Chapter 9

High Speed Digital Access

9-1 TELEPHONE NETWORK

Telephone networks ***use*** ***circuit switching***. ***The telephone network had its beginnings in the late 1800s. The entire network, which is referred to as the plain old telephone system (POTS), was originally an analog system using analog signals to transmit voice.***

Topics discussed in this section:

Major Components
LATAs (Local Access Transport Areas)
Signaling
Services Provided by Telephone Networks

Figure 9.1 *A telephone system*

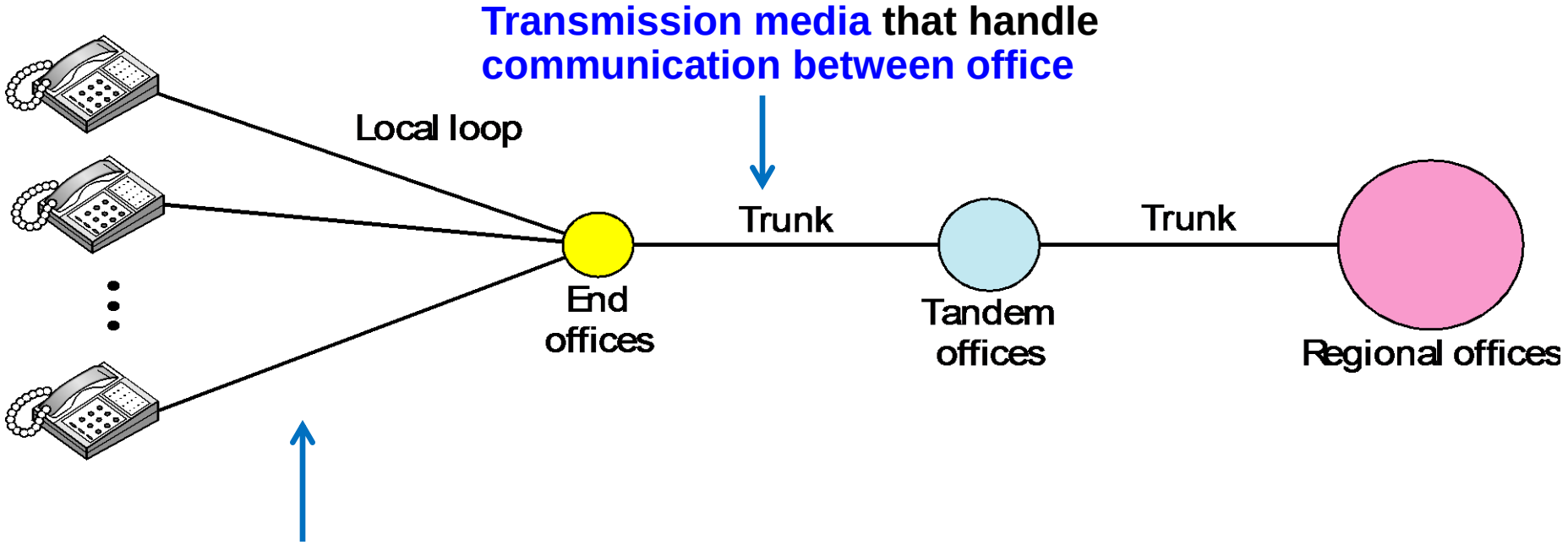
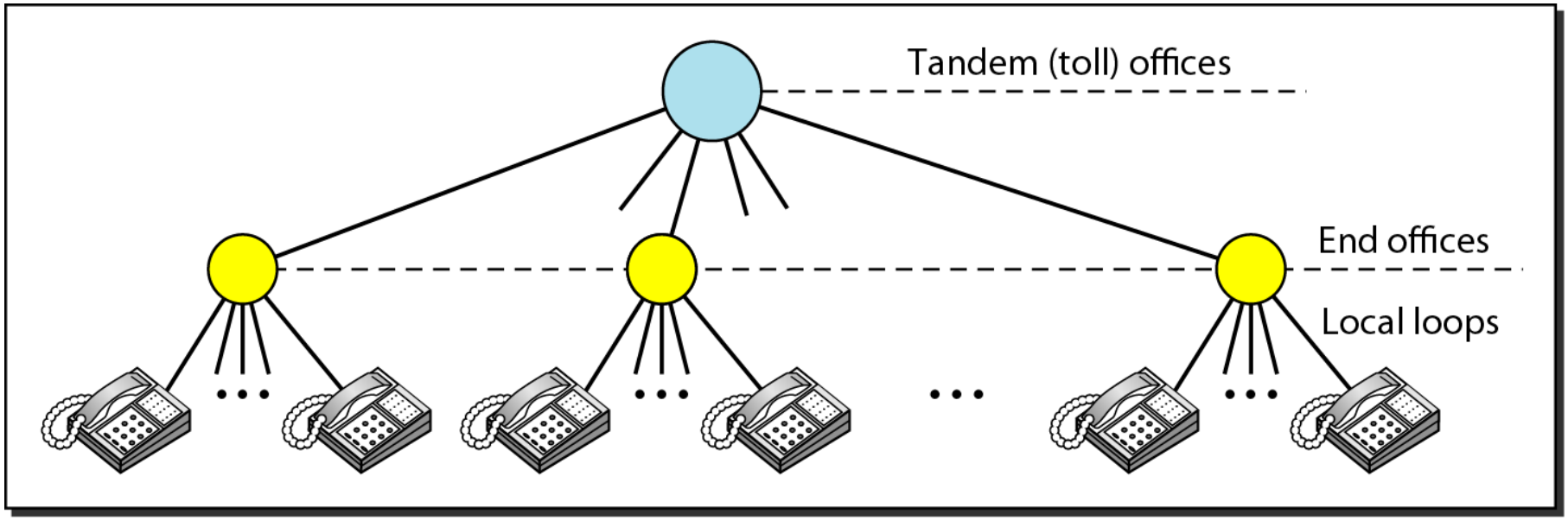
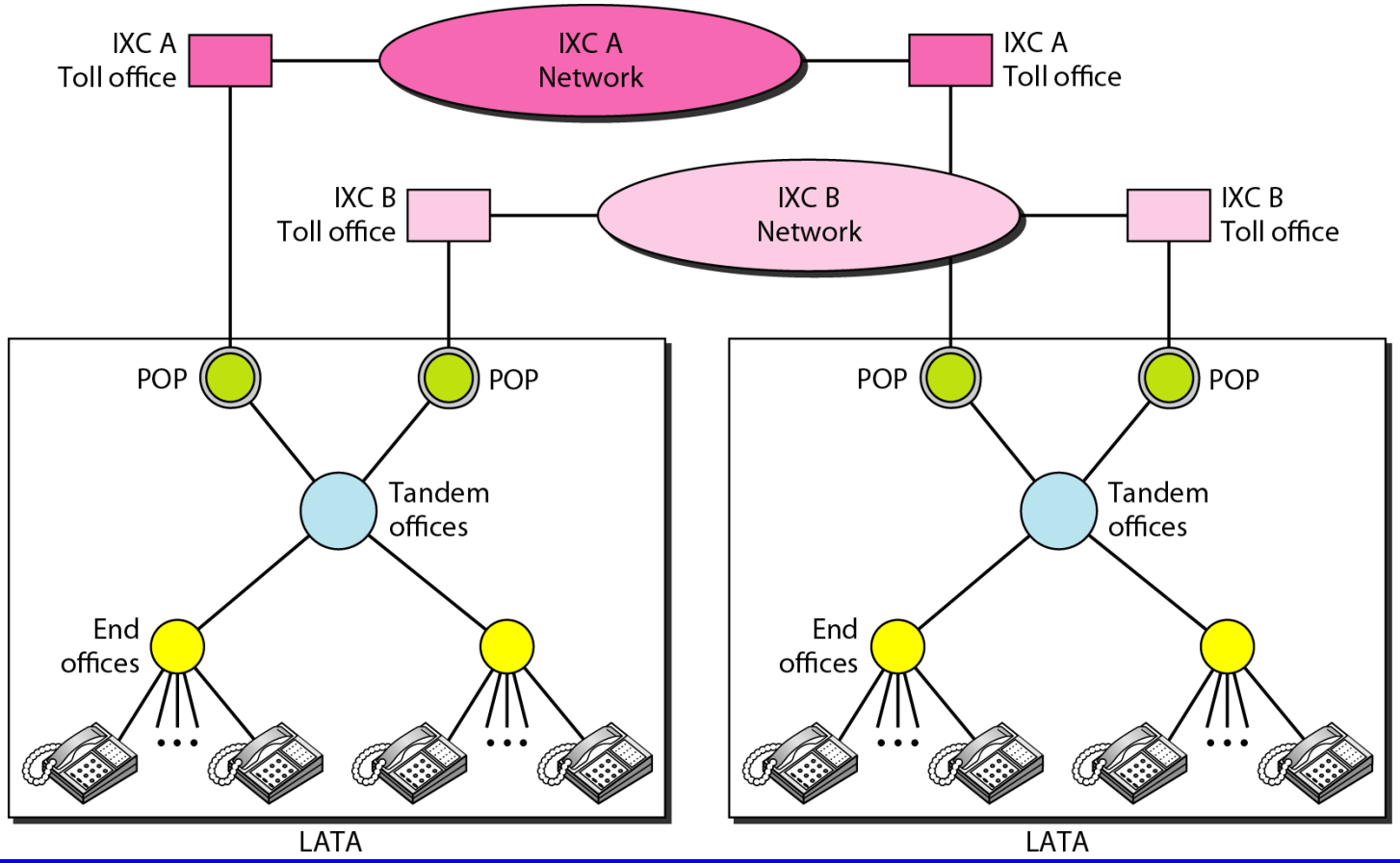


Figure 9.2 *Switching offices in a LATA (Local Access Transport Area)*



Intra-LATA service: services offered by common carriers (telephone companies) inside LATA

Figure 9.3 *Point Of Presences (POPs)*



Inter-LATA service: services between LATAs are handled by IntereXchange Carrier (sometime called long-distance companies)
- Inter-LATA services can be provided by several IXCs

9-3 DIGITAL SUBSCRIBER LINE

After traditional modems reached their peak data rate, telephone companies developed another technology, DSL, to provide higher-speed access to the Internet. Digital subscriber line (DSL) technology is one of the most promising for supporting high-speed digital communication over the existing local loops.

Topics discussed in this section:

Asymmetric DSL: ADSL, ADSL Lite, RADSL, VDSL

Symmetric DSL: HDSL, SDSL

Note

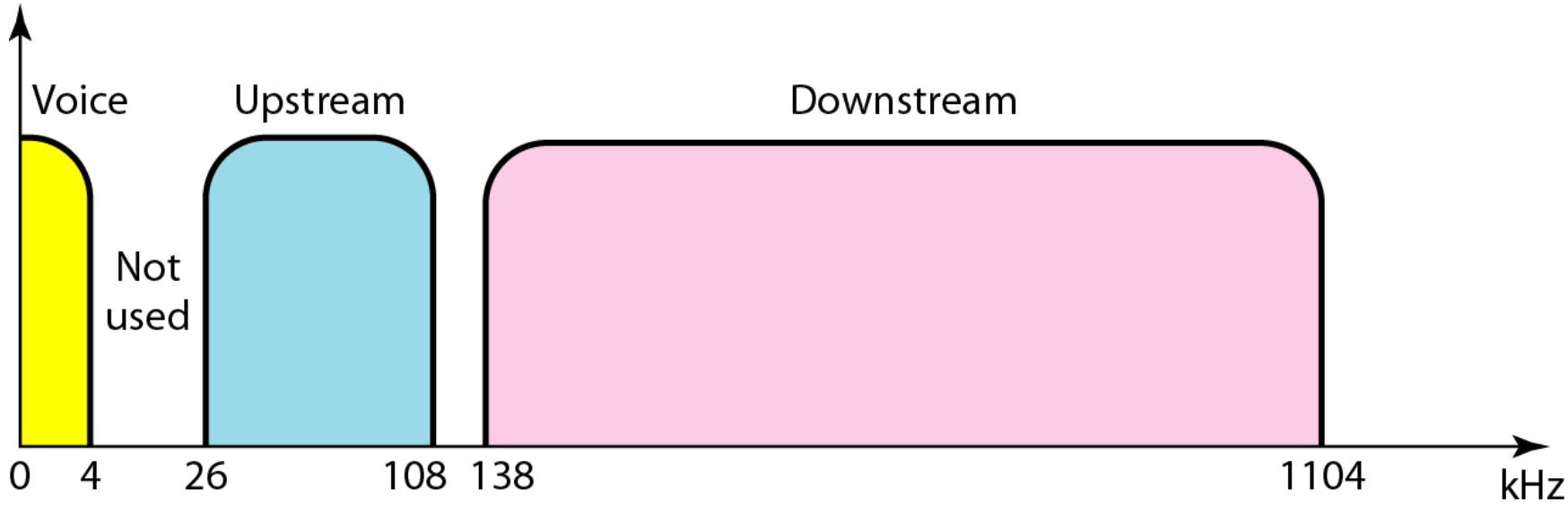
ADSL is an asymmetric communication technology designed for residential users; it is not suitable for businesses.

Upload speed < Download speed

The existing local loops can handle bandwidths up to 1.1 MHz.

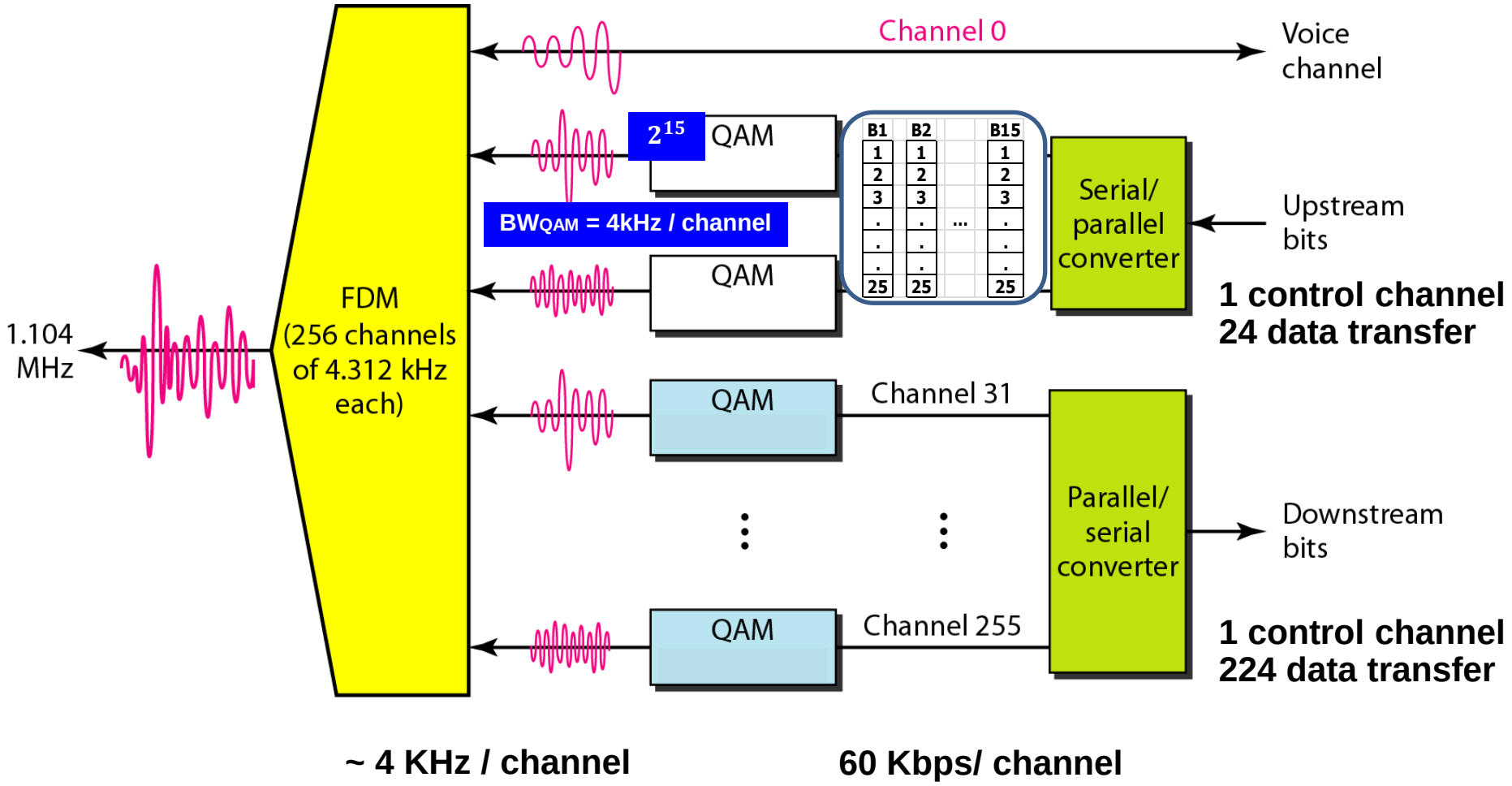
ADSL is an adaptive technology. The system uses a data rate based on the condition of the local loop line.

Figure 9.11 *Bandwidth division in ADSL*



- Transmission: twisted-pair (1 pair)
  - Divides 1.104 MHz bandwidth into three bands (256 channels; 4.312 KHz per channel)
    - POT (voice) (channel 0)
    - Upstream (channel 6-30; 25 channels),
    - Downstream (channel 31-255; 225 channels)

Figure 9.10 *Discrete Multitone Technique (DMT) : modulation technique standard for ADSL*



ANSI standard for ADSL

- Upstream (25-200 KHz -> 25 channels)
  - Each FDM sub channel: 4 KHz
  - Discrete Multitone Technique (DMT): 15 bits per baud
  - Data rate: 60 Kbps / channel
  - Upstream data rate (no noise) : 25 x 60Kbps = 1.5 Mbps
  - data rate (with noise) : 64 Kbps – 1 Mbps
- Downstream (250-100 KHz -> 200 channels)
  - Downstream data rate: 200 x 60 Kbps = 12 Mbps
  - data rate (with noise): 500 Kbps – 8 Mbps

Figure 9.12 *ADSL modem*

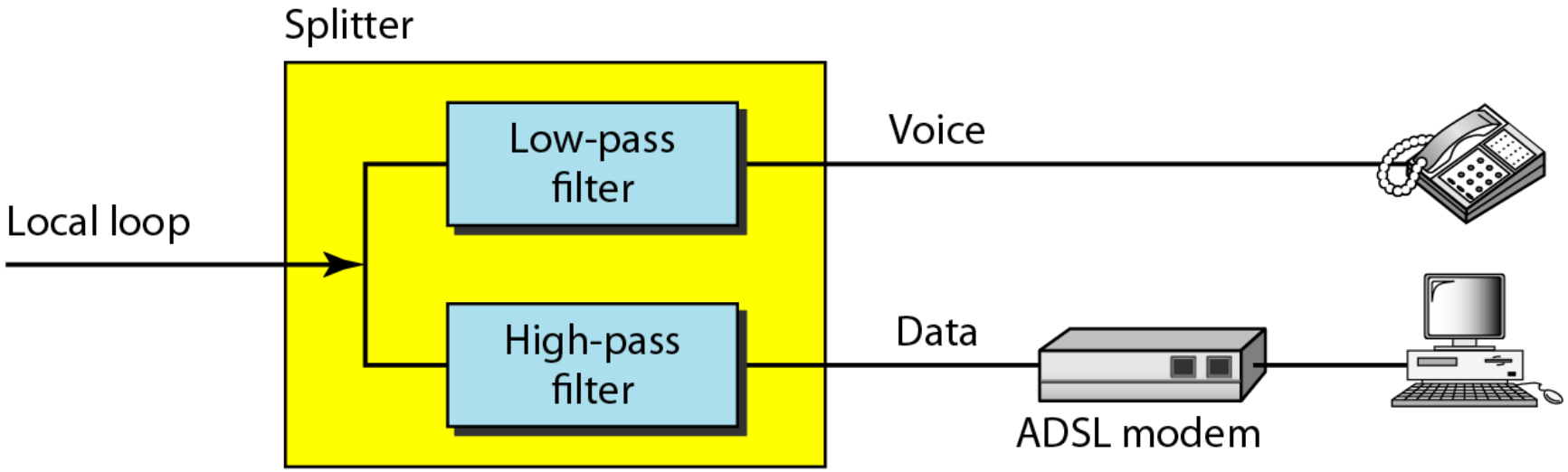
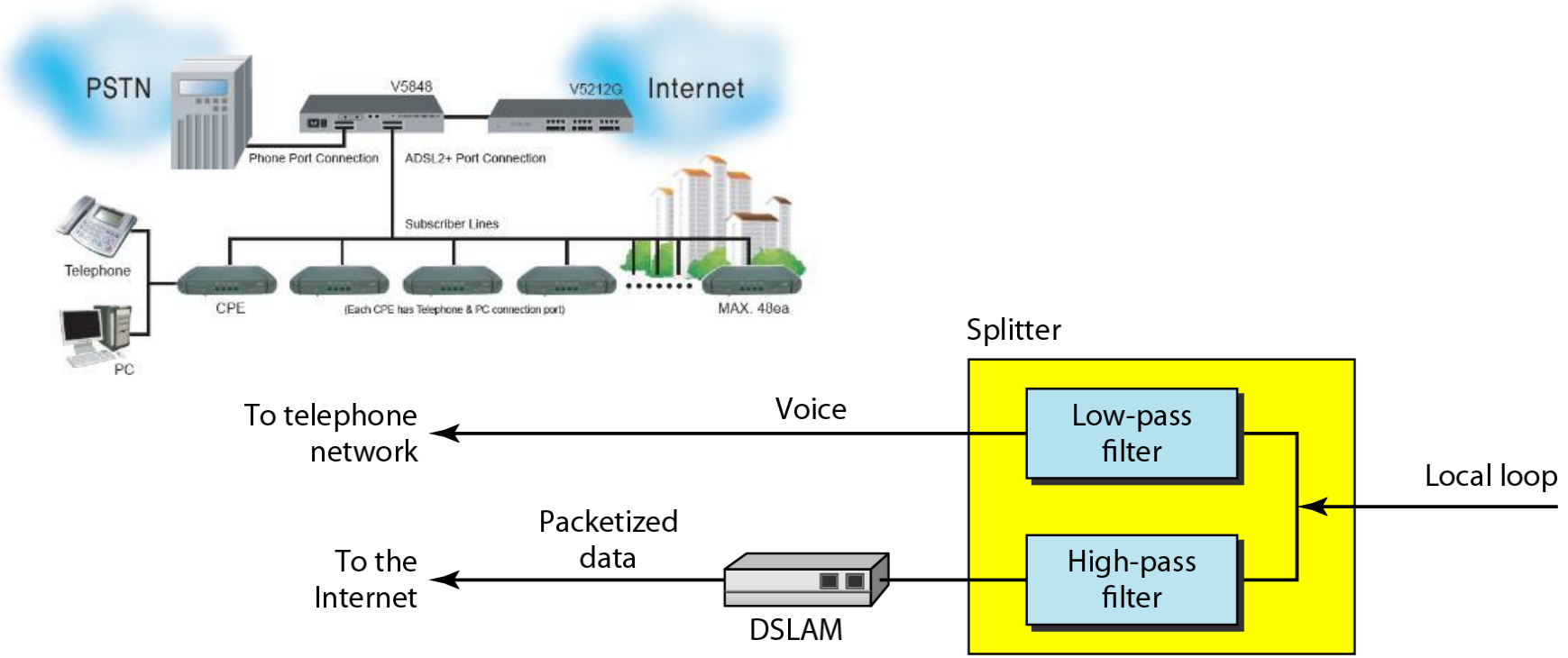


Figure 9.13 *DSLAM : Digital Subscriber Line Access* ***Multiplexer***



Digital Subscriber Line Access Multiplexer
-> multiplexing data from several ADSL users

Telephone Company Site

Rate adaptive asymmetrical digital subscriber line (RADSL)

- Based on ADSL technology
- The difference
  - Allowing different data rate and different bandwidth for different subscribers

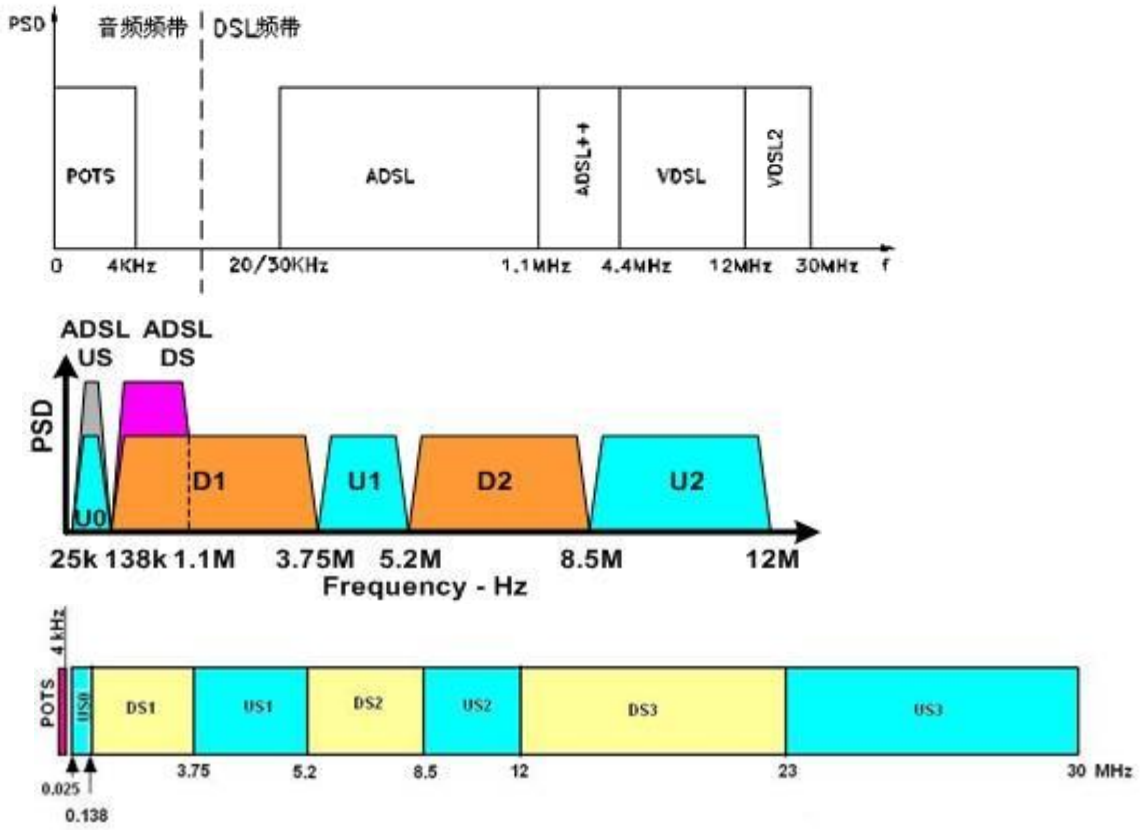
Very high bit rate digital subscriber line (VDSL)

- Newest technique similar to ADSL

- The difference
  - Transmission types:
    - coaxial, fiber optic, or twisted pair
  - Distance 3,000-10,000 ft

  - Modulation : DMT
    - Upstream: 3.2 Mbps
    - Downstream: 25 – 55 Mbps
  - Higher data rate with shorter distance

Very high bit rate digital subscriber line (VDSL)



Frequency Plan

High bit rate digital subscriber line (HDSL)

- Transmission: twisted-pair (2 pairs)
  - To achieve full-duplex transmission
- Can be used as an alternative to T-1 or E-1 line
  - Data rate: 1.544 Mbps – 2.048 Mbps
  - Up to distance of 12,000 ft (3.86 km)
- Encoding:

Alternative to T-1 line :
-T-1 uses AMI encoding : susceptible to attenuation high frequency
-Limits length of T-1 line to 3200 ft (1Km) (repeater is needed)

Symmetric digital subscriber line (SDSL)

- Similar to HDSL (one twisted-pair version of HDSL)
  - It provides full-duplex symmetric communication supporting up to 768 kbps in each direction

- The difference
  - Transmission: twisted-pair (1 pairs)
  - Using “Echo cancellation” to create full-duplex over one transmission line

Table 9.2 *Summary of DSL technologies*

Technology	*Downstream Rate*	*Upstream Rate*	*Distance (ft)*	*Twisted Pairs*	*Line Code*
ADSL	1.5–6.1 Mbps	16–640 kbps	12,000	1	DMT
ADSL Lite	1.5 Mbps	500 kbps	18,000	1	DMT
HDSL	1.5–2.0 Mbps	1.5–2.0 Mbps	12,000	2	2B1Q
SDSL	768 kbps	768 kbps	12,000	1	2B1Q
VDSL	25–55 Mbps	3.2 Mbps	3000–10,000	1	DMT

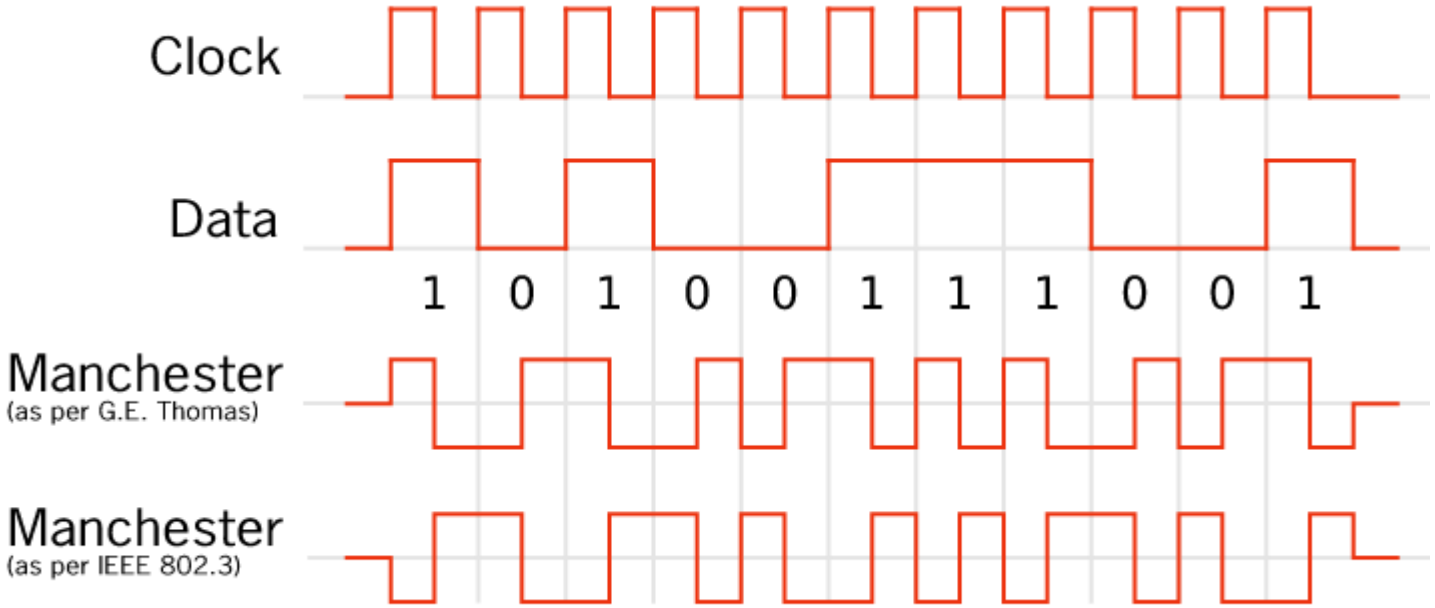
IEEE Ethernet Protocol

Variants [edit]

Speed [Mbit/s]	Distance [m]	Name	Standard / Year	Description
1	100 (nominally)	StarLAN	802.3e 1986[13]	Runs over four wires (two twisted pairs) on telephone twisted pair or Category 3 cable. An active hub sits in the middle and has a port for each node. Manchester coded signaling.
10	100 (nominally)	LattisNet	(pre) 802.3i 1987	Runs over AT&T Premises Distribution System (PDS) wiring or four wires (two twisted pairs) on telephone twisted pair or Category 3 cable.[7][14]
10	100 (nominally)[15]	10BASE-T	802.3i 1990	Runs over four wires (two twisted pairs) on a Category 3 or Category 5 cable. Star topology with an active hub or switch sits in the middle and has a port for each node. This is also the configuration used for 100BASE-T and gigabit Ethernet. Manchester coded signaling.
100	100	100BASE-TX	802.3u 1995	4B5B MLT-3 coded signaling, Category 5 cable copper cabling with two twisted pairs.
1000	100	1000BASE-T	802.3ab 1999	PAM-5 coded signaling. At least Category 5 cable with four twisted pairs copper cabling. Category 5 cable has since been deprecated and new installations use Category 5e. Each pair is used in both directions simultaneously.
10 000	100	10GBASE-T	802.3an 2006	THP PAM-16 coding. Uses category 6a cable.
40 000	≥30	40GBASE-T	802.3bq[5]	under development, uses encoding from 10GBASE-T on proposed Cat 8.1/8.2 shielded cable

- http://en.wikipedia.org/wiki/Ethernet_over_twisted_pair

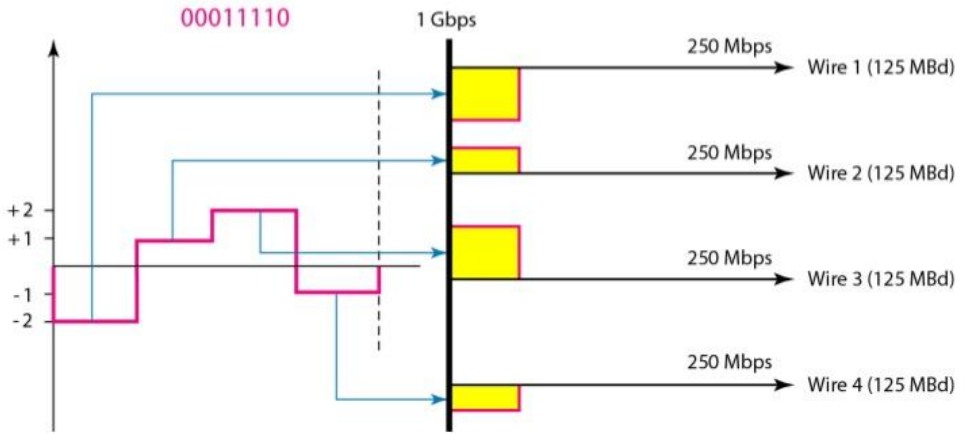
IEEE 802.3 (10BaseT-10Mbps)



4D-PAM5

- PAM-5 uses 5 different voltage levels, four to send data and one as a control bit. The data bits are defined as follows:
  - 00 → - 1.0 volts
  - 01 → - 0.5 volts
  - 10 → +0.5 volts
  - 11 → +1.0 volts
  - ***Control -> 0 volts***

Figure 4.12 *Multilevel: 4D-PAM5 scheme*



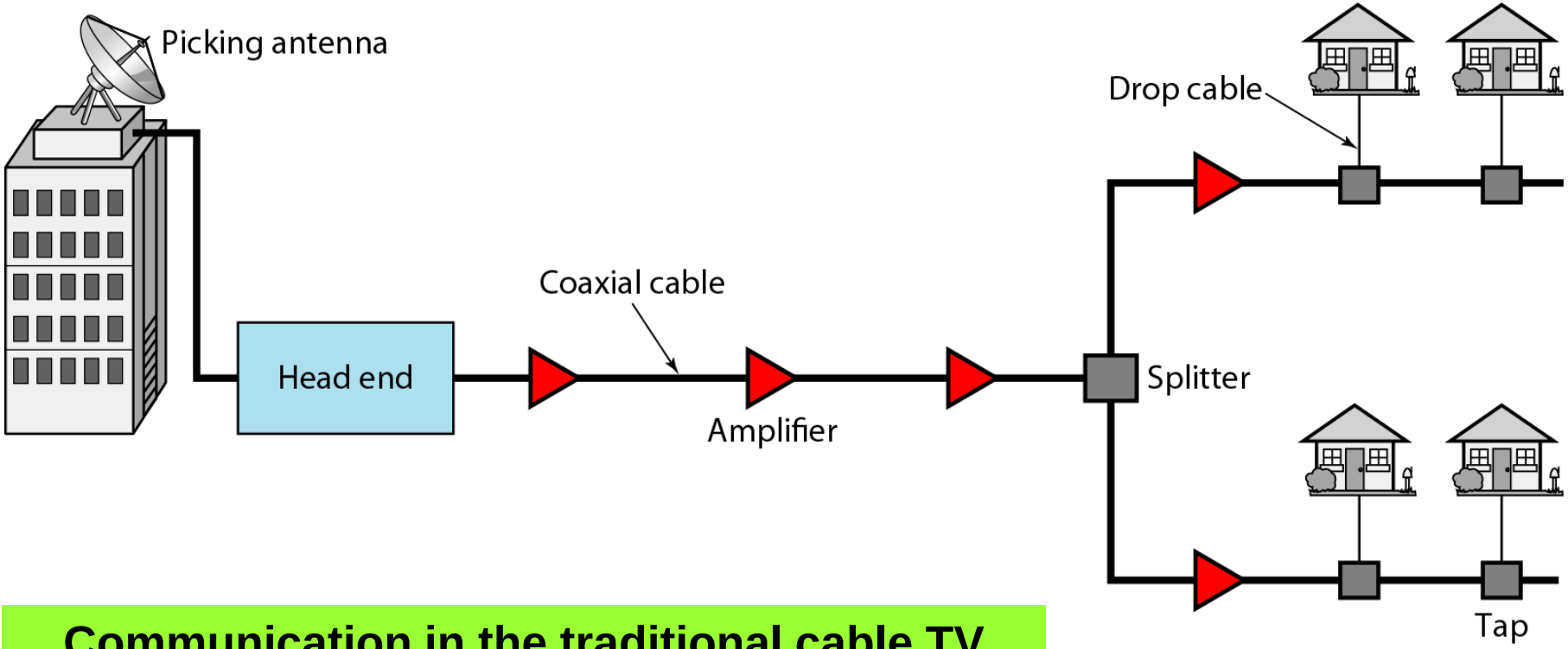
9-4 CABLE TV NETWORKS

The Cable TV network started as a video service provider, but it has moved to the business of Internet access. In this section, we discuss cable TV networks per se; in Section 9.5 we discuss how this network can be used to provide high-speed access to the Internet.

Topics discussed in this section:

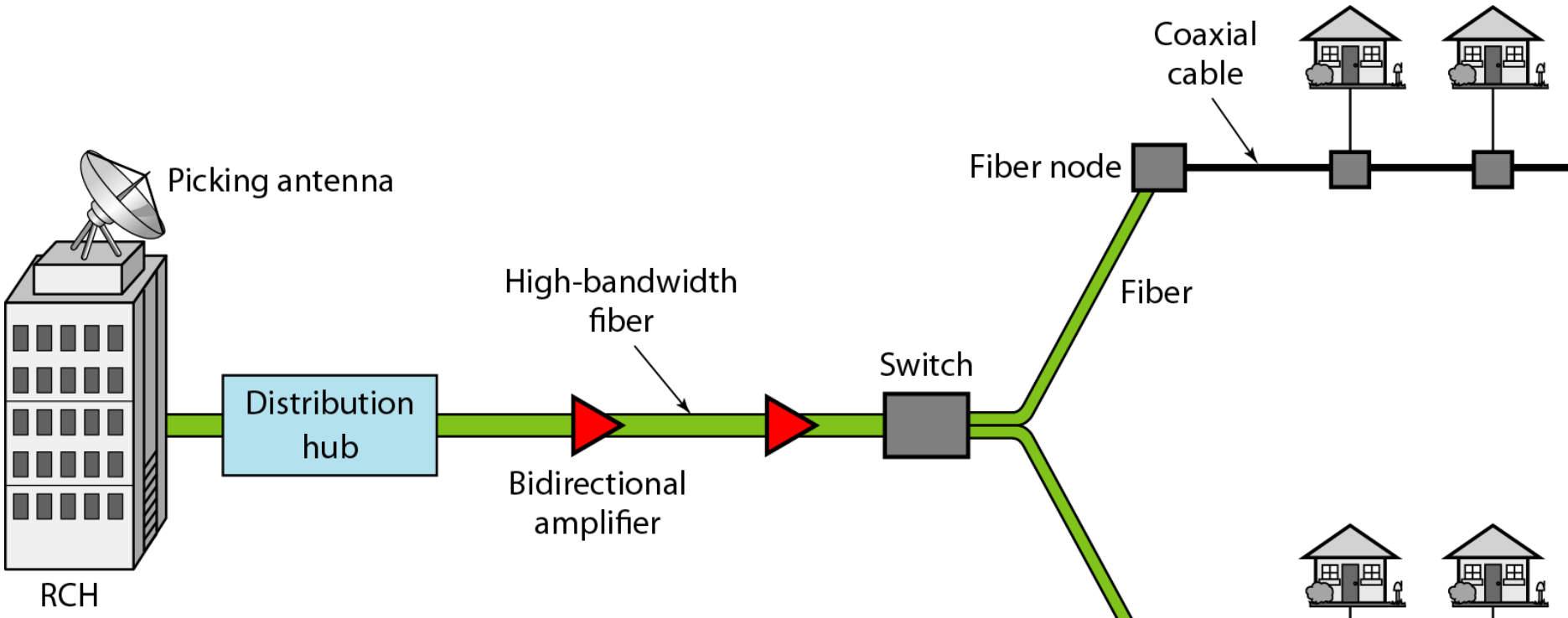
Traditional Cable Networks
Hybrid Fiber-Coaxial (HFC) Network

Figure 9.14 *Traditional cable TV network*



Communication in the traditional cable TV network is unidirectional.

Figure 9.15 *Hybrid fiber-coaxial (HFC) network*



Communication in an HFC cable TV network can be bidirectional.

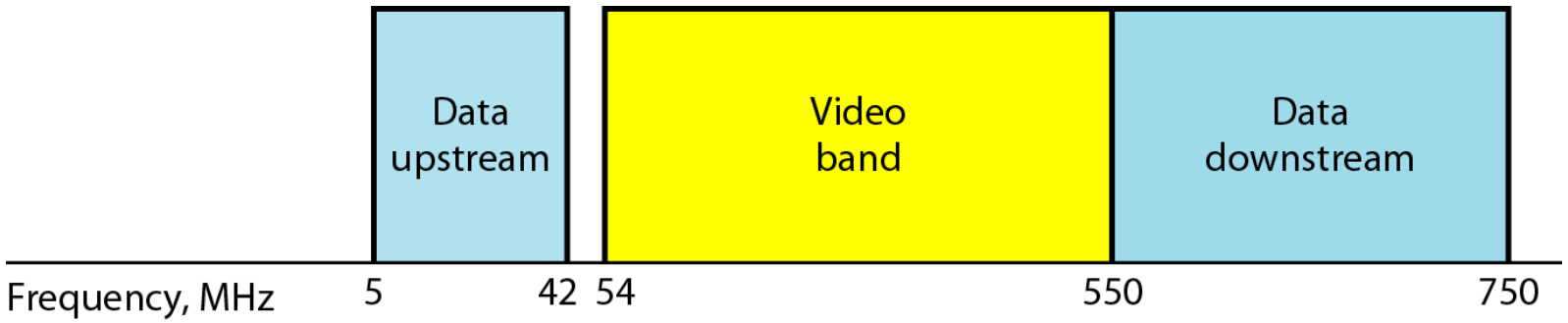
9-5 CABLE TV FOR DATA TRANSFER

Cable companies are now competing with telephone companies for the residential customer who wants high-speed data transfer. In this section, we briefly discuss this technology.

Topics discussed in this section:

Bandwidth
Sharing
Cable Modem (CM) and Cable Modem Transmission System (CMTS)
Data Transmission Schemes: Data Over Cable System Interface Specification (DOCSIS)

Figure 9.16 *Division of coaxial cable band by CATV*



- Subband division (6 MHz / channel)
  - Video: 54 – 550 MHz
  - Upstream: 5 - 42 MHz
  - Downstream: 550 – 750 MHz

- Modulation
  - Upstream: QPSK -> 12 Mbps
  - Downstream: 64 QAM -> 30 Mbps

Figure 9.17 *Cable Modem (CM)*

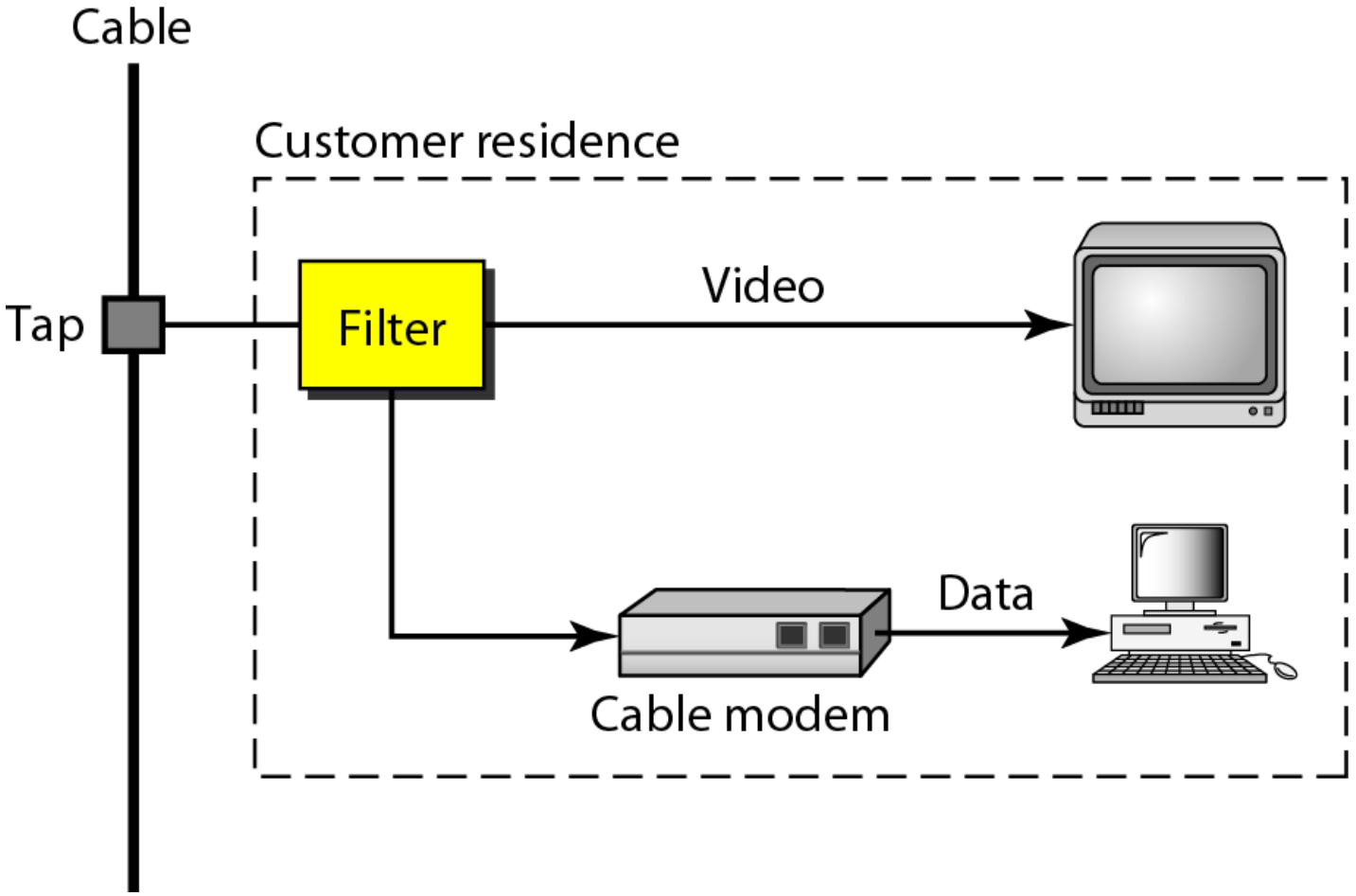
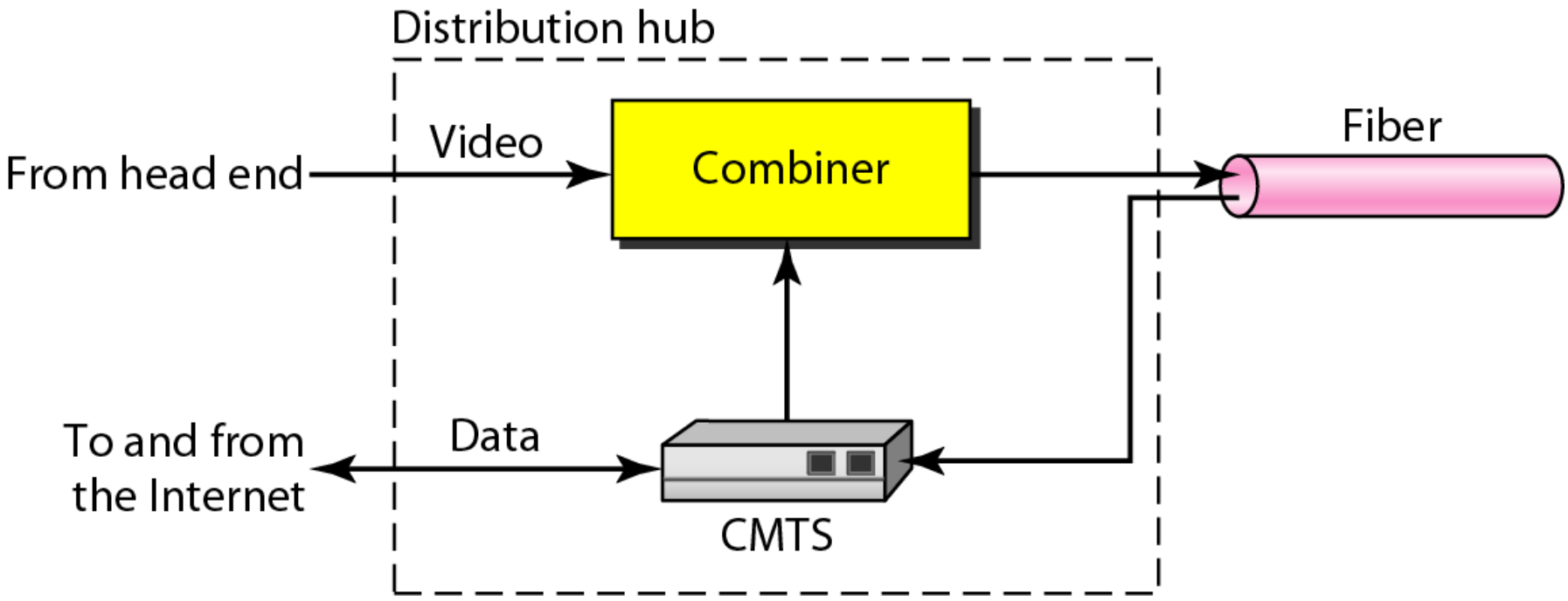


Figure 9.18 *Cable Modem Transmission System (CMTS)*



9.3 SONET
(Synchronous Optical NETworks)

SONET Devices

SONET Frame

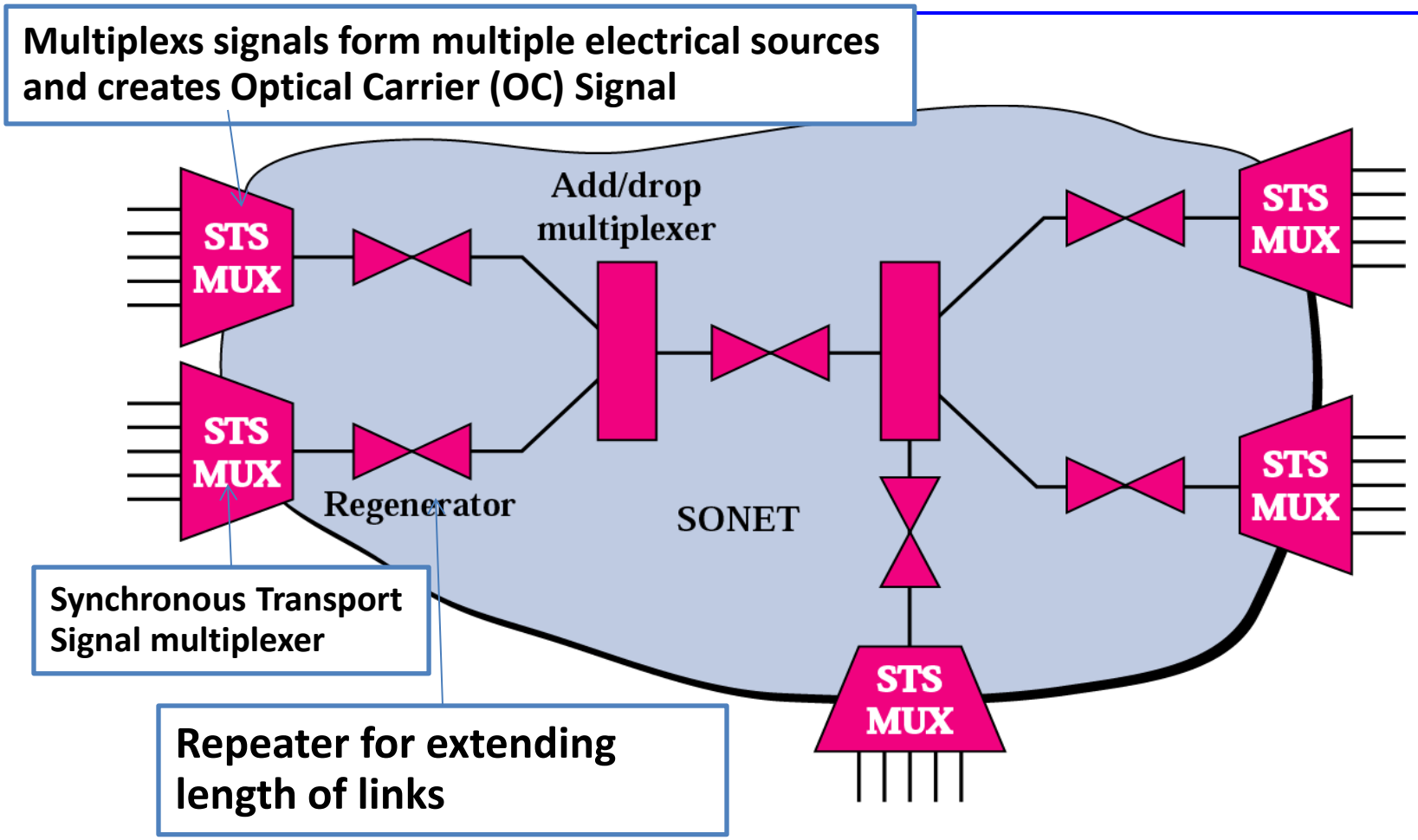
Frame Transmission

Synchronous Transport Signals
STS-1

Virtual Tributaries

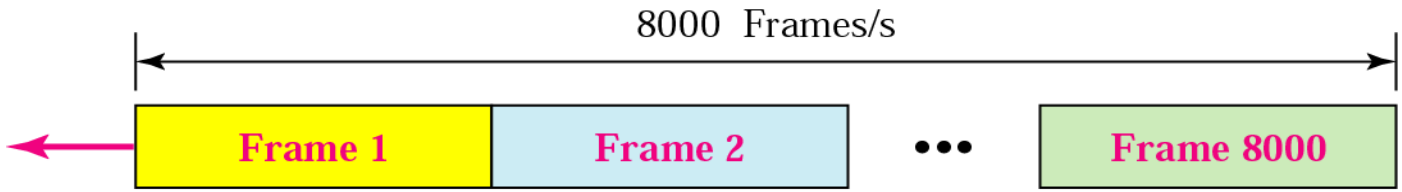
Higher-Rate Service

Figure 9.10 *A SONET (Synchronous Optical Networks)*



synchronous TDM system

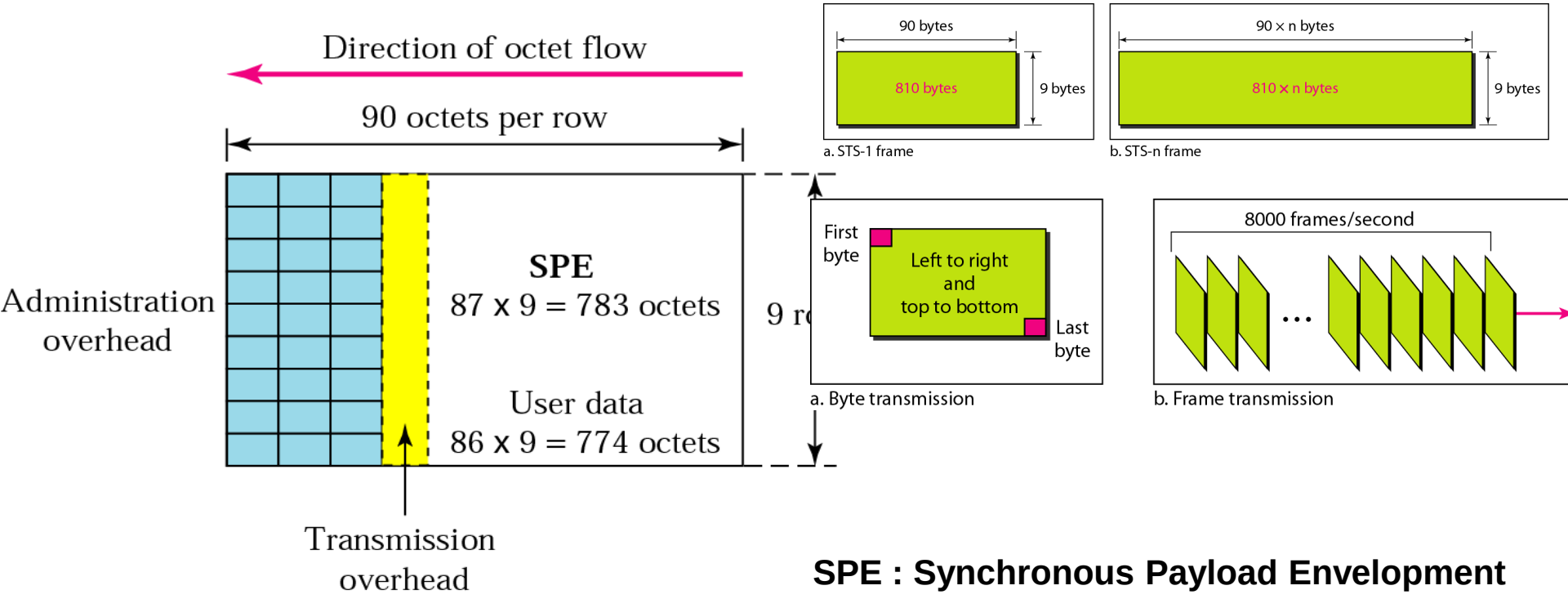
Figure 9.11 *Frame format*



Raw rate = 8000 frames/s x 9 x 90 x 8 = 51,840,000 bps

SPE rate = 8000 frames/s x 9 x 87 x 8 = 50,112,000 bps

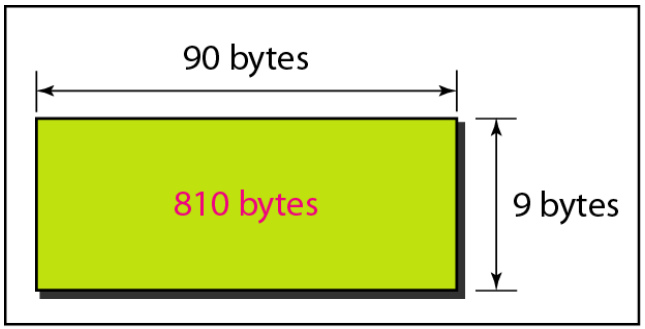
User rate = 8000 frames/s x 9 x 86 x 8 = 49,536,000 bps



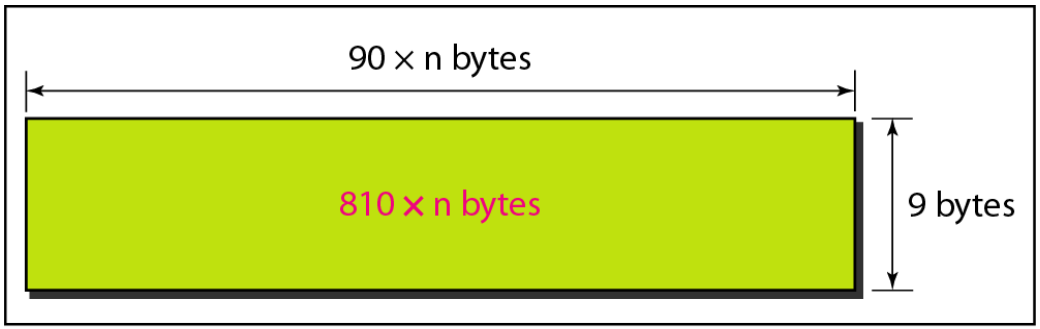
SPE : Synchronous Payload Envelopment

STS-1 frames

STS-n frames

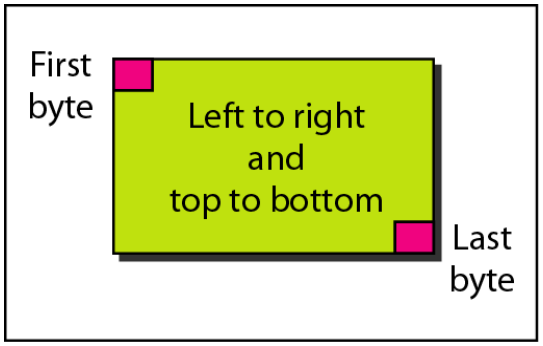


a. STS-1 frame

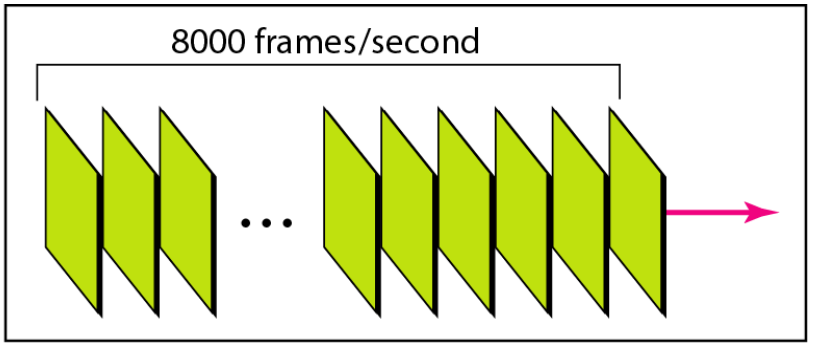


b. STS-n frame

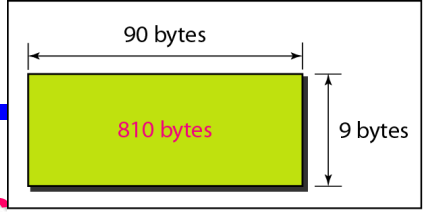
STS-1 frames in transition



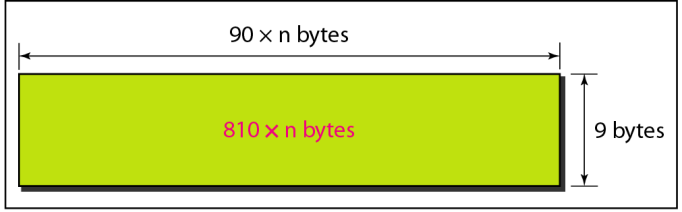
a. Byte transmission



b. Frame transmission



a. STS-1 frame



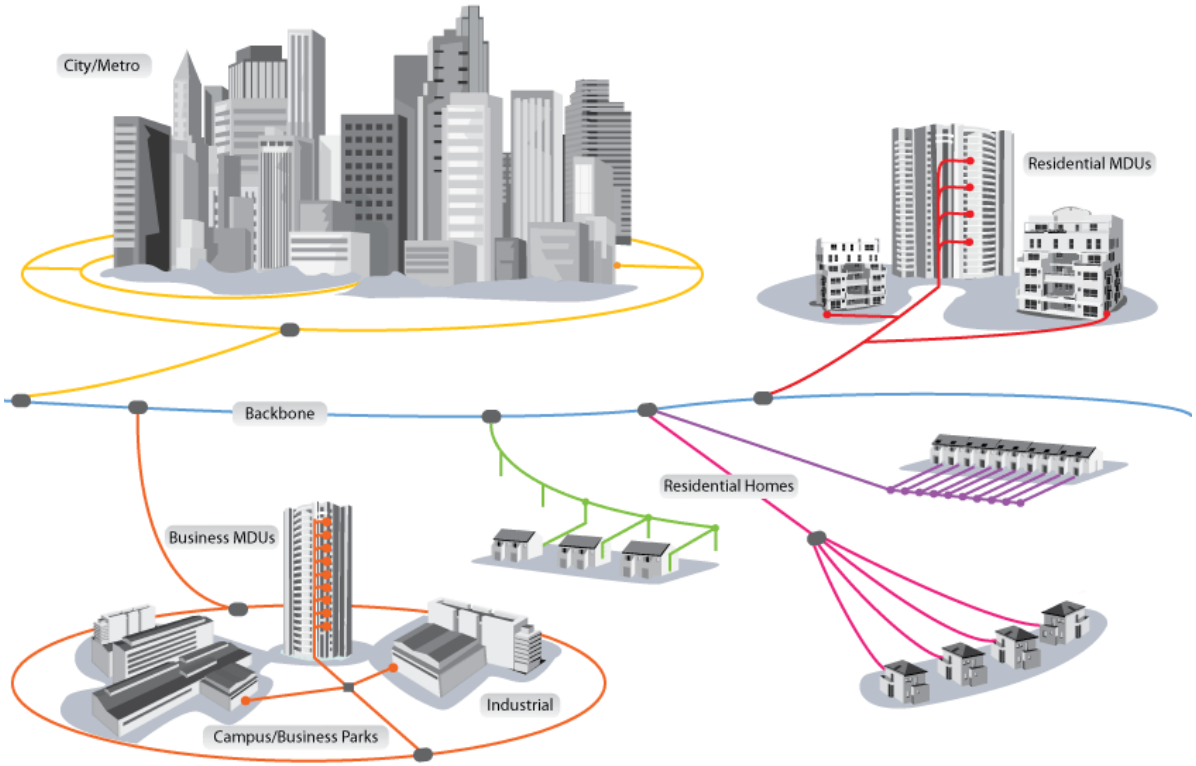
b. STS-n frame

Table 9.1 SONET rates

STS	OC	Rate (Mbps)	SPE (Mbps)	User (Mbps)
STS-1	OC-1	51.84	50.12	49.536
STS-3	OC-3	155.52	150.336	148.608
STS-9	OC-9	466.56	451.008	445.824
STS-12	OC-12	622.08	601.344	594.432
STS-18	OC-18	933.12	902.016	891.648
STS-24	OC-24	1244.16	1202.688	1188.864
STS-36	OC-36	1866.23	1804.032	1783.296
STS-48	OC-48	2488.32	2405.376	2377.728
STS-192	OC-192	9953.28	9621.604	9510.912

Fiber To The x (FTTx)

- Fiber-To-The-Home (FTTH) / Fiber-To-The-curb (FTTC) / Fiber-to-the-business (FTTC)
- Ultra Broadband
  - บริการบรอดแบนด์อินเทอร์เน็ตผ่านโครงข่ายใยแก้วนำแสง



Fiber To The x (FTTx)

- ความเร็ว 30Mbps – 1Gbps
- อุปกรณ์
  - Transceiver (optical signal -> electrical signal (RJ45)
  - ONT (FTTx Router)

กล่องพักสาย

Transceiver

Router