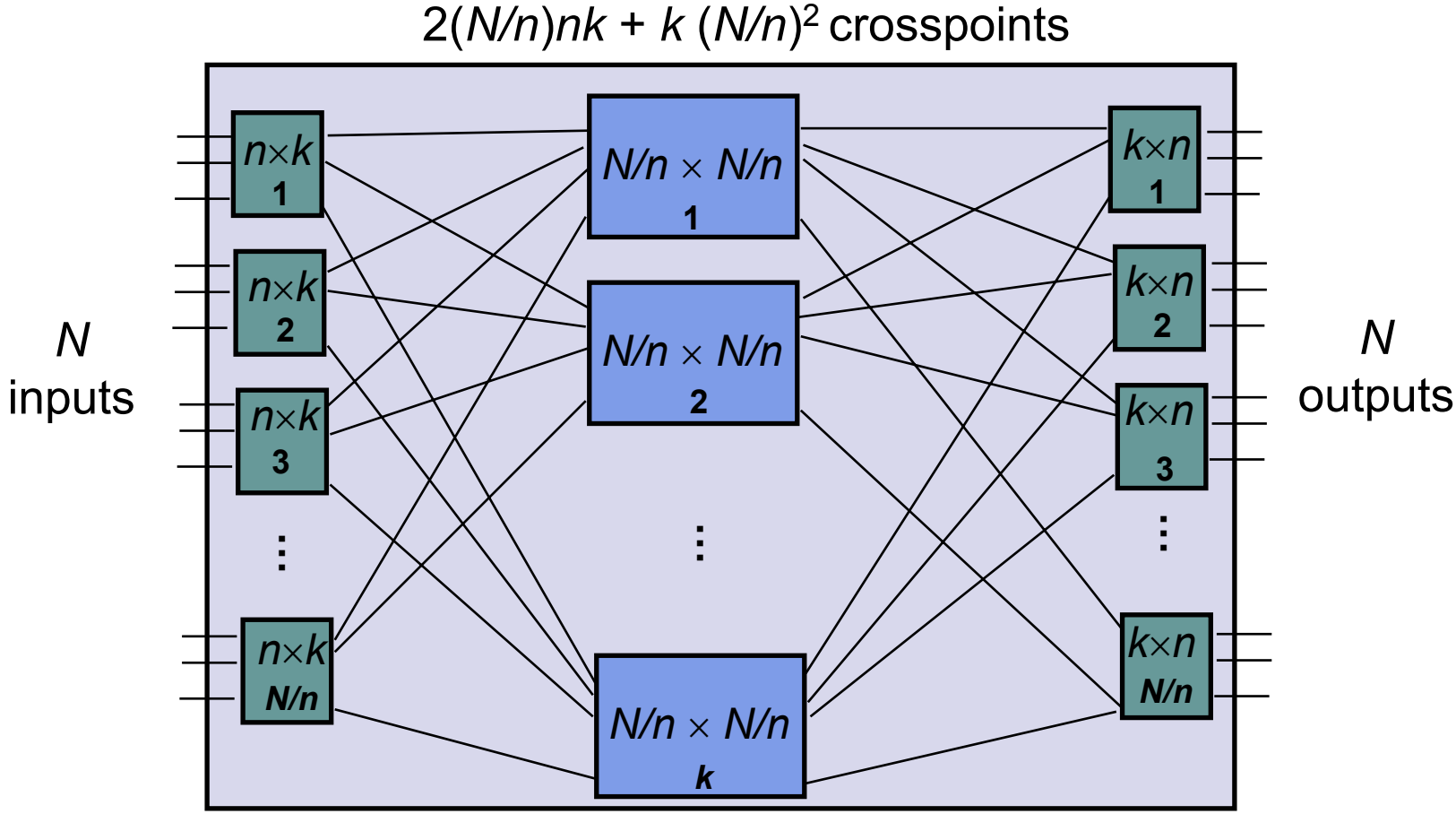
(b) WDM ring network

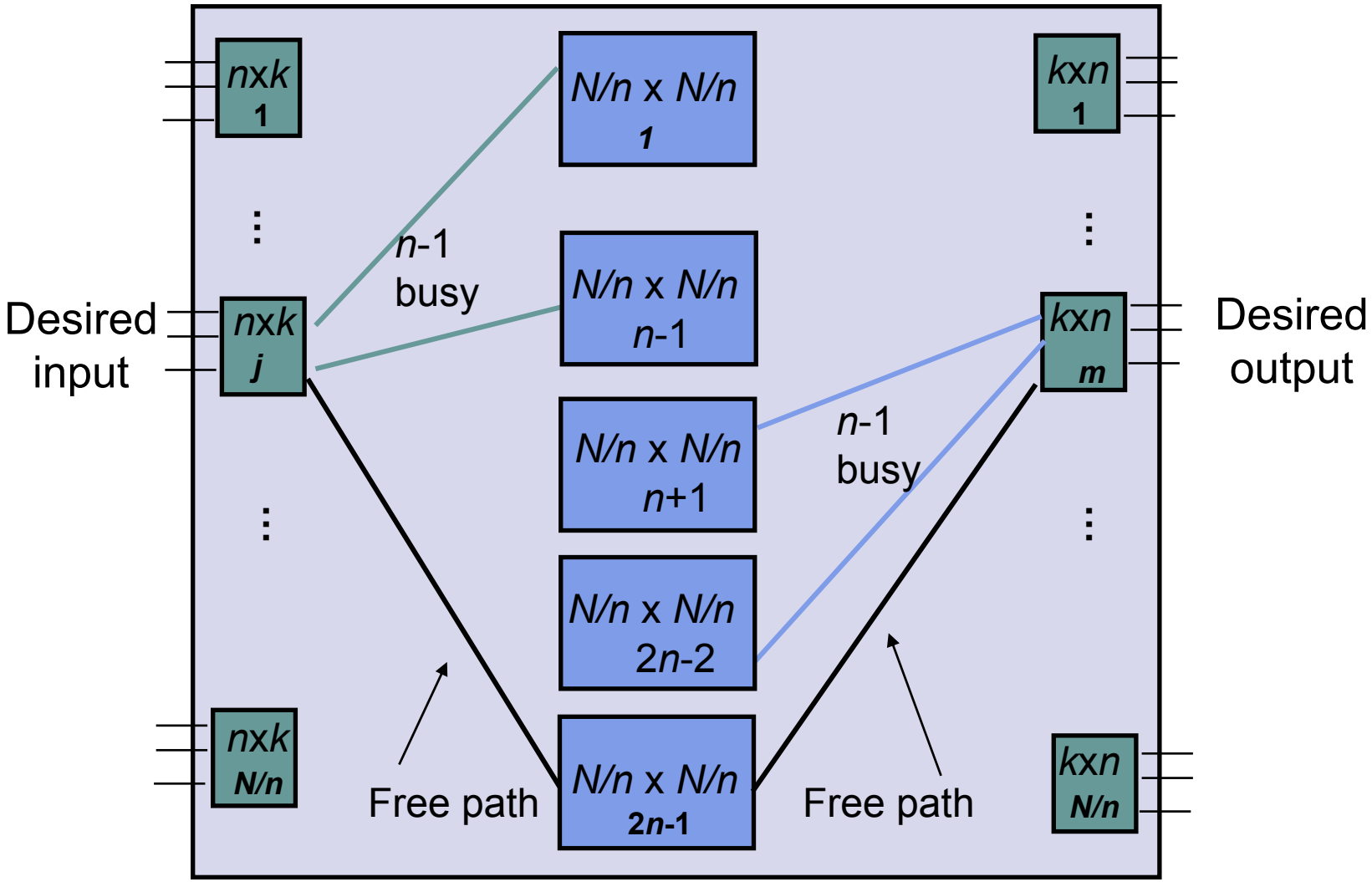


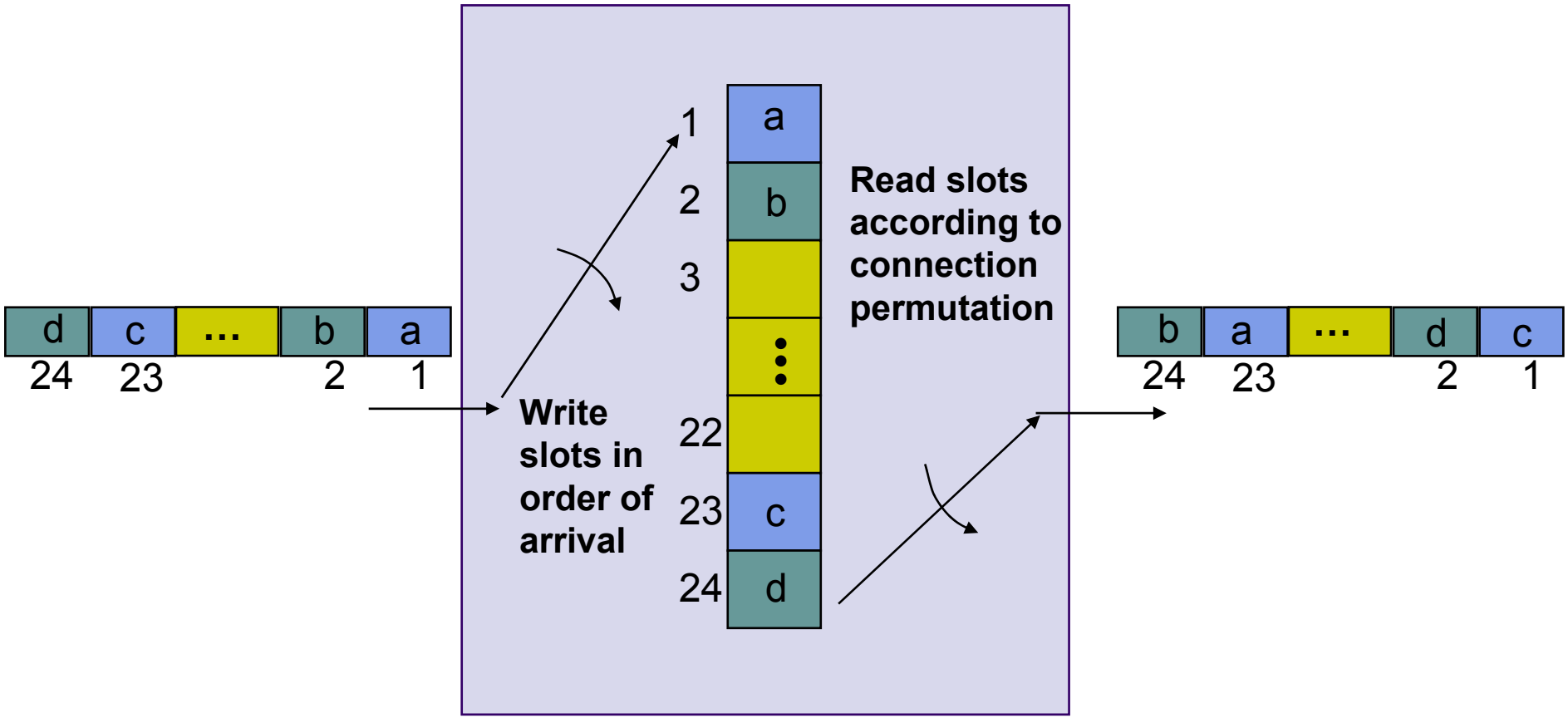

Optical
fiber switch
MUX
DeMUX
Output
Input
WDM
WDM
WDM
WDM
Wavelength
cross-connect
Dropped
wavelengths
Added
wavelengths


(a)
Link
Switch
User n
User n – 1
User 1
(b)
Control
1
2
3
N
Connection
of inputs
to outputs
1
2
3
N

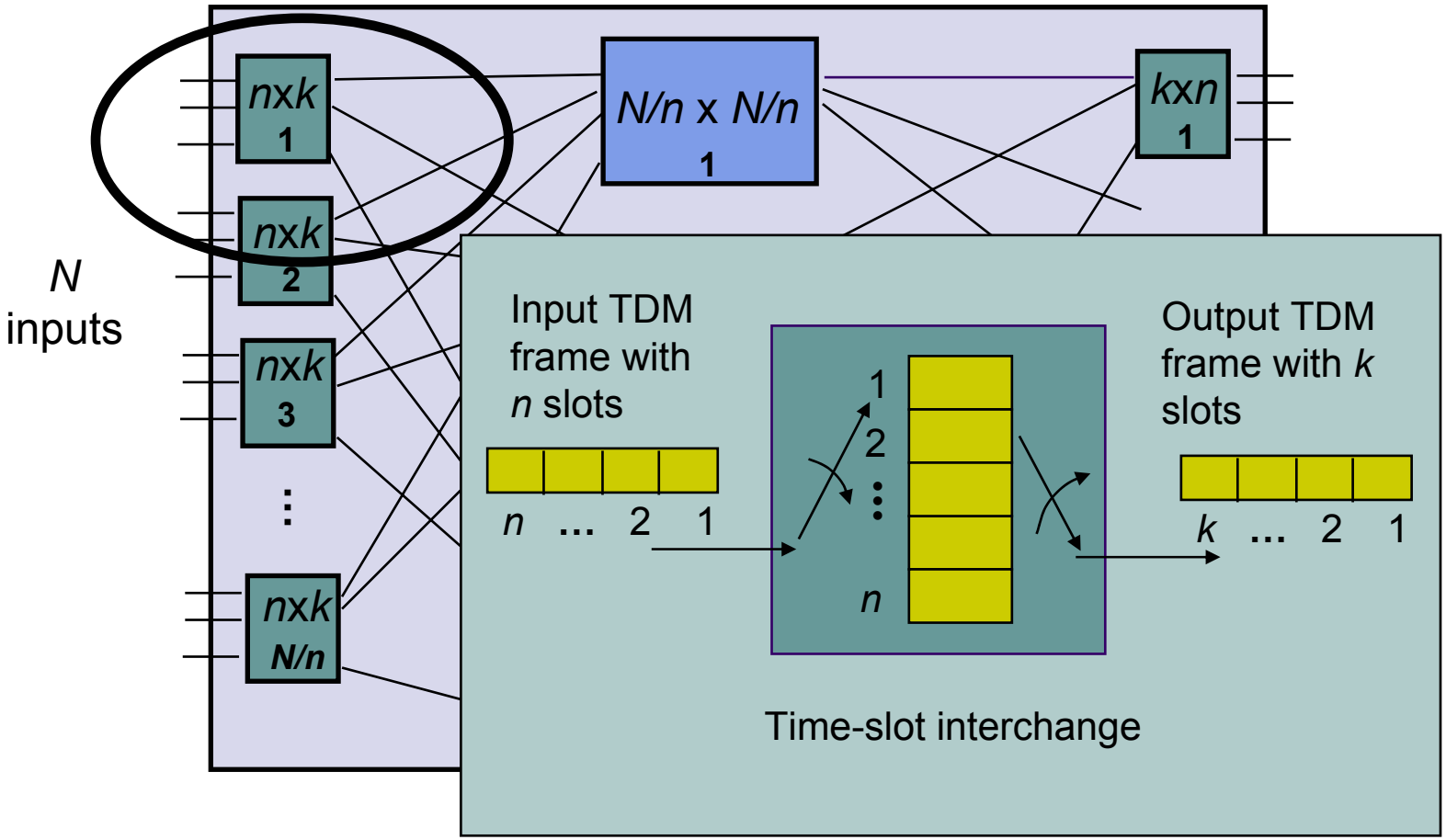

1
2
N
1
2
...
N –1
N

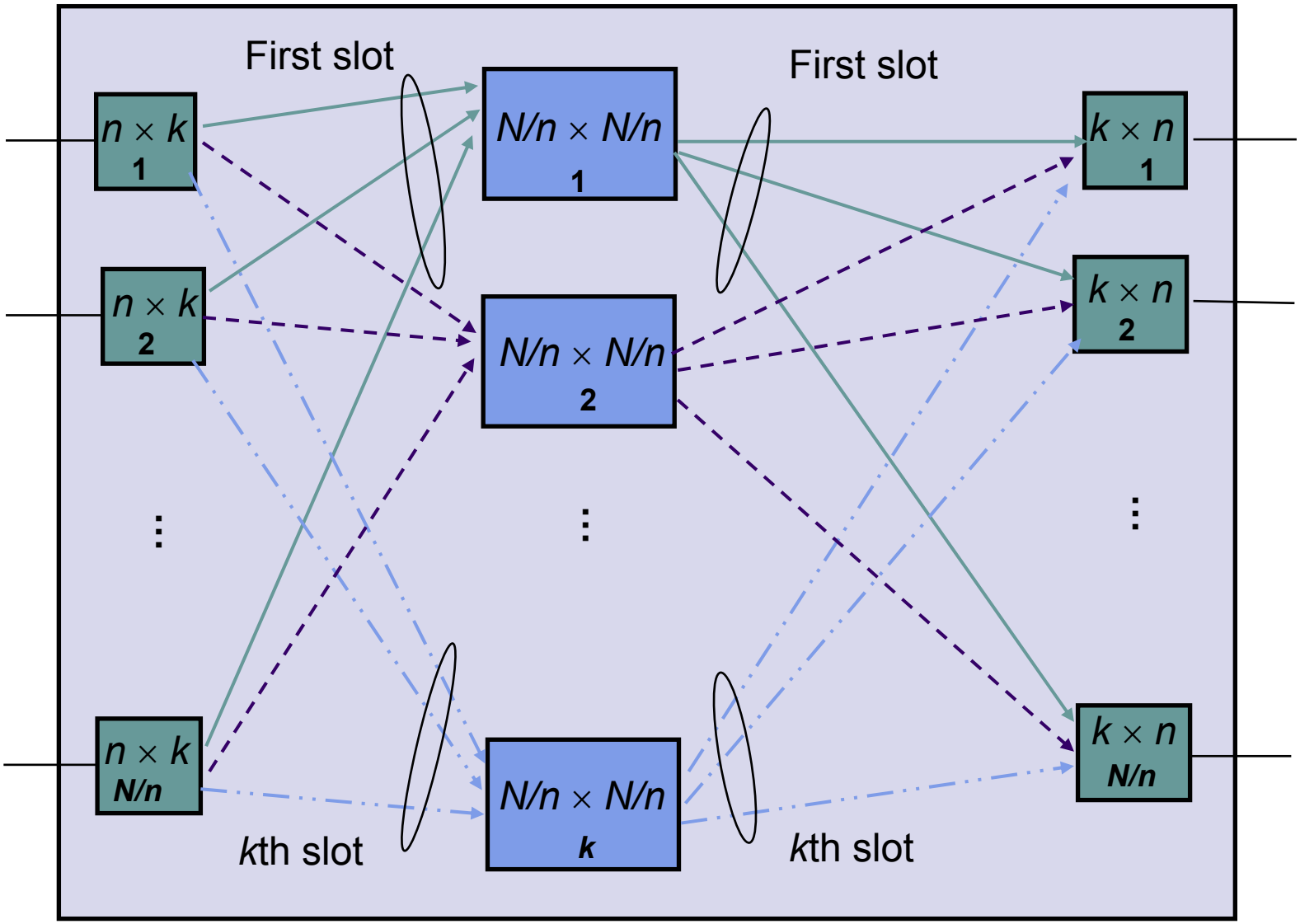

2(N/n)nk + k (N/n)2 crosspoints
N
inputs
n×k
1
n×k
2
n×k
3
n×k
N/n
N/n × N/n
1
N/n × N/n
2
N/n × N/n
k
k×n
1
k×n
2
k×n
3
k×n
N/n
N
outputs

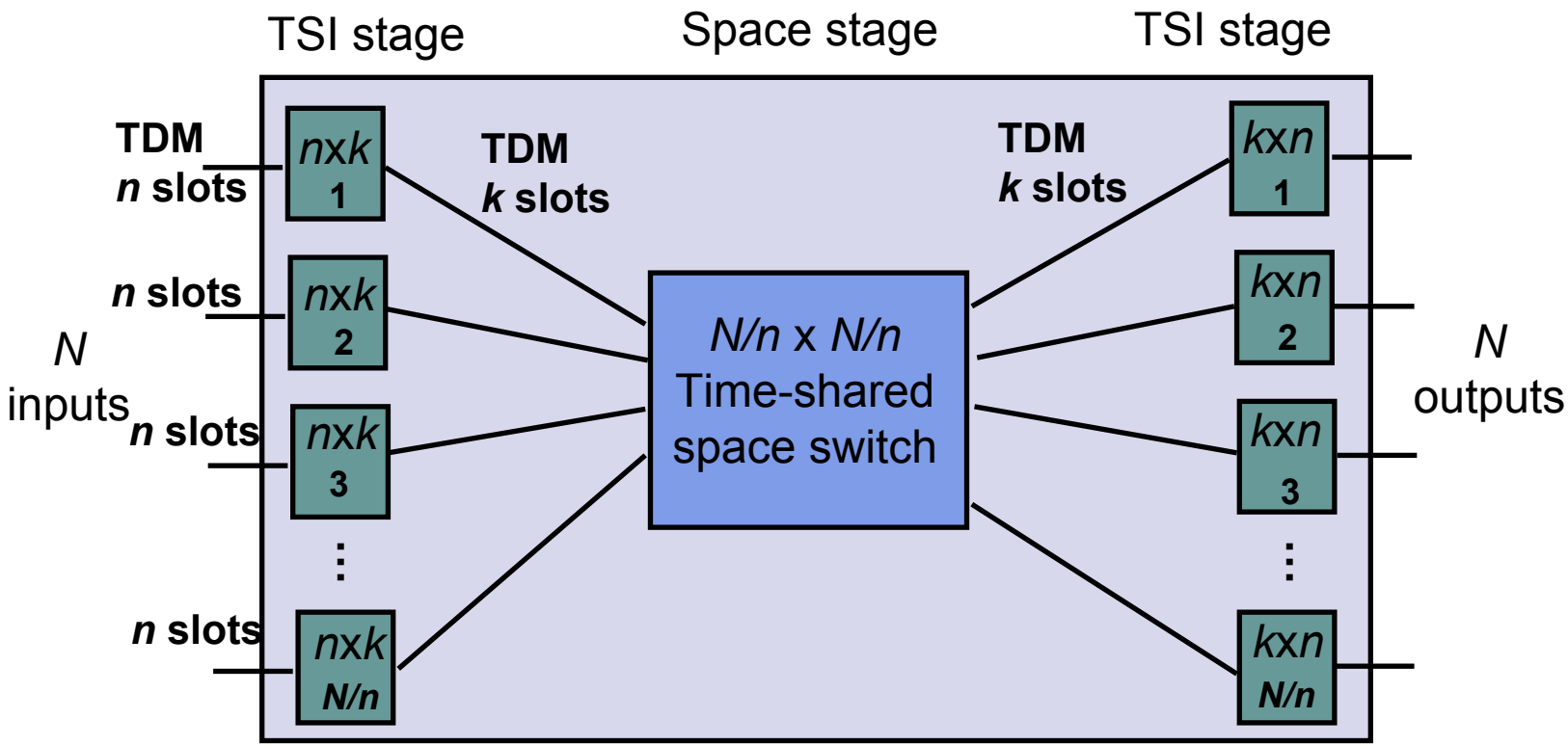

nxk
1
nxk
j
nxk
N/n
N/n x N/n
1
N/n x N/n
n-1
N/n x N/n
n+1
N/n x N/n
2n-2
N/n x N/n
2n-1
kxn
1
kxn
m
kxn
N/n
n-1
busy
n-1
busy
Desired
input
Desired
output
Free path
Free path

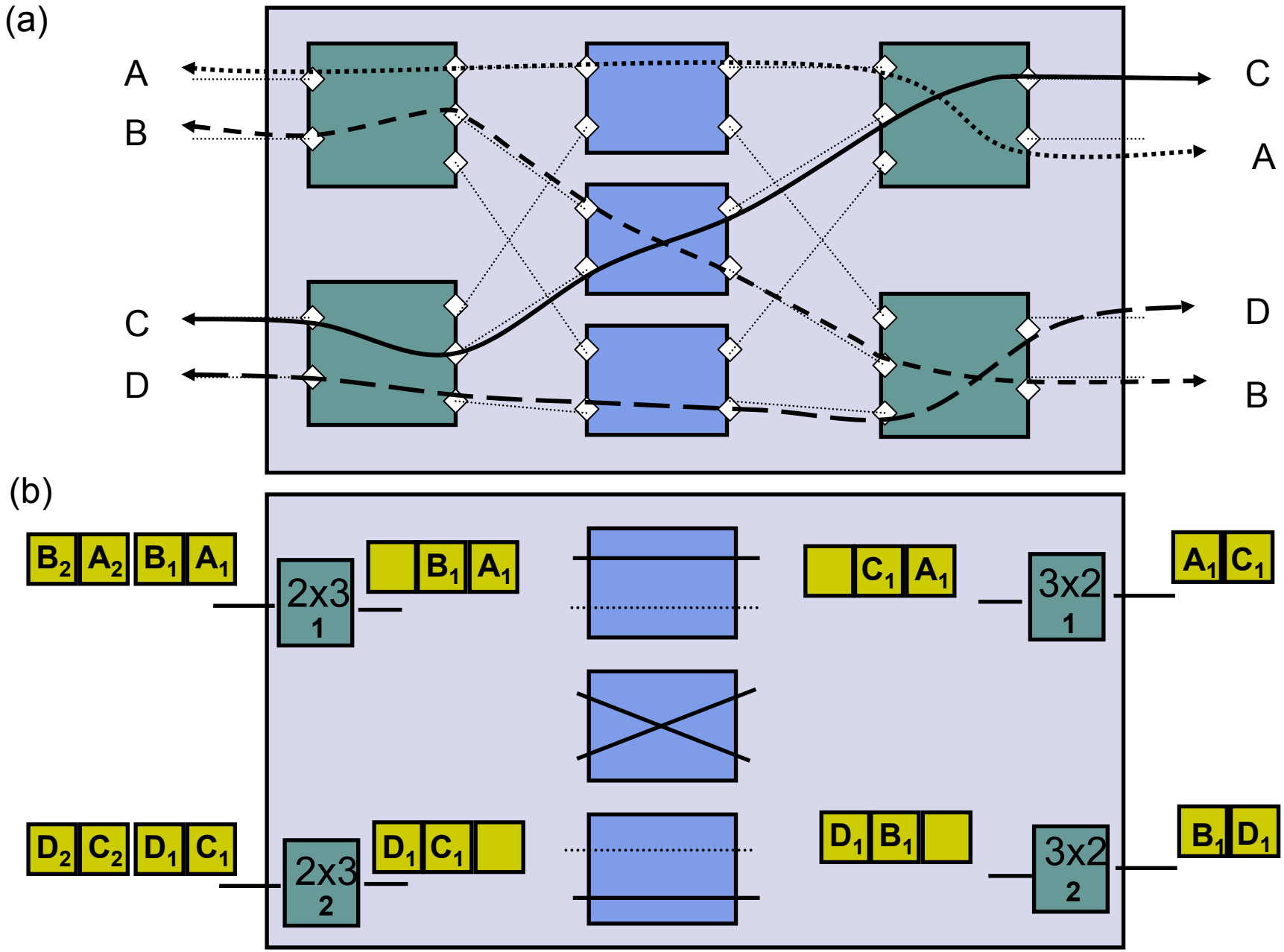


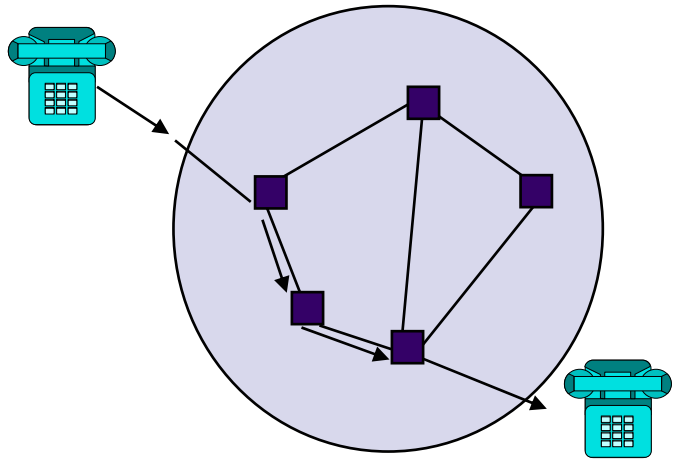
Time-slot interchange

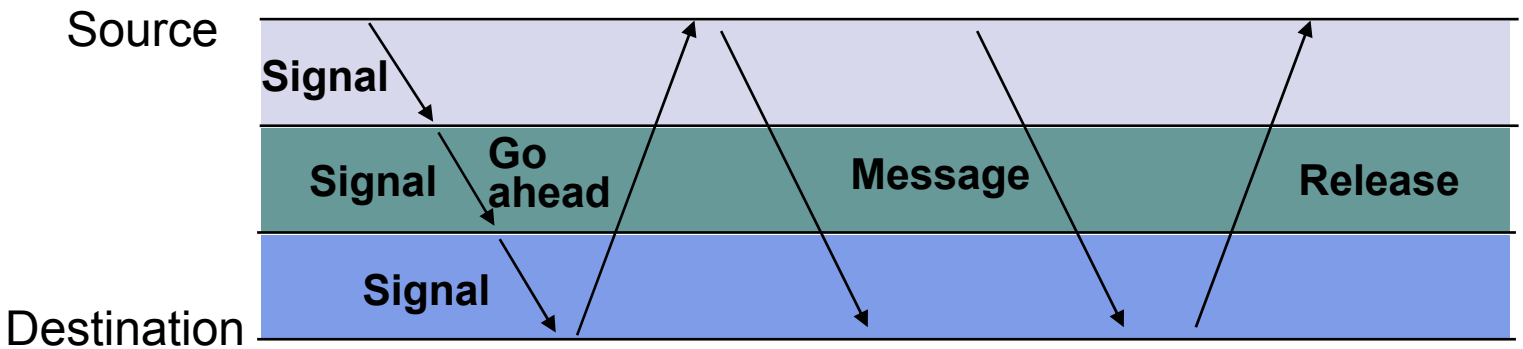

N
inputs
nxk
1
nxk
2
nxk
3
nxk
N/n
N/n x N/n
1
kxn
1
Input TDM
frame with
n slots
n ... 2 1
1
2
n
Output TDM
frame with k
slots
k ... 2 1
Time-slot interchange

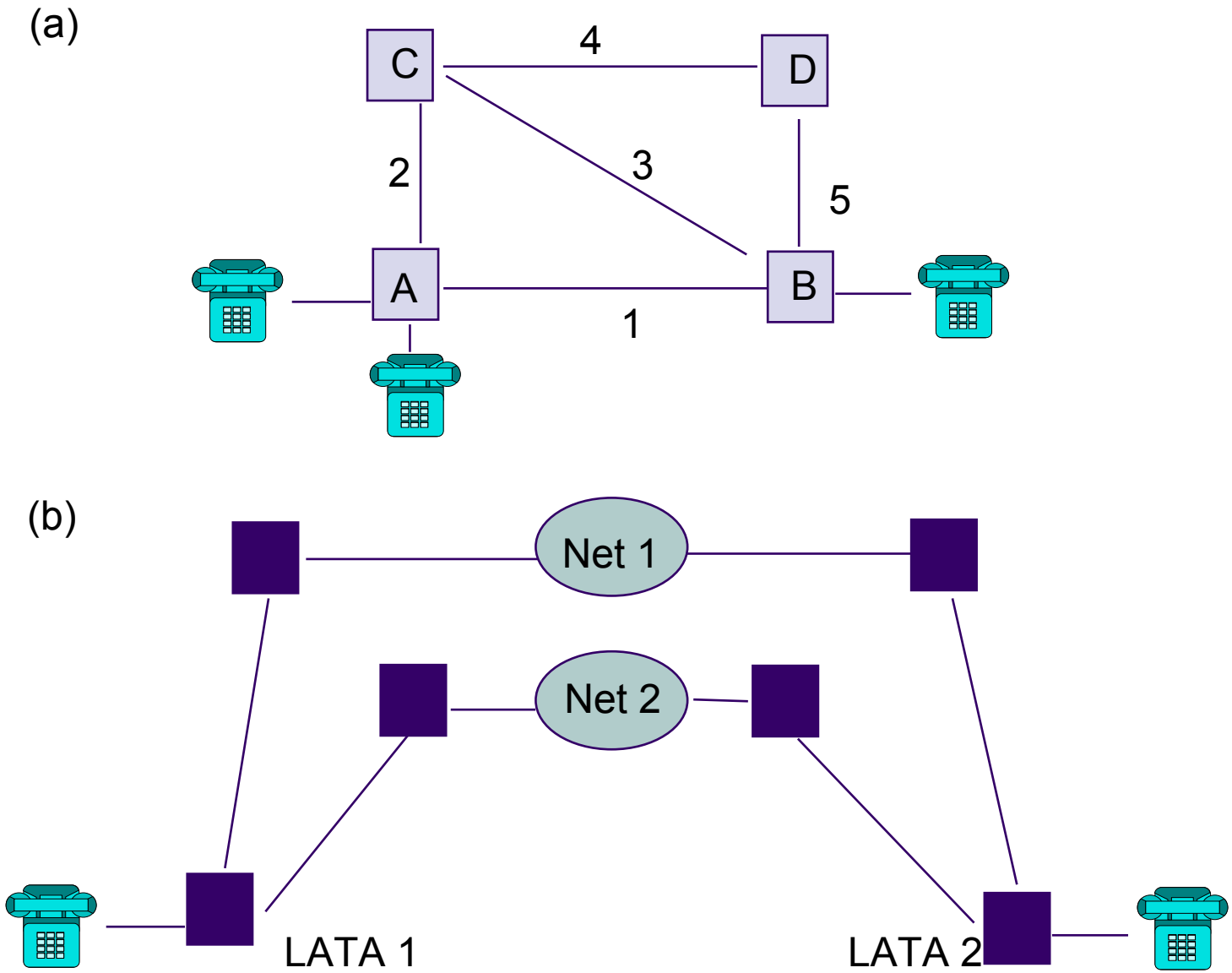

First slot
First slot
n × k
1
n × k
2
n × k
N/n
N/n × N/n
1
N/n × N/n
2
N/n × N/n
k
k × n
1
k × n
2
k × n
N/n
kth slot
kth slot

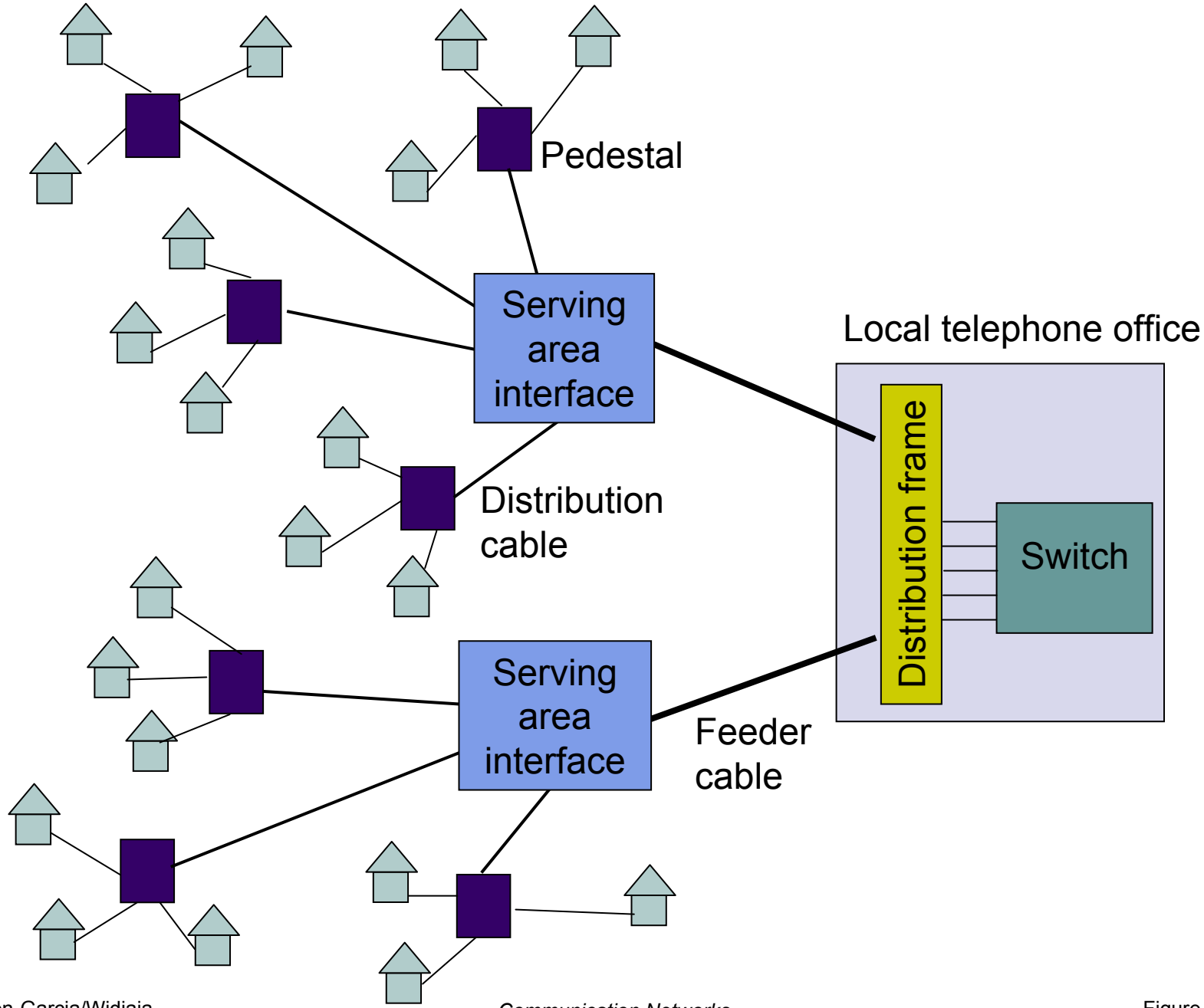

TSI stage
Space stage
TSI stage
TDM
n slots
n slots
n slots
n slots
N
inputs
nxk
1
nxk
2
nxk
3
nxk
N/n
TDM
k slots
N/n x N/n
Time-shared
space switch
TDM
k slots
kxn
1
kxn
2
kxn
3
kxn
N/n
N
outputs

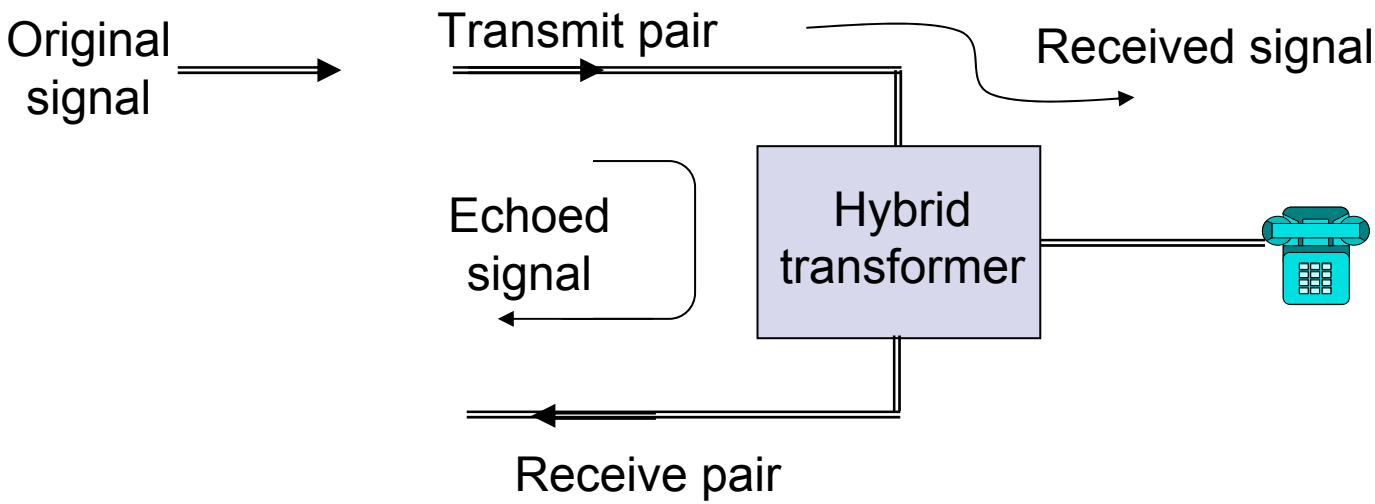

(a)
A
B
C
D
C
A
D
B
(b)
B2 A2 B1 A1
2x3
1
B1 A1
C1 A1
3x2
1
A1 C1
D2 C2 D1 C1
2x3
2
D1 C1
D1 B1
3x2
2
B1 D1

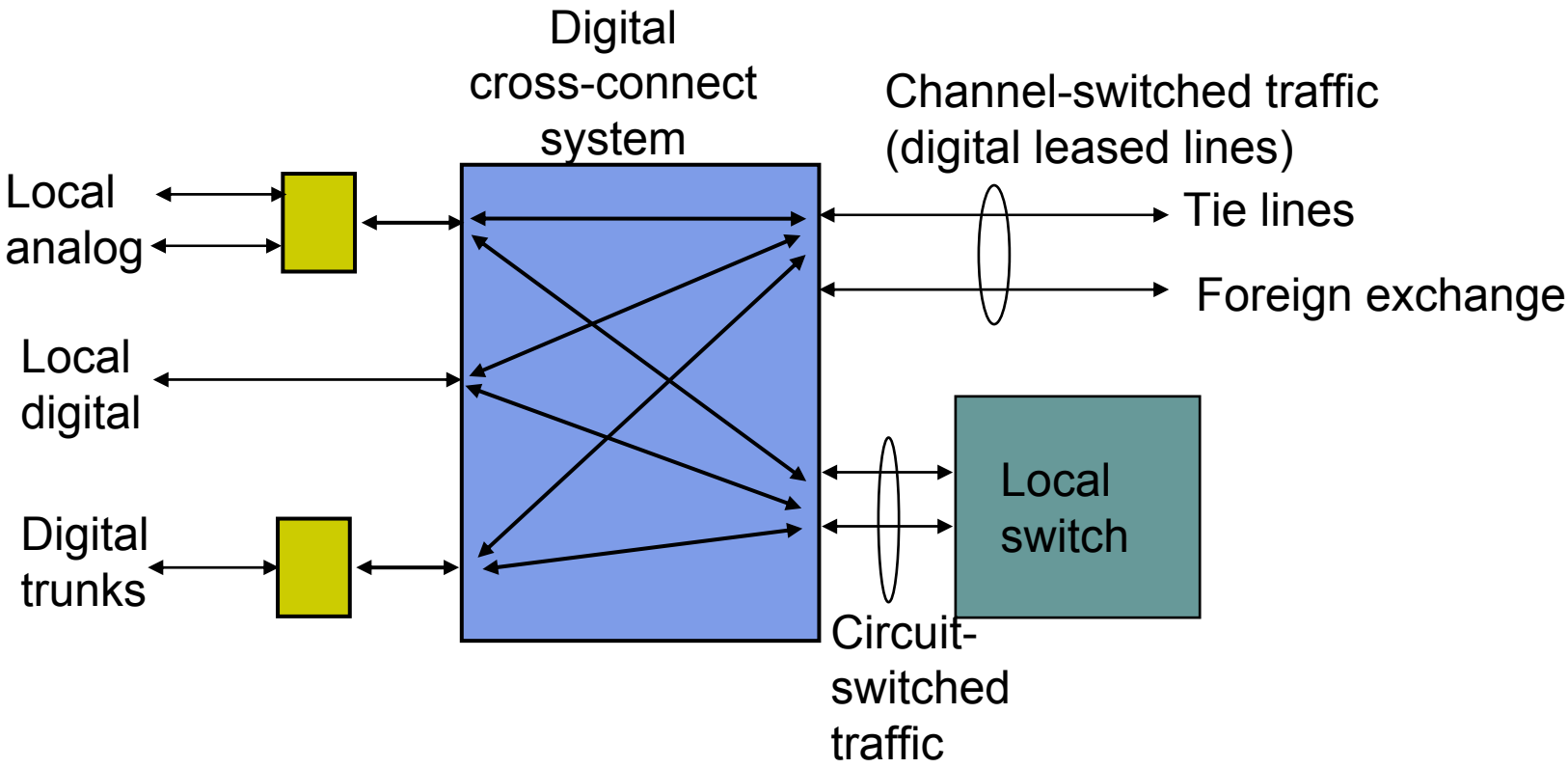


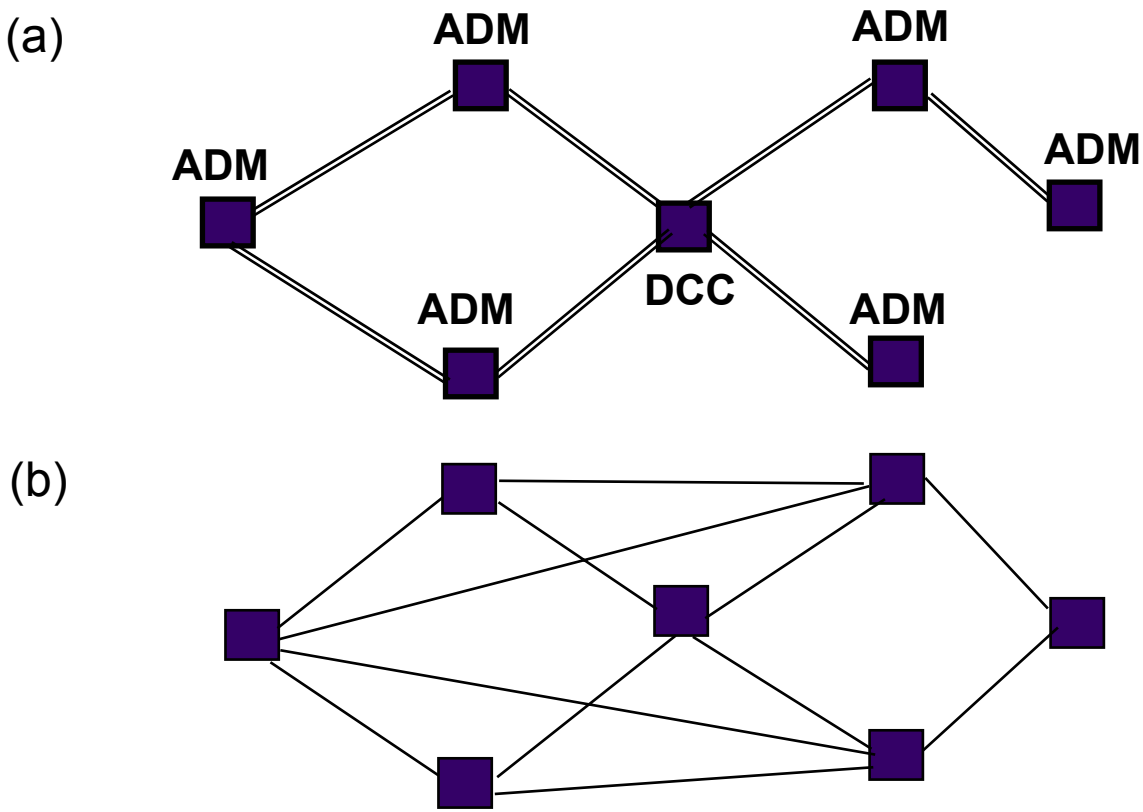

Source
Signal
Signal
Go ahead
Message
Release
Signal
Destination

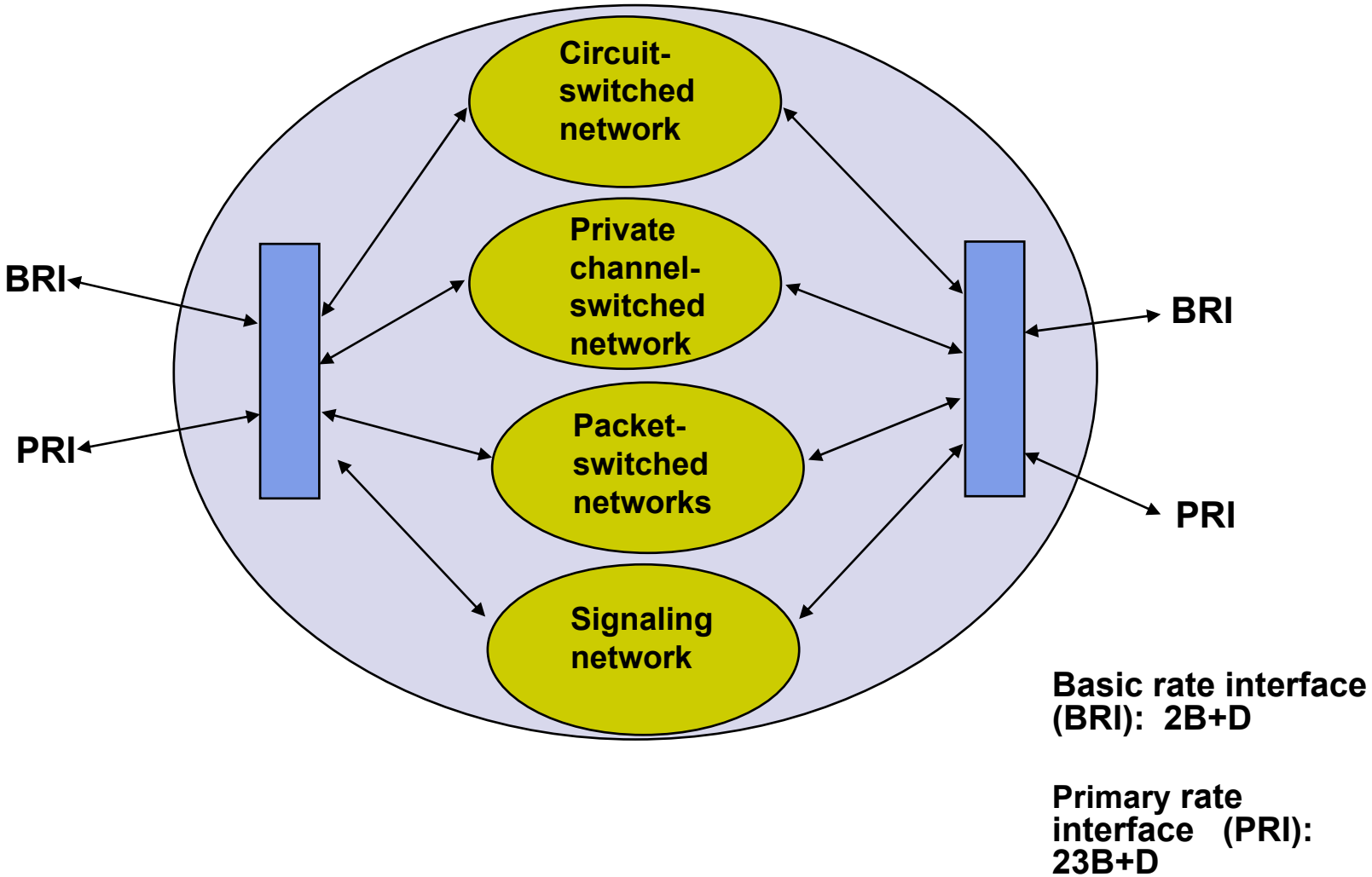

(a)
C
D
A
B
4
2
3
5
1
(b)
Net 1
Net 2
LATA 1
LATA 2

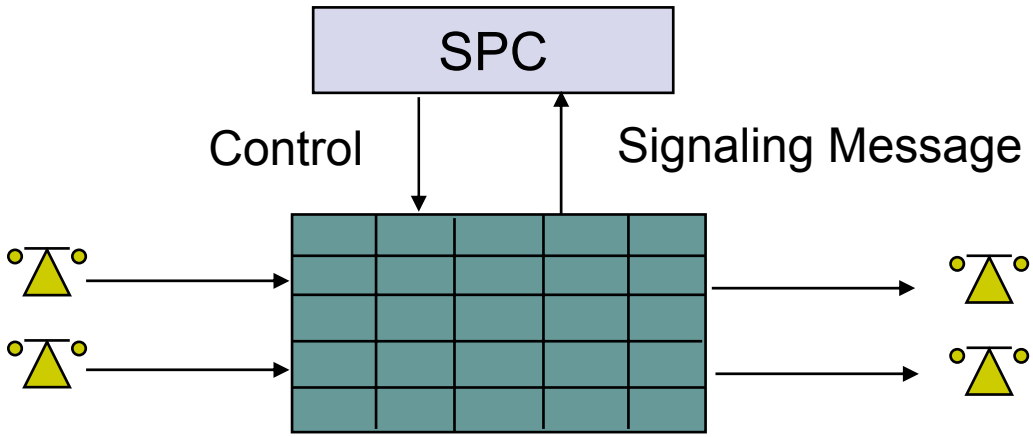

Pedestal
Serving area interface
Local telephone office
Distribution frame
Switch
Distribution cable
Serving area interface
Feeder cable

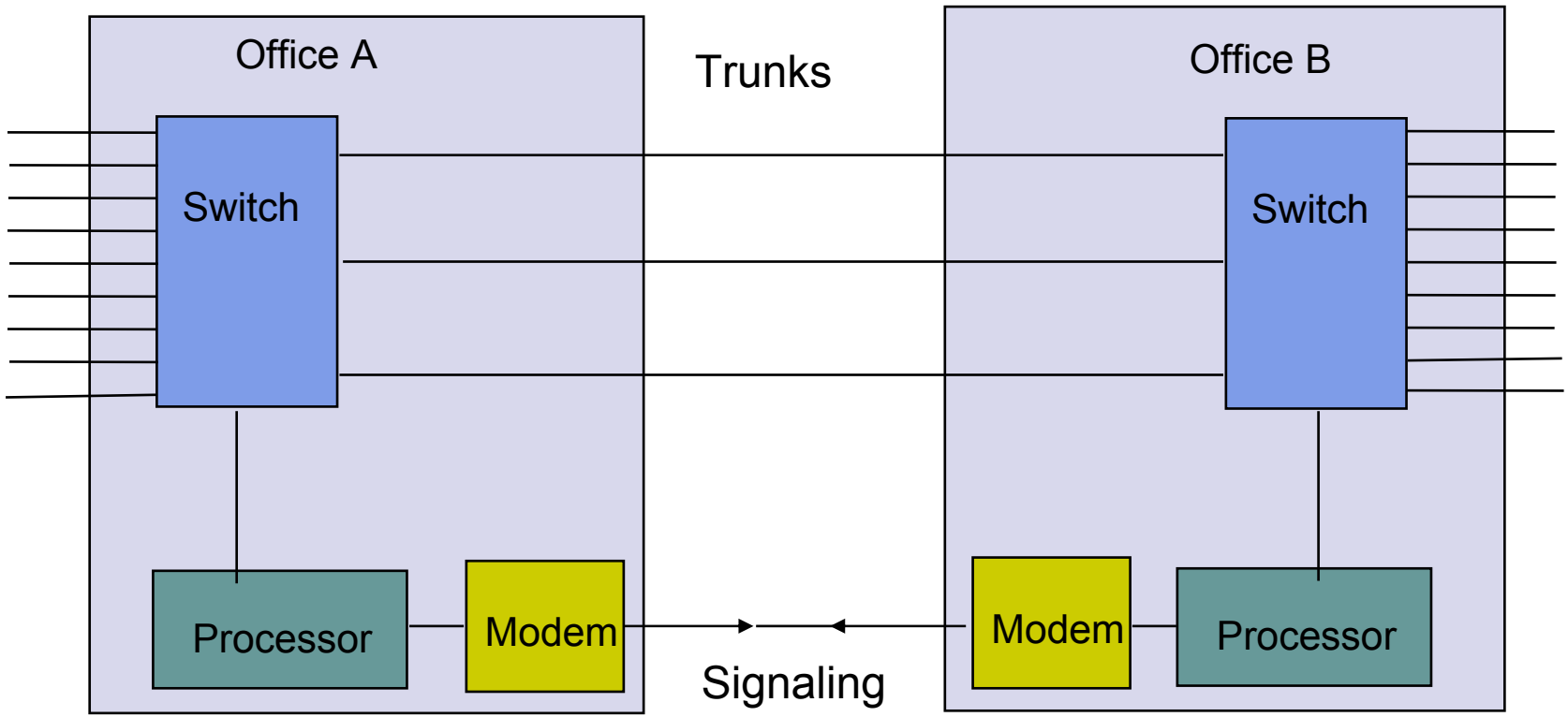

Original signal
Transmit pair
Received signal
Echoed signal
Hybrid transformer
Receive pair

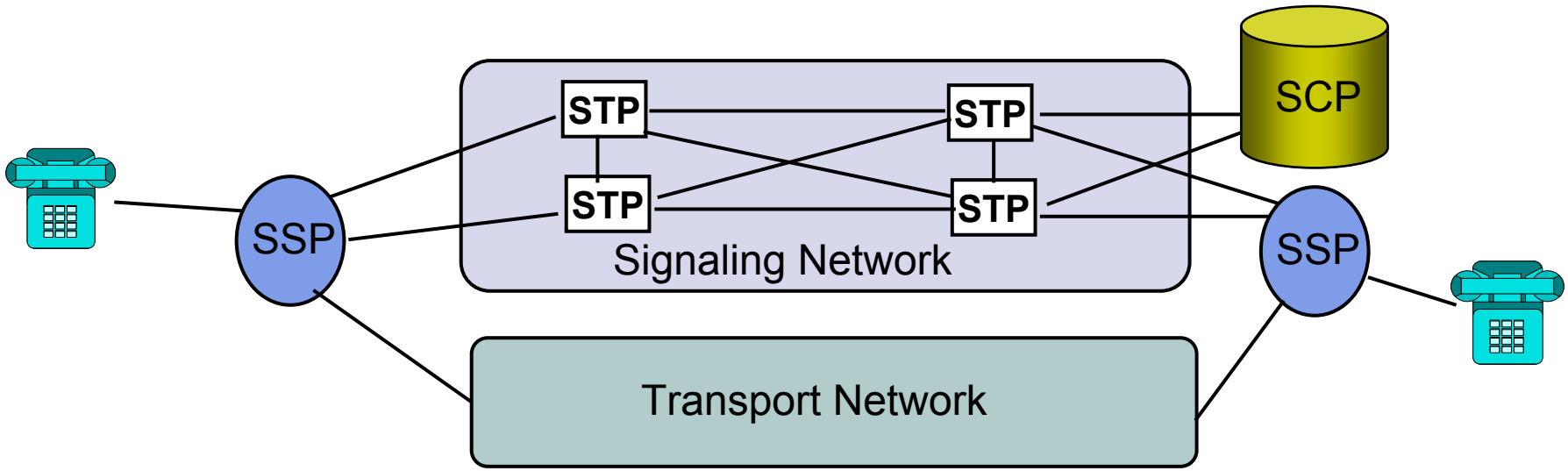

Digital
cross-connect
system
Channel-switched traffic
(digital leased lines)
Local
analog
Tie lines
Foreign exchange
Local
digital
Local
switch
Digital
trunks
Circuit-
switched
traffic


(a)
ADM
ADM
ADM
ADM
DCC
ADM
ADM
(b)

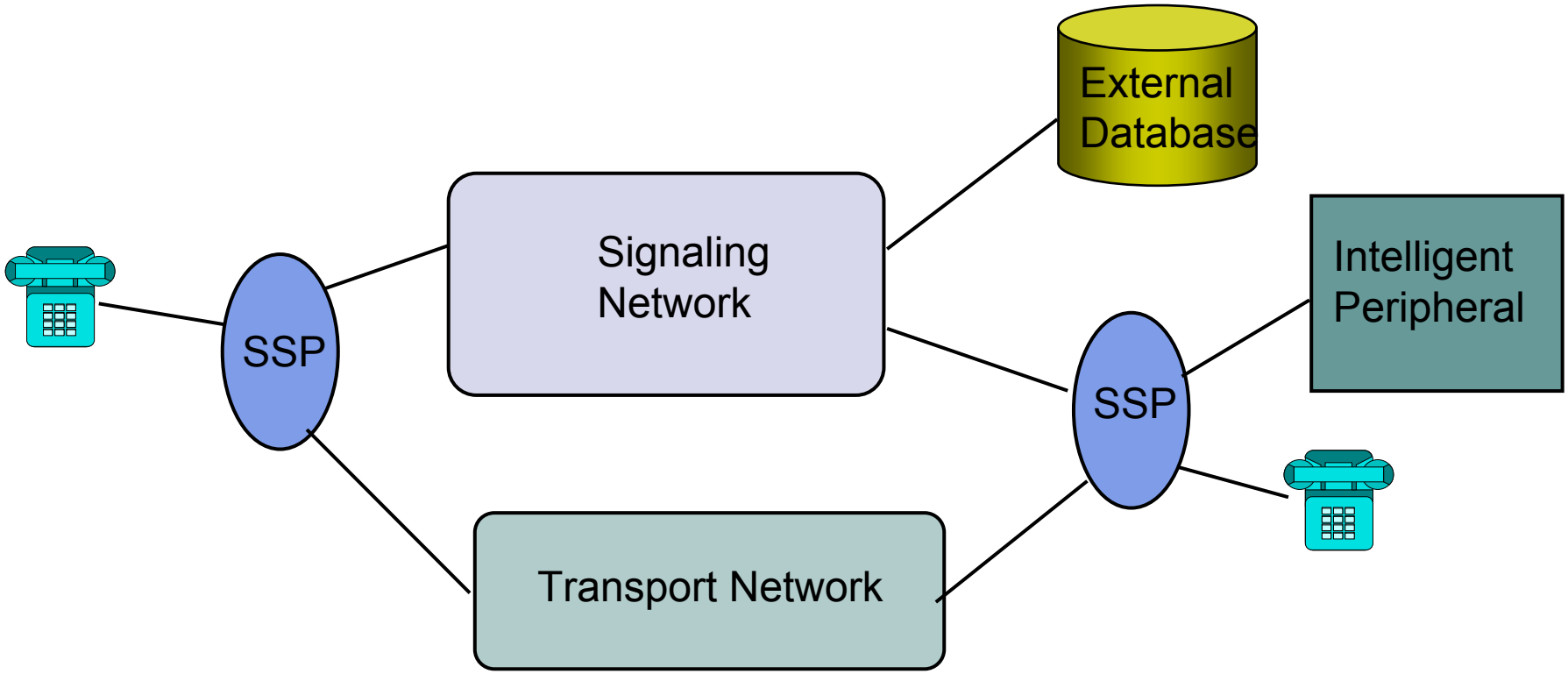

Circuit-switched network
Private channel-switched network
Packet-switched networks
Signaling network
BRI
PRI
BRI
PRI
Basic rate interface (BRI): 2B+D
Primary rate interface (PRI): 23B+D

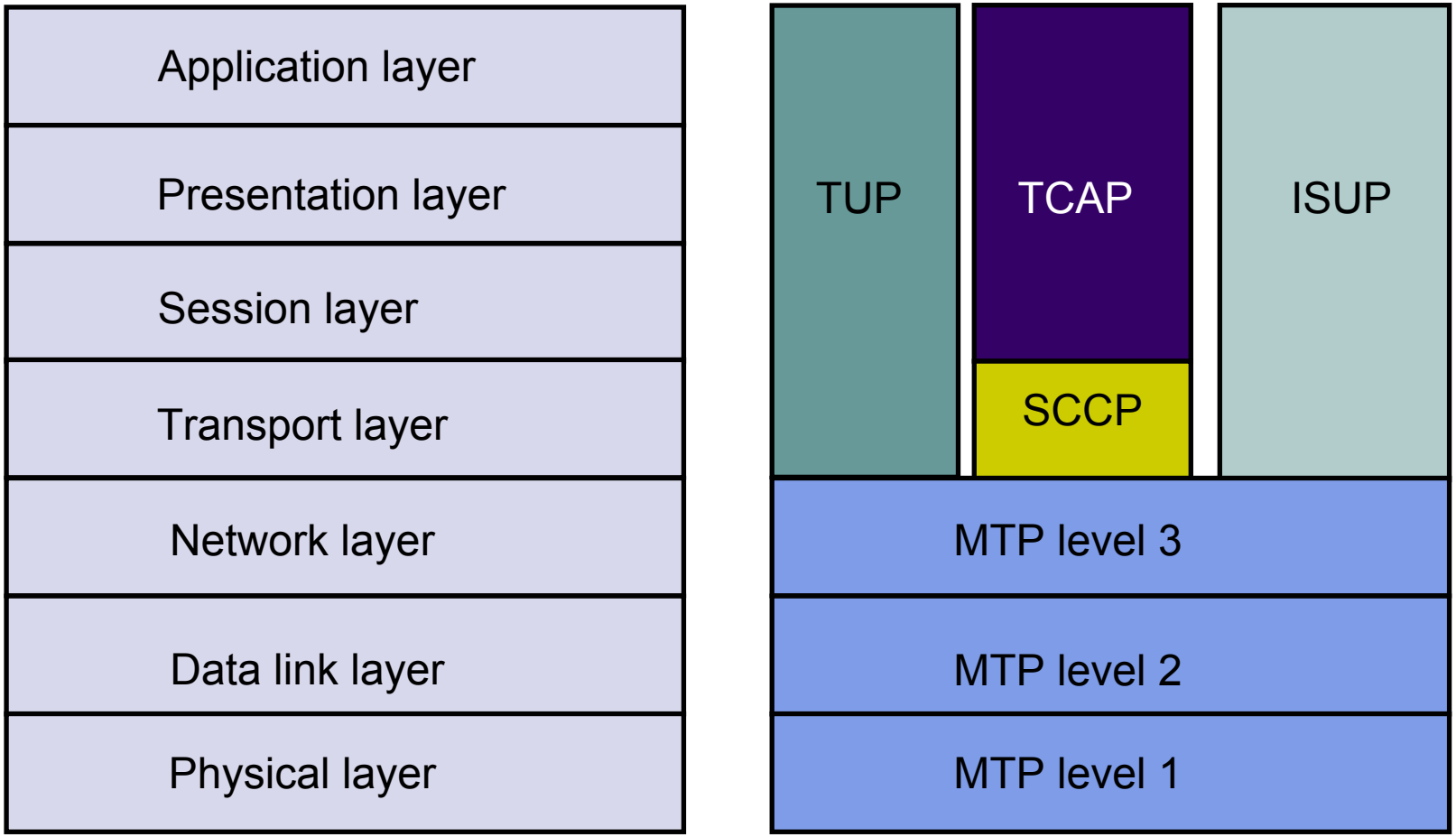

SPC
Control
Signaling Message


Office A
Trunks
Office B
Switch
Switch
Processor
Modem
Modem
Processor
Signaling



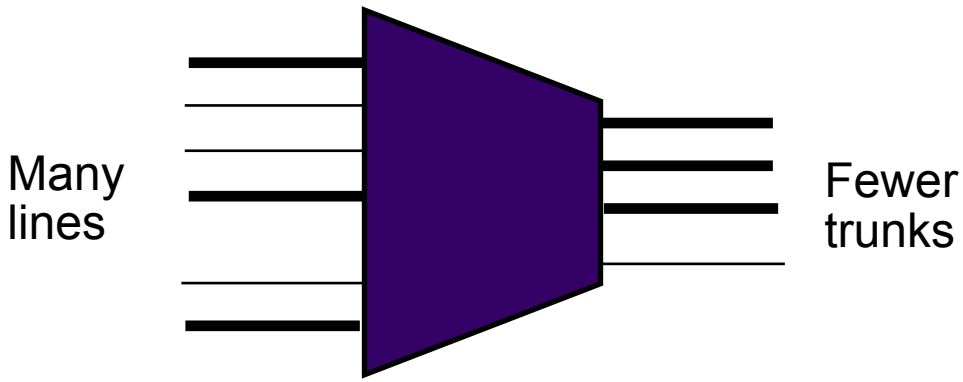
SSP = service switching point (signal to message)
STP = signal transfer point (message transfer)
SCP = service control point (processing)

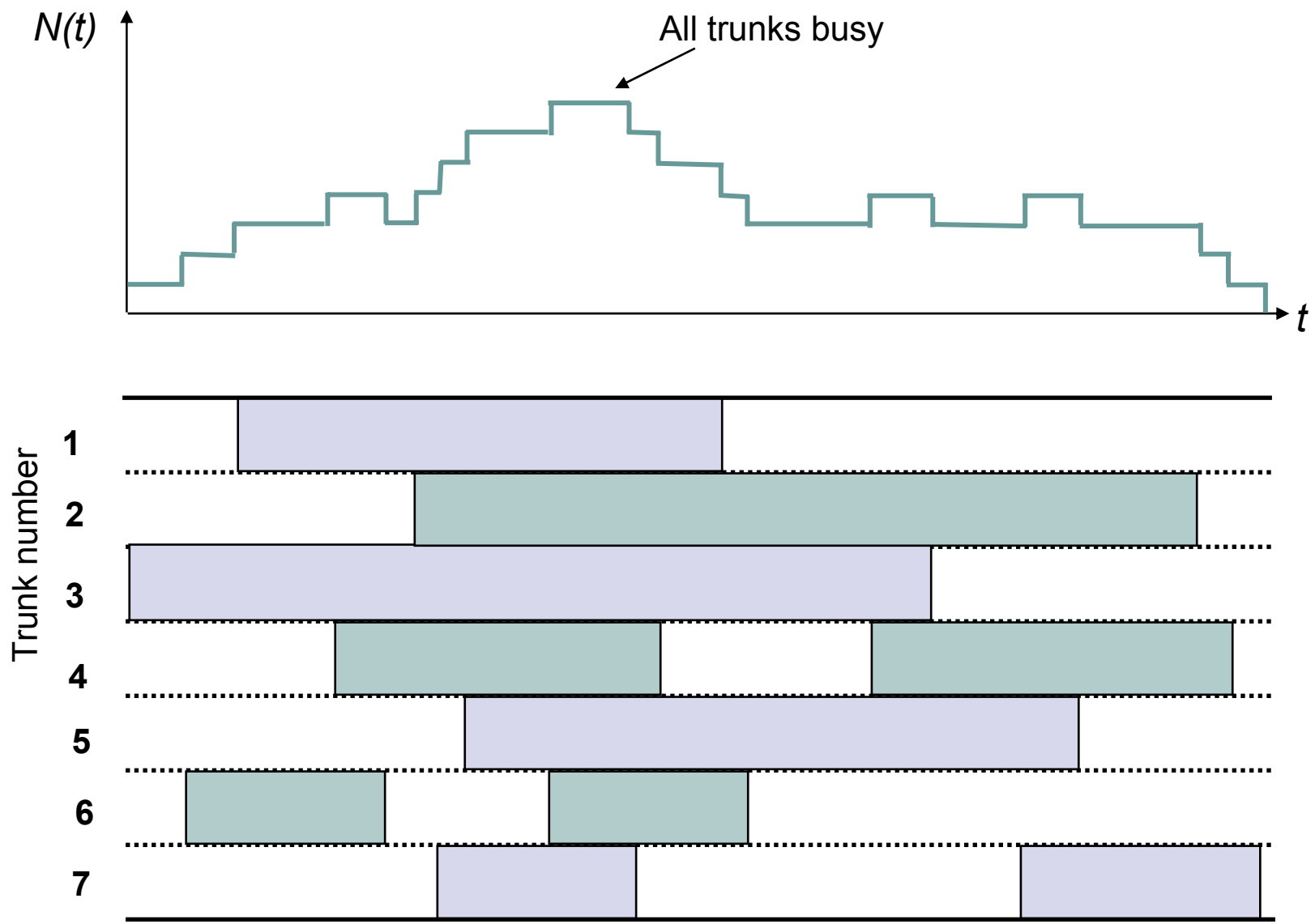

External Database
Signaling Network
Intelligent Peripheral
SSP
SSP
Transport Network

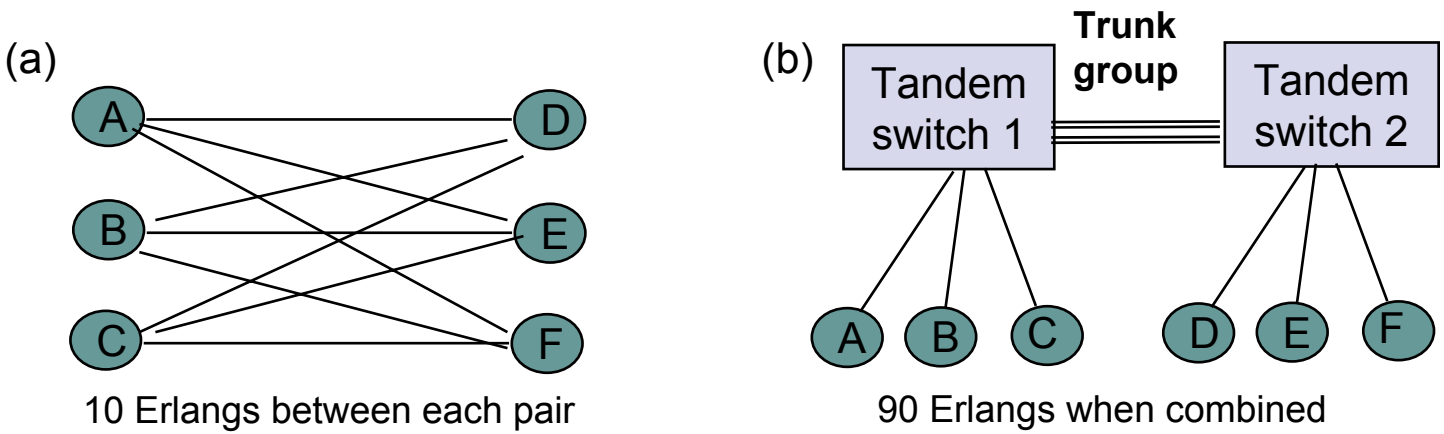


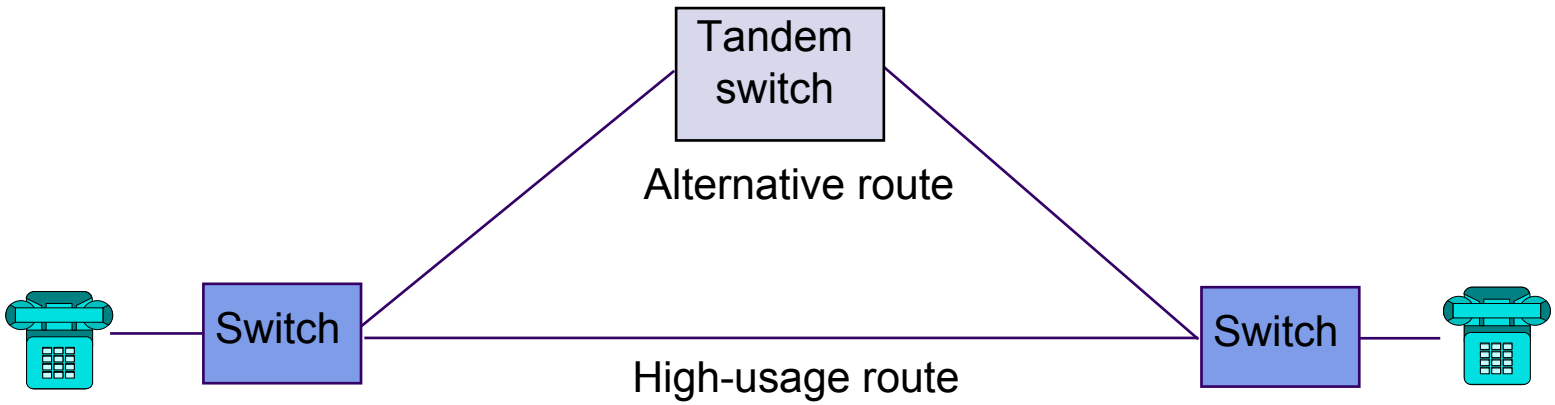
ISUP = ISDN user part
SSCP = signaling connection control part
TUP = telephone user part

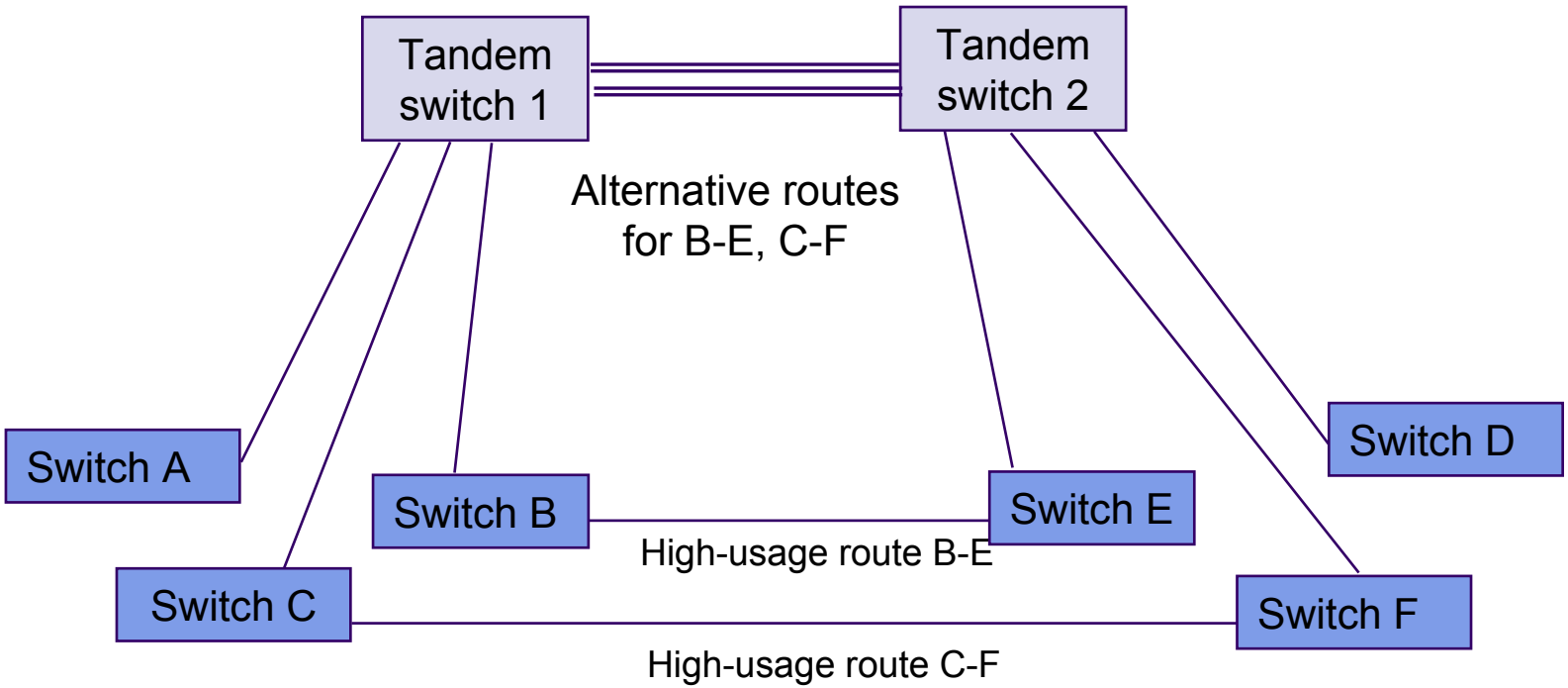
MTP = message transfer part
TCAP = transaction capabilities part

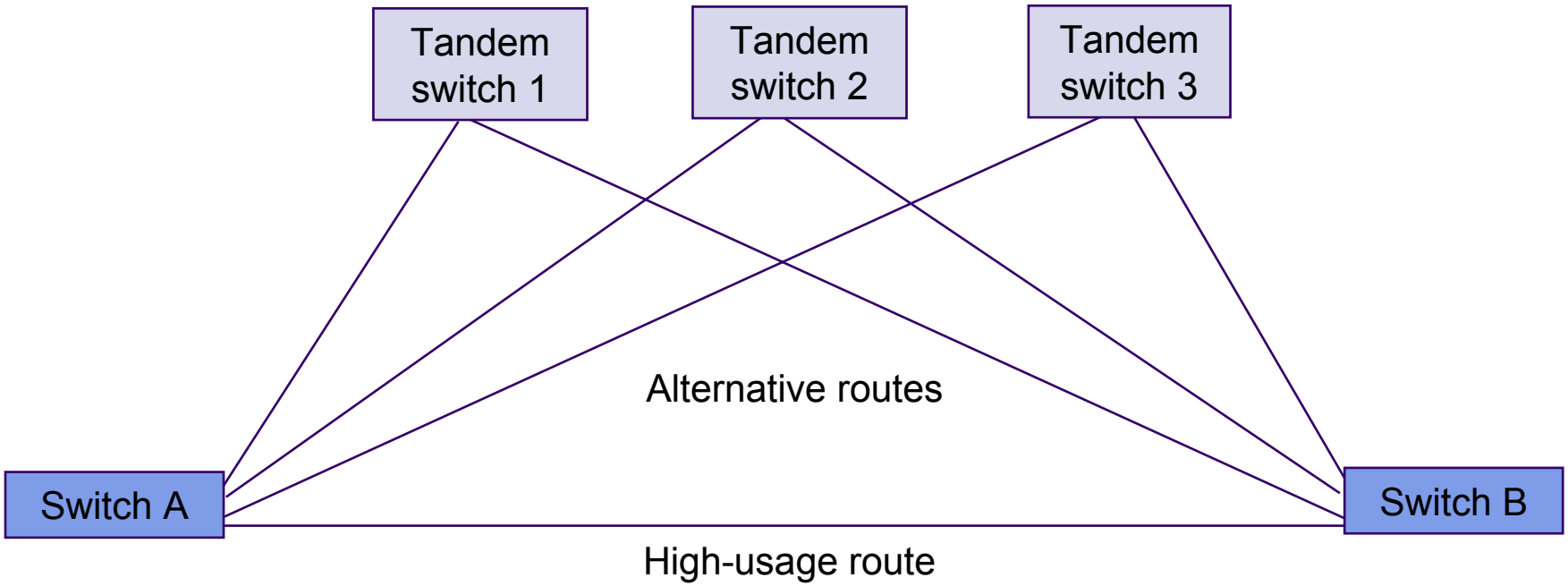

Many
lines
Fewer
trunks

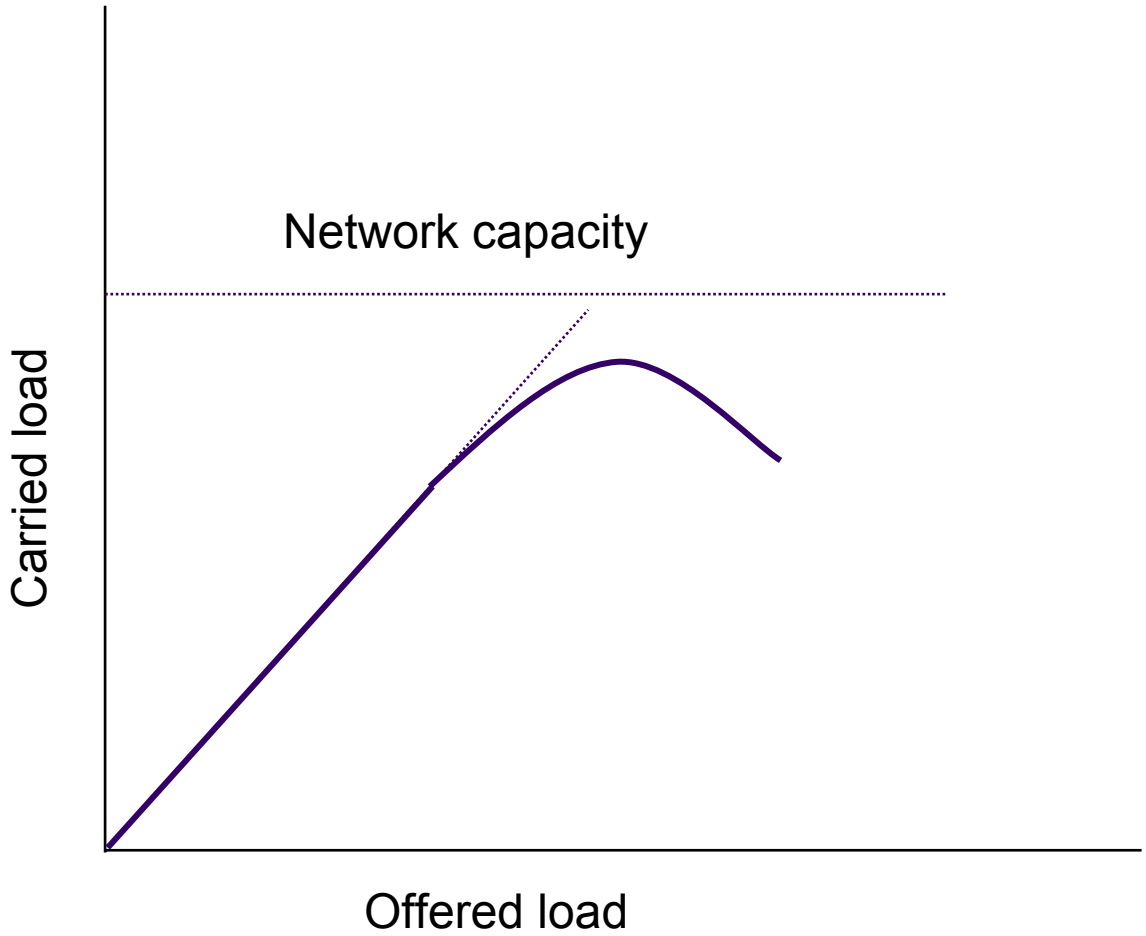

N(t)
All trunks busy
t
Trunk number
1
2
3
4
5
6
7

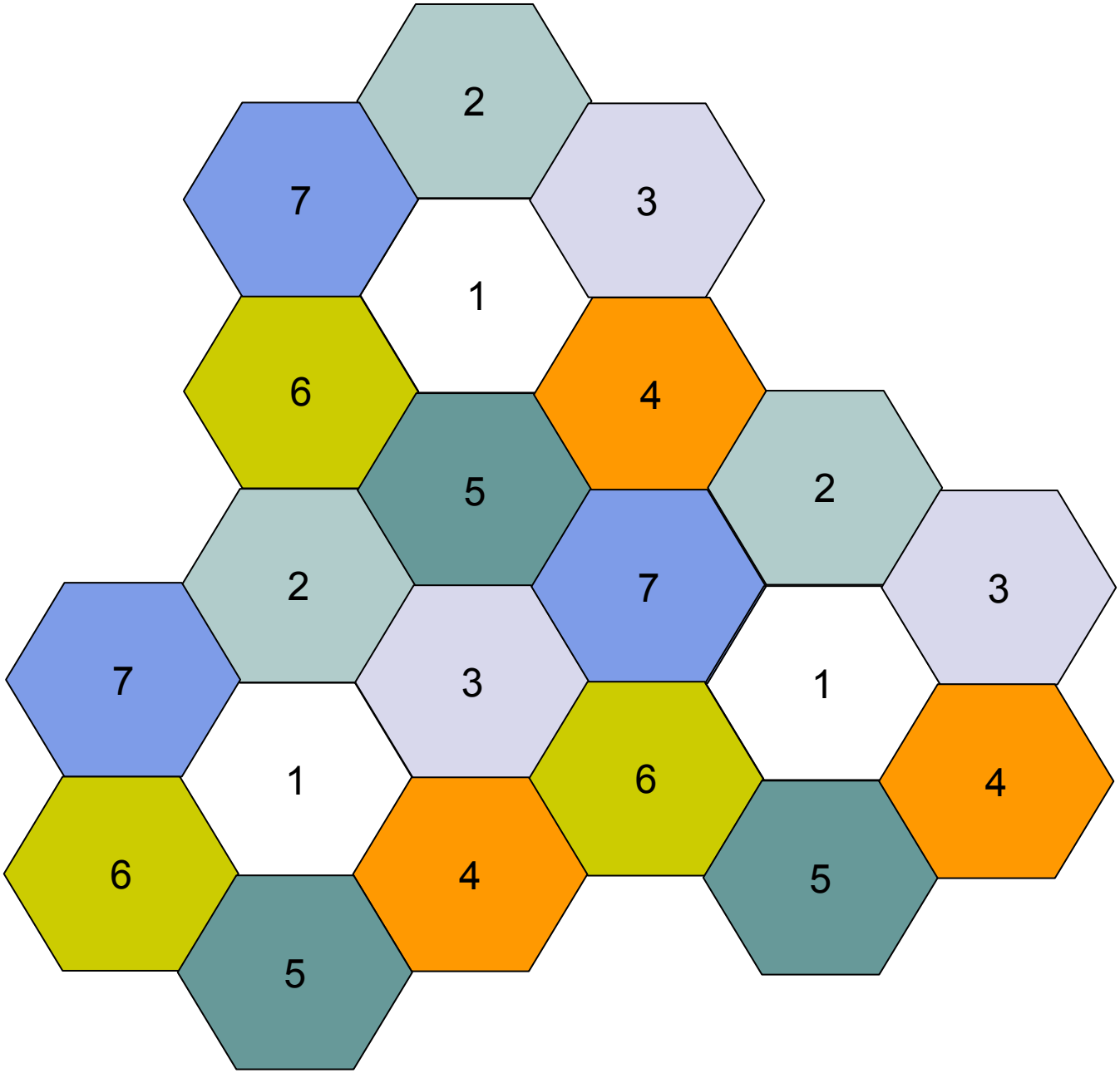

(a)
A
B
C
D
E
F
10 Erlangs between each pair
(b)
Trunk group
Tandem switch 1
Tandem switch 2
A
B
C
D
E
F
90 Erlangs when combined

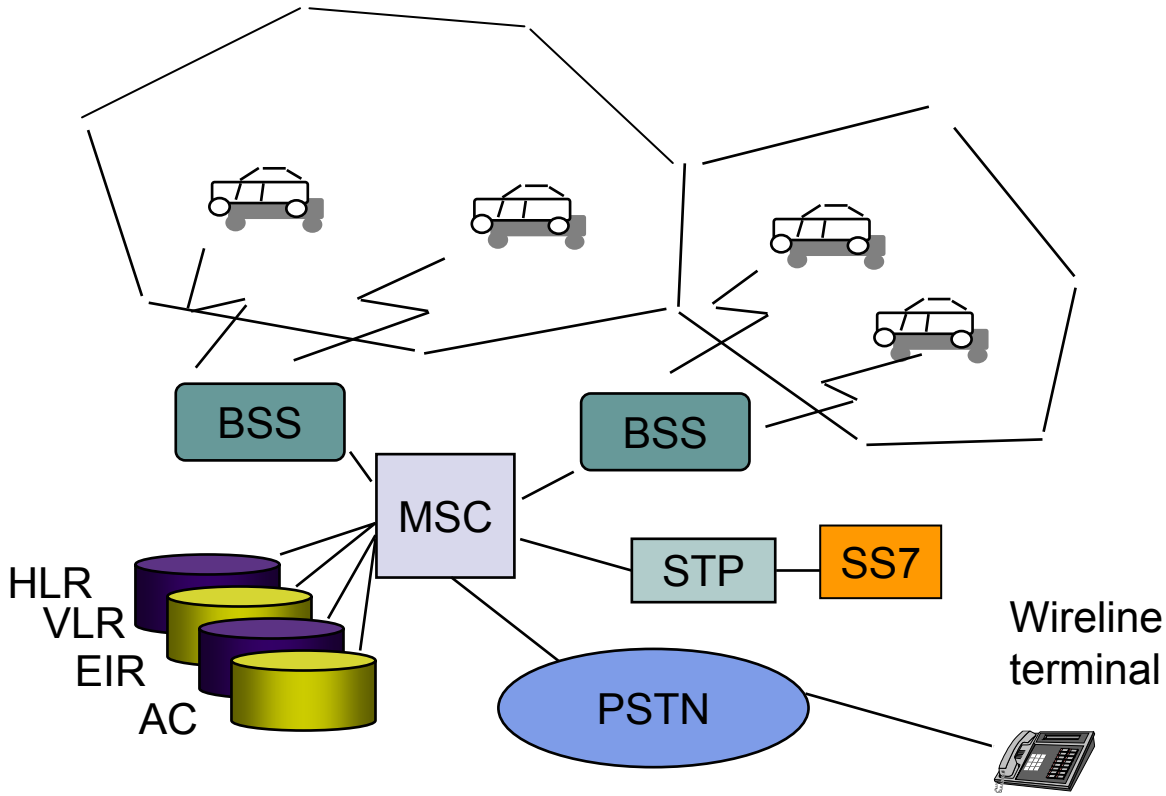

Tandem switch
Alternative route
Switch
Switch
High-usage route


Tandem switch 1
Tandem switch 2
Alternative routes for B-E, C-F
Switch A
Switch B
Switch C
Switch D
Switch E
Switch F
High-usage route B-E
High-usage route C-F

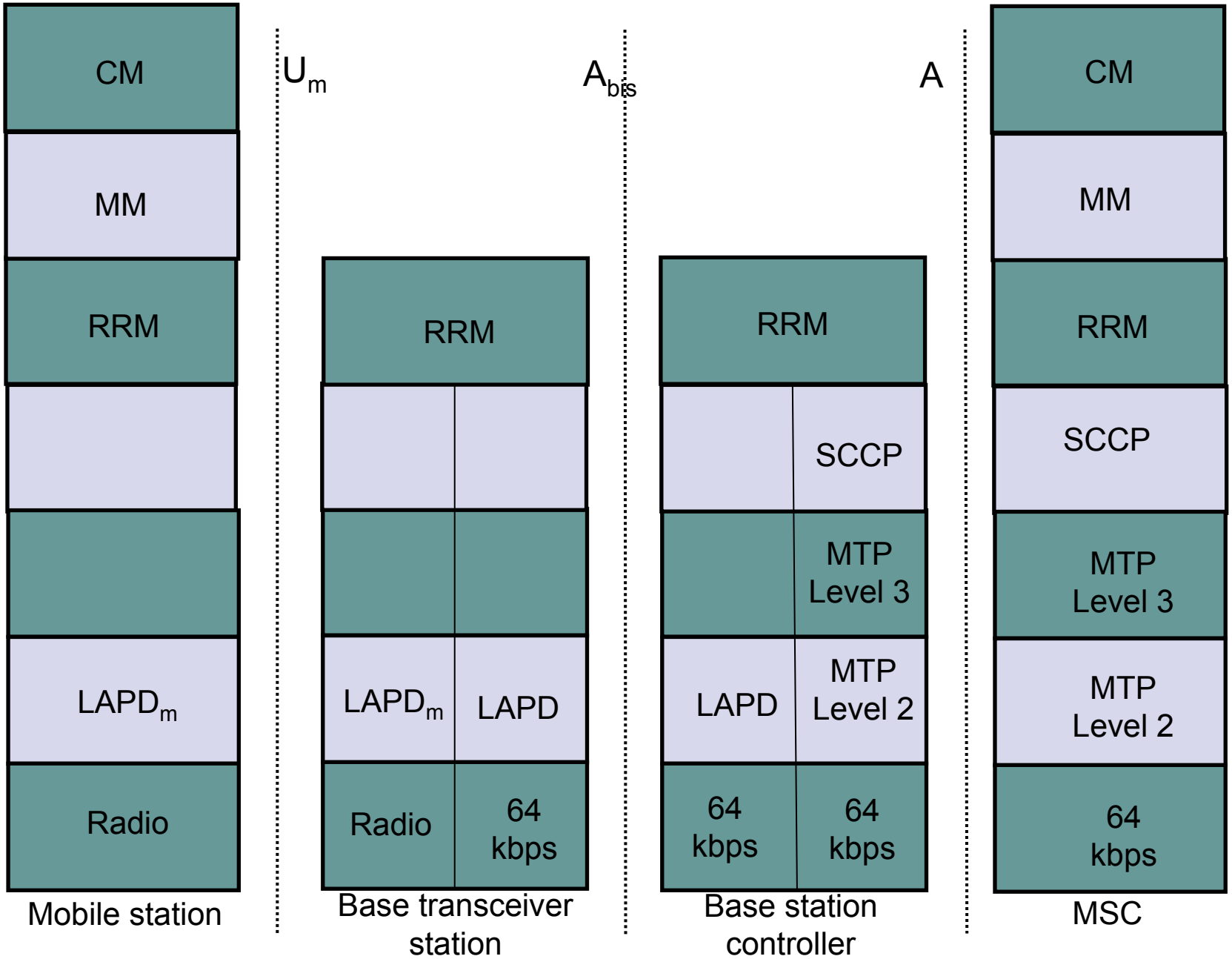

Tandem switch 1
Tandem switch 2
Tandem switch 3
Alternative routes
Switch A
Switch B
High-usage route


Network capacity
Carried load
Offered load


2
7
3
1
6
4
5
2
2
7
3
7
3
1
1
6
4
6
4
5
5



AC = authentication center
BSS = base station subsystem
EIR = equipment identity register
HLR = home location register
MSC = mobile switching center
PSTN = public switched telephone network
STP = signal transfer point
VLR = visitor location register


CM
MM
RRM
LAPDm
Radio
Mobile station
Um
RRM
LAPDm
LAPD
Radio
64 kbps
Base transceiver station
Abis
RRM
SCCP
MTP Level 3
LAPD
MTP Level 2
64 kbps
64 kbps
Base station controller
A
CM
MM
RRM
SCCP
MTP Level 3
MTP Level 2
64 kbps
MSC