Chapter 7 Wide Area Networks

Wide Area Networks – BackBone Network

7.1 Introduction

7.2 Transmission systems (WAN Technologies)

-> Bandwidth

7.3 Switching systems (Routers in Backbone)

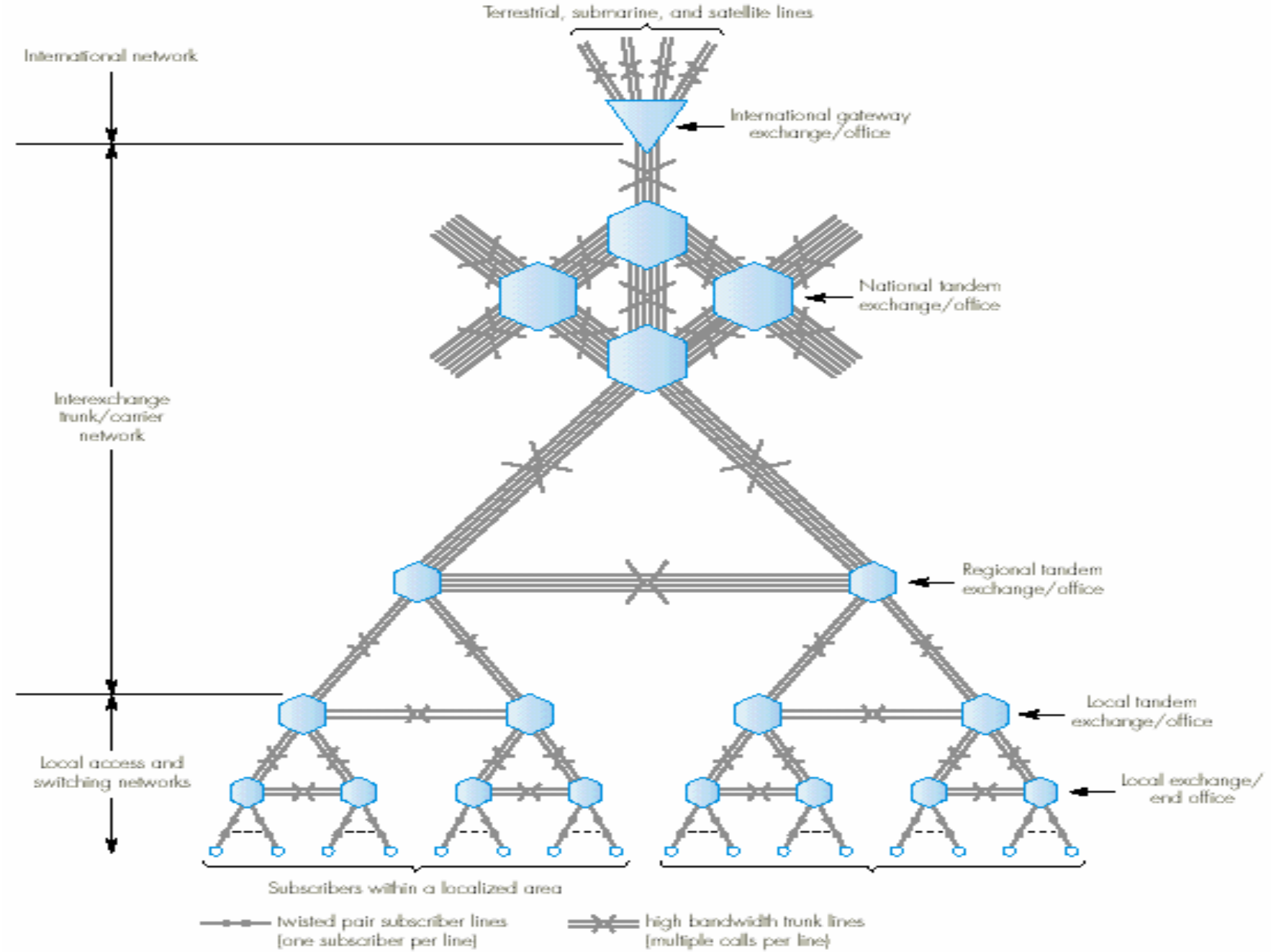
7.4 Signaling systems

7.1 Introduction (1)

- PSTN, ISDN

- Three hierarchical sub-networks
  - local access and switching networks
    - » LE: Local Exchange
    - » EO: End Office
  - inter-exchange trunk/carrier networks
  - international networks
- Local exchange carriers (LXCs)
- Inter-exchange carriers (IXCs)

- Three inter-related systems for overall network
  - transmission
  - switching
  - signaling


Terrestrial, submarine, and satellite lines
International network
International gateway exchange/office
National tandem exchange/office
Interexchange trunk/carrier network
Regional tandem exchange/office
Local tandem exchange/office
Local access and switching networks
Local exchange/ end office
Subscribers within a localized area
twisted pair subscriber lines (one subscriber per line)
high bandwidth trunk lines (multiple calls per line)

7.1 Introduction (2)

- Transmission systems
  - customer line, subscriber line
    - in PSTN, analog transmission
      - » a BW of 200Hz to 3.4kHz
    - in ISDN, digital transmission : digital subscriber line (DSL)
      - » 1.5Mbps or 2Mbps (24calls/30calls)

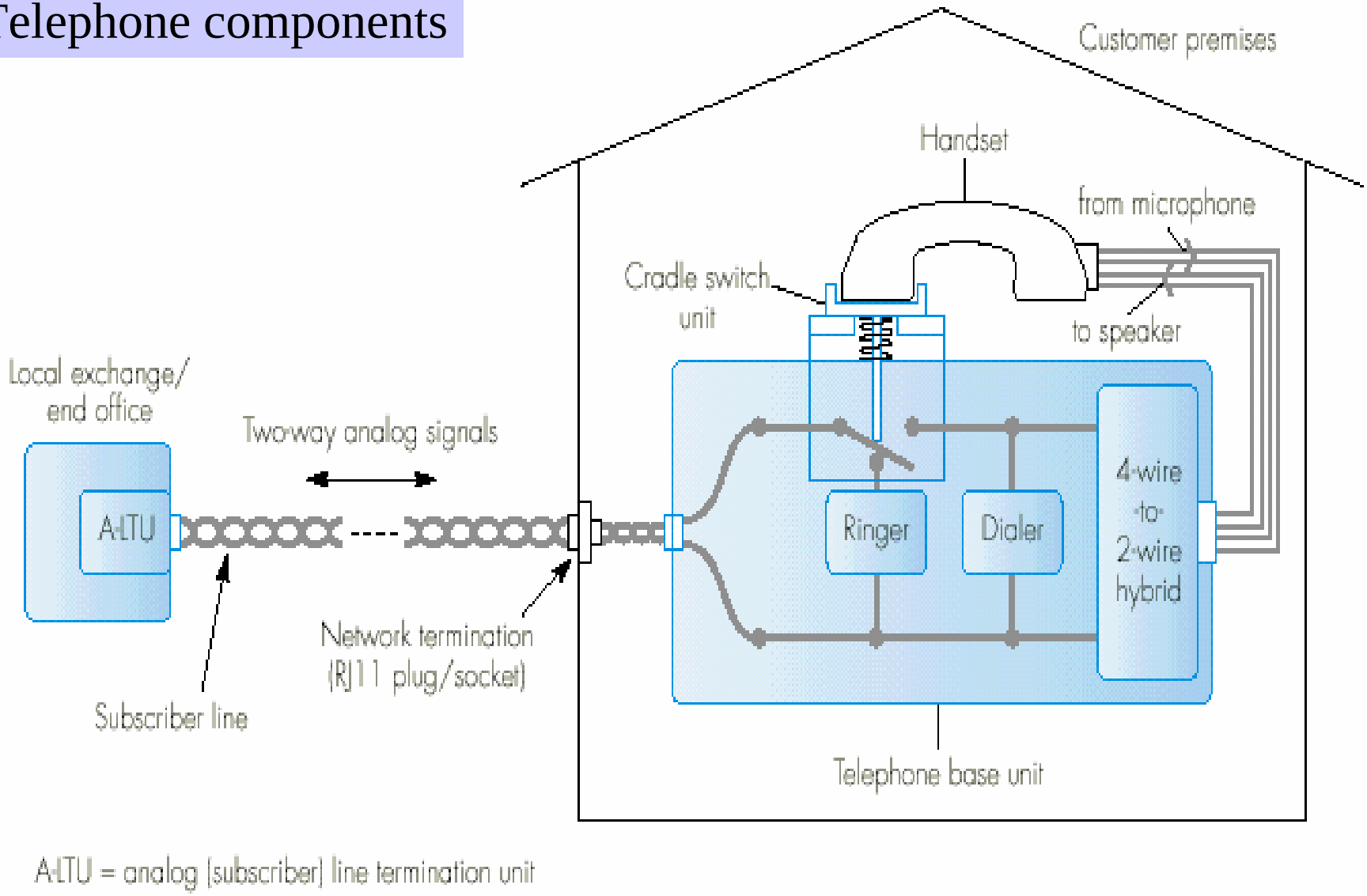
- Switching system
  - to support a defined number of simultaneous calls/connections

- Signaling system
  - transfer of a defined set of control message
    - » call control
    - » connect control
  - between calling and called subscriber

7.2 Transmission systems

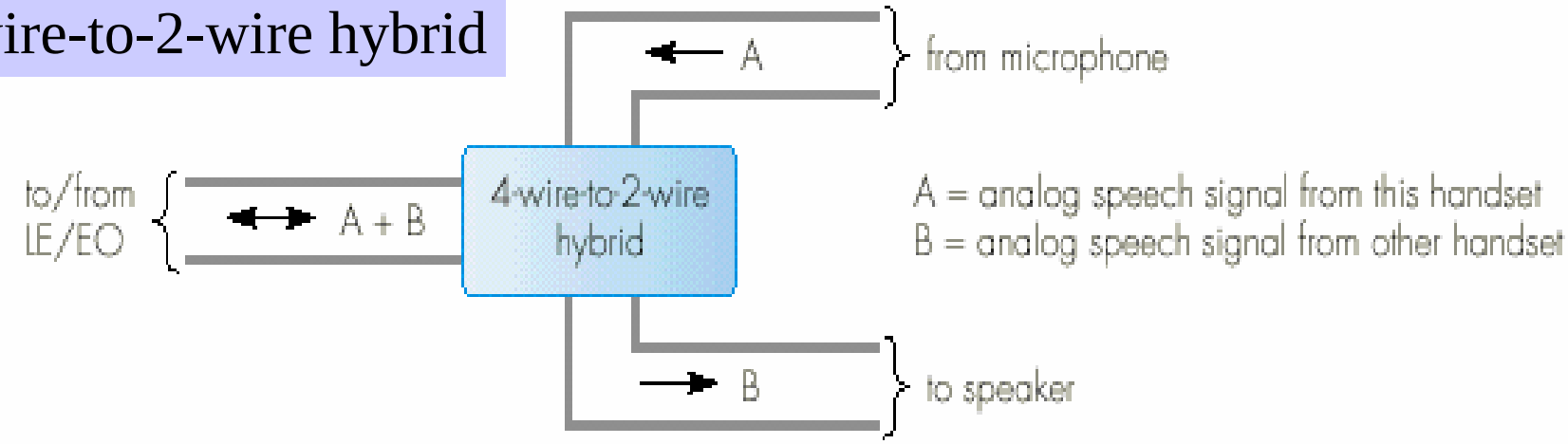
- Transmission system
  - in the local access network
    - » PSTN : 전화 라인
    - » xDSL : 전화 라인를 Digiatal로 변환시킨 것
    - » Digital line
  - in the trunk network
    - » digital transmission via switch
    - » PDH: plesiochronous digital hierarchy
    - » SDH: synchronous digital hierarchy
- Analog subscriber lines

Telephone components

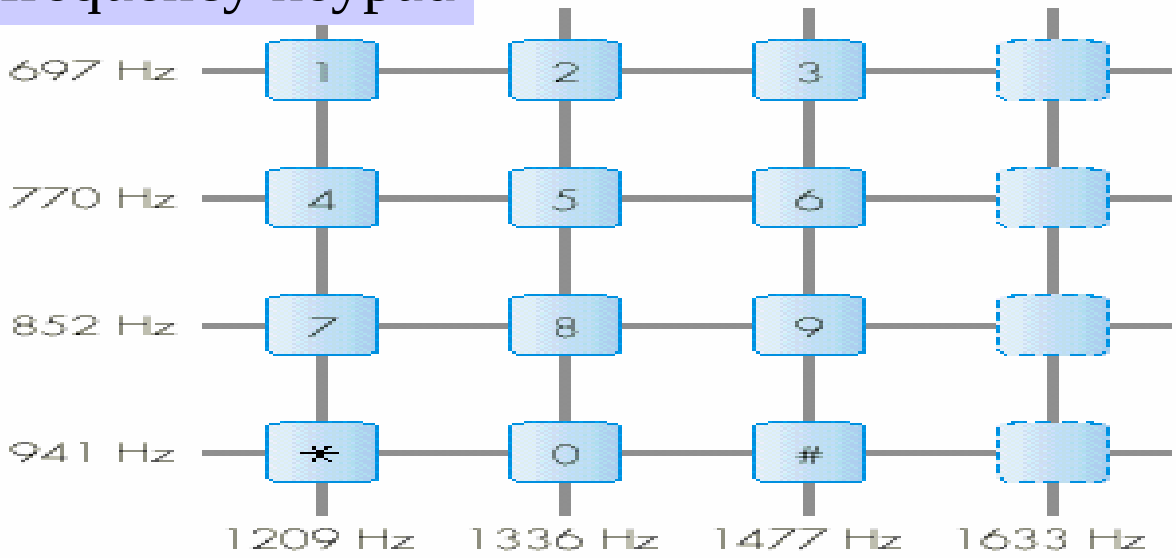


A-LTU = analog [subscriber] line termination unit

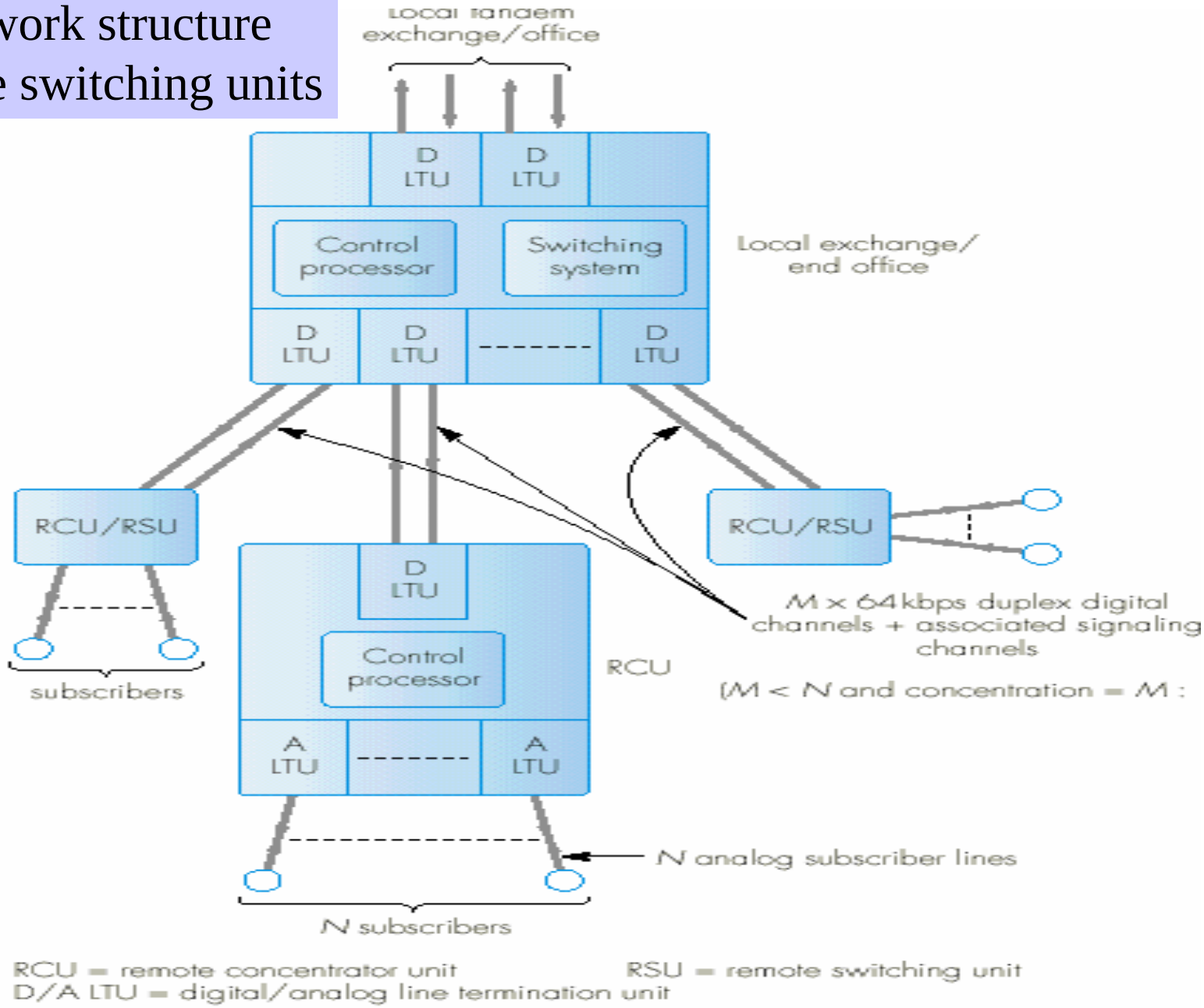
4-wire-to-2-wire hybrid



Dual-tone multi-frequency keypad

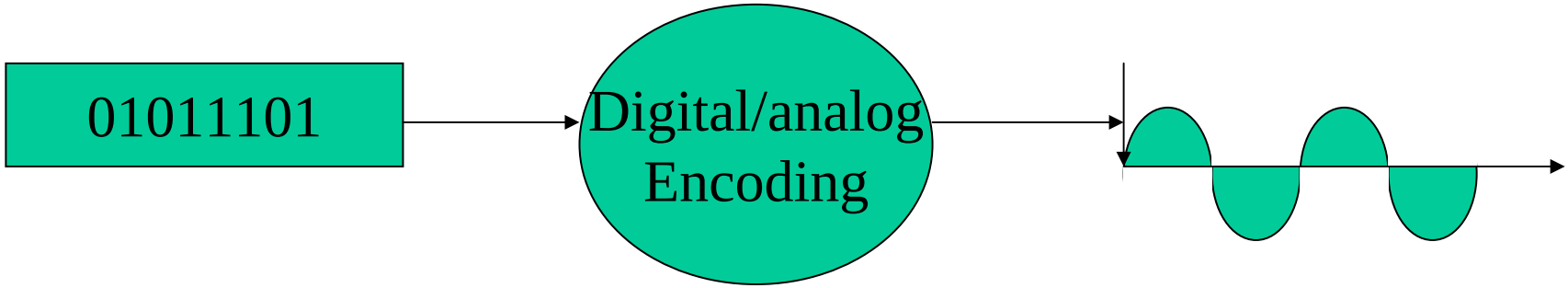


Access network structure with remote switching units



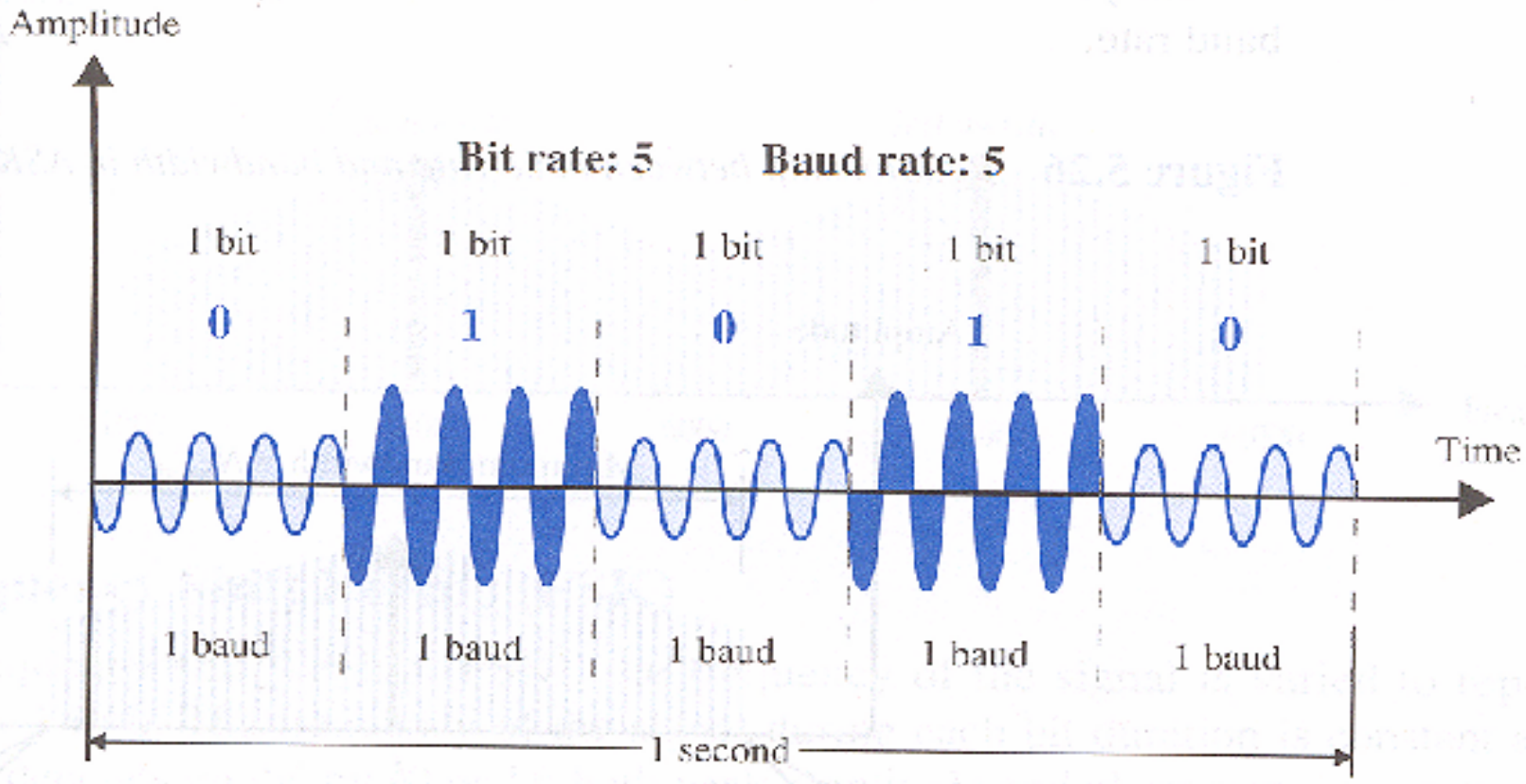
PSTN modems (1)

- The representation of digital information by an analog signal
  - ex: transmit data from an computer to a public telecommunication line

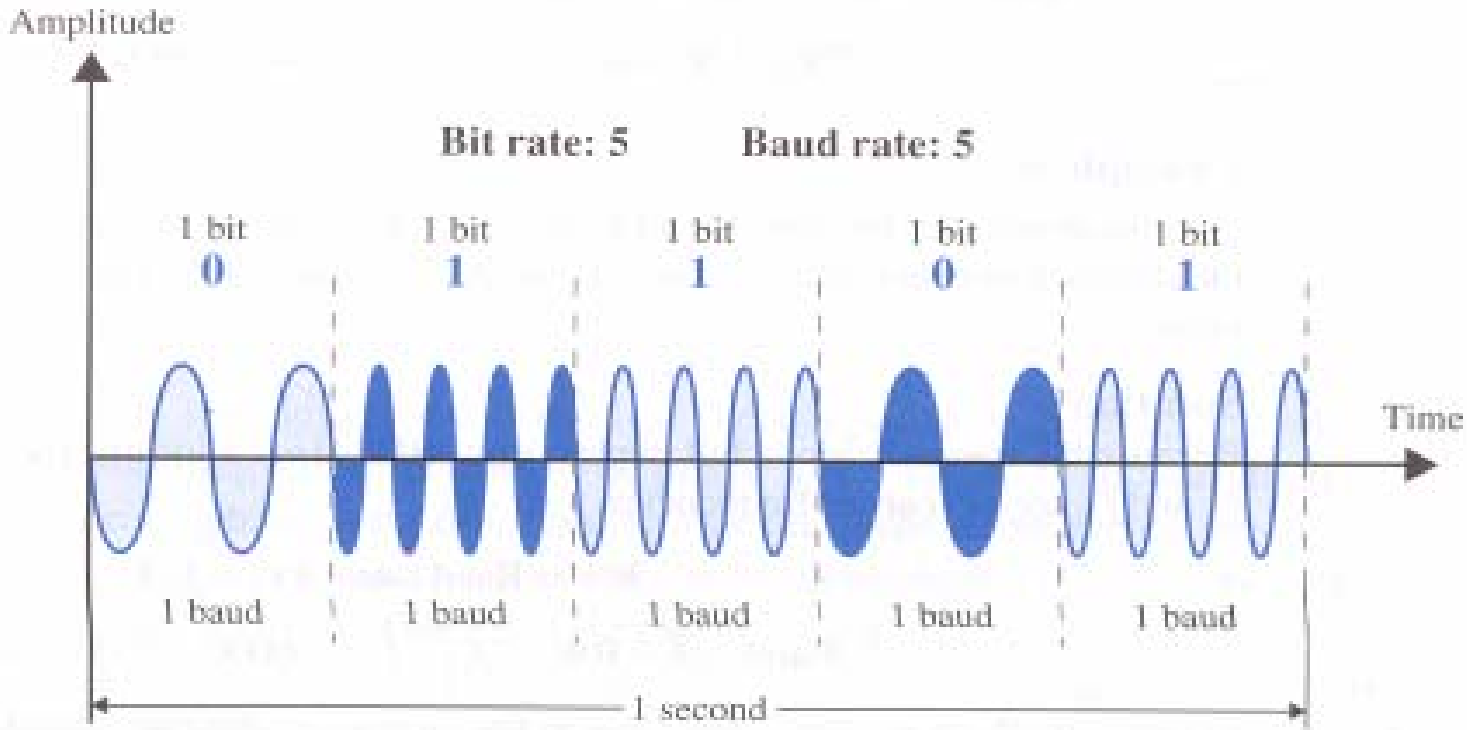


- Based on
  - Amplitude Shift Keying (ASK)
  - Frequency Shift Keying (FSK)
  - Phase Shift Keying (PSK)
  - Quadrature Amplitude Modulation (QAM)
    - combines changes in both amplitude and phase
    - used in all modern modems

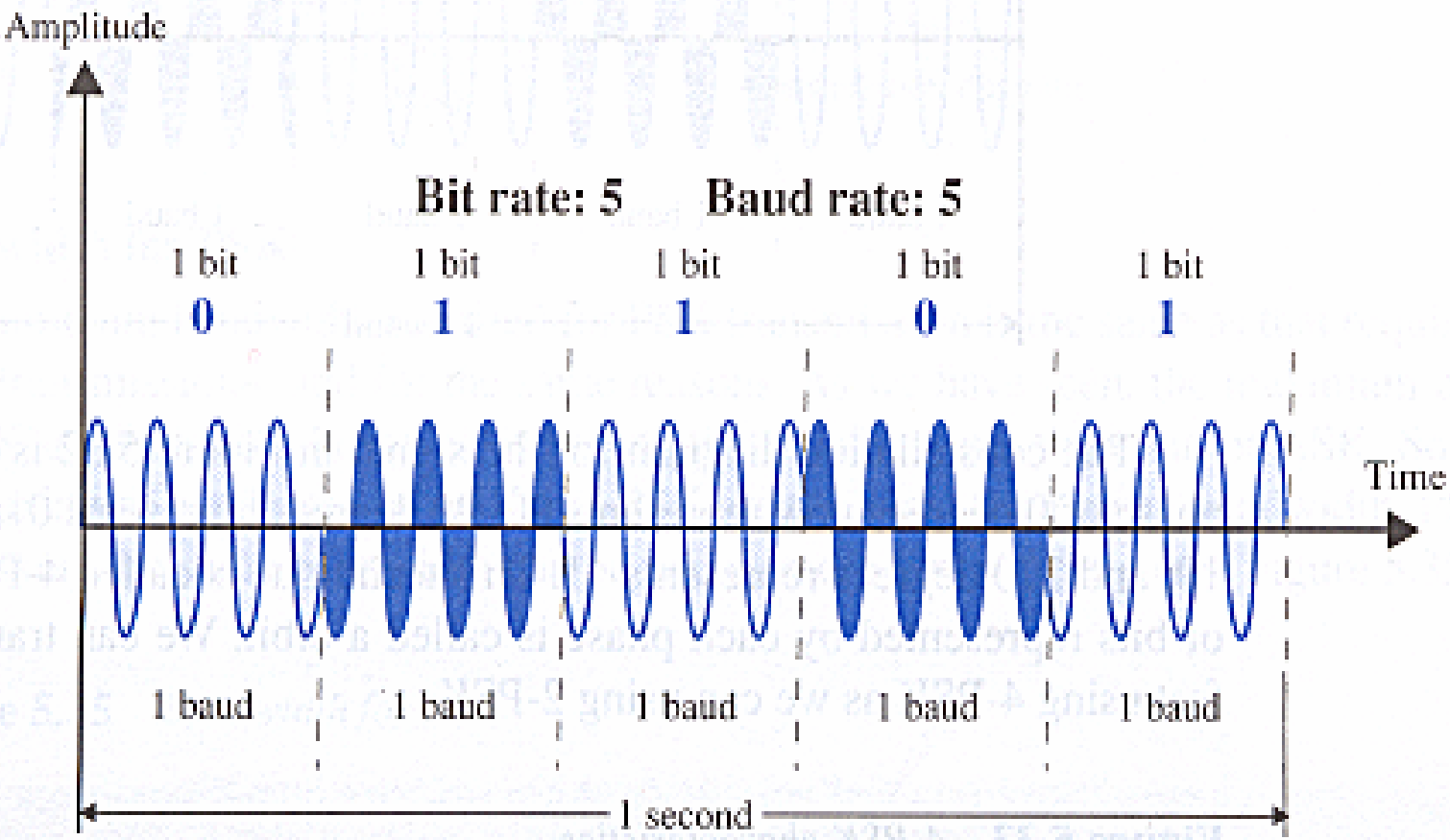
ASK Encoding



FSK Encoding



PSK Encoding



PSTN modems (2)

- Amplitude Shift Keying (ASK)
  - the strength of the signal is varied to represent binary 1 or 0
  - both frequency and phase are constant
  - Problem
    - noise interference: by heat or electromagnetic
      - » changes the amplitude
  - on-off-keying:
    - one of the bit values is no voltage
    - reduction in amount of energy for transmission
  - Bandwidth for ASK
    - $BW = (1+d) \times N_{baud}$
      - d : a factor related to the line condition
      - N_{baud}: baud rate

PSTN modems (3)

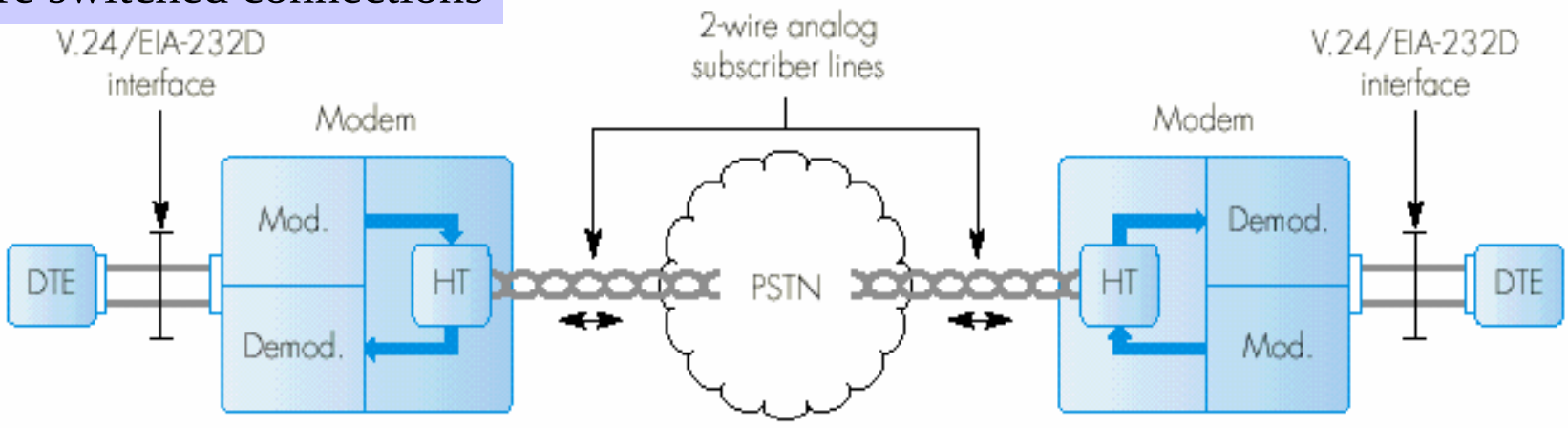
- Phase Shift Keying (PSK)
  - the phase is varied to represent binary 1 or 0
  - Type of PSK
    - 2-PSK (See Figure 5.30 and 5.31)
      - a phase of 0 degrees is binary 0
      - a phase of 180 degree is binary 1
    - 4-PSK (See Figure 5.32, and 5.33)
      - a phase of 0 degrees is binary 00
      - a phase of 90 degree is binary 01
      - a phase of 180 degrees is binary 10
      - a phase of 270 degree is binary 11
    - 8-PSK (See Figure 5.34)
  - Bandwidth for PSK
    - Minimum bandwidth = N baud

PSTN modems (4)

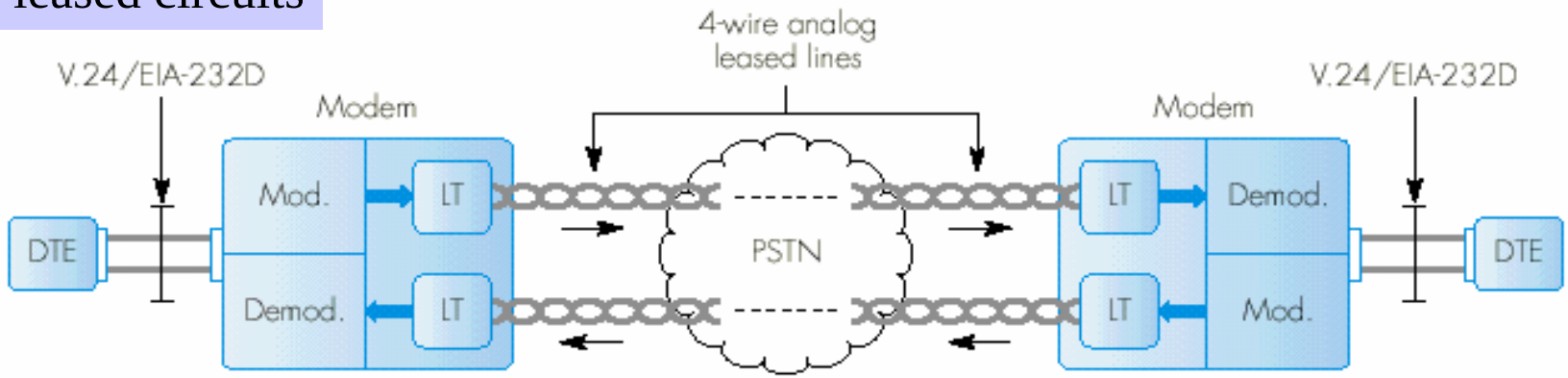
- Quadrature Amplitude Modulation (QAM)
  - combining ASK and PSK in such a way that we have maximum contrast between each bit, dibit, tribit, quadbit, and so on
  - various configuration (see Figure 5.36)
    - 4-QAM (2bits)
      - 1 amplitude and 4 phases
    - 8-QAM (3bits)
      - 2 amplitudes and 4 phases
    - 16-QAM (4bits)
      - 3 amplitudes and 12 phases : ITU-T recommendation
      - 4 amplitudes and 8 phases : OSI recommendation
      - 2 amplitudes and 8 phases
  - Bandwidth for QAM
    - the same for ASK and PSK transmission

PSTN modems (5)

2-wire switched connections



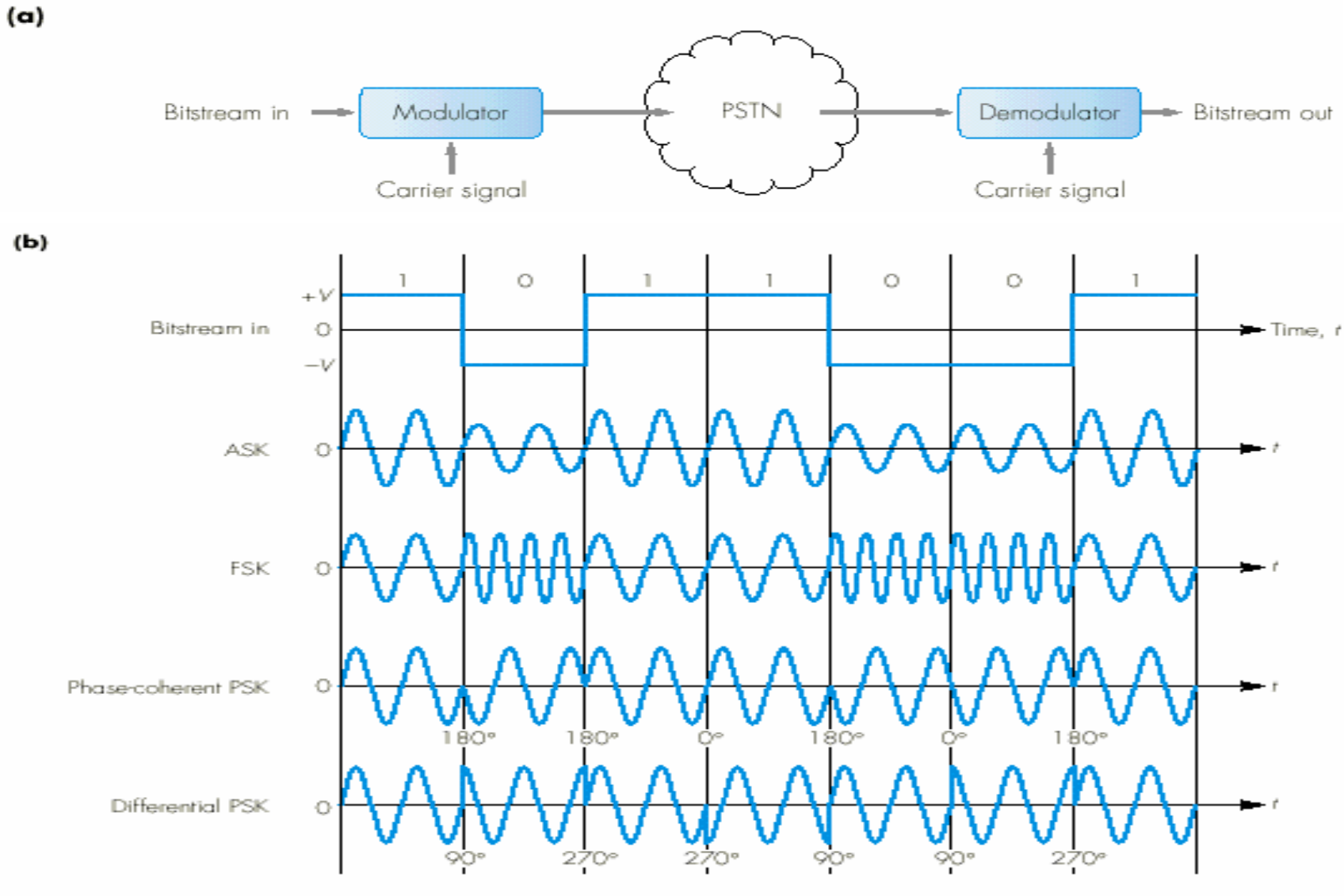
4-wire leased circuits



Mod. = modulator section
Demod. = demodulator section
DTE = data/digital terminal equipment

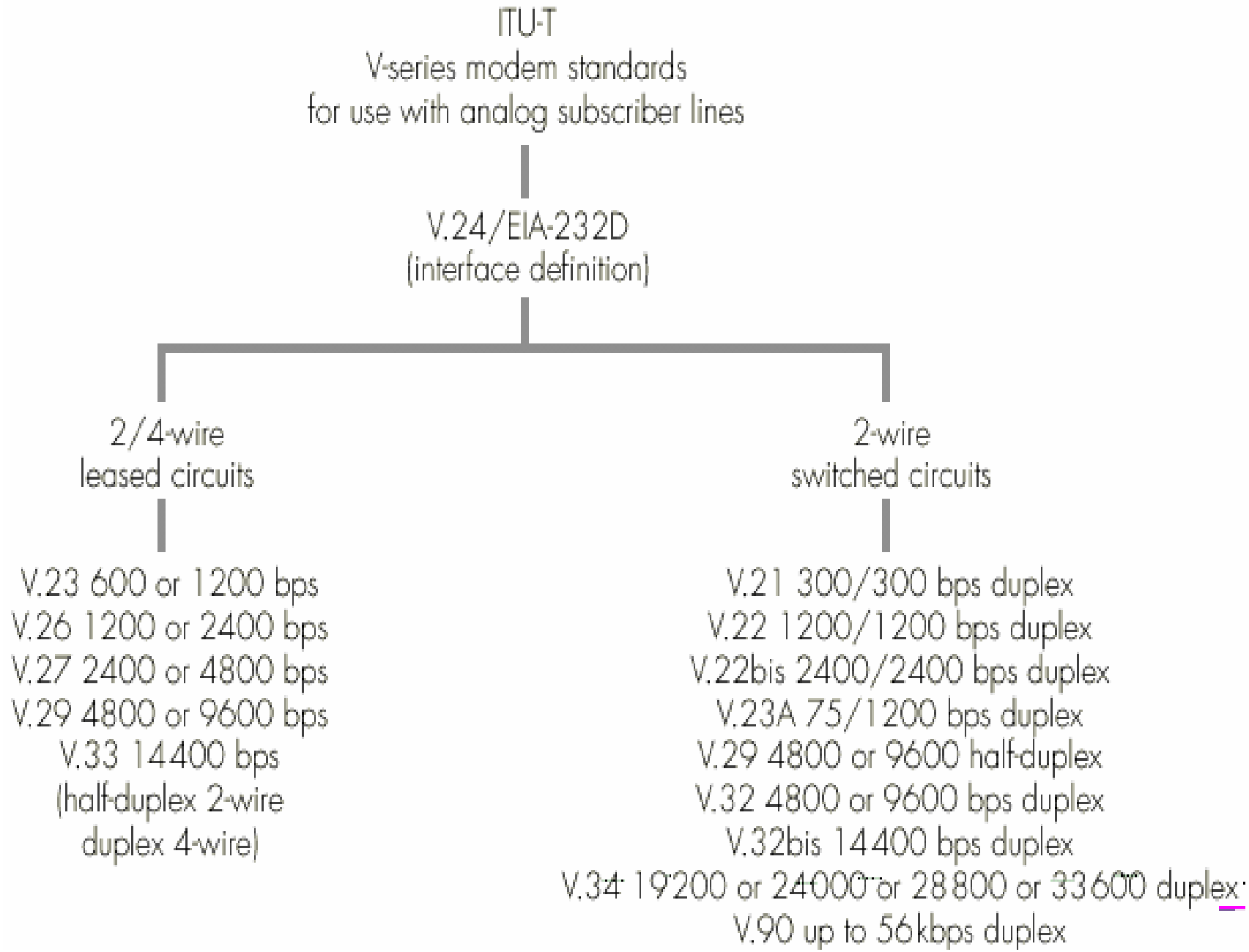
HT = hybrid transformer
LT = line transformer

PSTN modems (6)

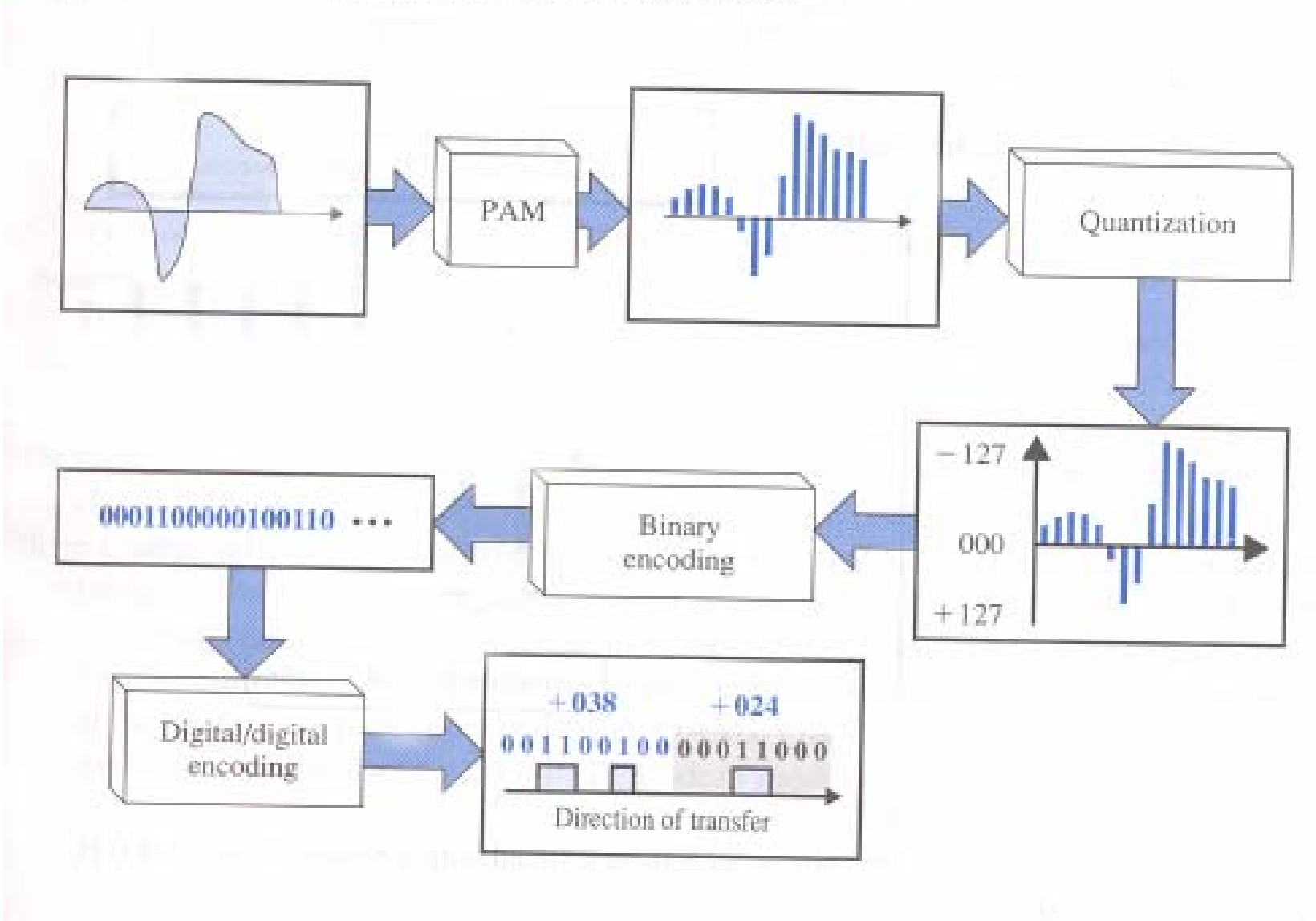


ITU-T modem standards

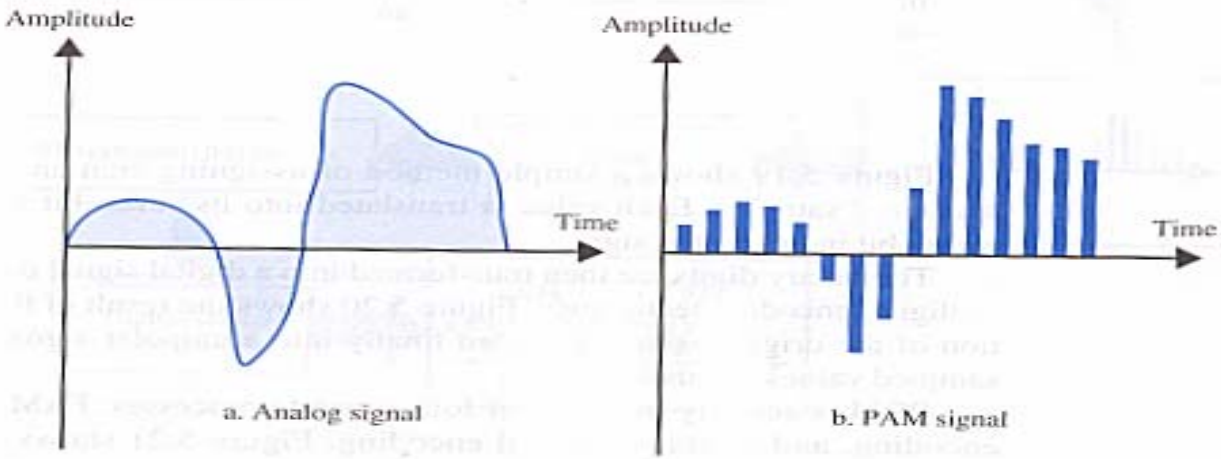
V.22bis FDX 600 baud 1200/2400 bps 2-wire		Two speeds: 1200 bps using 4-DPSK or 2400 bps using 16-QAM
V.32 FDX 2400 baud 9600 bps 2-wire		32-QAM allows five bits per baud: four data bits plus one redundant bit
V.32bis FDX 2400 baud 14,400 bps 4-wire		The first modem standard with a data rate of 14,400 bps
V.32terbo FDX 2400 baud 19,200 bps 4-wire		
V.33 FDX 2400 baud 14,400 bps 4-wire		128-QAM allows 7 bits per baud: 6 data bits plus one redundant bit
V.34 FDX 2400 baud 28,800 bps 4-wire		Standard speed: 28,800 bps, but with data compression can achieve speeds up to three times that rate


ITU-T
V-series modem standards
for use with analog subscriber lines
V.24/EIA-232D
(interface definition)
2/4-wire
leased circuits
2-wire
switched circuits
V.23 600 or 1200 bps
V.26 1200 or 2400 bps
V.27 2400 or 4800 bps
V.29 4800 or 9600 bps
V.33 14400 bps
(half-duplex 2-wire
duplex 4-wire)
V.21 300/300 bps duplex
V.22 1200/1200 bps duplex
V.22bis 2400/2400 bps duplex
V.23A 75/1200 bps duplex
V.29 4800 or 9600 half-duplex
V.32 4800 or 9600 bps duplex
V.32bis 14400 bps duplex
V.34 19200 or 24000 or 28800 or 33600 duplex
V.90 up to 56kbps duplex

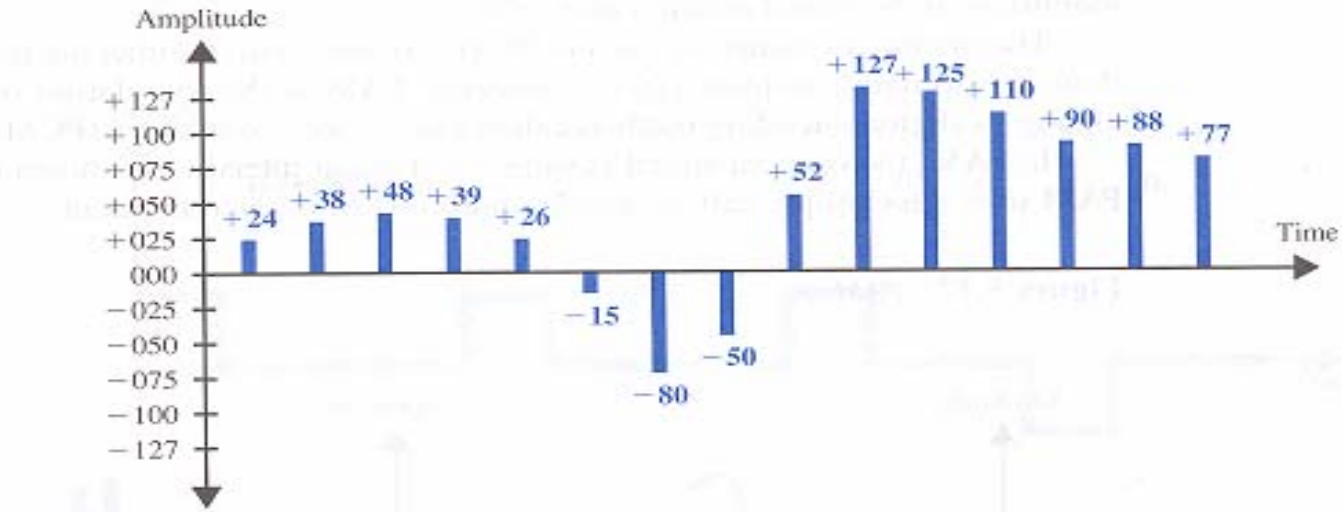
From analog signal to PCM digital code



PAM



Quantized PAM signal

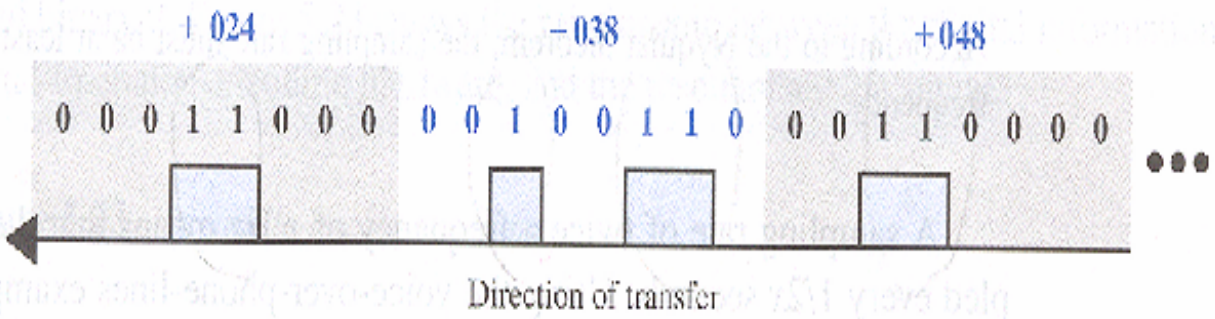


Quantizing using sign and magnitude

+024	00011000	−015	10001111	+125	01111101
+038	00100110	−080	11010000	+110	01101110
+048	00110000	−050	10110010	+090	01011010
+039	00100111	+052	00110110	−088	01011000
+026	00011010	+127	01111111	−077	01001101

Sign bit
+ is 0 − is 1

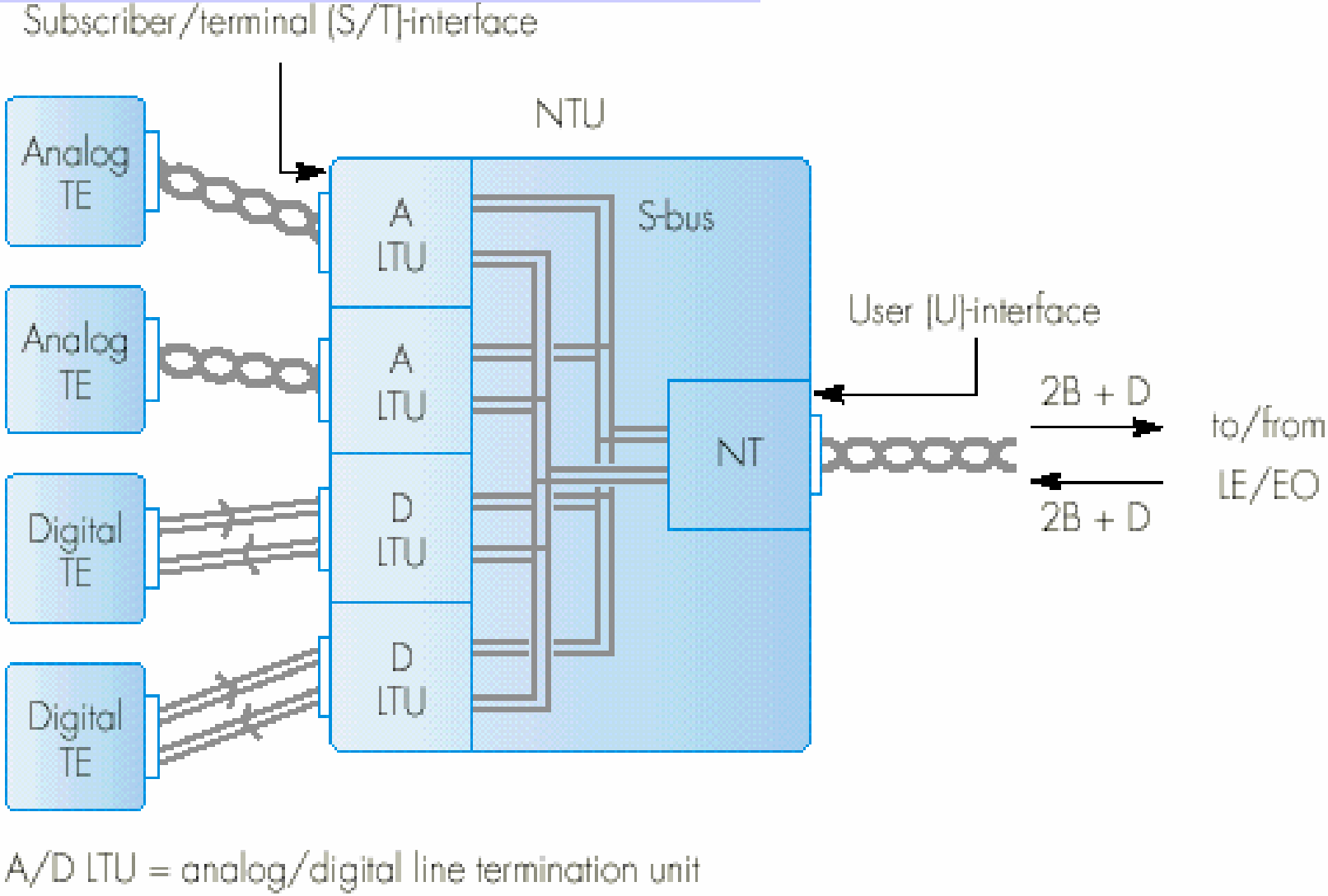
PCM



7.2.3 Digital subscriber lines

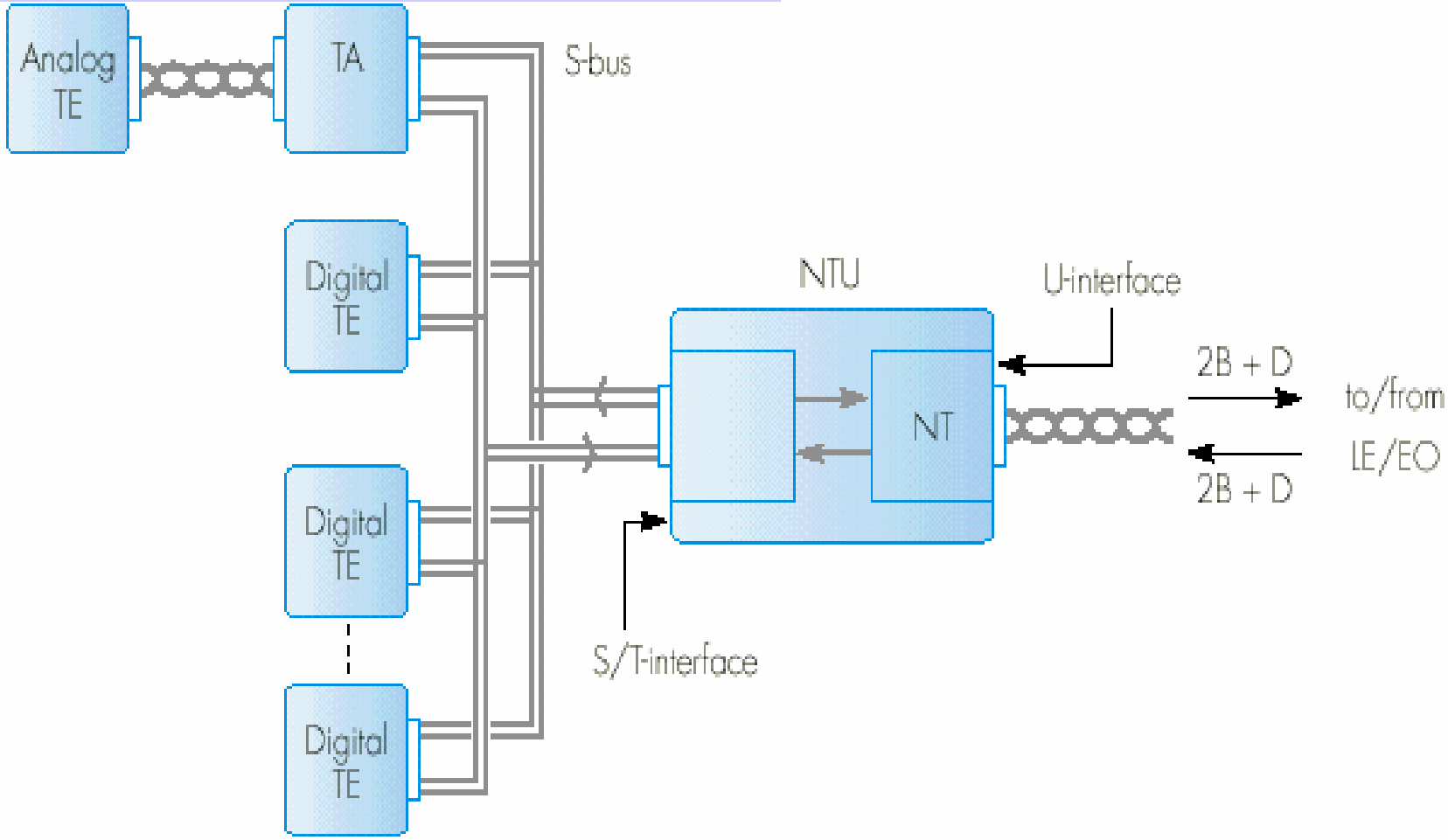
- NTU
  - Network Termination Unit
    - B-channel : Bearer
      - » 64kbps user channel
    - D-channel : 16kbps signaling channel
  - 2B + 1D : 64*2 + 16 = 144kbps duplex
    - 48 bit frames for time-sharing 2B and D channel
      - » 8B1, 1D, 8B2, 1D, 8B1, 1D, 8B2, 1D
      - » 16 bits * 2B ch + 4 bits * D ch + 12bits

ISDN network termination: 4-port NTU

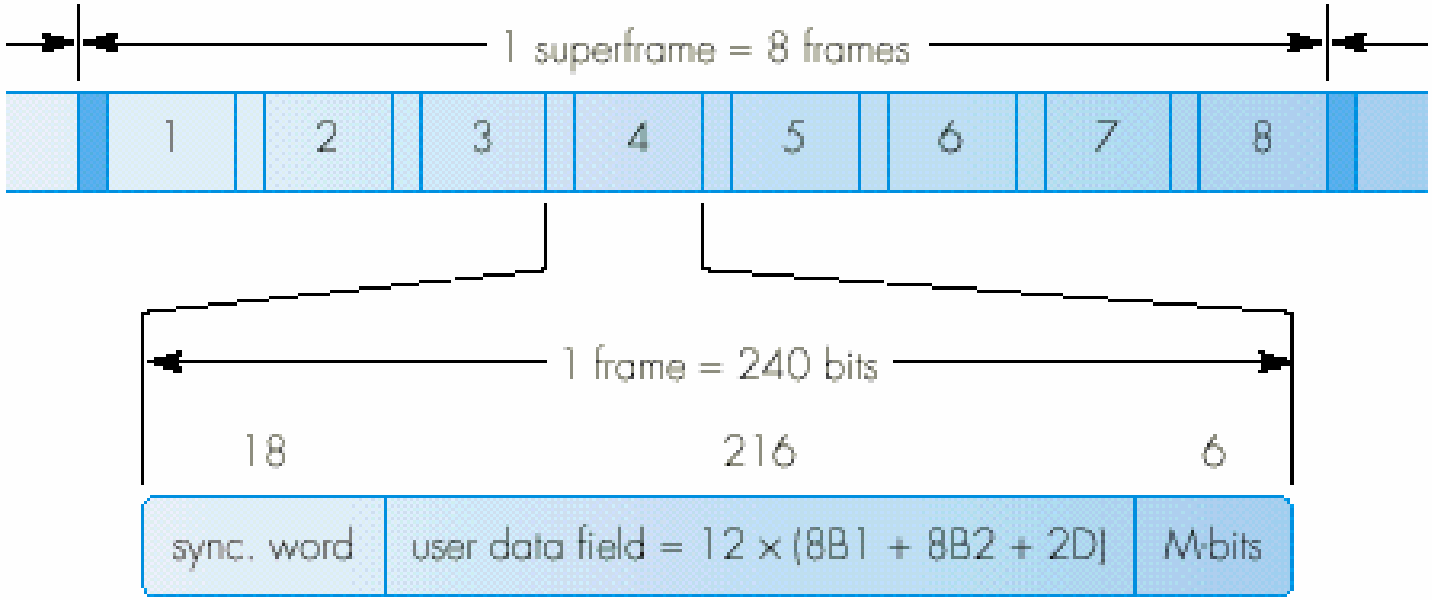


ISDN network termination: S-bus NTU

ITU-T I.430



(c)



2B+D bit-stream

. 18 bit synchronization word

. 12 groups of 18 bits : user data field

. Maintenance message

Example 7.1

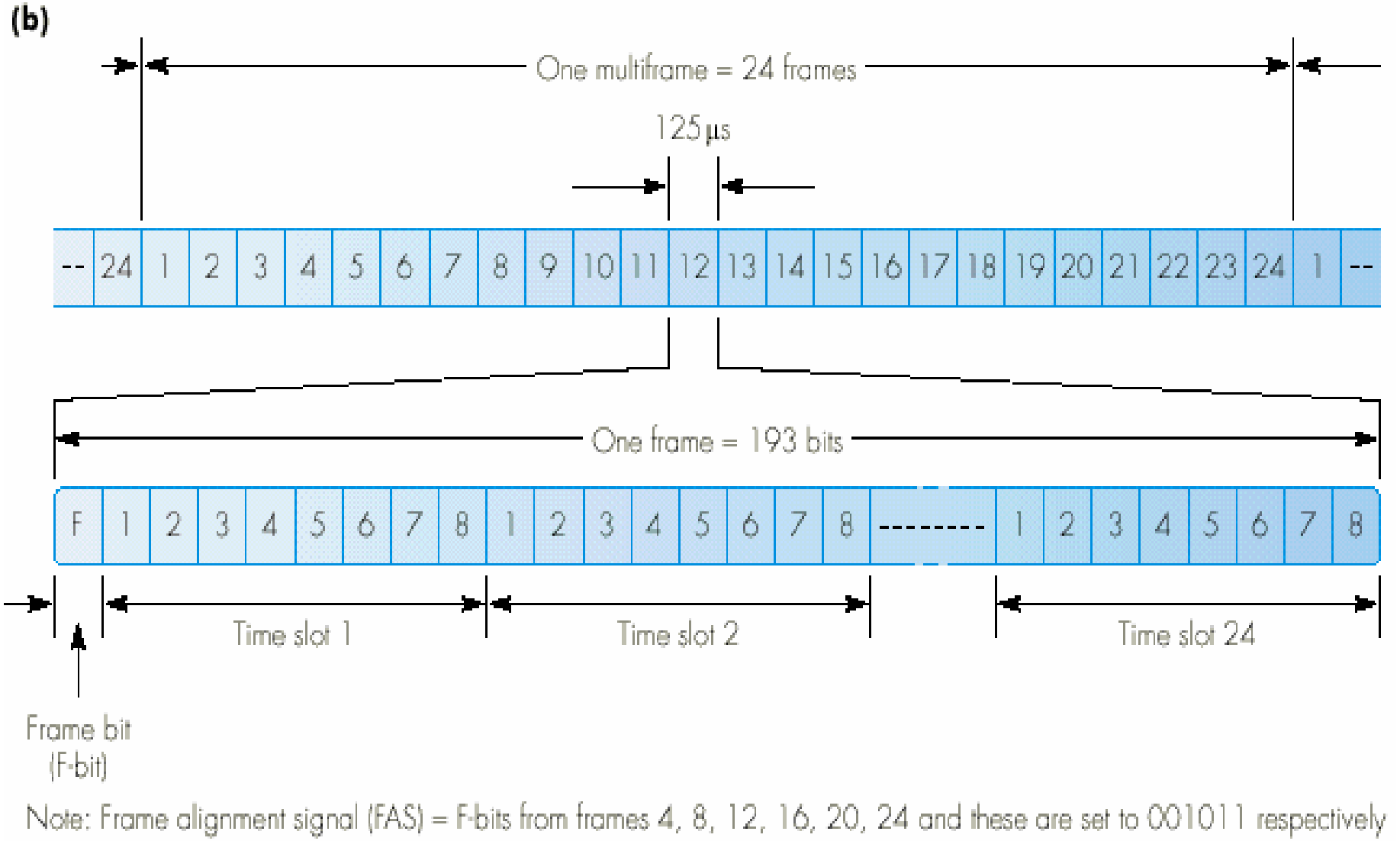
Q) bit rate and baud rate of BRI line

A) 64 x 240/96 = 160 kbps (12x8 = 96bits per B channel)

80 k baud (2bits per signal element)

T1 line: 1.544 Mbps PRI: frame and multi-frame structure

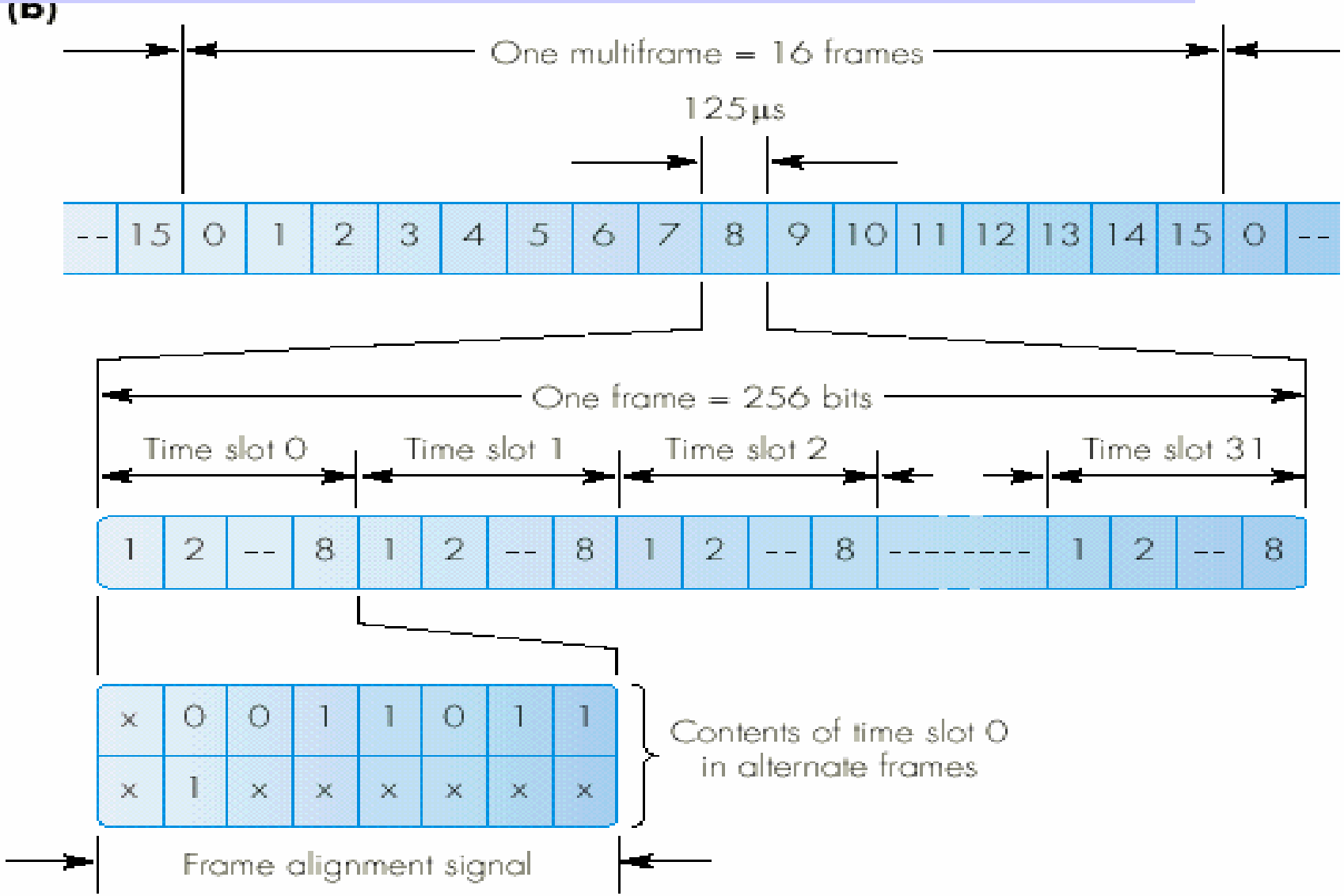
193 bits / 125 * 10^{-6} sec= 1.544 Mbps



Note: Frame alignment signal (FAS) = F-bits from frames 4, 8, 12, 16, 20, 24 and these are set to 001011 respectively

E1 line: 2.048 Mbps PRI: frame and multi-frame structure

256 bits / 125 * 10^{-6} sec= 2.048 Mbps



7.2.4 Plesiochronous digital hierarchy

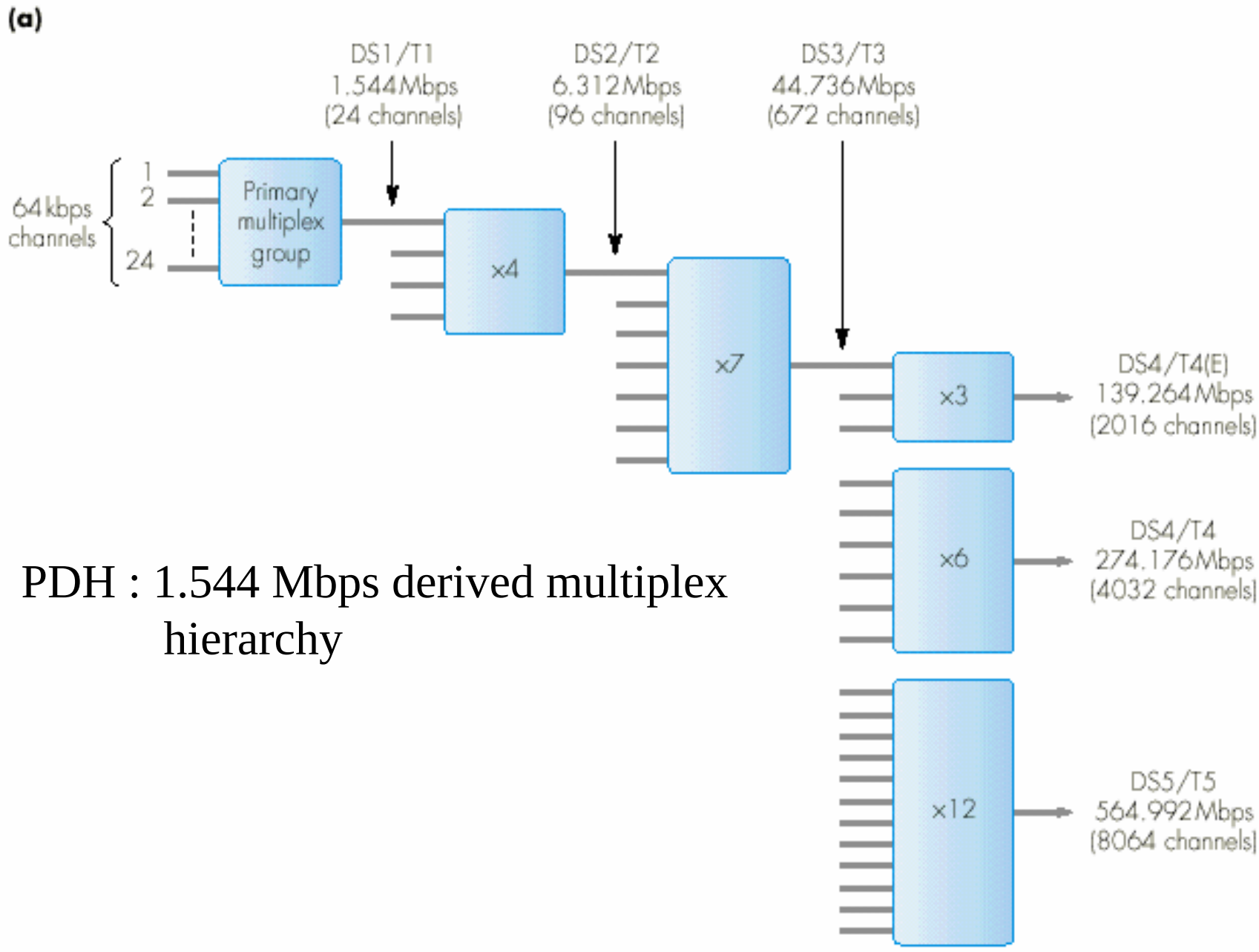
- A hierarchical way by progressively multiplexing together multiple lower-level multiplexed streams

- Justification bits
  - compensate for the small differences in the timing of each stream

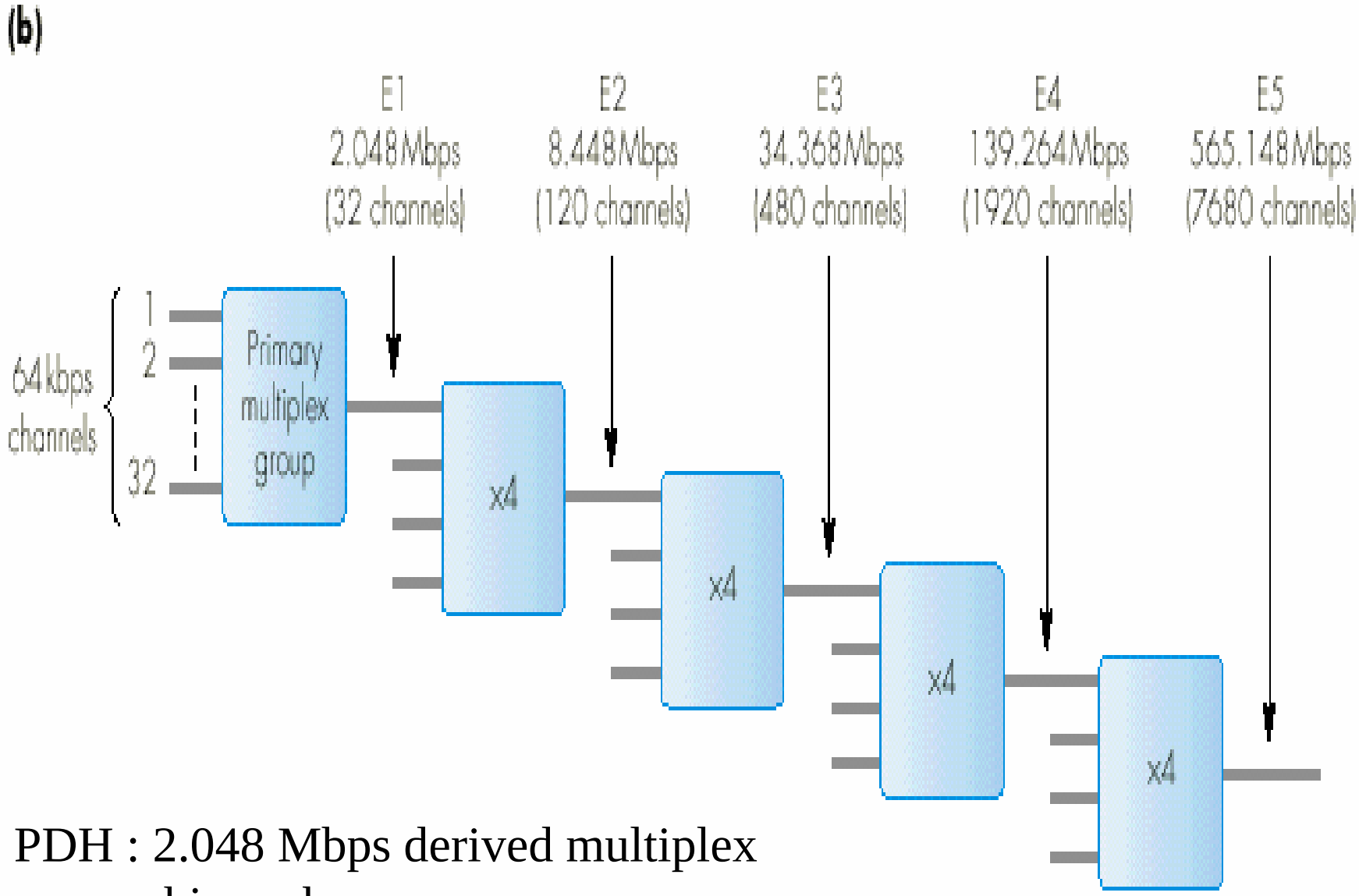
    example: E1 is 2.048 Mbps

    E2 = 4 * 2.048 + JB = 8.192 + 0.256 = 8.448Mbps

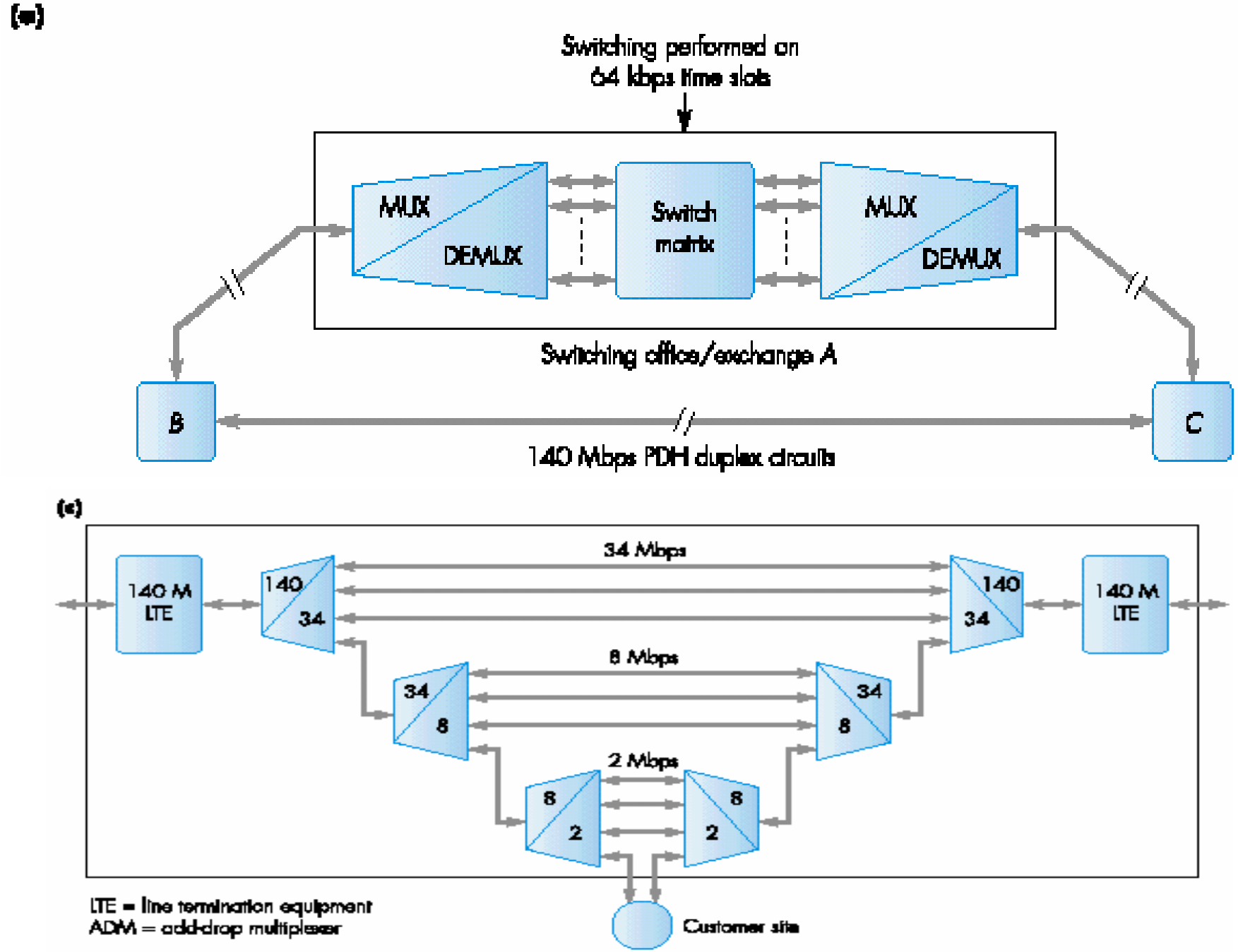
- Drop-and-Insert or Add-Drop Multiplexer (ADM)
  - multiplexing and demultiplexing of BW for user requirement and transmission



PDH : 1.544 Mbps derived multiplex hierarchy

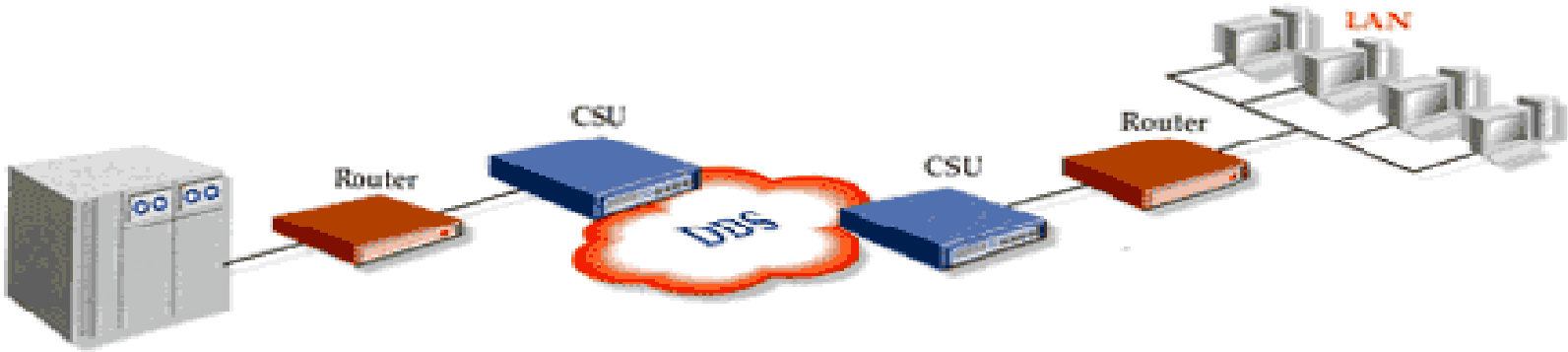


PDH : 2.048 Mbps derived multiplex hierarchy

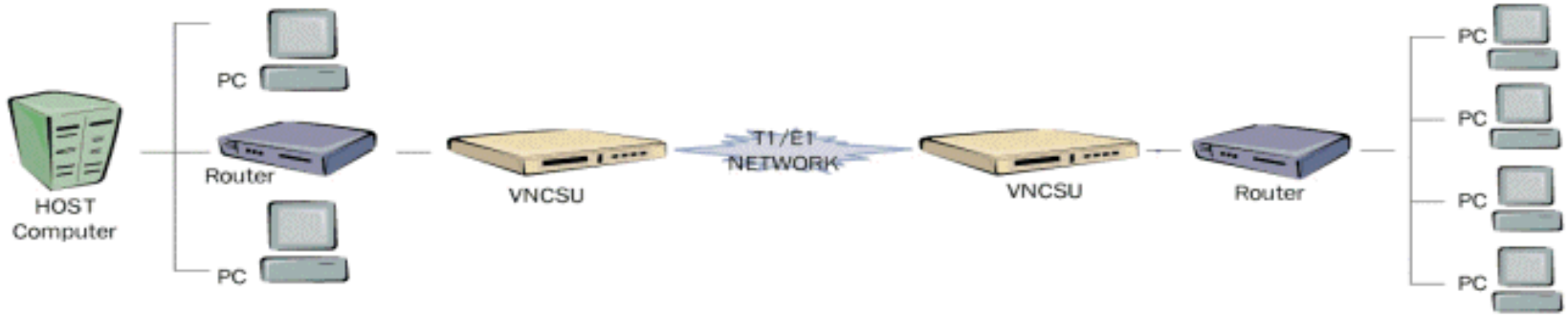

(a)
Switching performed on
64 kbps time slots
MUX
DEMUX
Switch
matrix
MUX
DEMUX
Switching office/exchange A
B
C
140 Mbps PDH duplex circuits
(c)
140 M
LTE
140
34
34 Mbps
140
34
140 M
LTE
8 Mbps
34
8
34
8
2 Mbps
8
2
8
2
LTE = line termination equipment
ADM = add-drop multiplexer
Customer site

CSU(Channel Service Unit)

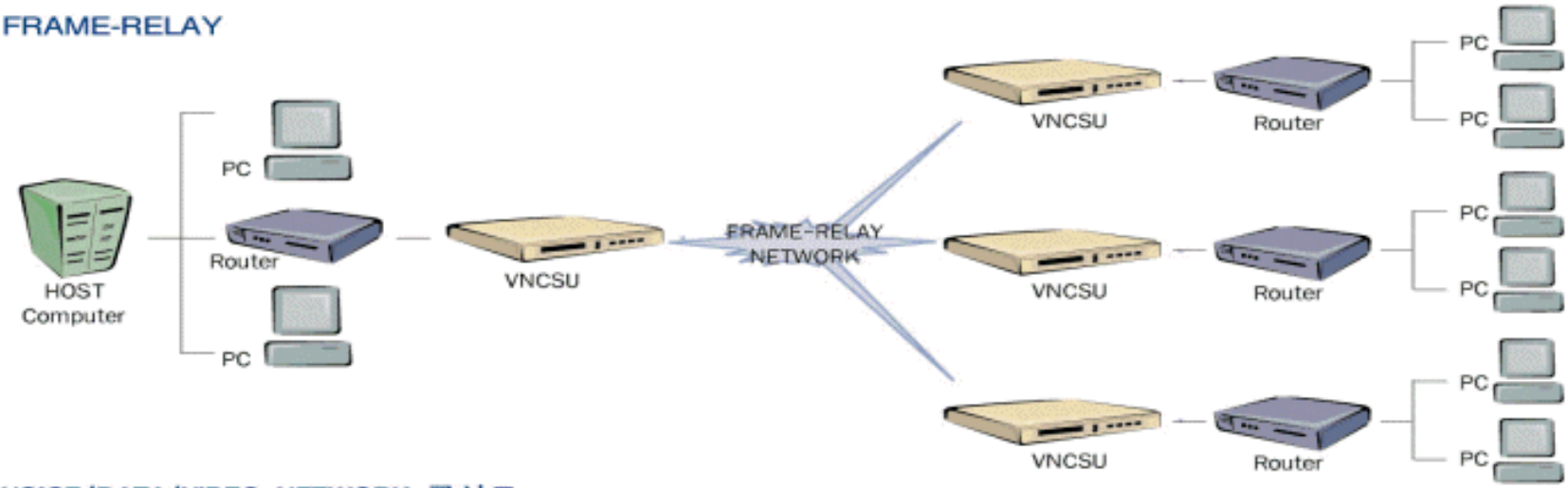
- CSU는 Channel Service Unit의 약자로 T1 또는 E1 트렁크를 수용할 수 있는 장비로서 각각의 트렁크를 받아서 속도에 맞게 나누어 분할하여 쓸 수 있는 장비
- Mux라는 집중 장비가 여러개의 채널들을 모아서 하나의 대용량 전송로를 통하여 한꺼번에 전송되는 트렁크 방식으로 전송
- 부호화(Encoding)하여 상대방으로 전송하고 또한 부호화되어 들어오는 정보를 원래의 신호인 디지털로 복호화(Decoding) 하는 것이 "CSU, 채널 서비스 장치" 의 역할



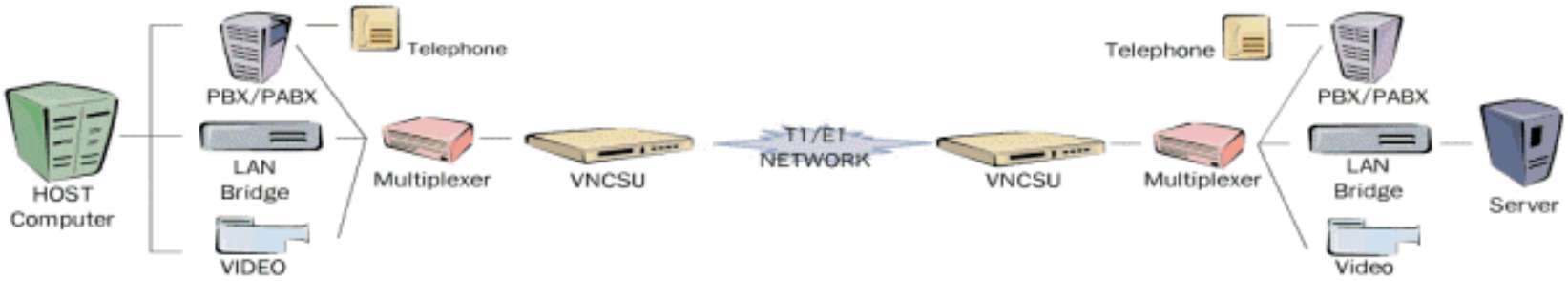
LAN To LAN

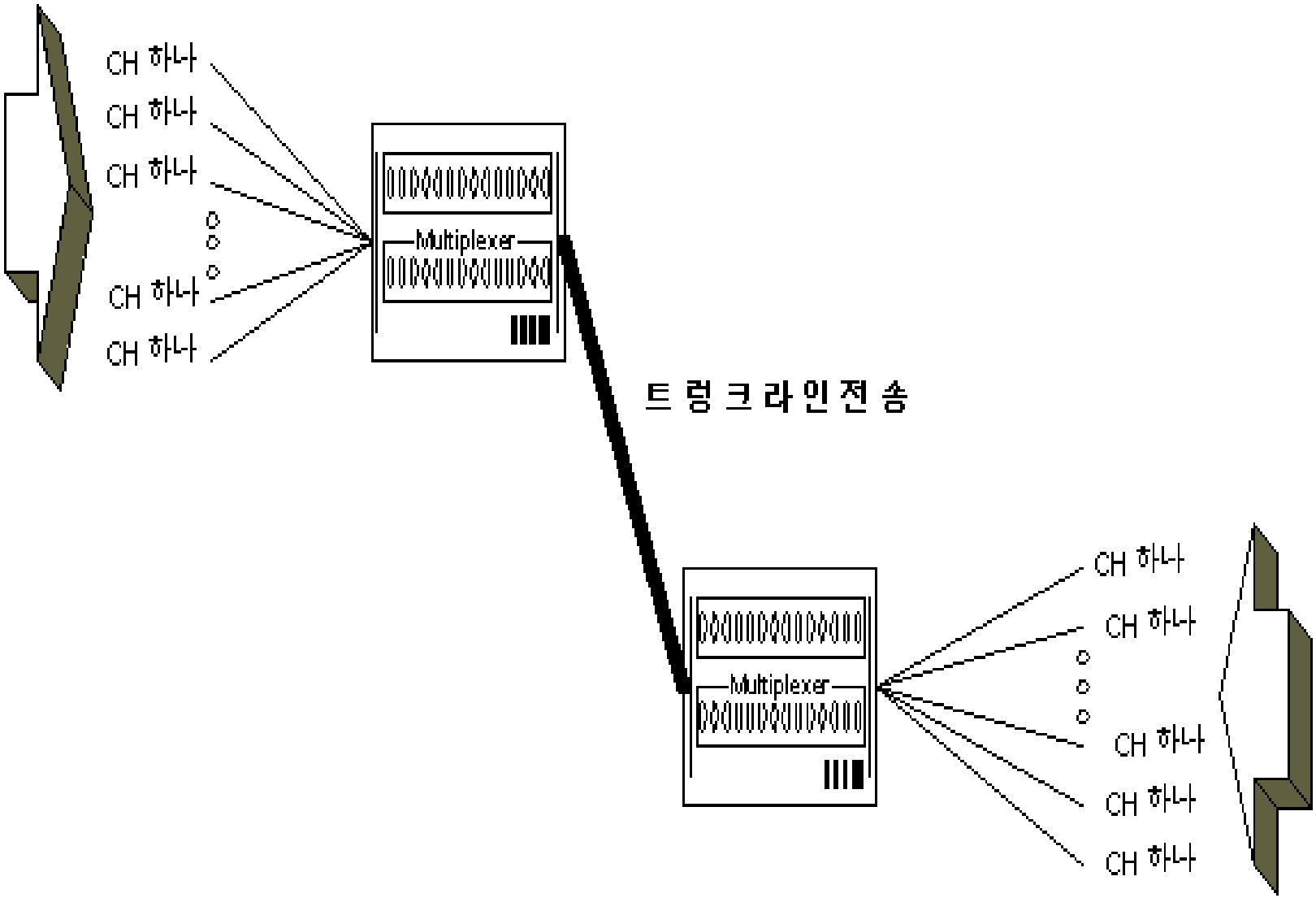


FRAME-RELAY



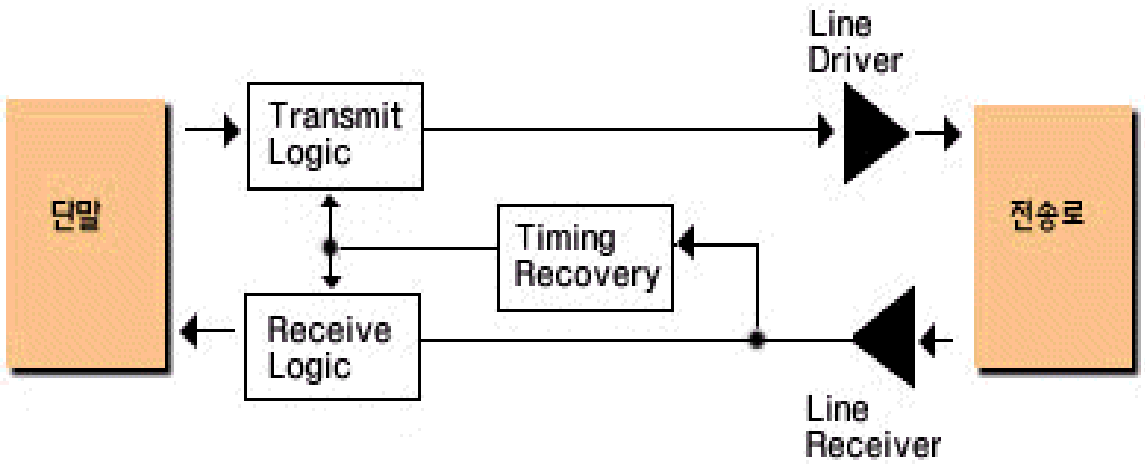
VOICE/DATA/VIDEO NETWORK 구성도



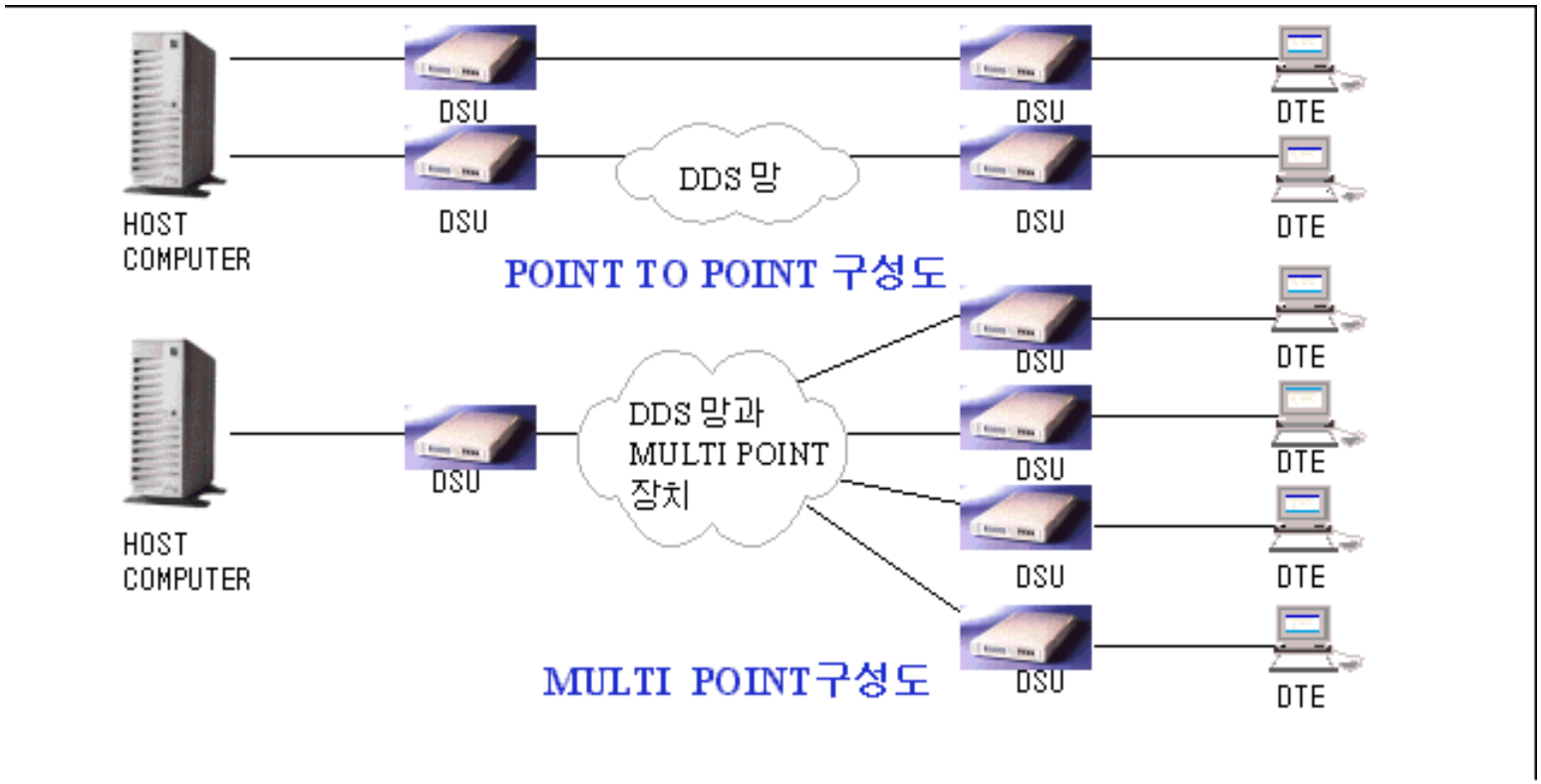

CH 하나
CH 하나
CH 하나
CH 하나
CH 하나
Multiplexer
트렁크라인전송
Multiplexer
CH 하나
CH 하나
CH 하나
CH 하나
CH 하나

DSU (Digital/Data Service Unit)

- DSU는 디지틀전용회선을 사용할 때 필요한 장비로 DSU가 처리할 수 있는 속도는 9.6Kbps - 64Kbps
- 만약 128Kbps이상의 속도를 사용하게 될 때는 DSU가 아닌 HDSL등의 장비 사용
- DSU는 대역폭이 그렇게 크지 않은 56Kbps를 가장 많이 사용하기 때문에 일반 실선에 바로 연결을 해서 사용
- DSU의 주요 구성 모듈은 Bipolar (eg, RZ) Encoder/Decoder와 Digital Phase Lock Loop




전화국
MX13
MUX
(T3)
T1/E1
HDSL
4wire 실선
2B1Q
HDSL
Unipolar
Signal
T1/E1
CSU
ROUTER


HOST
COMPUTER
DSU
DSU
DDS 망
DSU
DSU
DTE
DTE
POINT TO POINT 구성도
HOST
COMPUTER
DSU
DDS 망과
MULTI POINT
장치
DSU
DSU
DSU
DTE
DTE
DTE
DTE
MULTI POINT구성도

7.2.5 Synchronous Digital Hierarchy

- SDH
  - developed by Bellcore under SONET
    - Synchronous Optical NETwork
  - basic transmission rate
    - 155.52 Mbps
    - STM-1 : synchronous transport module level 1
      - » STM-4: 622 Mbps
      - » STM-16: 2.4 Gbps
- SONET
  - synchronous transport signal (STS)
  - optical signal (OC)
    - STS-1/OC-1 : 51.84Mpbs

SDH/SONET multiplexing

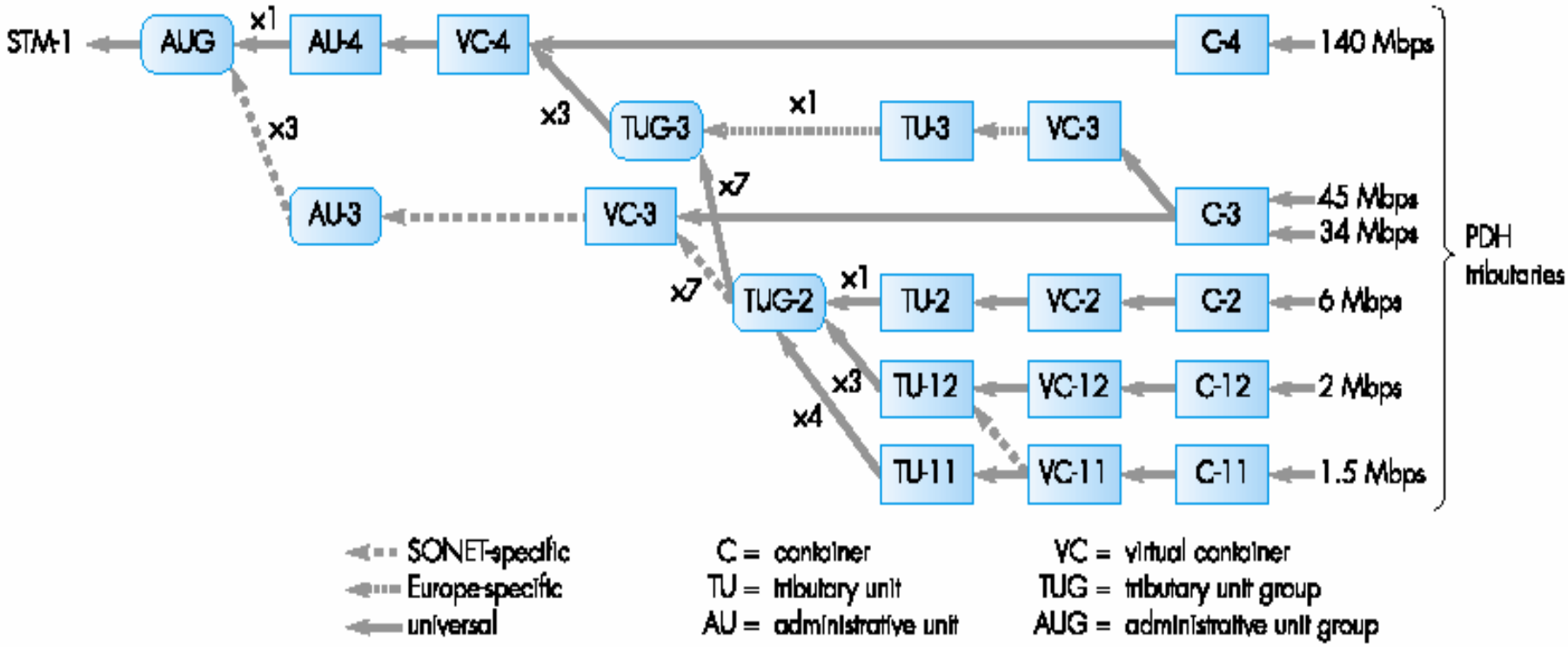
- Container
  - contains the information content to carry multiple 1.5/2/6/34/45/140 Mbps PDH streams
  - contains additional stuffing bits, control information
    - path overhead , control BER (bit error rate)

      » Virtual Container

  - see figure 7.19 : SDH/SONET multiplexing hierarchy and terminology

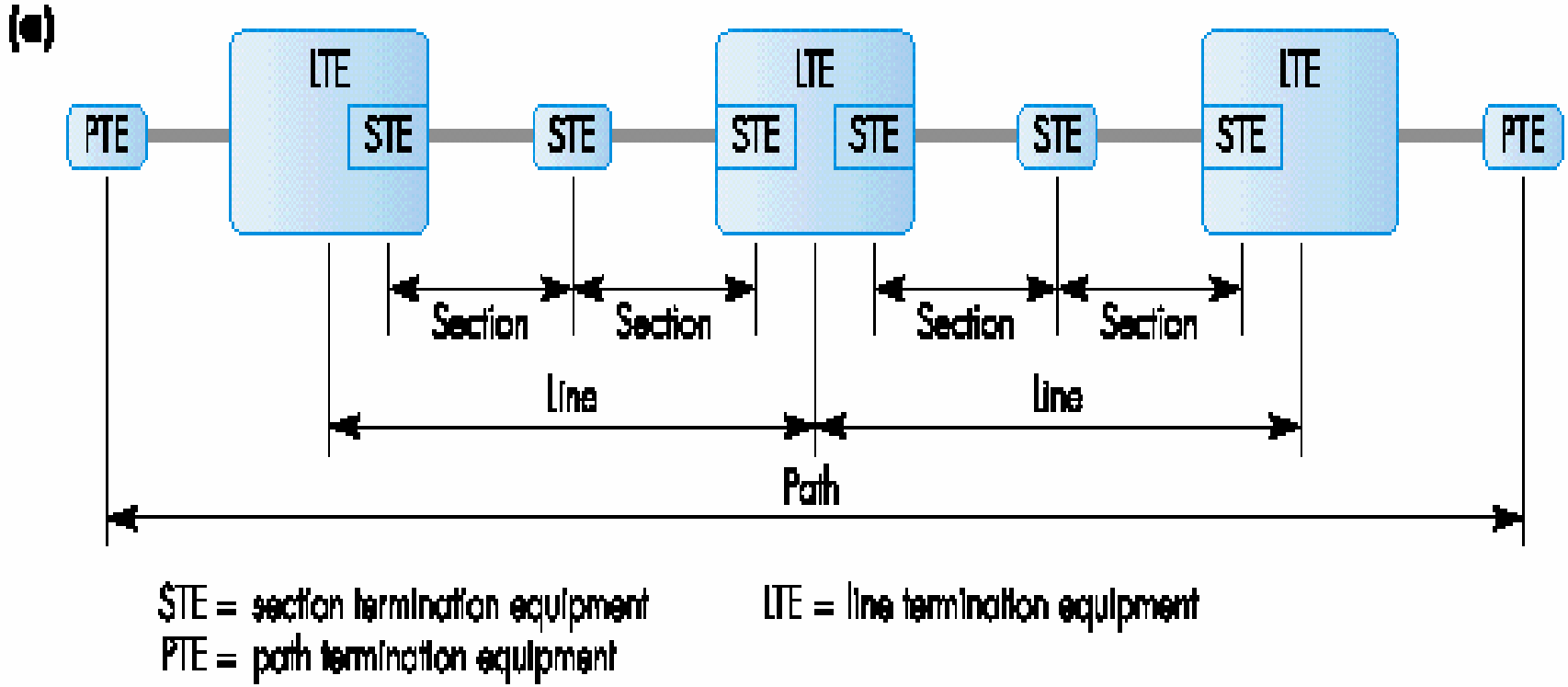
Figure 7.19

SONET	SDH	Bit rate (Mbps)
STS-1/OC-1		51.84
STS-3/OC-3	STM-1	155.52
STS-9/OC-9		466.56
STS-12/OC-12	STM-4	622.08
STS-18/OC-18		933.12
STS-24/OC-24		1244.16
STS-36/OC-36		1866.24
STS-48/OC-48	STM-16	2488.32

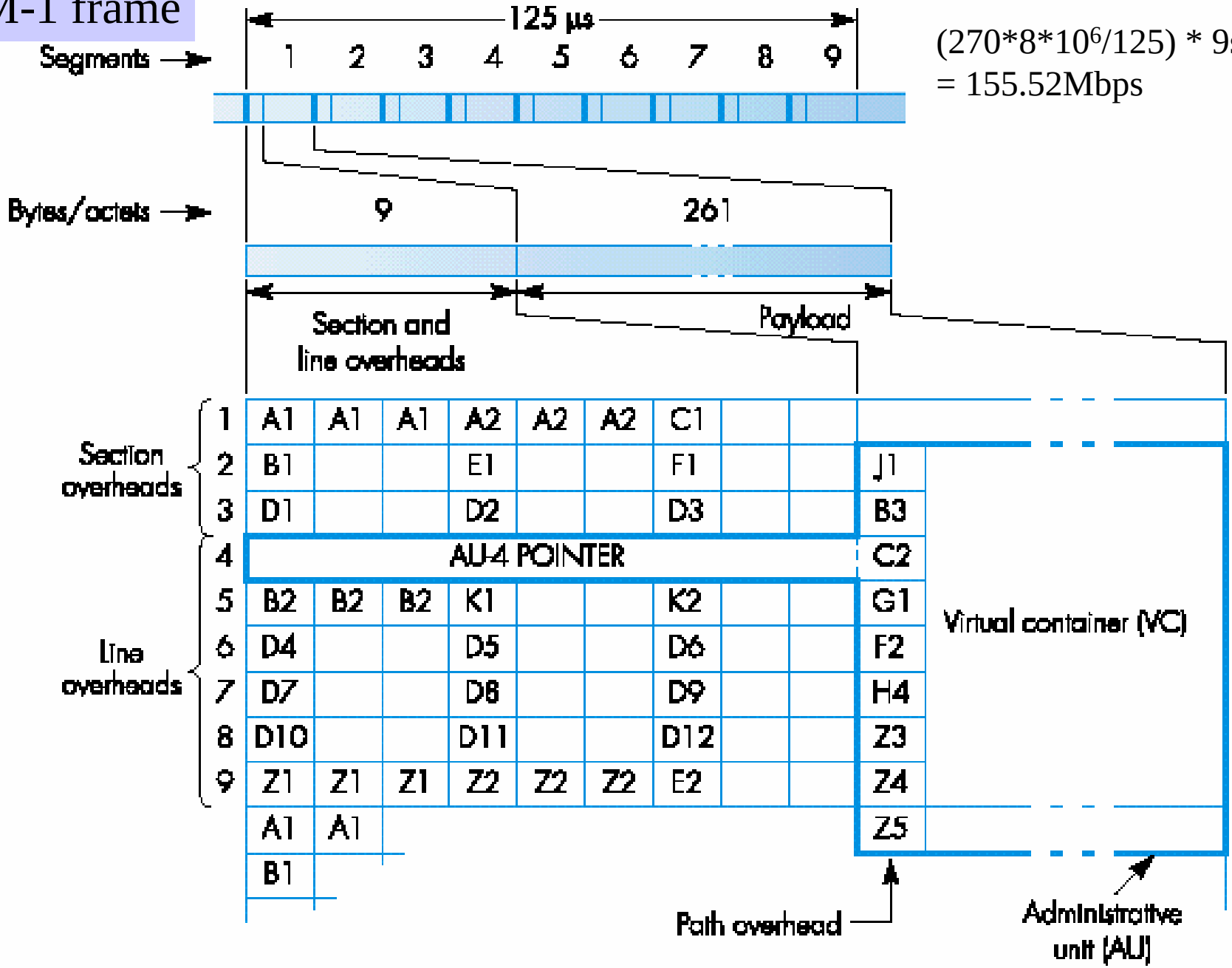


SDH/SONET detail

- The Structure of SDH/SONET frame
  - sections: a single length of transmission cable, between STE
  - lines: extends across multiple cable, between LTE
  - paths: an end-to-end transmission path through the complete TS

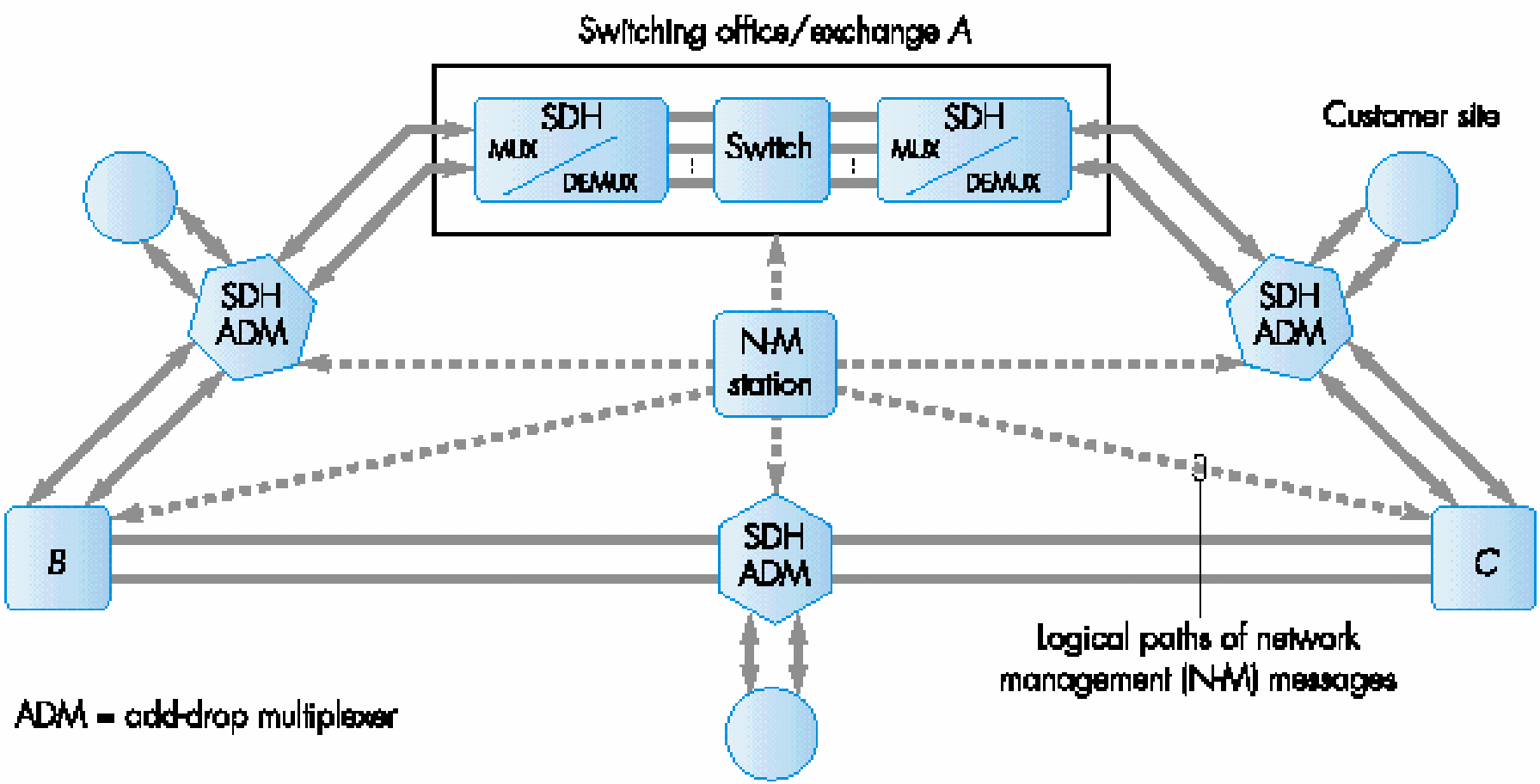


STM-1 frame



(270*8*10^6/125) * 9seg
= 155.52Mbps

Service provision with SDH equipment using NM



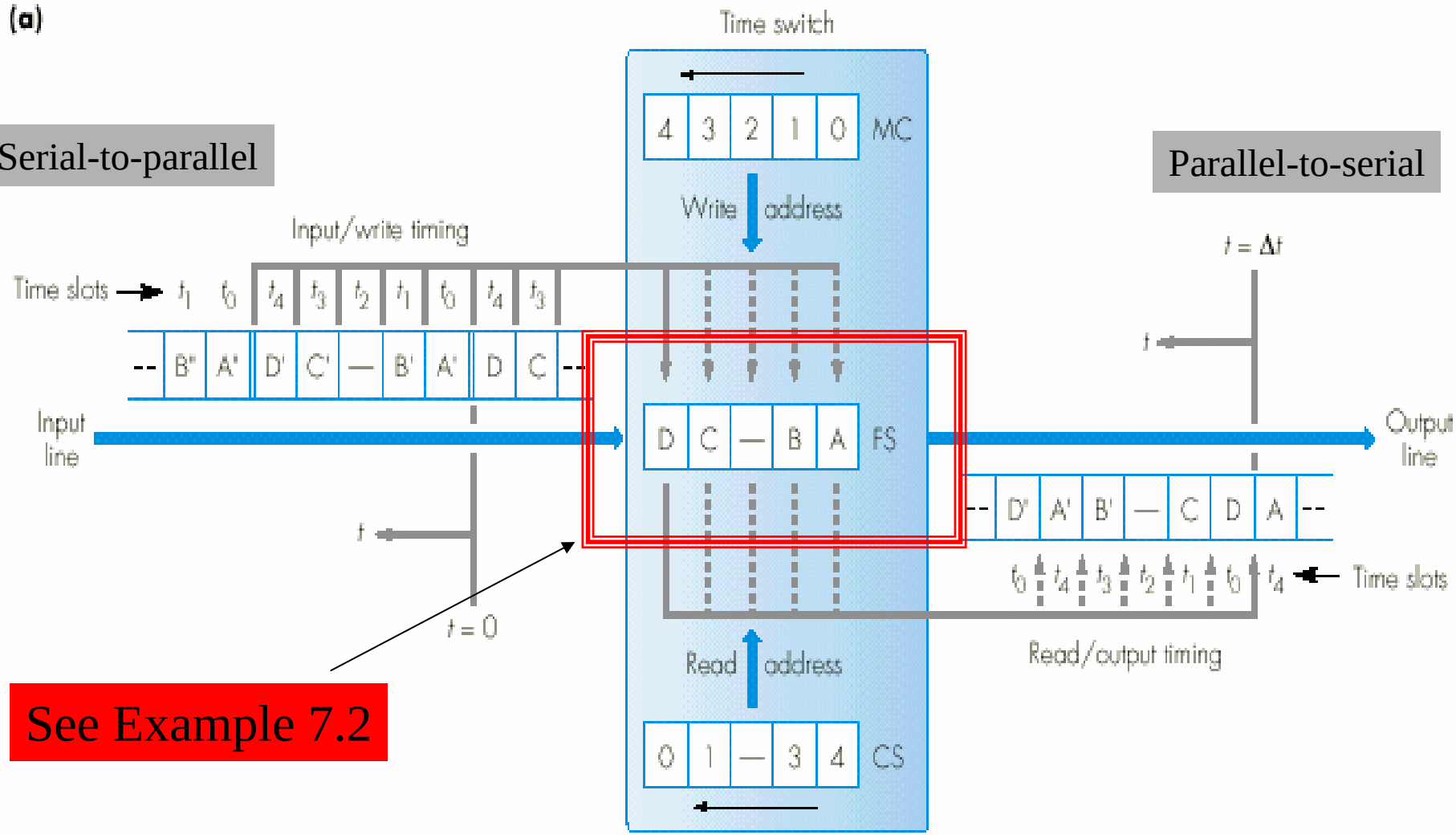
7.3 Switching Systems

- Switching Capacity
  - local exchange/ end offices
  - regional tandem exchanges
  - national tandem exchanges
  - remote concentrators

    - major difference is the volume of traffic switched

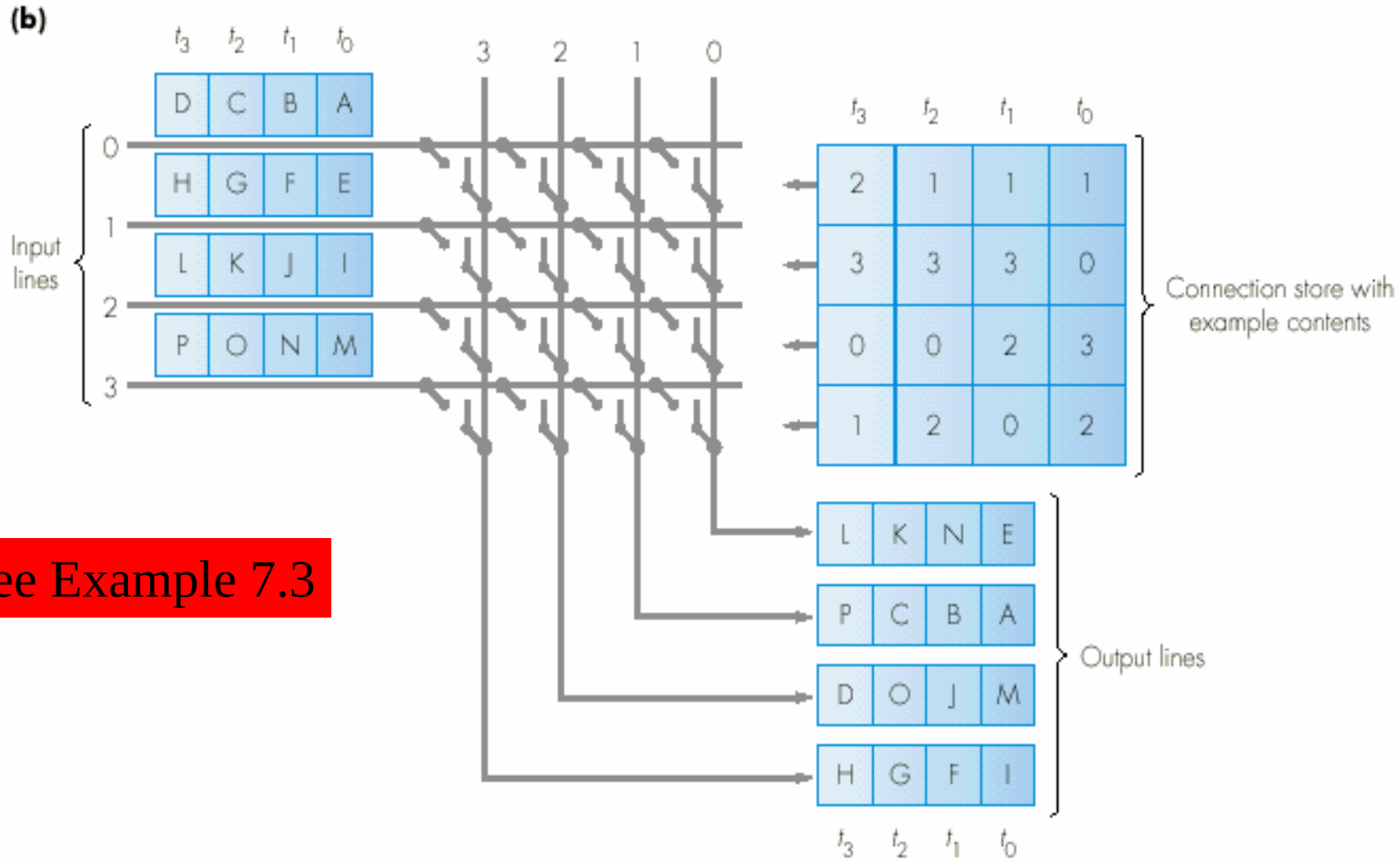
- Two kinds
  - space switching: an array of M input and N output lines
  - time switching: N time slots

Time Switching



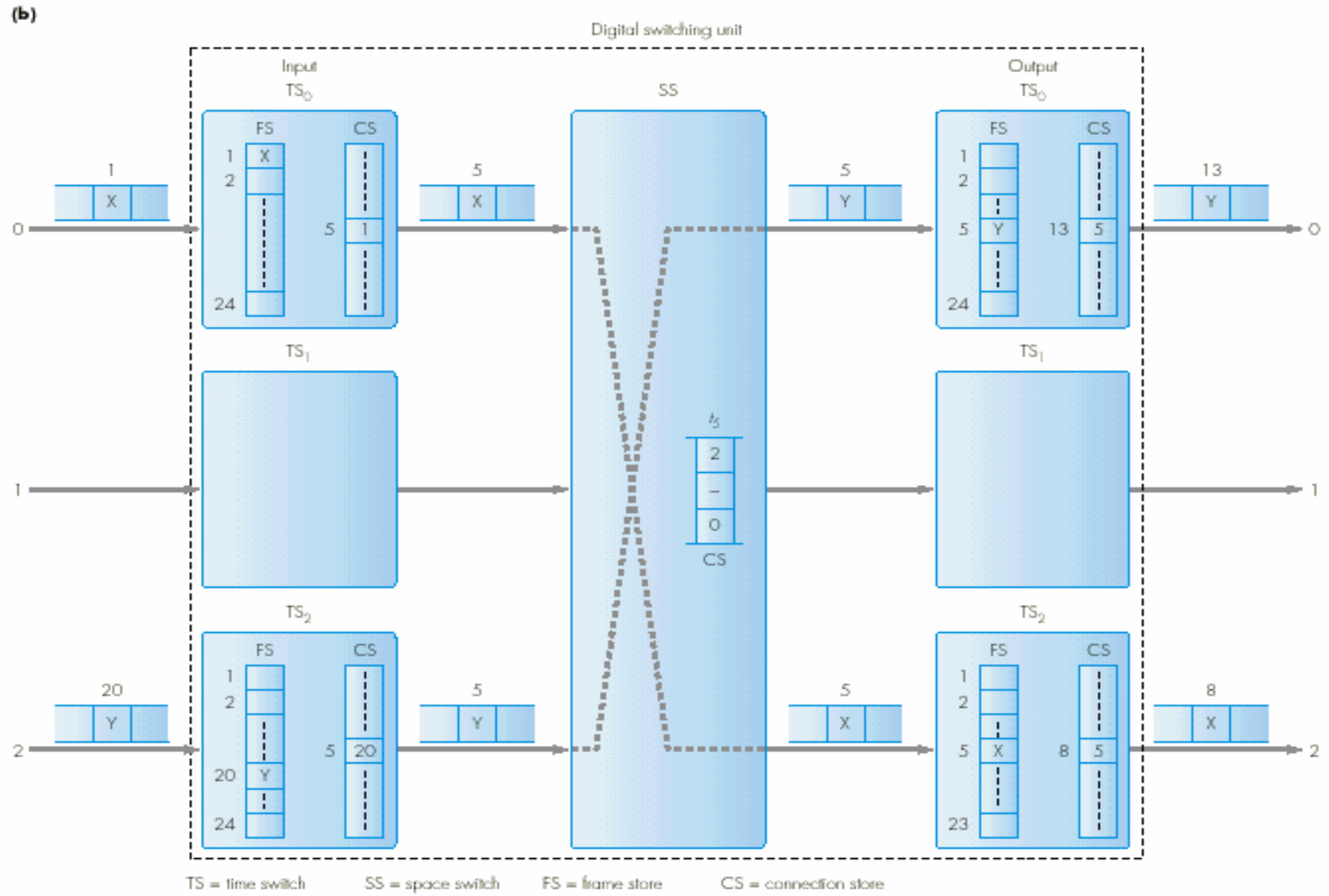
See Example 7.2

Space Switching



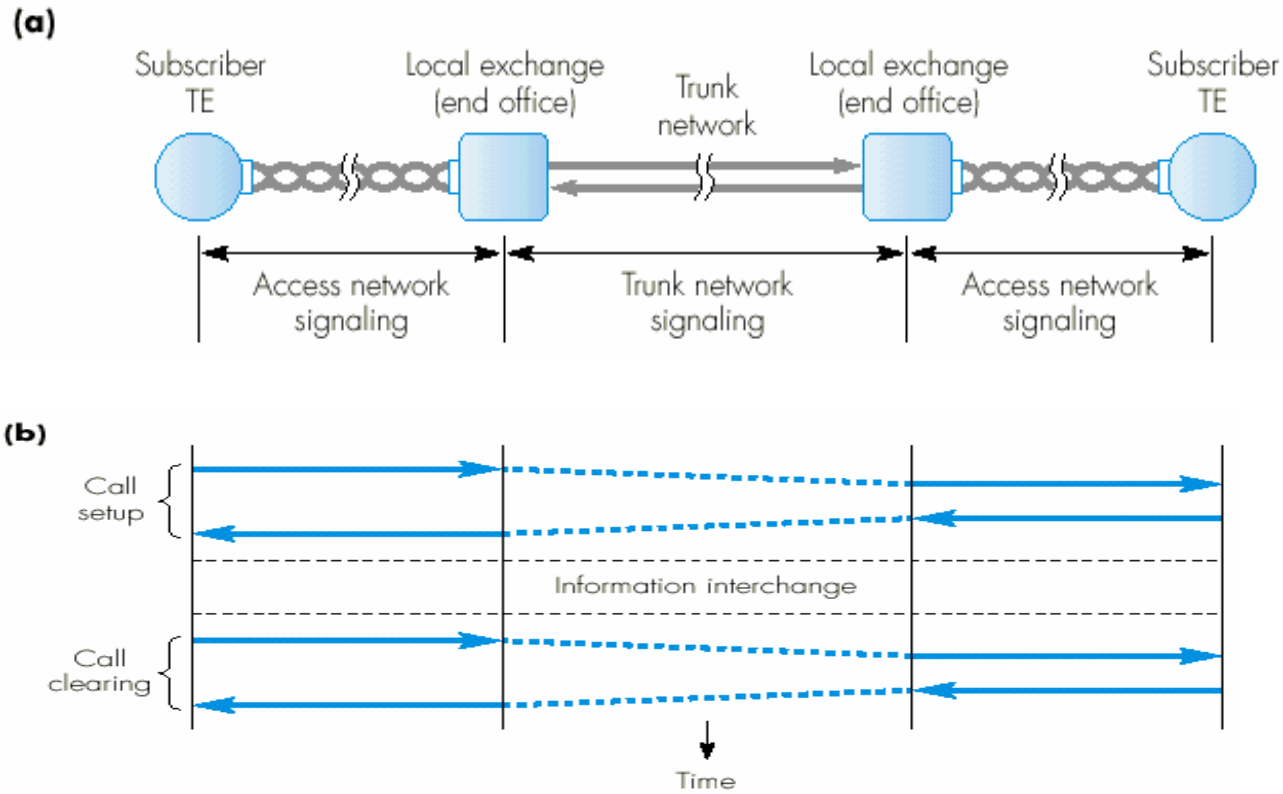
See Example 7.3

Time-Space-time switch (digital switching units)



7.4 Signaling Systems

- Signaling operation
  - the setting up and clearing of a connection between two subscriber
  - two separate signaling systems
    - first which operates over the local access networks
    - second which operates over the core trunk network



7.4.1 Access network signaling

- Basic steps
  - call setup
  - information interchange
  - call closing

- two kinds of access network
  - analog access circuits
    - telephone line : see Figure 7.26
    - a modem
      - link access procedure for modems
      - see Figure 7.27
  - digital access circuits : see Figure 7.28, 7.29, 7.30, 7.31

Figure 7.26 Analog access signaling

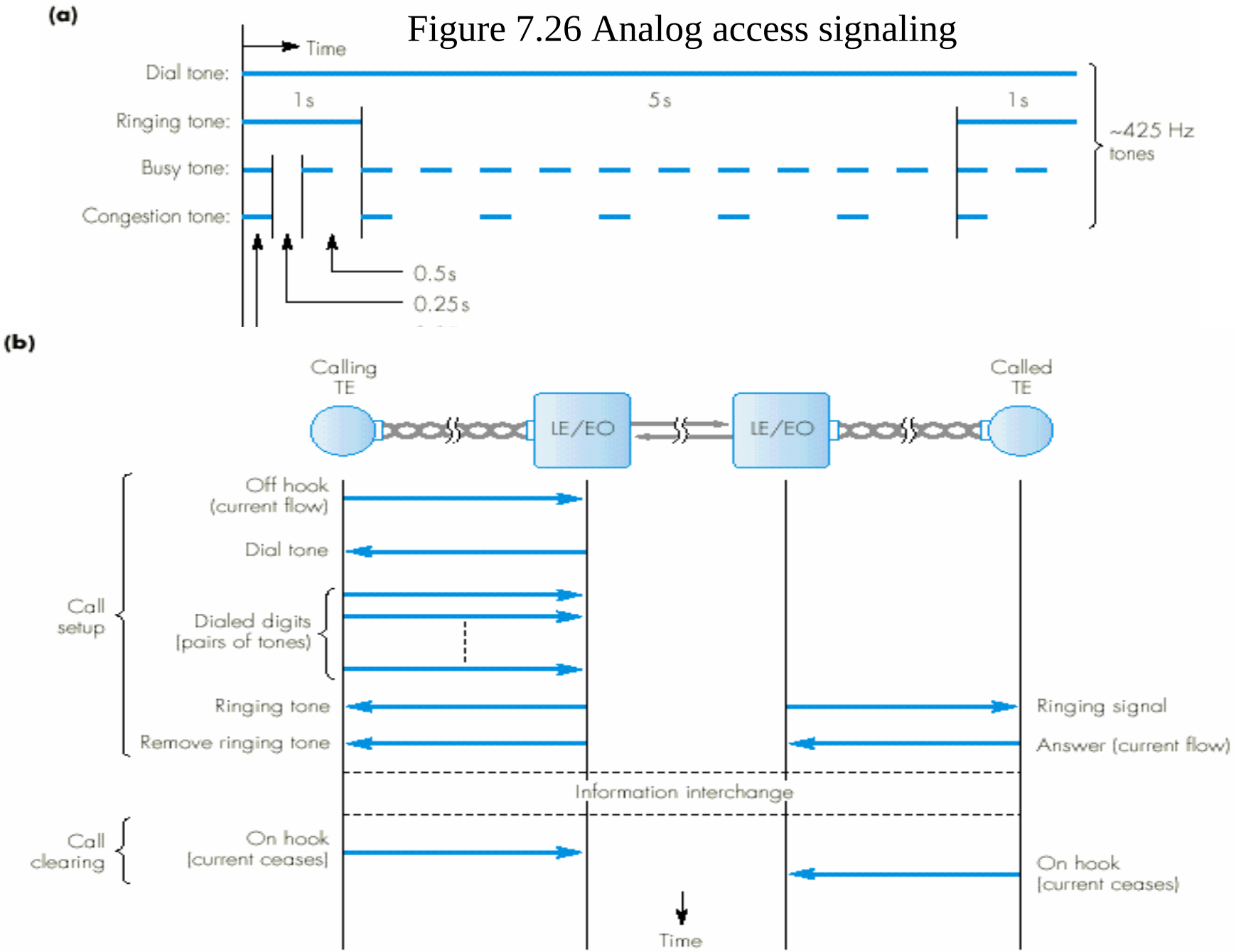
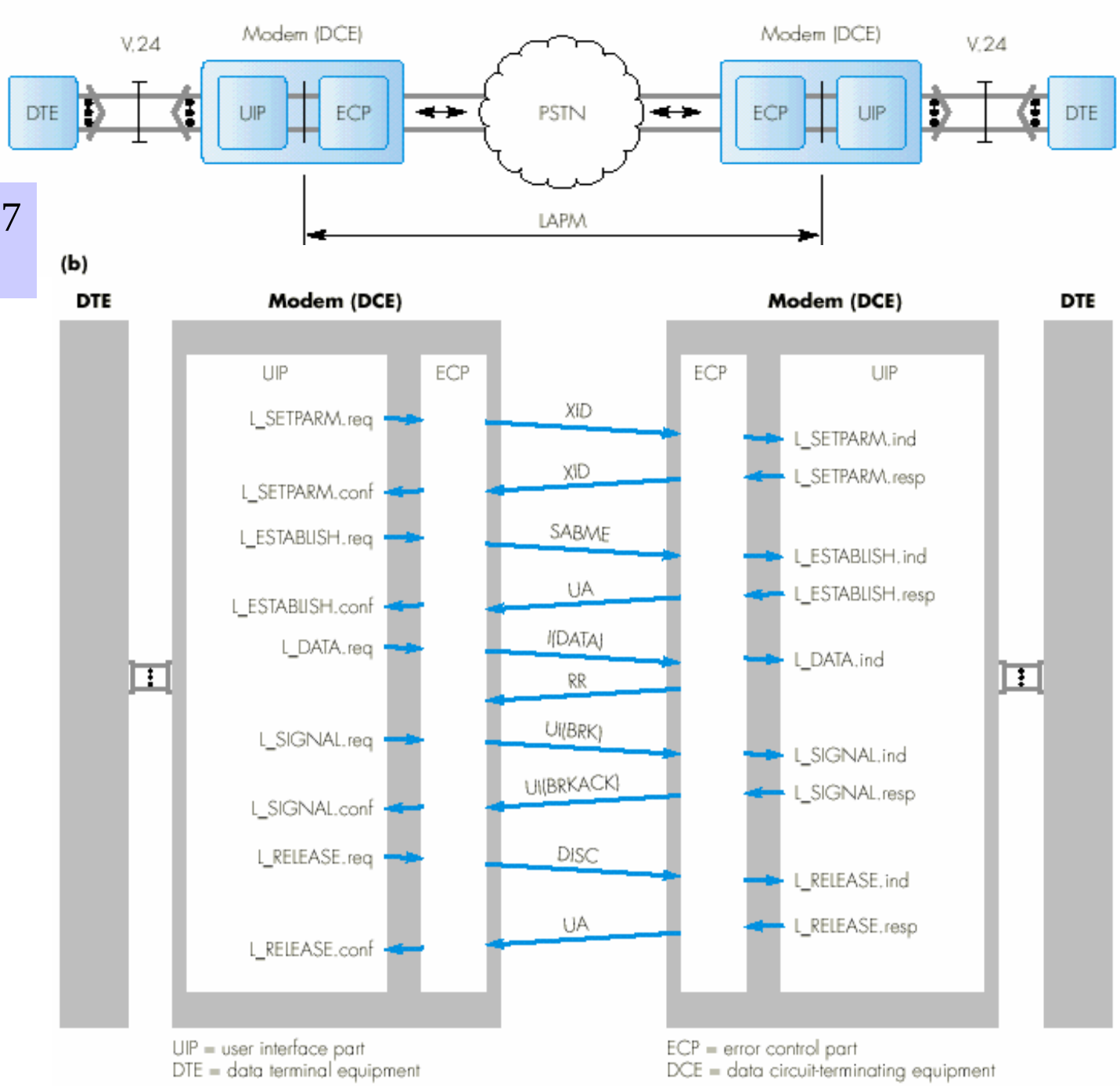


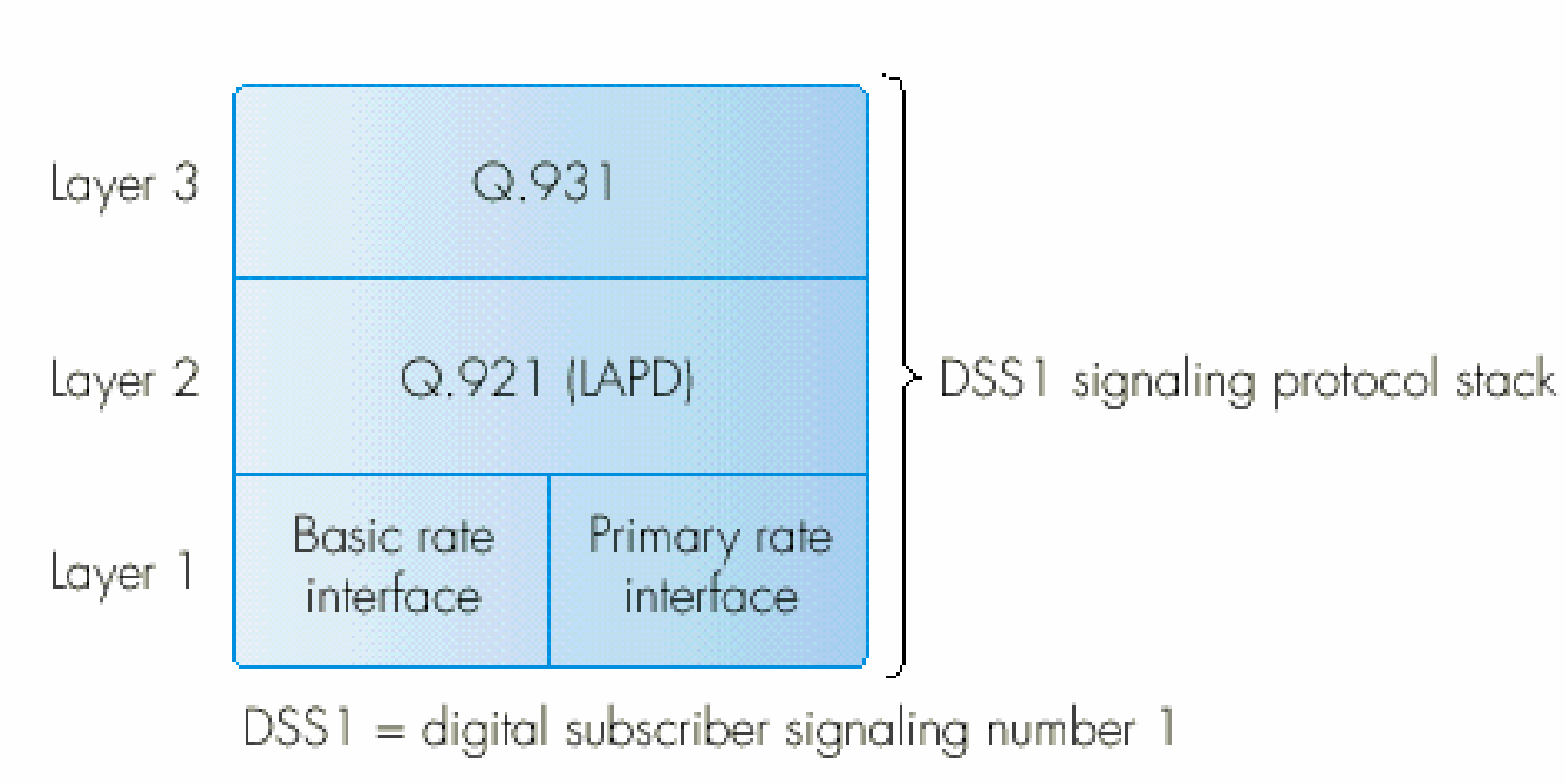
Figure 7.27
LAPM



ISDN

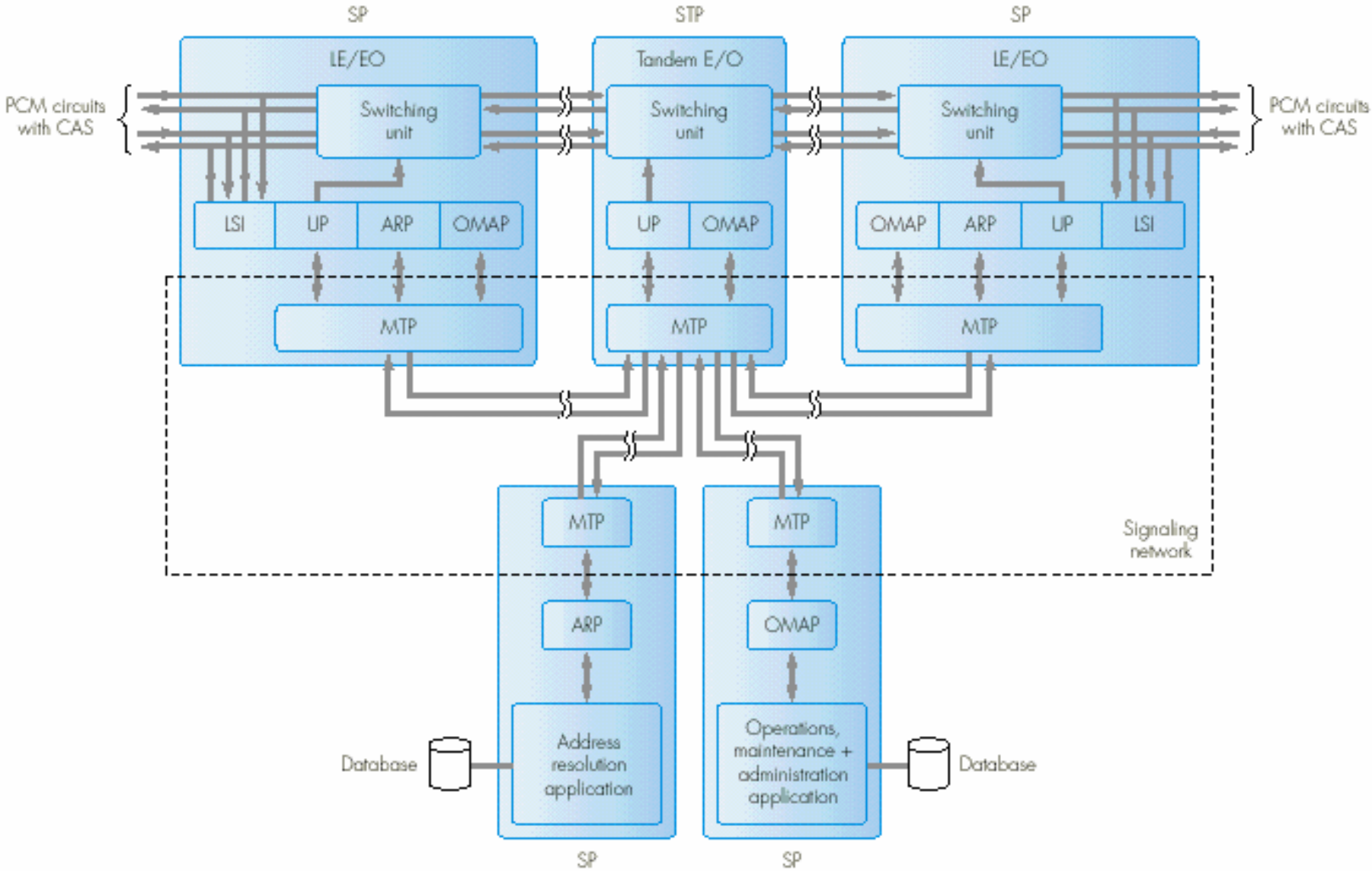
- D-channel ; carry out the exchange of signaling message
- Channel associated signaling (CAS)

-> Digital Subscriber Signaling 1 (DSS1)

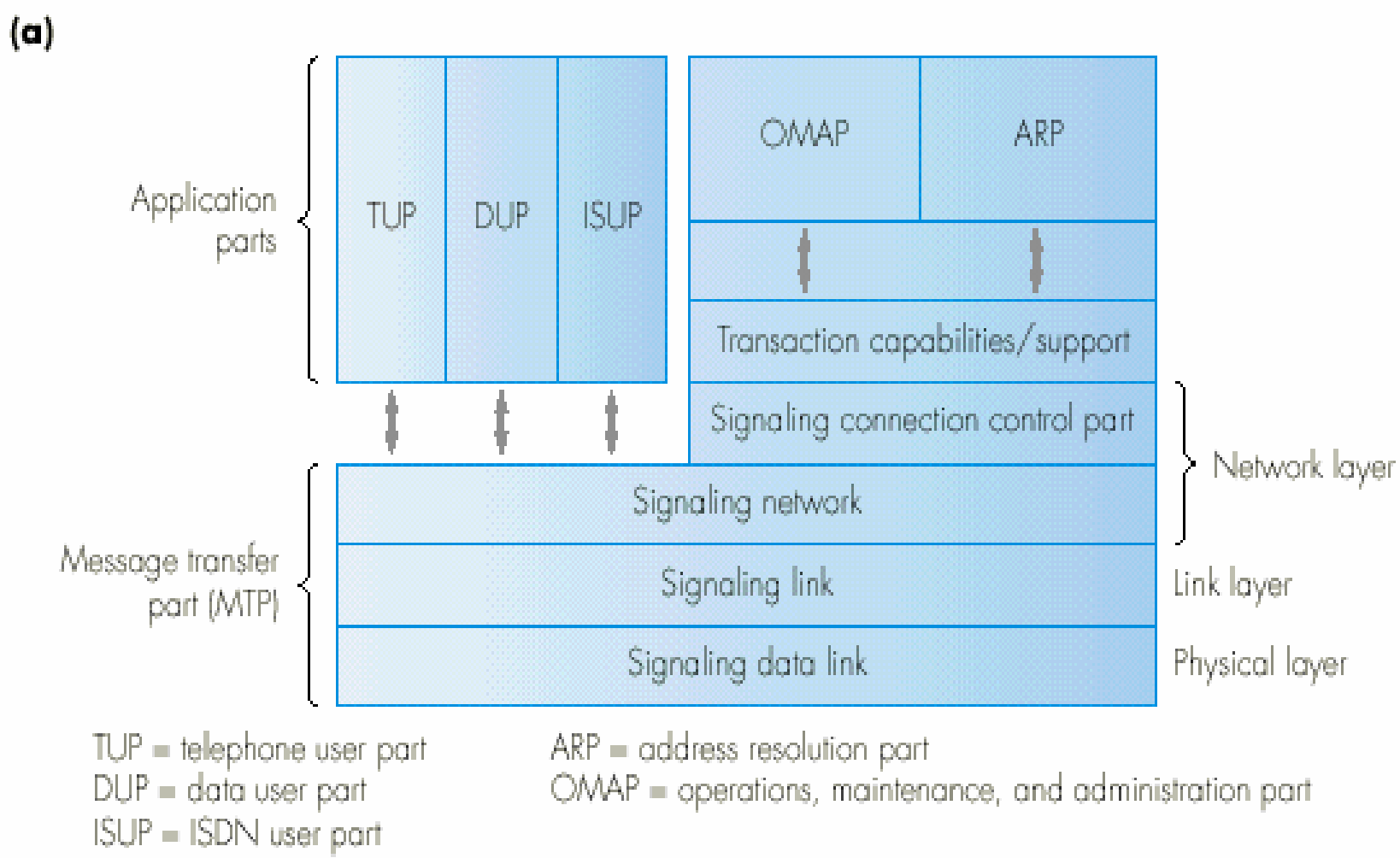


7.4.2 Trunk network signaling

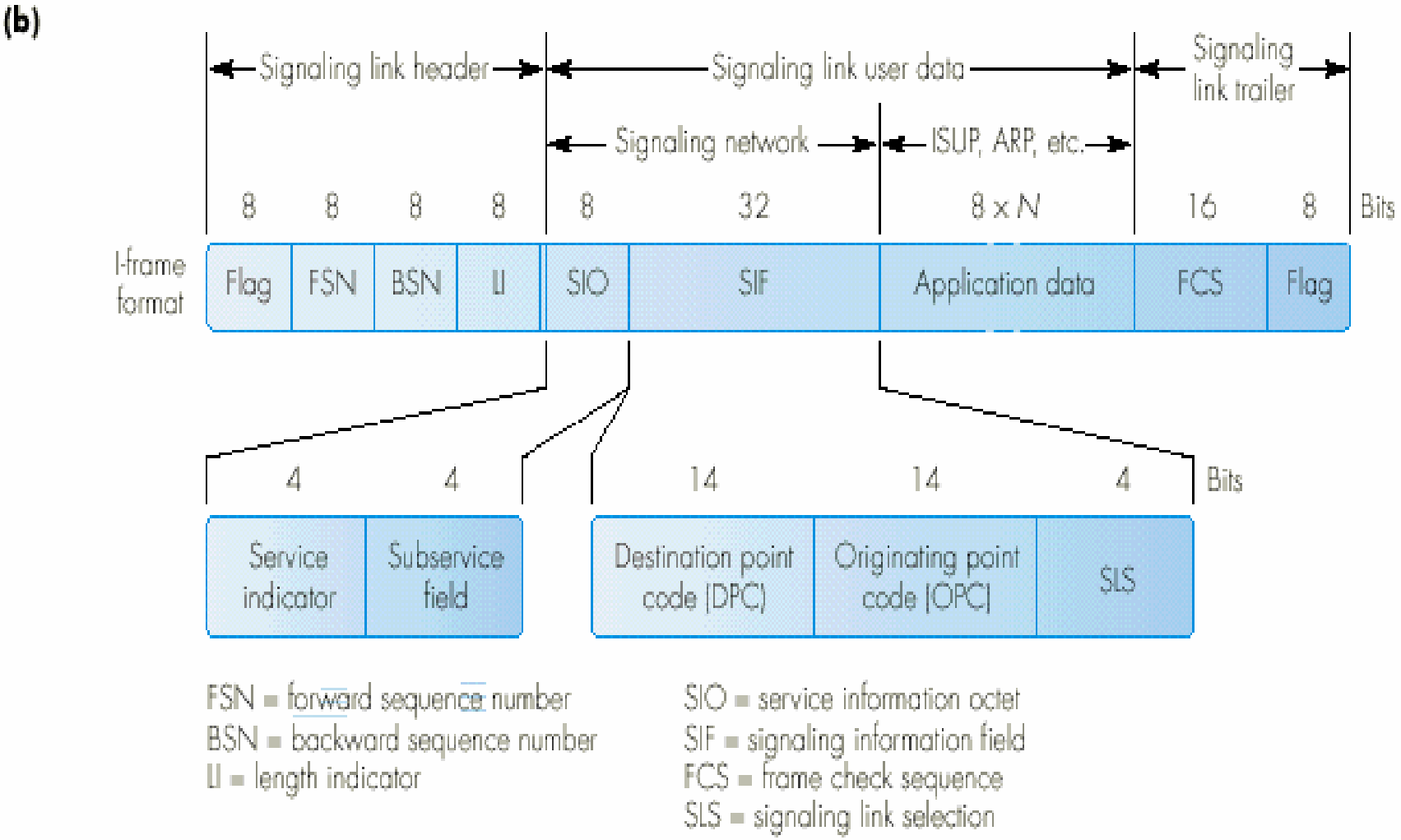
- Common channel signaling (CCS)
  - common channel signaling system number 7
    - » SS7

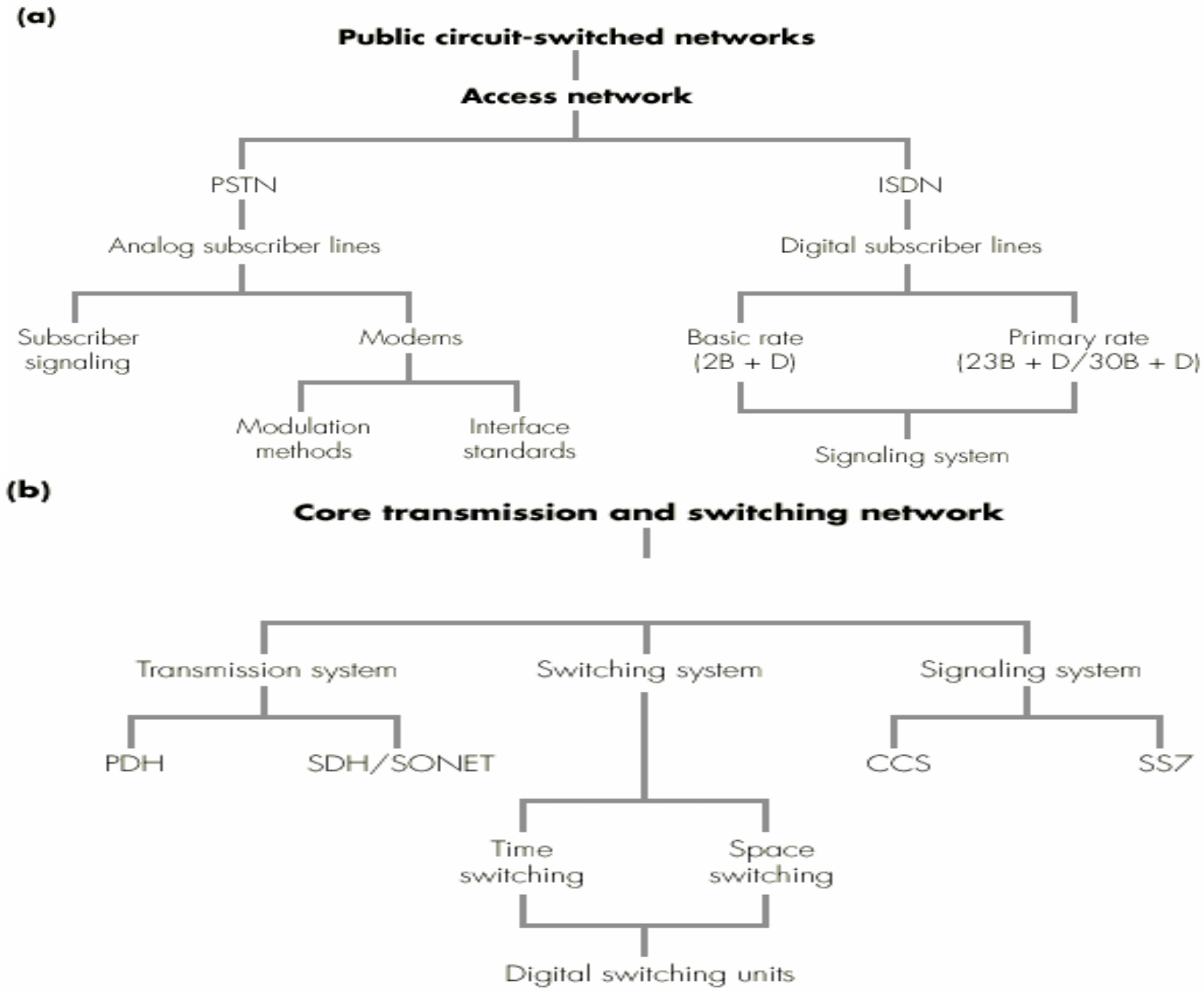

SP
STP
SP
LE/EO
Tandem E/O
LE/EO
PCM circuits with CAS
Switching unit
Switching unit
Switching unit
PCM circuits with CAS
LSI
UP
ARP
OMAP
UP
OMAP
OMAP
ARP
UP
LSI
MTP
MTP
MTP
MTP
MTP
Signaling network
ARP
OMAP
Database
Address resolution application
Operations, maintenance + administration application
Database
SP
SP
ARP = address resolution part
UP = user part
OMAP = operations, maintenance, and administration part
LSI = local signaling interface
MTP = message transfer part
SP = signaling point
STP = signaling transfer point

SS7: protocol architecture



Format of MTP message




(a)
Public circuit-switched networks
Access network
PSTN
ISDN
Analog subscriber lines
Digital subscriber lines
Subscriber signaling
Modems
Basic rate (2B + D)
Primary rate (23B + D/30B + D)
Modulation methods
Interface standards
Signaling system
(b)
Core transmission and switching network
Transmission system
Switching system
Signaling system
PDH
SDH/SONET
CCS
SS7
Time switching
Space switching
Digital switching units