Chapter 2
from Tanenbaum - modified

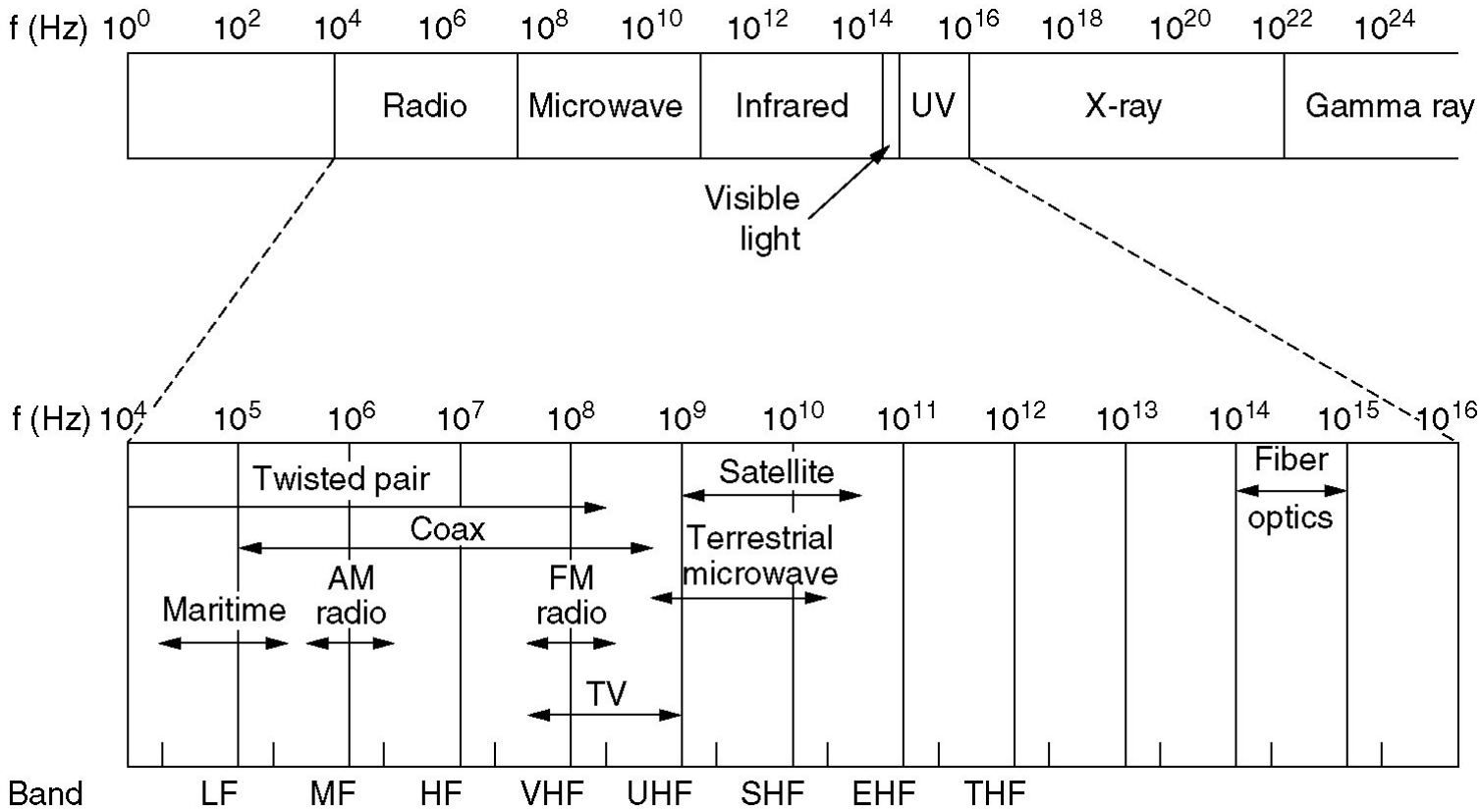
The Physical Layer

Ref: A.S. Tanenbaum, *Computer Networks*, 4th Ed., Prentice-Hall, 2003, ISBN: 0-13-038488-7.

Data Communications over Wireless and Digital Wired Systems

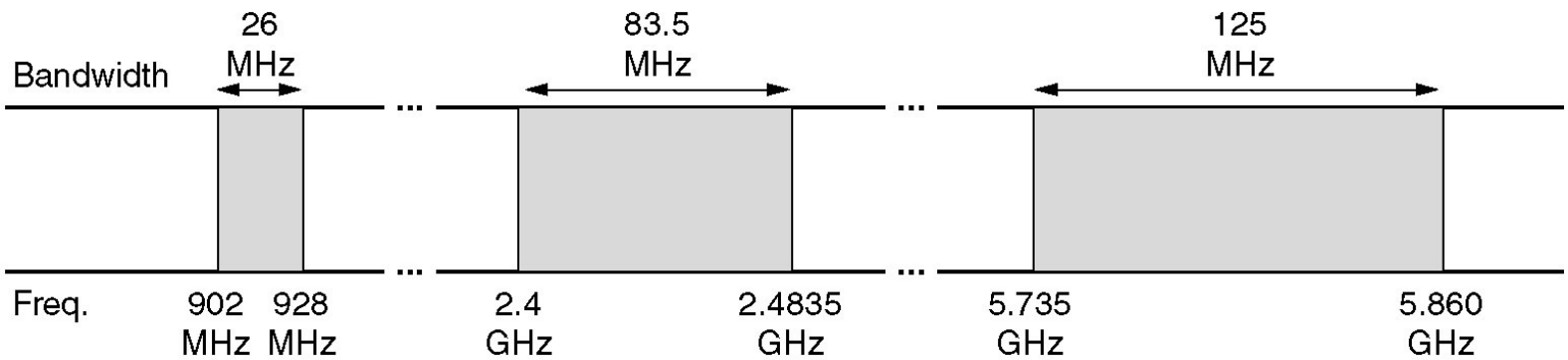
- The Electromagnetic Spectrum
- Public Switched Telephone System
- Digital Subscriber Lines
- Wireless Local Loop
- CATV & INTERNET Access over Cable

The Electromagnetic Spectrum



The electromagnetic spectrum and its uses for communication.

Politics of the Electromagnetic Spectrum



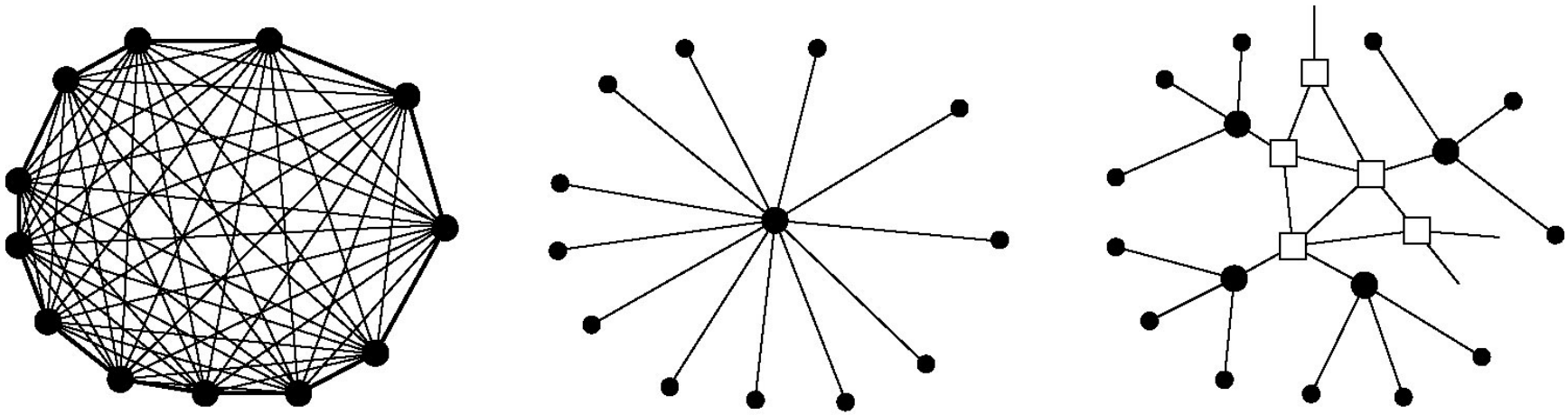
The ISM bands in the United States.

(ISM: Industrial, Scientific, Medical)

Public Switched Telephone System

- Structure of the Telephone System
- The Politics of Telephones
- The Local Loop: Modems, ADSL and Wireless
- Trunks and Multiplexing
- Switching

Structure of the Telephone System

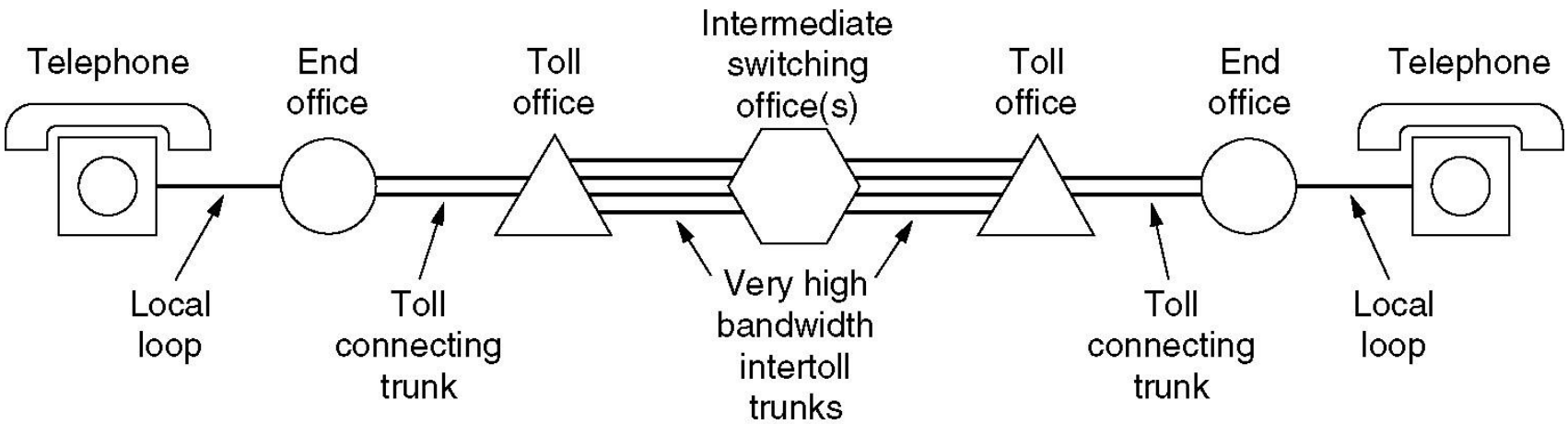


(a) Fully-interconnected network.

(b) Centralized switch.

(c) Two-level hierarchy.

Structure of the Telephone System (2)

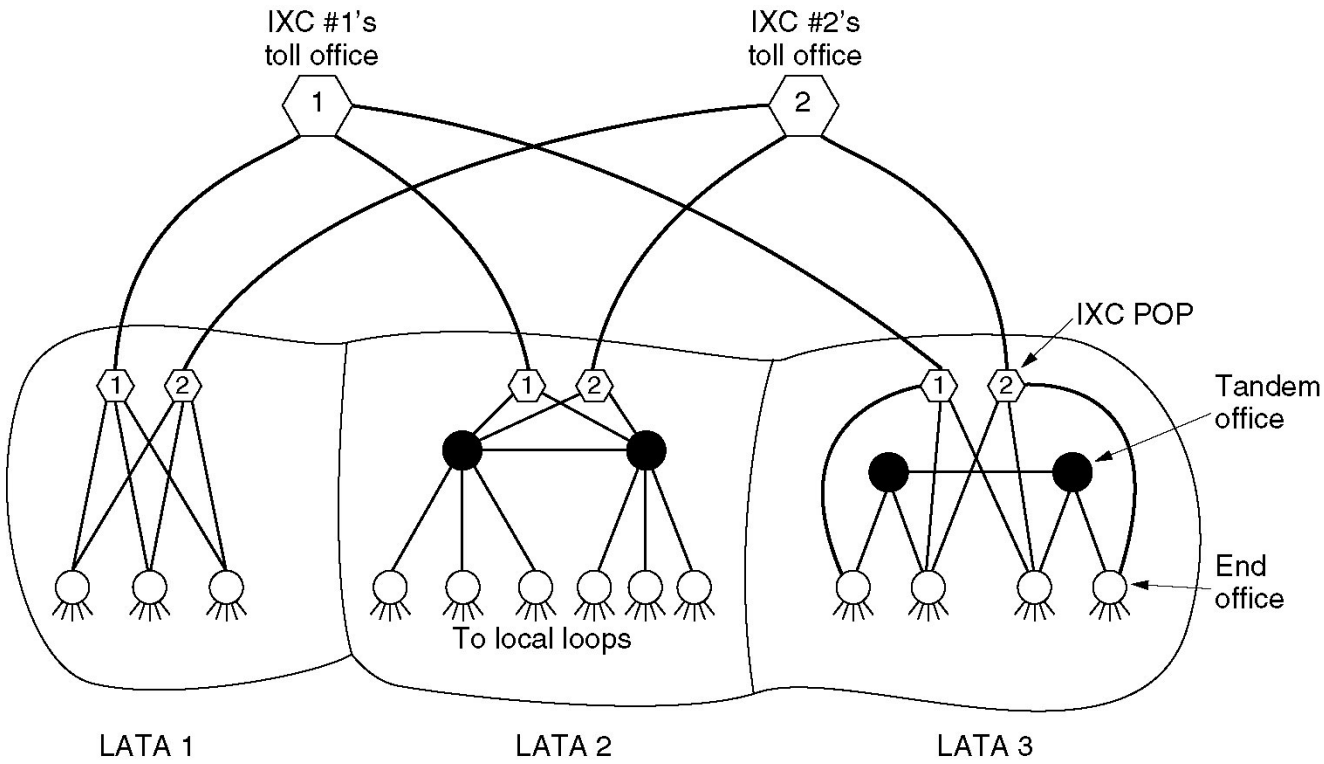


A typical circuit route for a medium-distance call.

Major Components of the Telephone System

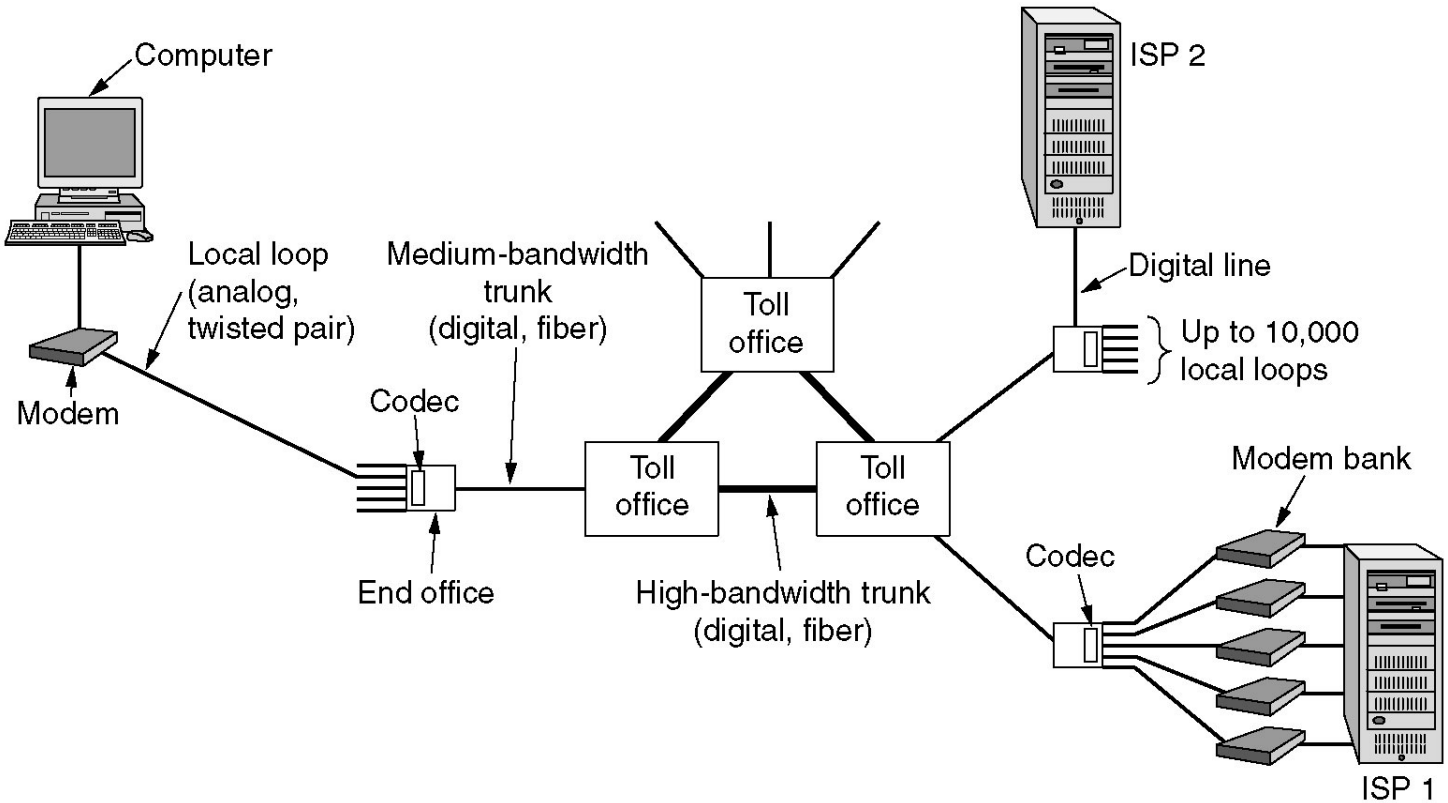
- Local loops
  - Analog twisted pairs going to houses and businesses
- Trunks
  - Digital fiber optics connecting the switching offices
- Switching offices
  - Where calls are moved from one trunk to another

The Politics of Telephones



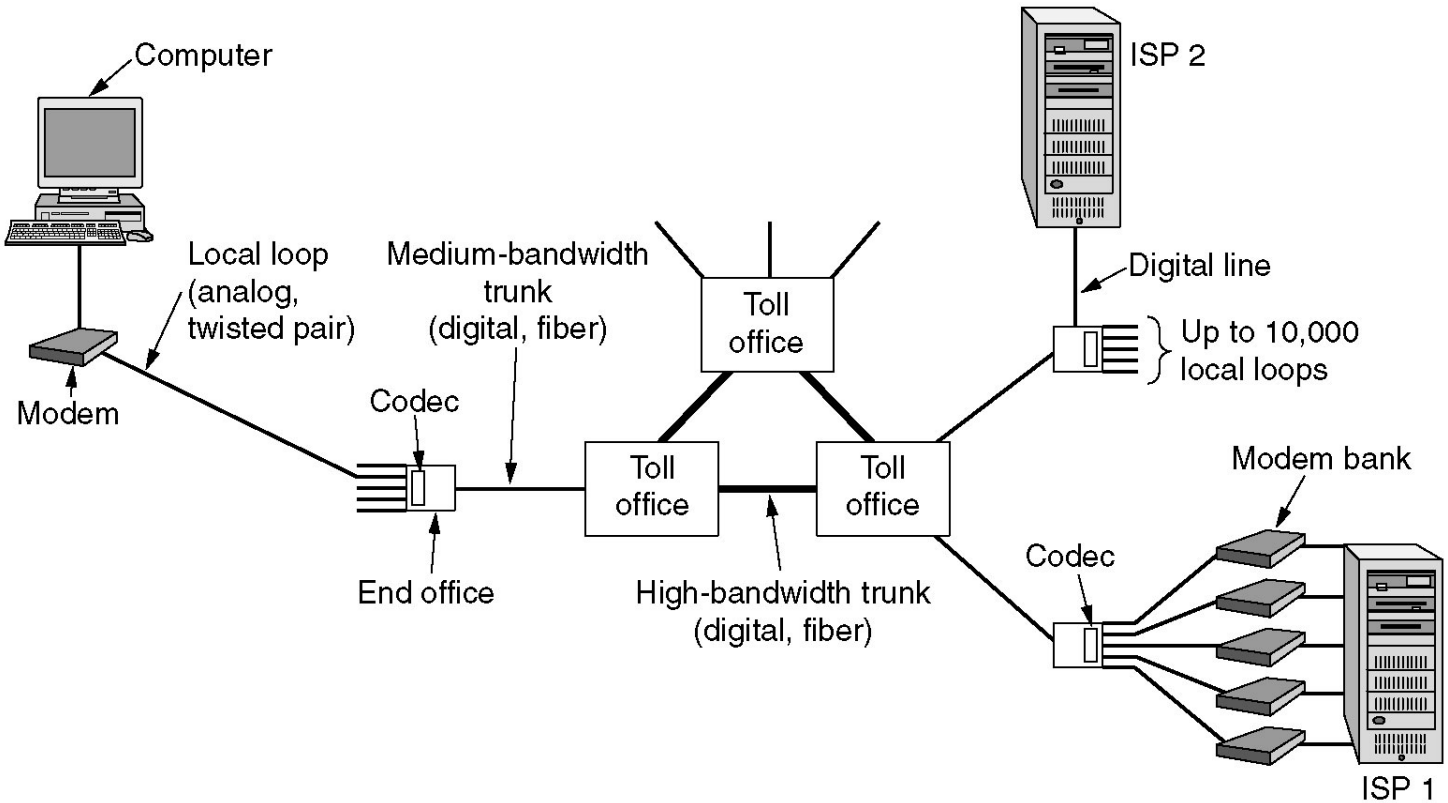
The relationship of LATAs, LECs, and IXCs. All the circles are LEC switching offices. Each hexagon belongs to the IXC whose number is on it.

The Local Loop: Modems, ADSL, and Wireless



The use of both analog and digital transmissions for a computer to computer call. Conversion is done by the modems and codecs.

The Local Loop: Modems, ADSL, and Wireless



The use of both analog and digital transmissions for a computer to computer call. Conversion is done by the **modems** and **codecs**.

Modem: modulator/demodulator **Codec**: coder/decoder

Transmission Impairments

Transmission lines suffer from 3 major problems:

1. Attenuation: loss of energy as the signal travels outward. On guided media (wires and optical fibers) it falls off logarithmically with the distance. Loss is expressed in decibels per km.

2. Delay distortion: different Fourier components travel at different speeds. This increases the probability of incorrect reception.

3. Noise: unwanted energy from sources other than the transmitter.
Thermal noise: due to random noise from electrons in a wire.

Cross talk: inductive coupling between two wires due to their proximity.

Impulse noise: caused by spikes on the power line or other causes.

Digital Subscriber Lines

- **xDSL**: Digital Subscriber Loop for various *x* : the customer loops are connected to a kind of new switch that removes the filters used in PSTNs to limit bandwidth to 3,100 Hz. Capacity of local loop depends on: (length , thickness and general quality).

  Goals: i) services must work over Cat3-UTP; ii) must not affect existing tel & fax machines; iii) must be much faster than 56 kbps; iv) must be always on with monthly charge (no per-minute charge).

Digital Subscriber Lines (2)

Different types of xDSL services are:

- **ADSL**: Asymmetric DSL (stds.: ANSI T1.413 and ITU G992.1)

  8 Mbps/1 Mbps down/up – stream. Typical: 512 kbps/64 kbps (standard service) and 1 Mbps/256 kbps (premium service). Sapling rate: 4,000 baud; QAM; 15 bits/baud. With 224 downstream channels this gives a d/stream B/W of 13.44 Mbps.
- **SHDSL**: (**Symmetric High-Speed Digital Subscriber Line)**: Industry standard providing rate adaptation, greater reach, spectral compatibility, low power, application flexibility and high-speed symmetric service for businesses and Small Office Home Office (SOHO) customers.

(Ref: http://www.dslforum.org/learndsl/aboutvdsl.shtml)

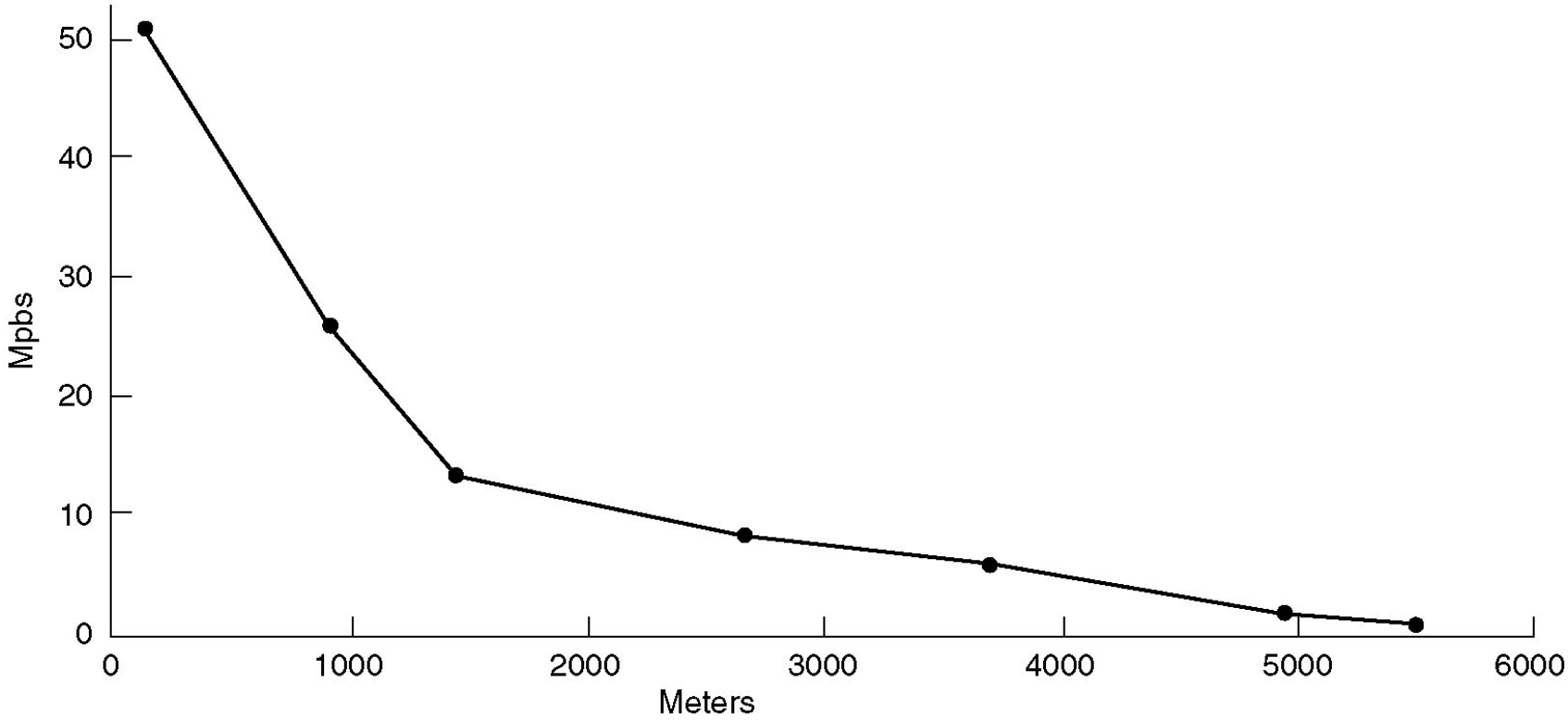
Digital Subscriber Lines (3)

- **ADSL2 & ADSL2plus**: Standardized in 2004, (also known as ADSL-Reach Extended) they are provided as ADSL upgrades. By using this standard, service providers can provide even higher speed offerings to an extended service area. This has opened the door to new **Video service** support capabilities and a host of new service offerings from the service providers.
- **VDSL & VDSL2**: Very high speed Digital Subscriber Lines (VDSL): extremely high speed DSL options that have really taken root in Asia where the digital lifestyle has incorporated such a variety of devices, all online and demanding an exacting quality of experience for the user.

VDLS2 enables/allows: **i) Very high speed Internet access:** of up to symmetrical 100 Mbps (both up and downstream), **ii) Support for applications** such as multi-channel high definition TV (HDTV), video on demand, videoconferencing, and VoIP, all using the existing ubiquitous copper telephone line infrastructure. **iii) ATM, Ethernet and IP compatibility** and **iv) the capacity for multimode implementations** enabling interoperability with existing ADSL equipment, means that VDSL2 will integrate readily into legacy and next generation telecommunication networks.

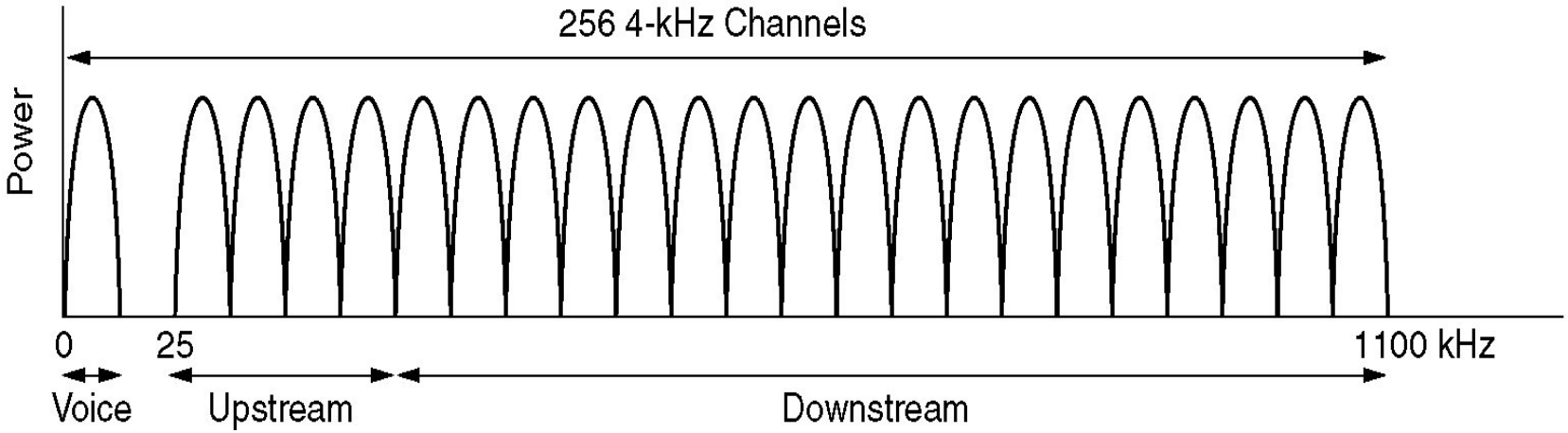
(Ref: http://www.dslforum.org/learndsl/aboutvdsl.shtml)

Digital Subscriber Lines (4)



Bandwidth versus distance over category 3 UTP for DSL.

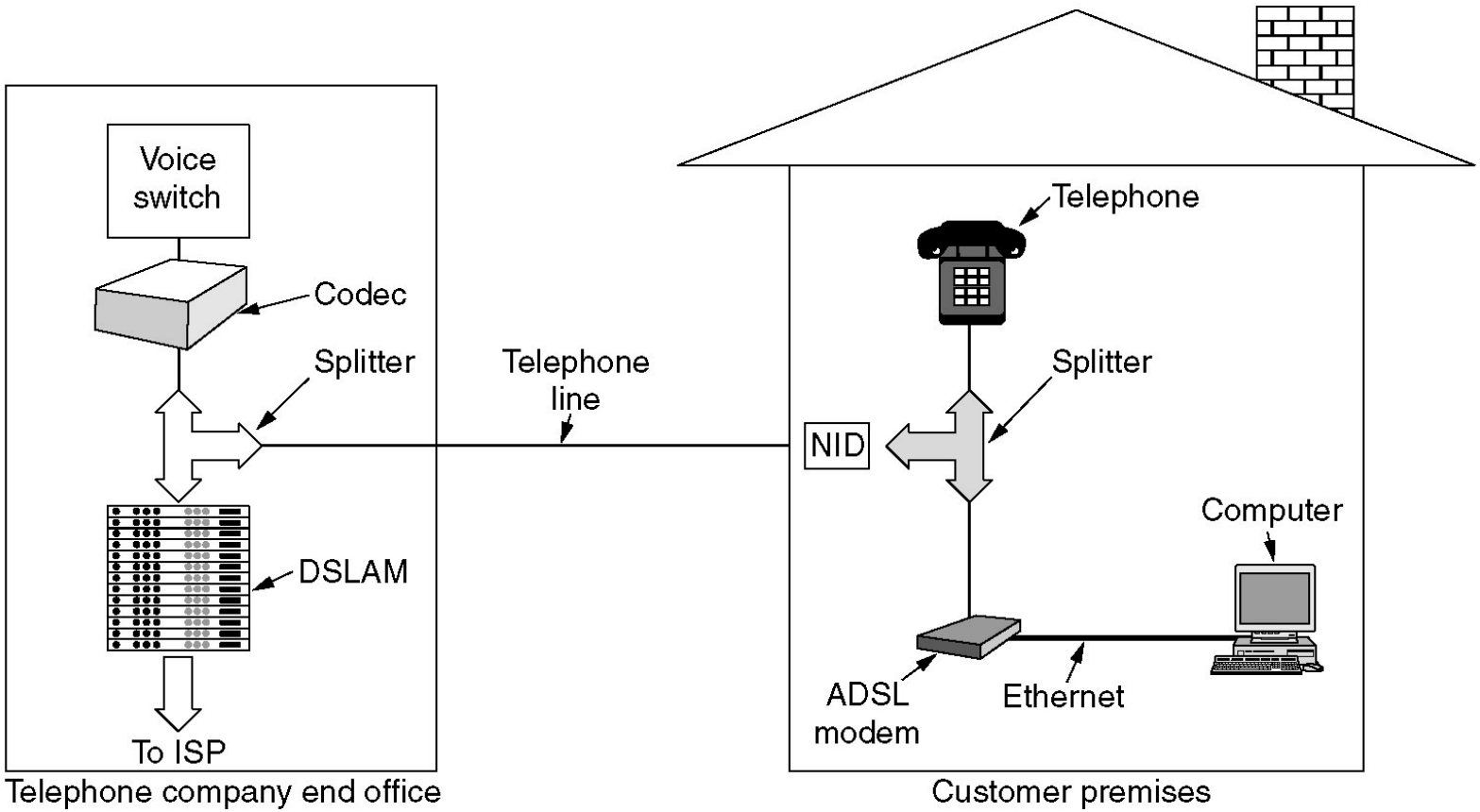
Digital Subscriber Lines (5)



Operation of ADSL using Discrete MultiTone (DMT) modulation.

1.1 MHz spectrum is divided into 256 independent 4,312.5 Hz channels. Channel 0 is used for POTS; channels 1-5 are not used. Of the remaining 250 chs; 2 chs are used for upstream & downstream control (one for each). This leaves 248 channels for splitting into upstream and downstream usage. Typically 32 upstream and 216 downstream channels are used.

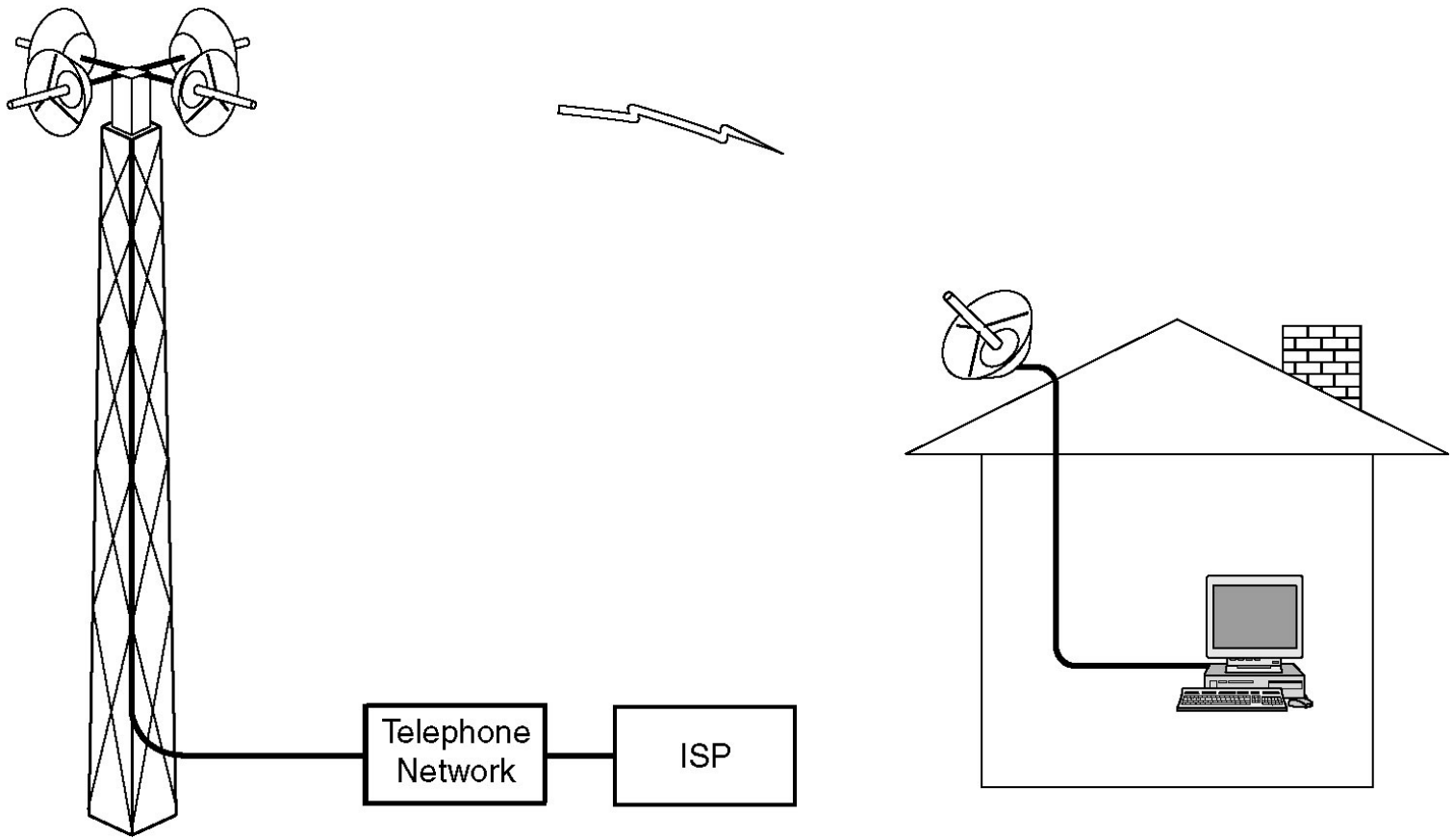
Digital Subscriber Lines (6)



A typical ADSL equipment configuration.

NID: Network Interface Device DSLM: Digital Subscriber Line Access Multiplexer
ISP: Internet Service Provider.

Wireless Local Loops (WLL)



Architecture of an LMDS system.
LMDS: Local Multipoint Distribution Service

WLL (2)

a) **MMDS: Multichannel Multipoint Distribution Service**: 2.1-2.5 GHz band (a total of 198 MHz) : microwave wavelengths are: 10-12 cm. Range: 50 km; can penetrate vegetation and rain moderately well. MDS can be regarded as a MAN (Metropolitan Area Network).

b) **LMDS: Local Multipoint Distribution Service:** frequency band 28-31 GHz (USA) and 40 GHz (EU) (a total of 1.3 GHz in USA) for new wireless local loop service has been assigned. **Range:** 2-5 km and **absorbed by:** tree leaves and rain**.**

c) **Other options are: VSAT, WLAN (Wireless LAN), CDPD (Cellular Digital Packet Data)** and many other advancing techniques.

d) **Wireless local loop** (WLL), also called **radio in the loop** (RITL) or **fixed-radio access** (FRA) or **fixed-wireless access**(FWA), is the use of wireless connection as the last mile for delivering (POTS) to customers. (ref: http://en.wikipedia.org/wiki/Wireless_local_loop)

WLL (3)

e) ***C****ellular* ***D****igital* ***P****acket* ***D****ata*, a data transmission technology developed for use on cellular phone frequencies. CDPD uses unused cellular channels (in the 800- to 900-MHz range) to transmit data in packets. This technology offers data transfer rates of up to 19.2 Kbps, quicker call set up, and better error correction than using modems on an analog cellular channel.

(Ref: http://www.webopedia.com/TERM/C/CDPD.html)

f) IEEE 802.16 has been set up for LMDS standardization. 802.16 std. was published in 2002 and it is called WMAN: Wireless MAN.

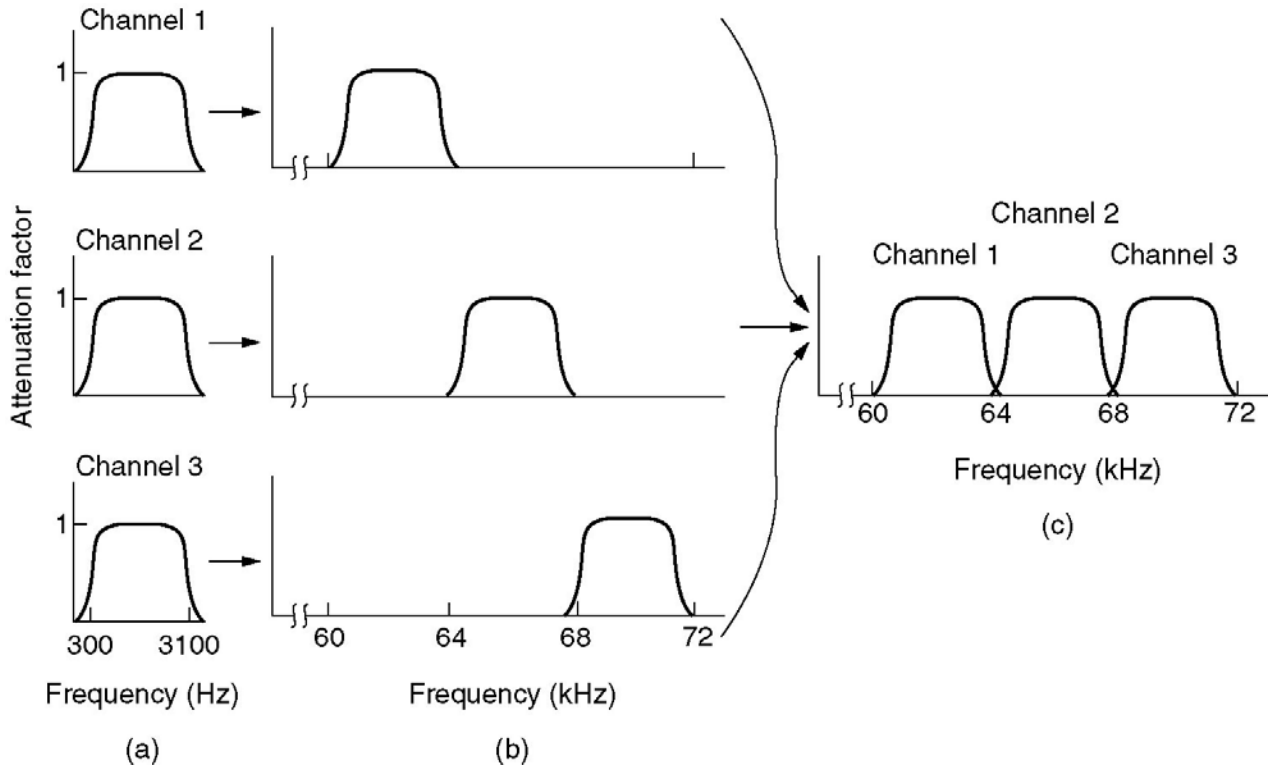
INTERNET Service Access Options

a) PSTN: Public Switched Telephone Network
b) ISDN: Integrated Services Digital Networks
c) ADSL: Asymmetric DSL
d) Cable Modem (through Cable TV)
e) Wireless Local Loop (Fixed wireless access; Mobile wireless access: GSM; GPRS; EDGE)
f) Satellite Access

TRUNKS and MULIPLEXING

a) **FDM**: Frequency Division Multiplexing
b) **WDM**: Wavelength Division Multiplexing
c) **TDM**: Time Division Multiplexing

Frequency Division Multiplexing

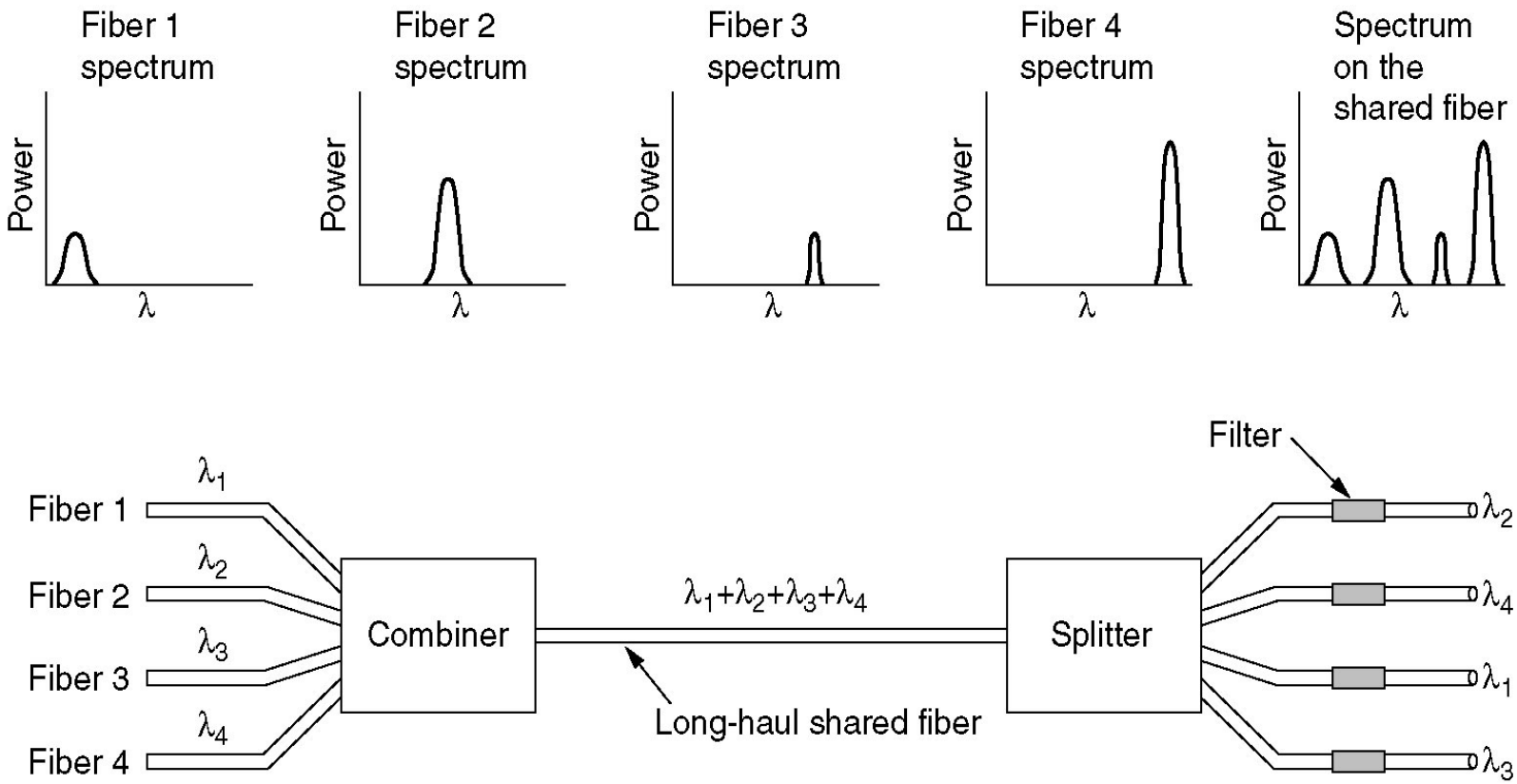


(a) The original bandwidths.

(b) The bandwidths raised in frequency.

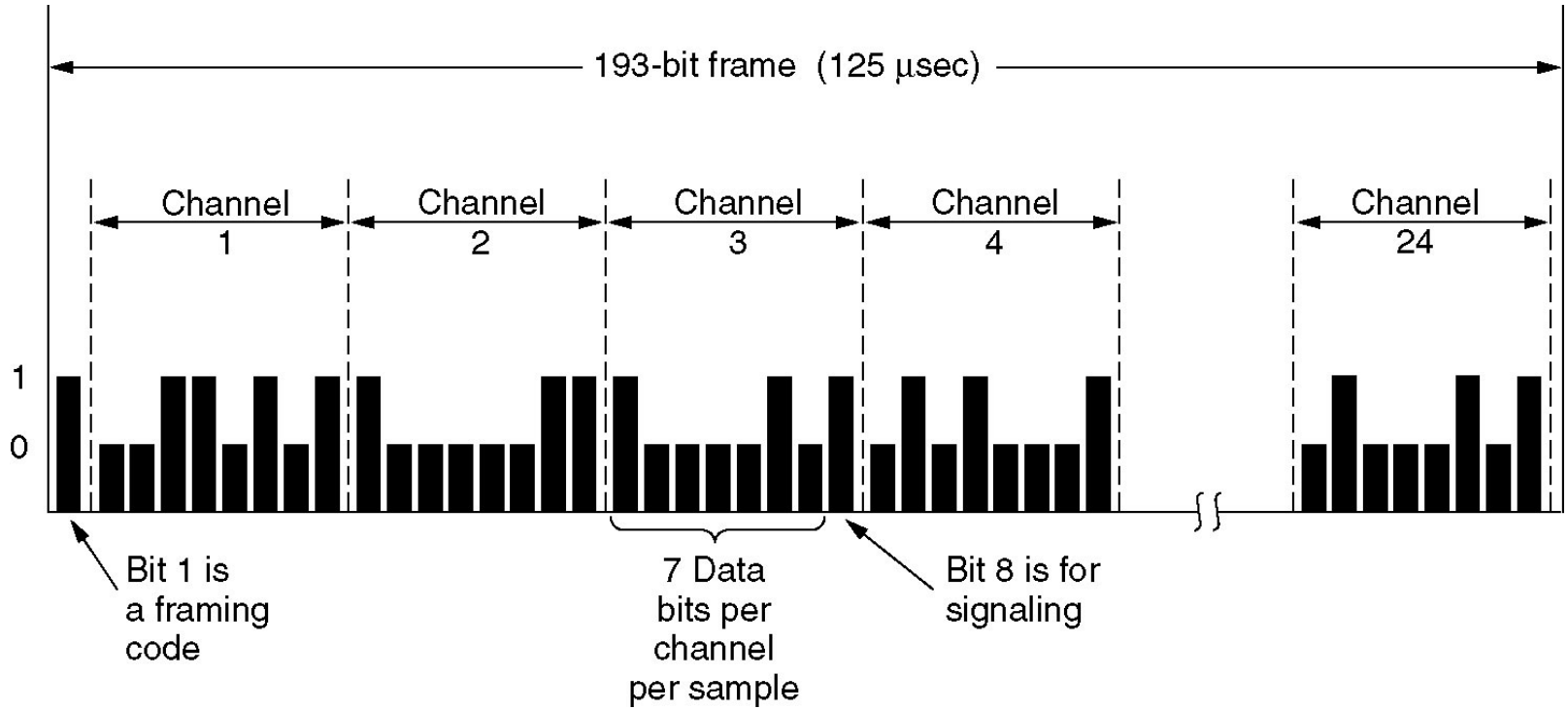
(b) The multiplexed channel.

Wavelength Division Multiplexing



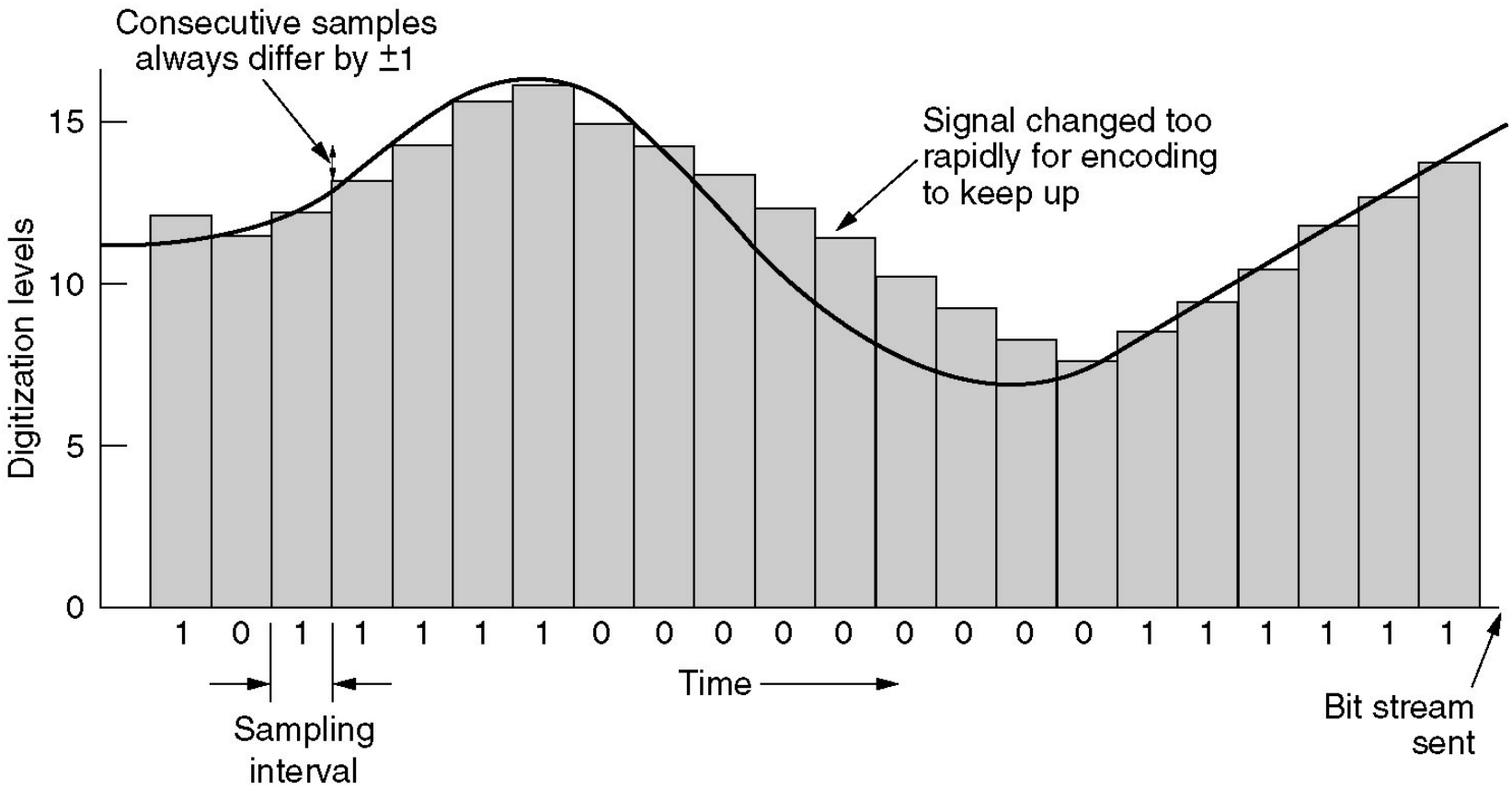
Wavelength division multiplexing.

Time Division Multiplexing



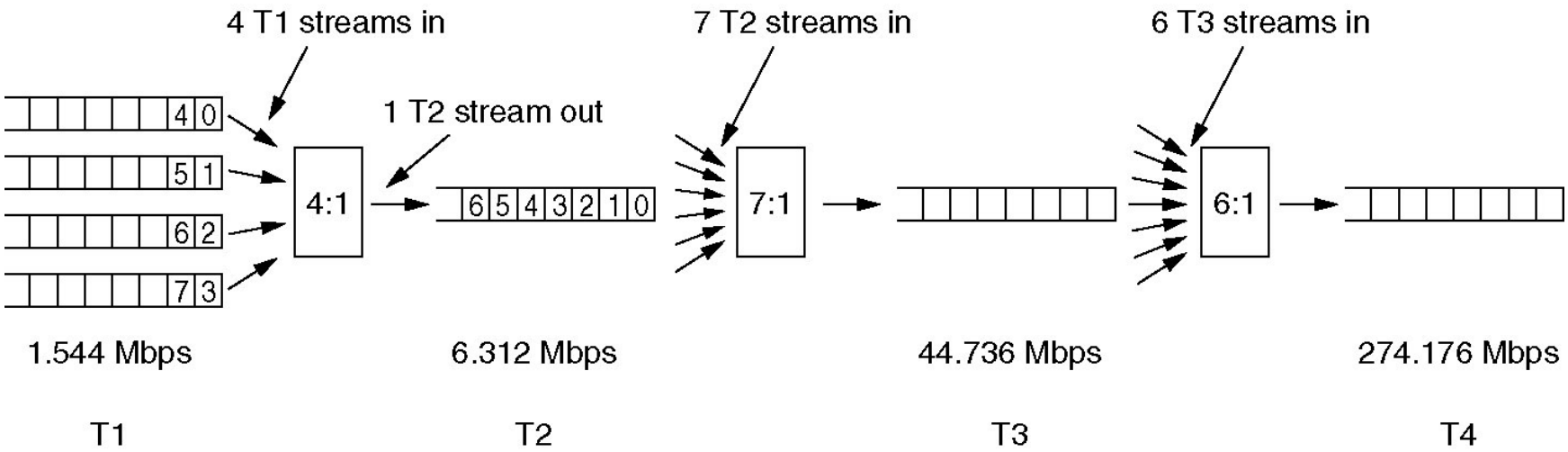
The T1 carrier (1.544 Mbps).

Time Division Multiplexing (2)



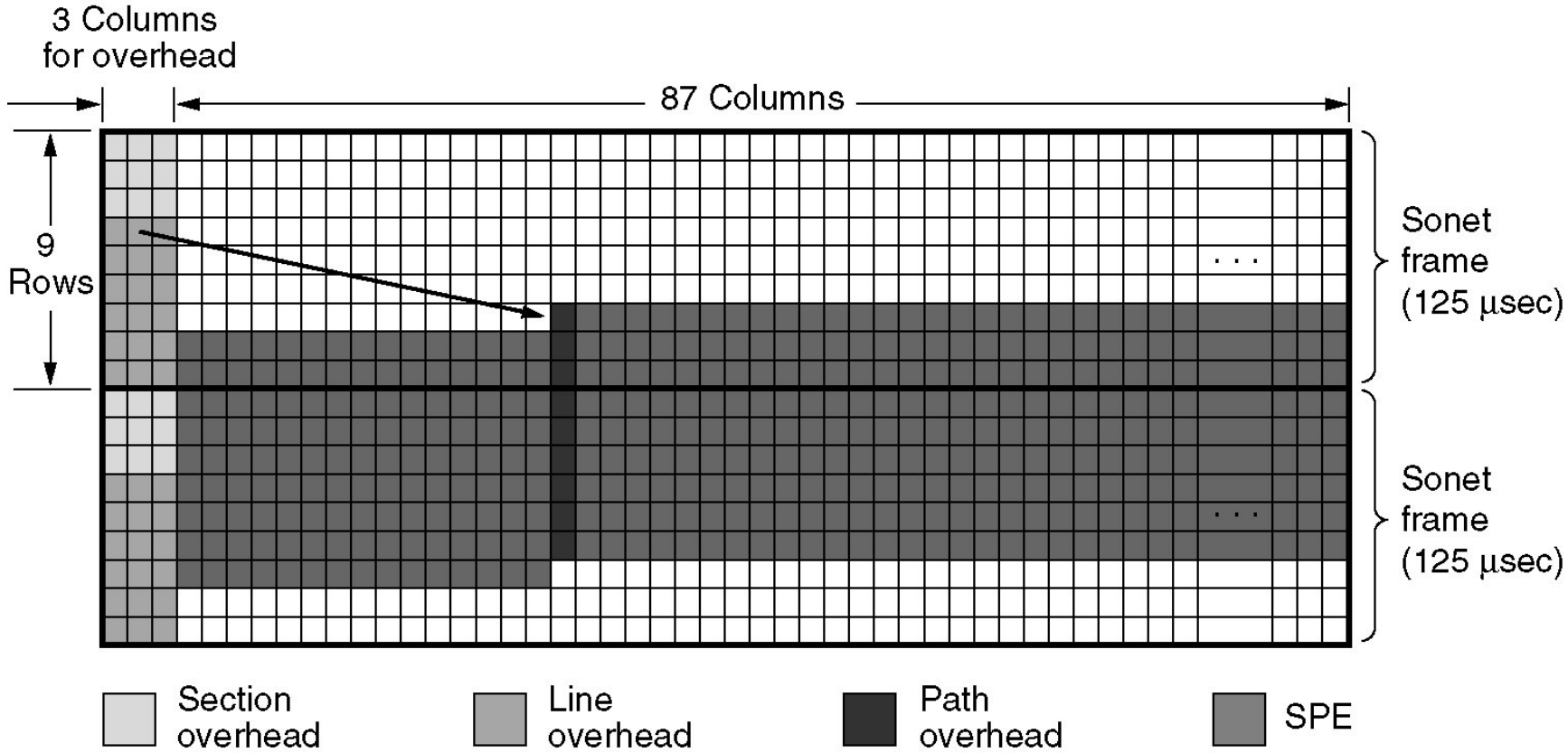
Delta modulation.

Time Division Multiplexing (3)



Multiplexing T1 streams into higher carriers.

Time Division Multiplexing (4)



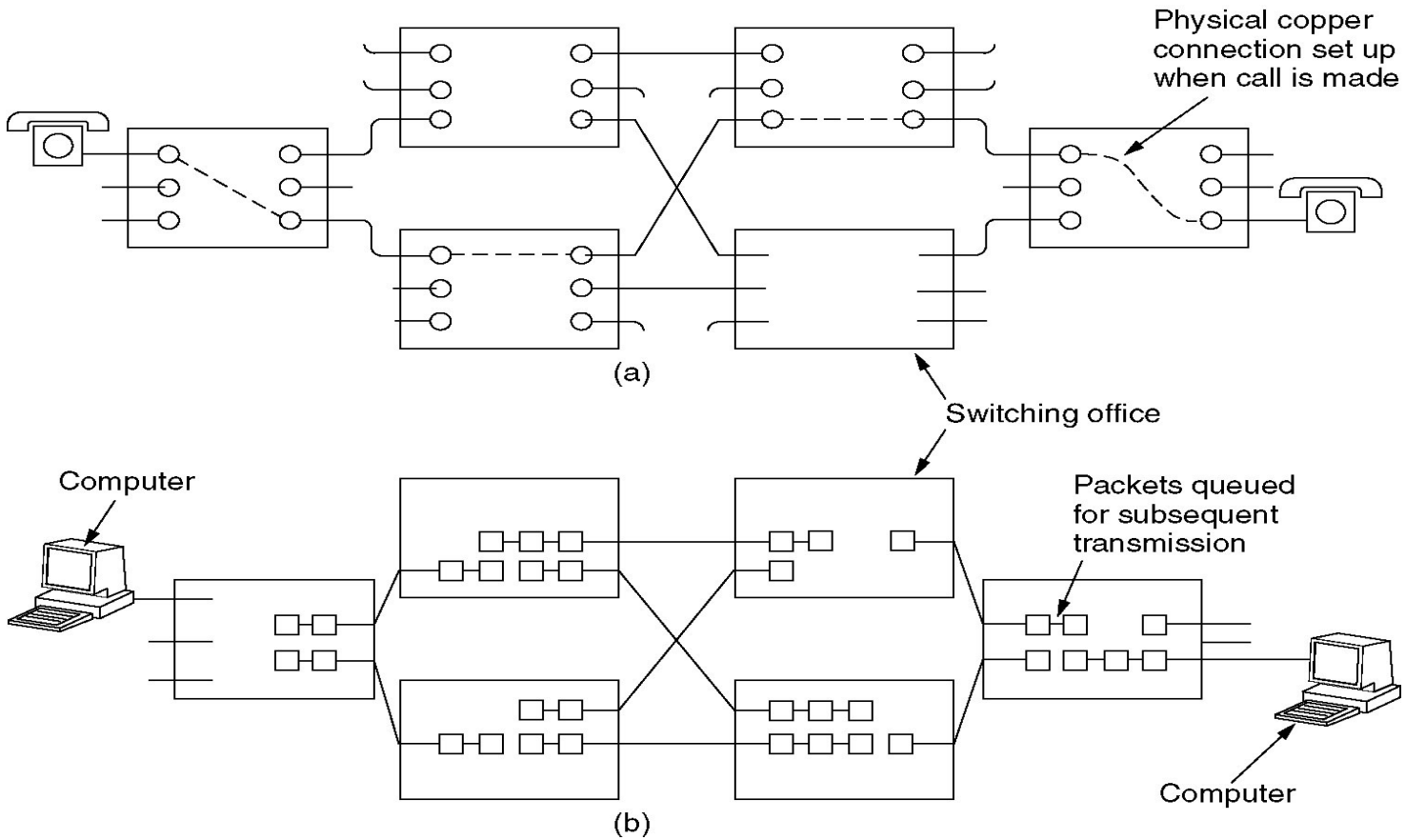
Two back-to-back SONET frames.

Time Division Multiplexing (5)

SONET		SDH	Data rate (Mbps)		
Electrical	Optical	Optical	Gross	SPE	User
STS-1	OC-1		51.84	50.112	49.536
STS-3	OC-3	STM-1	155.52	150.336	148.608
STS-9	OC-9	STM-3	466.56	451.008	445.824
STS-12	OC-12	STM-4	622.08	601.344	594.432
STS-18	OC-18	STM-6	933.12	902.016	891.648
STS-24	OC-24	STM-8	1244.16	1202.688	1188.864
STS-36	OC-36	STM-12	1866.24	1804.032	1783.296
STS-48	OC-48	STM-16	2488.32	2405.376	2377.728
STS-192	OC-192	STM-64	9953.28	9621.504	9510.912

SONET and SDH multiplex rates.

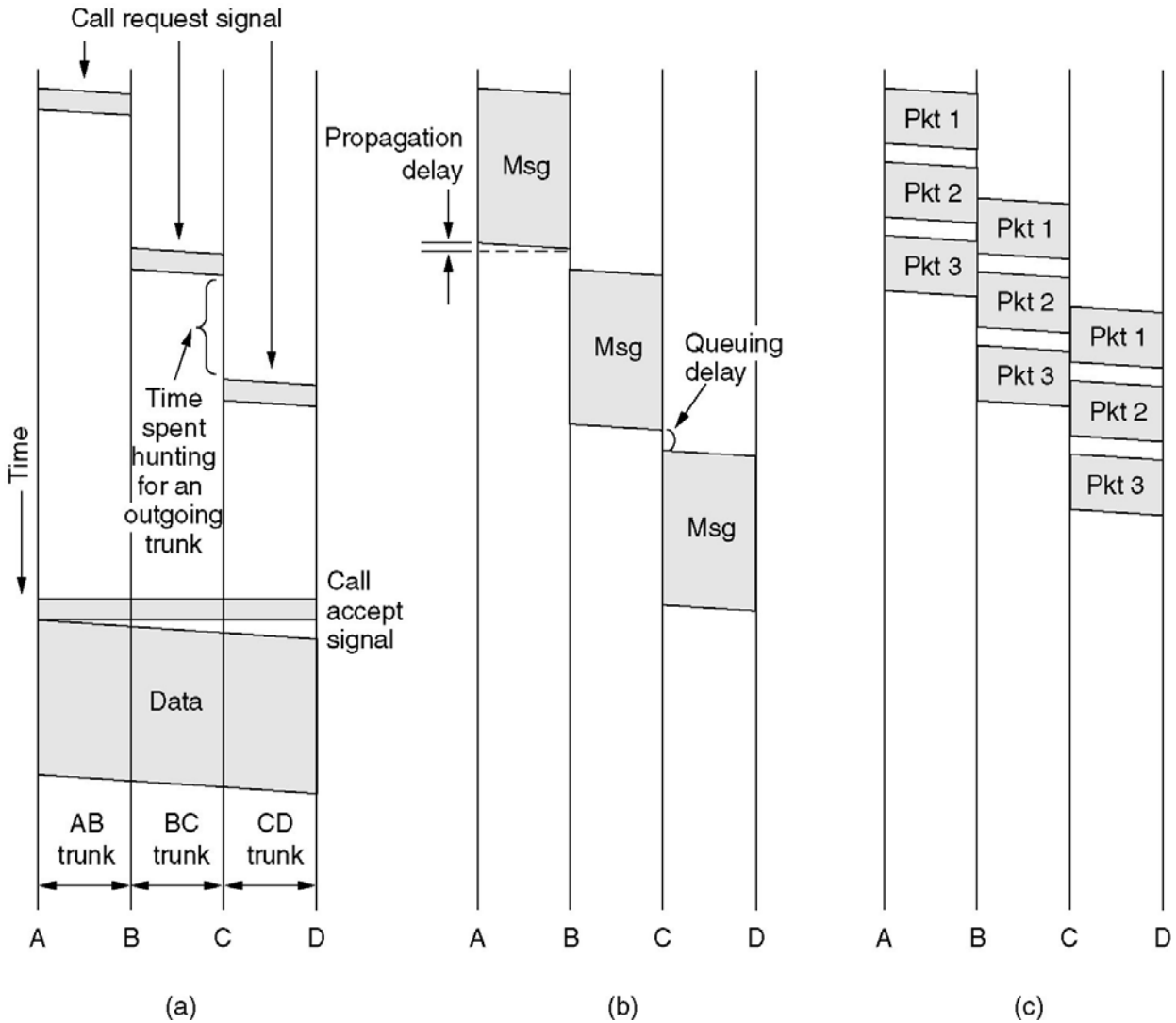
Circuit Switching



(a) Circuit switching.

(b) Packet switching.

Message Switching



(a) Circuit switching (b) Message switching (c) Packet switching

Packet Switching

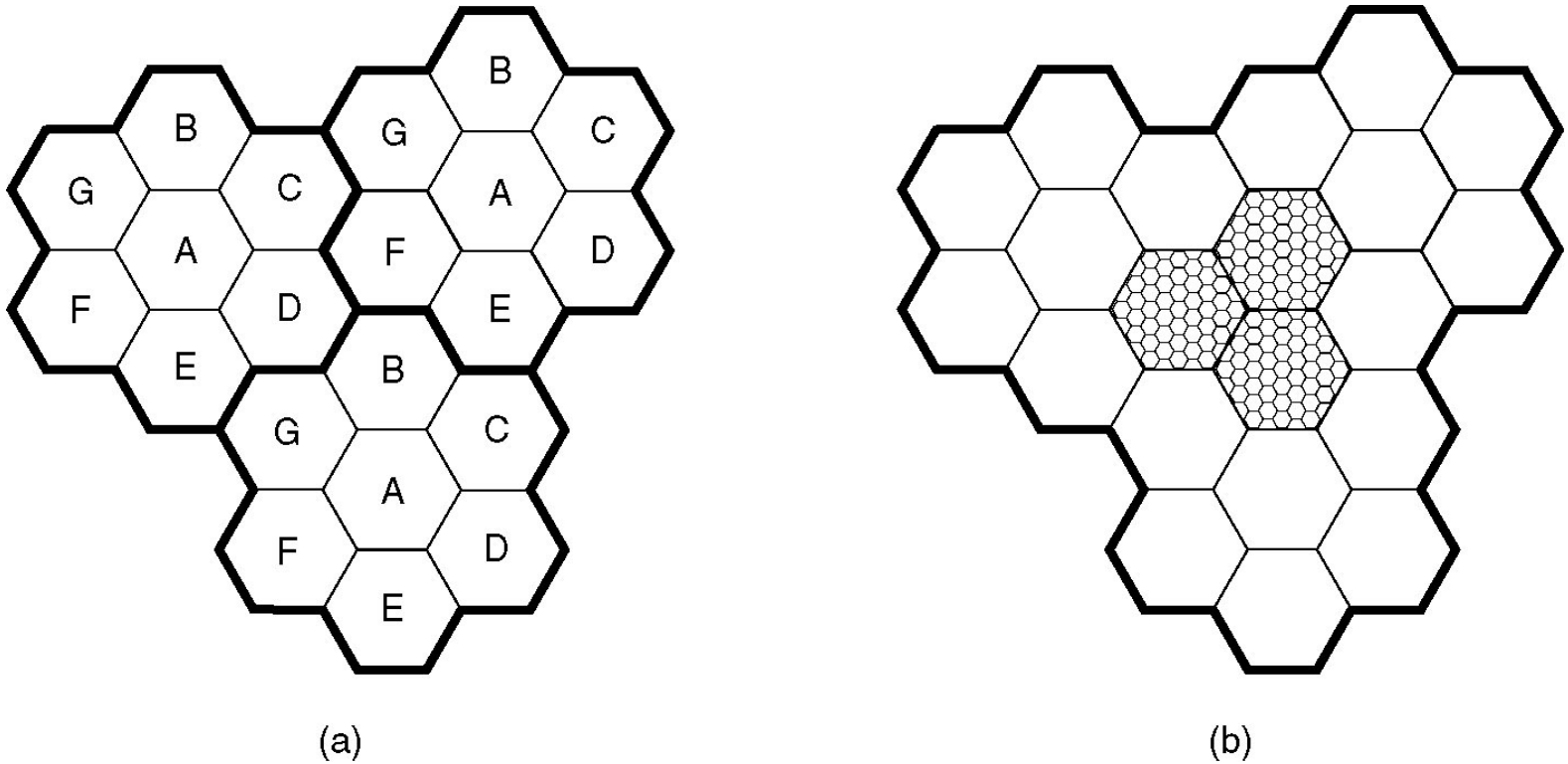
Item	Circuit-switched	Packet-switched
Call setup	Required	Not needed
Dedicated physical path	Yes	No
Each packet follows the same route	Yes	No
Packets arrive in order	Yes	No
Is a switch crash fatal	Yes	No
Bandwidth available	Fixed	Dynamic
When can congestion occur	At setup time	On every packet
Potentially wasted bandwidth	Yes	No
Store-and-forward transmission	No	Yes
Transparency	Yes	No
Charging	Per minute	Per packet

A comparison of circuit switched and packet-switched networks.

The Mobile Telephone System

- First-Generation Mobile Phones: Analog Voice
- Second-Generation Mobile Phones: Digital Voice
- Third-Generation Mobile Phones: Digital Voice and Data

Advanced Mobile Phone System



(a) (b)

(a) Frequencies are not reused in adjacent cells.

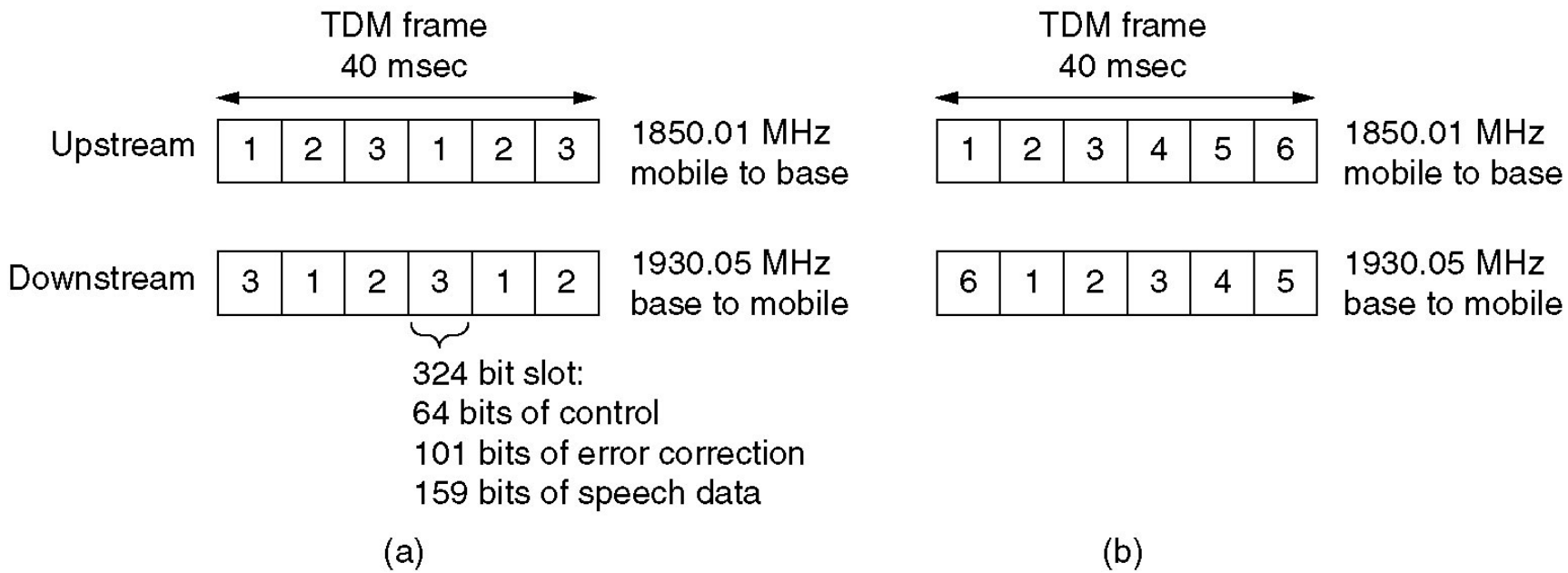
(b) To add more users, smaller cells can be used.

Channel Categories

The 832 channels are divided into four categories:

- Control (base to mobile) to manage the system
- Paging (base to mobile) to alert users to calls for them
- Access (bidirectional) for call setup and channel assignment
- Data (bidirectional) for voice, fax, or data

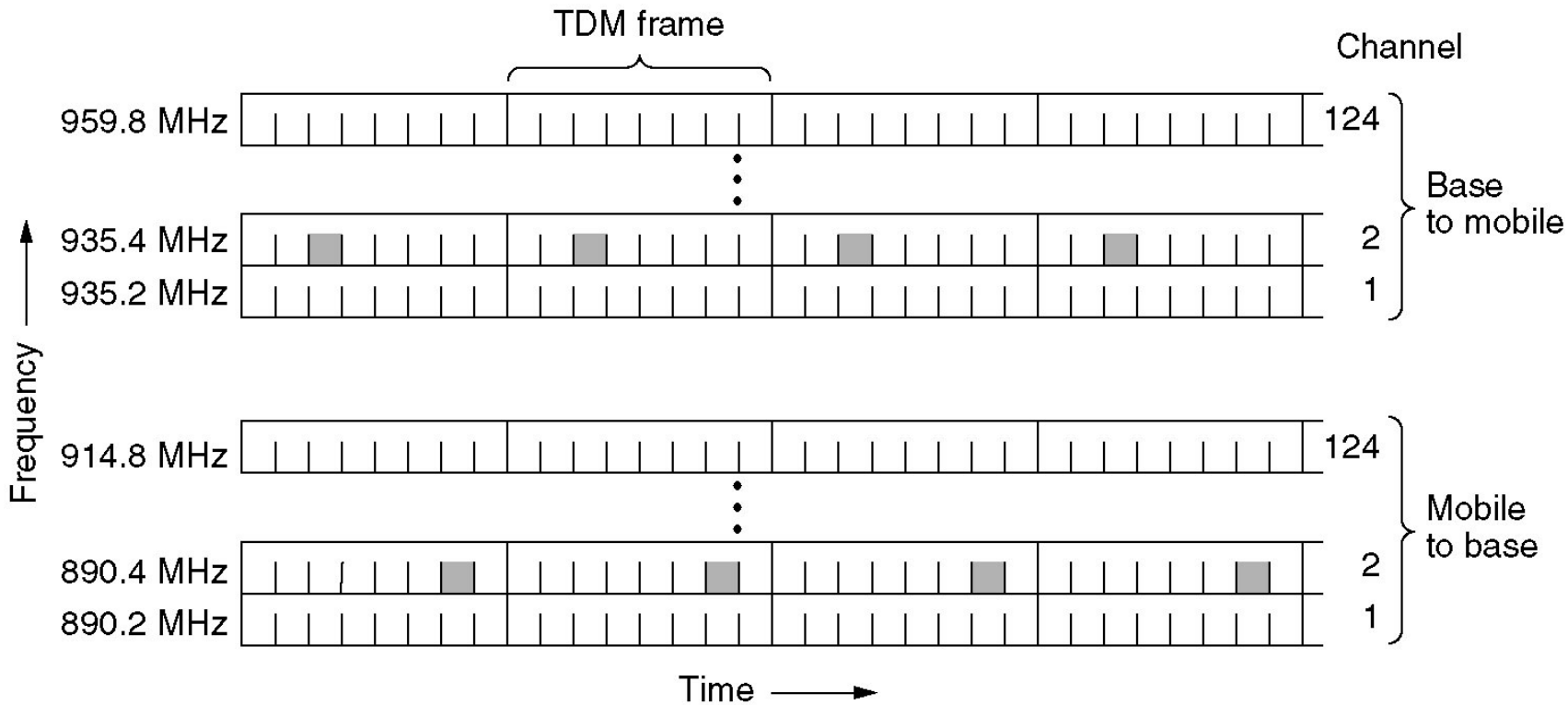
D-AMPS
Digital Advanced Mobile Phone System



(a) A D-AMPS channel with three users.

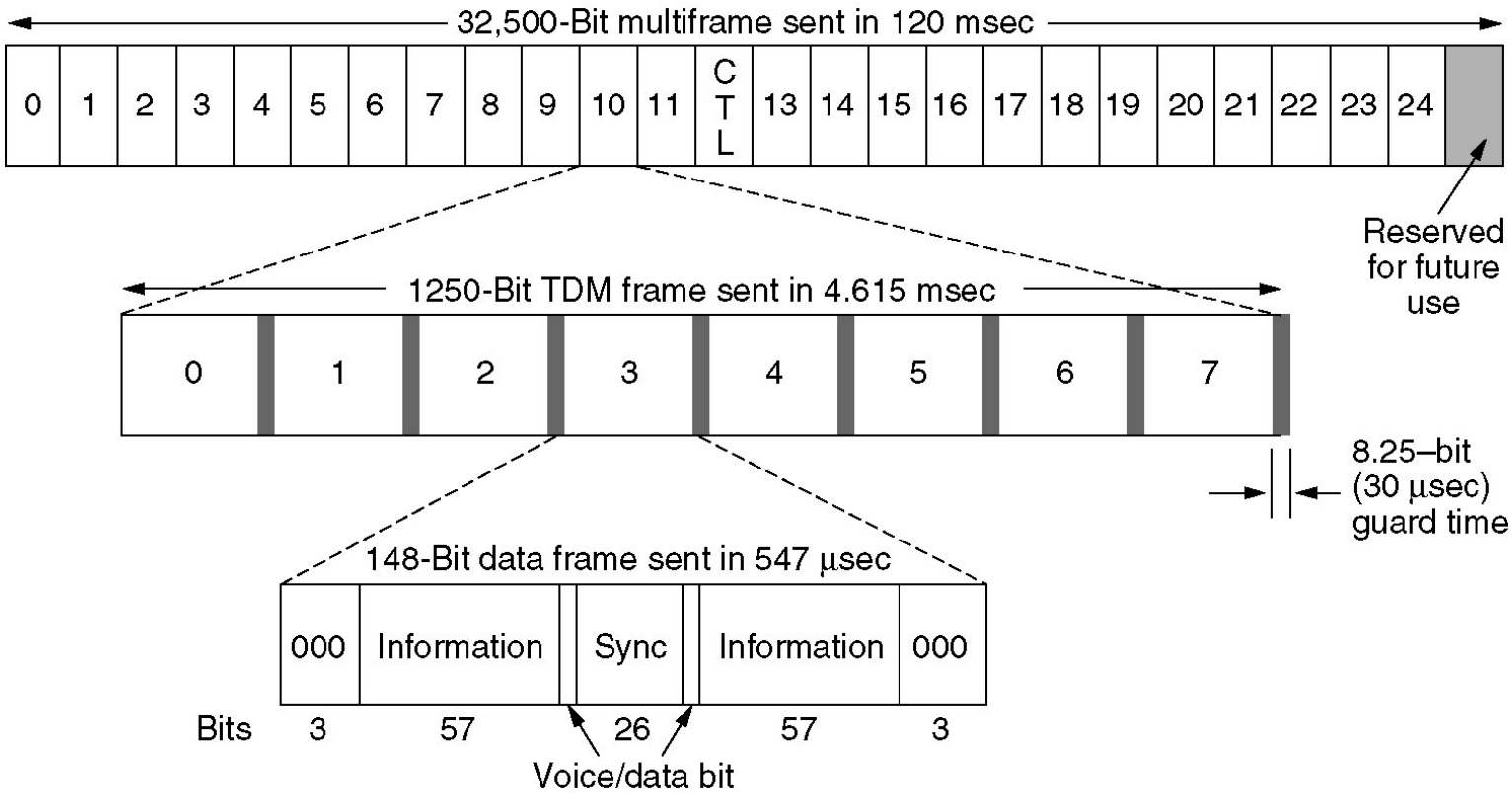
(b) A D-AMPS channel with six users.

GSM
Global System for Mobile Communications



GSM uses 124 frequency channels, each of which uses an eight-slot TDM system

GSM (2)



A portion of the GSM framing structure.

CDMA – Code Division Multiple Access

A: 0 0 0 1 1 0 1 1
B: 0 0 1 0 1 1 1 0
C: 0 1 0 1 1 1 0 0
D: 0 1 0 0 0 0 1 0

(a)

A: (–1 –1 –1 +1 +1 –1 +1 +1)
B: (–1 –1 +1 –1 +1 +1 +1 –1)
C: (–1 +1 –1 +1 +1 +1 –1 –1)
D: (–1 +1 –1 –1 –1 –1 +1 –1)

(b)

Six examples:

– – 1 –	**C**	$S_1 = (-1\ +1\ -1\ +1\ +1\ +1\ -1\ -1)$
– 1 1 –	**B** + $\overline{\mathbf{C}}$	$S_2 = (-2\ \ 0\ \ 0\ \ 0\ +2\ +2\ \ 0\ -2)$
1 0 – –	**A** + $\overline{\mathbf{B}}$	$S_3 = (\ 0\ \ 0\ -2\ +2\ \ 0\ -2\ \ 0\ +2)$
1 0 1 –	**A** + $\overline{\mathbf{B}}$ + **C**	$S_4 = (-1\ +1\ -3\ +3\ +1\ -1\ -1\ +1)$
1 1 1 1	**A** + **B** + **C** + **D**	$S_5 = (-4\ \ 0\ -2\ \ 0\ +2\ \ 0\ +2\ -2)$
1 1 0 1	**A** + **B** + $\overline{\mathbf{C}}$ + **D**	$S_6 = (-2\ -2\ \ 0\ -2\ \ 0\ -2\ +4\ \ 0)$

(c)

$S_1 \bullet C = (1 +1 +1 +1 +1 +1 +1 +1)/8 = 1$
$S_2 \bullet C = (2 +0 +0 +0 +2 +2 +0 +2)/8 = 1$
$S_3 \bullet C = (0 +0 +2 +2 +0 -2 +0 -2)/8 = 0$
$S_4 \bullet C = (1 +1 +3 +3 +1 -1 +1 -1)/8 = 1$
$S_5 \bullet C = (4 +0 +2 +0 +2 +0 -2 +2)/8 = 1$
$S_6 \bullet C = (2 -2 +0 -2 +0 -2 -4 +0)/8 = -1$

(d)

(a) Binary chip sequences for four stations
(b) Bipolar chip sequences
(c) Six examples of transmissions
(d) Recovery of station C's signal

Third-Generation Mobile Phones: Digital Voice and Data

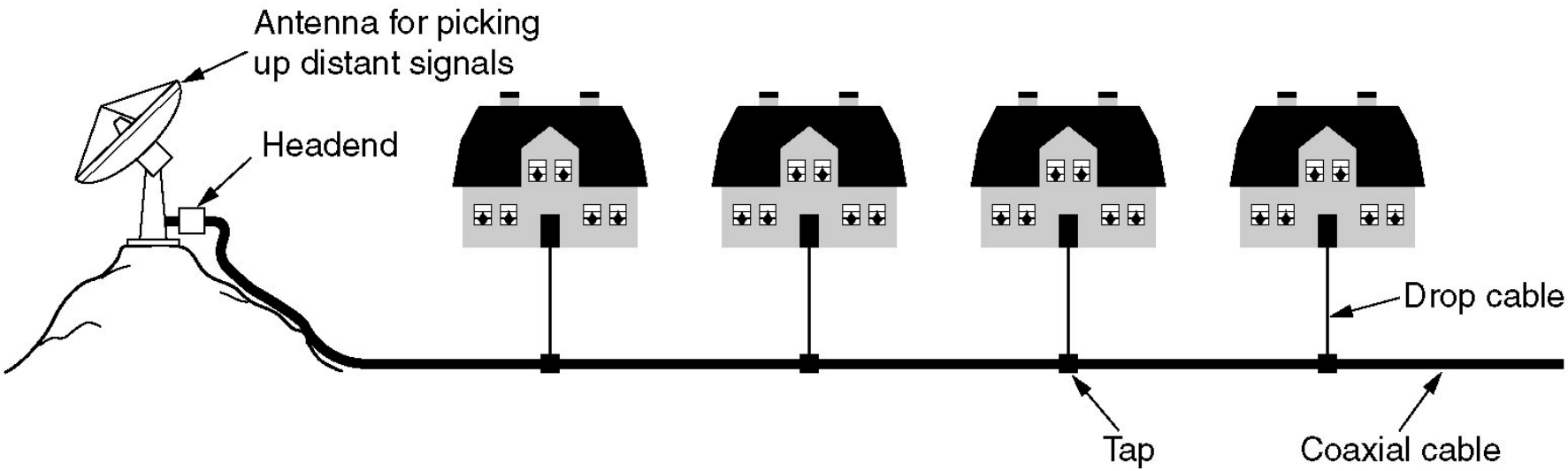
Basic services an IMT-2000 network should provide

- High-quality voice transmission
- Messaging (replace e-mail, fax, SMS, chat, etc.)
- Multimedia (music, videos, films, TV, etc.)
- Internet access (web surfing, w/multimedia.)

Cable Television

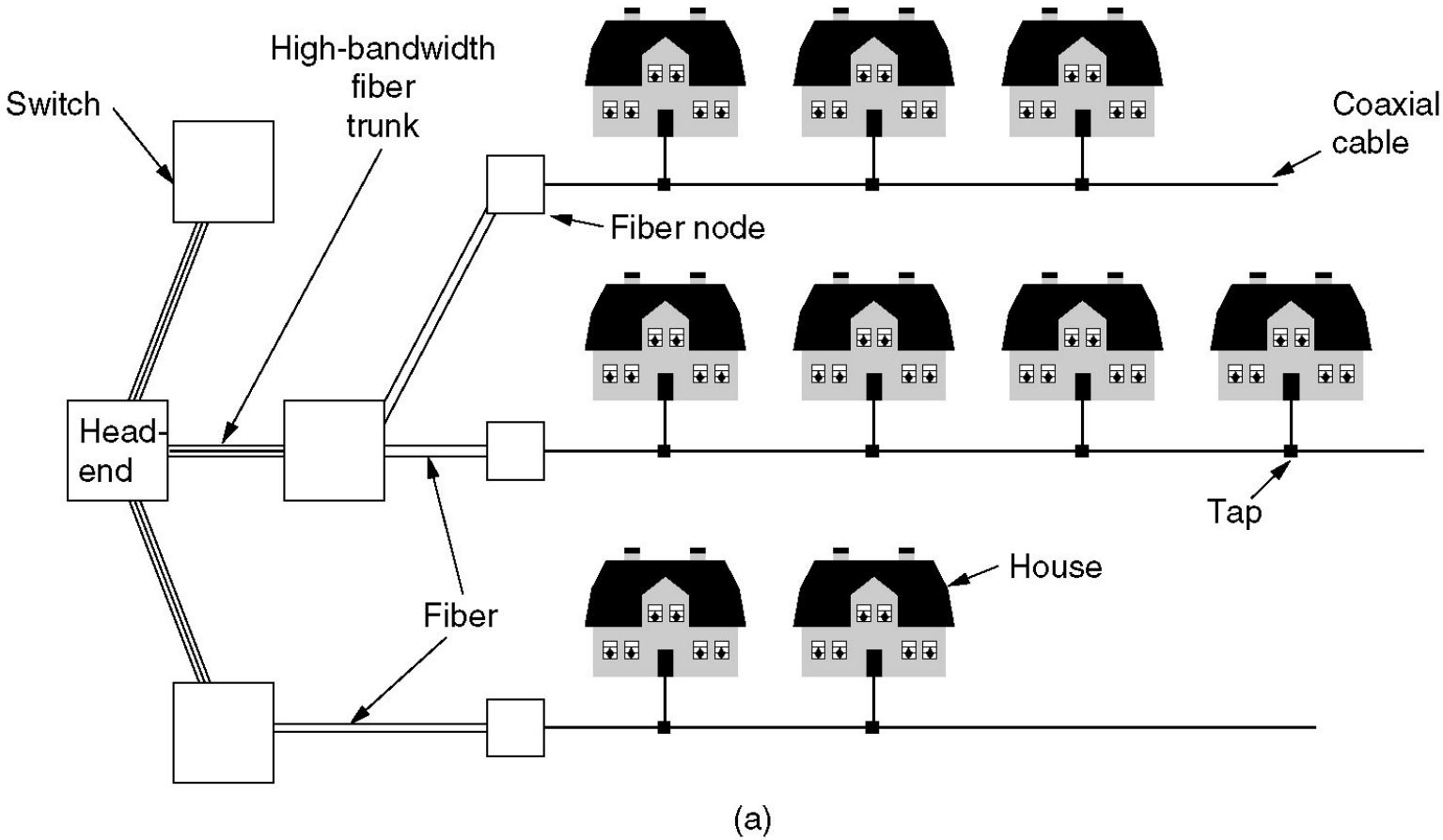
- Community Antenna Television
- Internet over Cable
- Spectrum Allocation
- Cable Modems
- ADSL versus Cable

Community Antenna Television



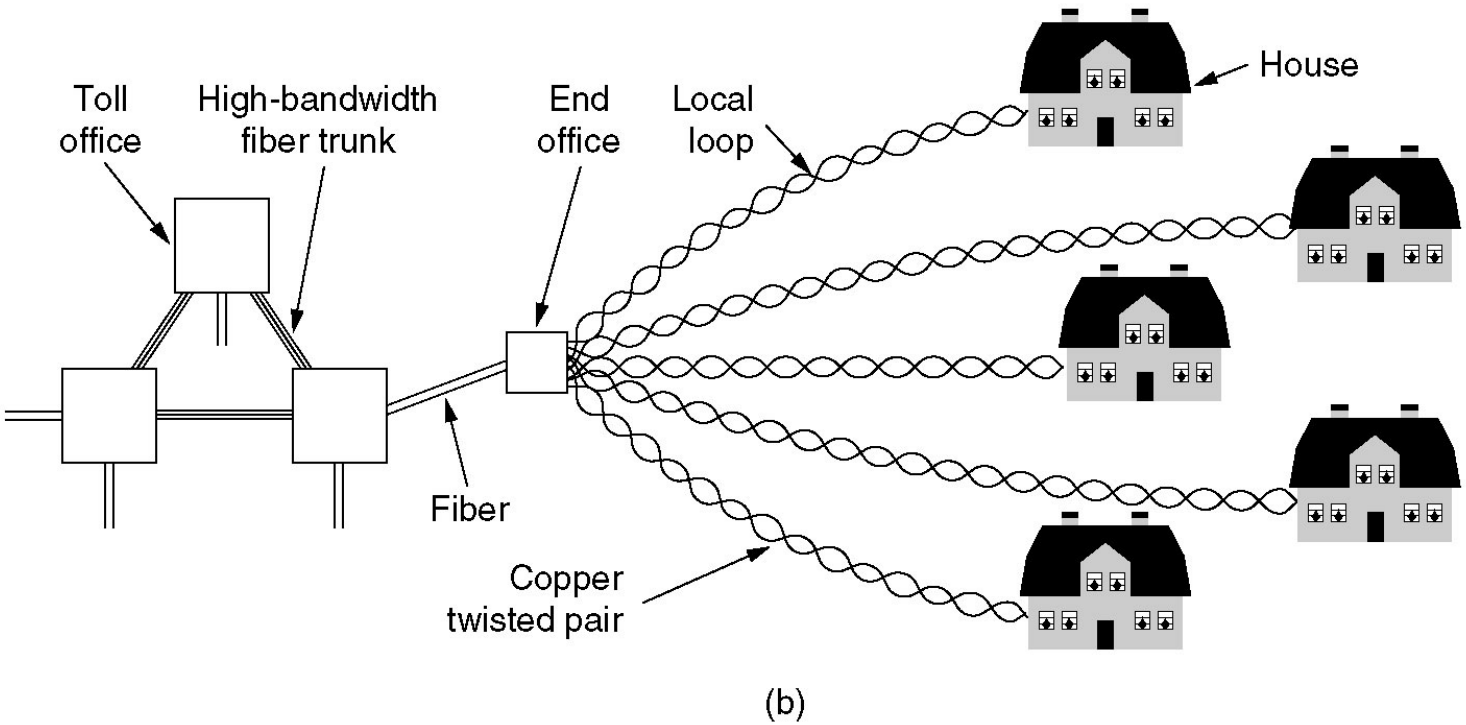
An early cable television system.

Internet over Cable



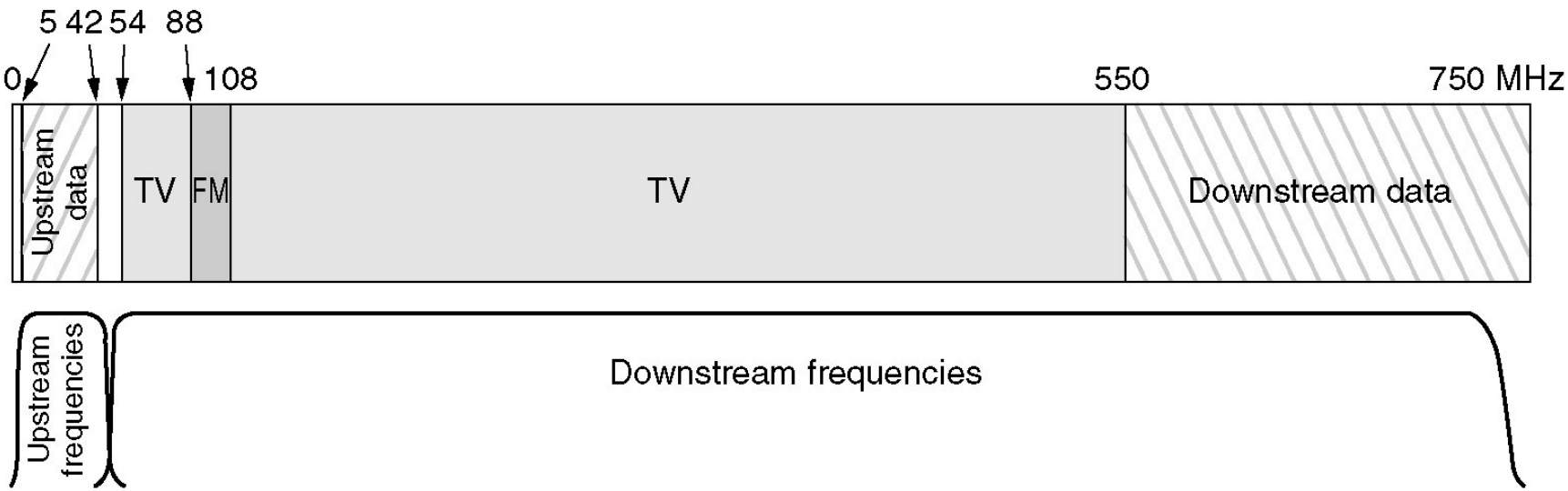
Cable television

Internet over Cable (2)



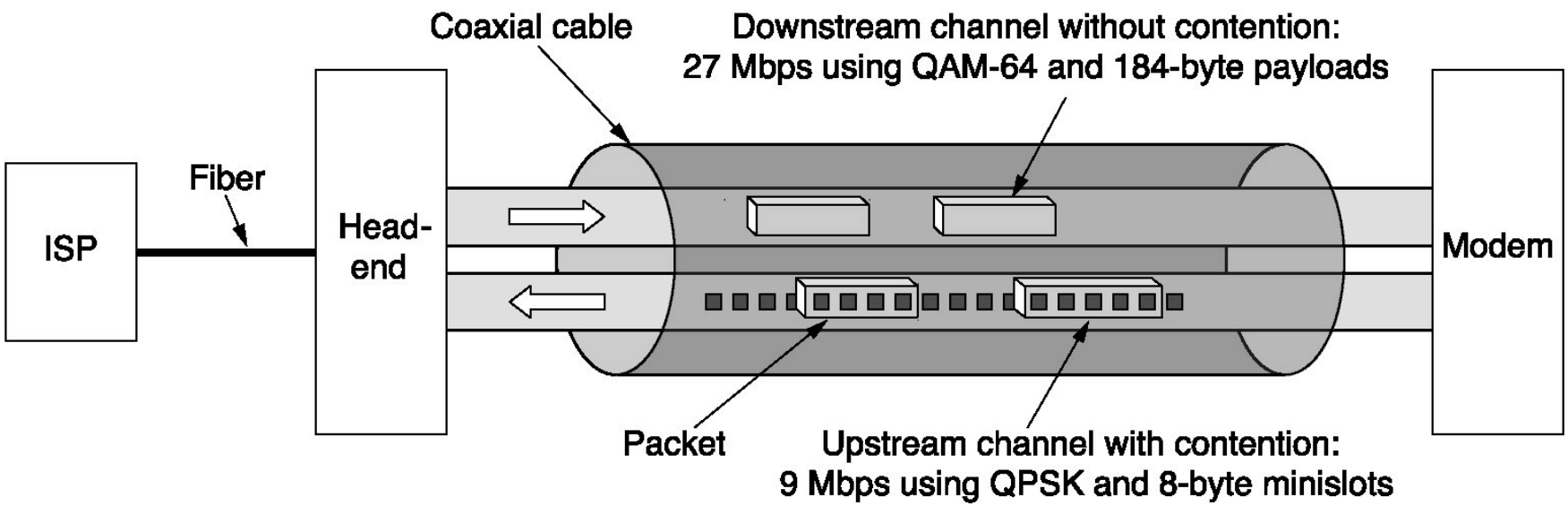
The fixed telephone system.

Spectrum Allocation



Frequency allocation in a typical cable TV system used for Internet access

Cable Modems



Typical details of the upstream and downstream channels in North America.