COMPUTER NETWORKS

Chapter 2. The Physical Layer

Part 2

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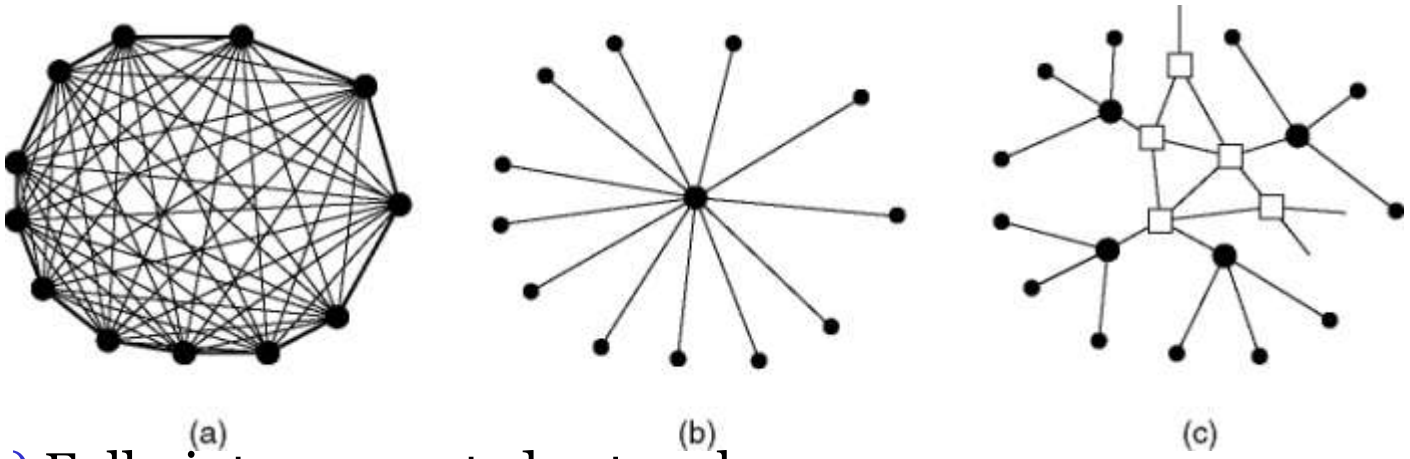
Outline

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

Structure of the Telephone System

- The **PSTN** (Public Switched Telephone Network) is the world's collection of interconnected voice-oriented public telephone networks. It's also referred to as the **POTS** (Plain Old Telephone Service).



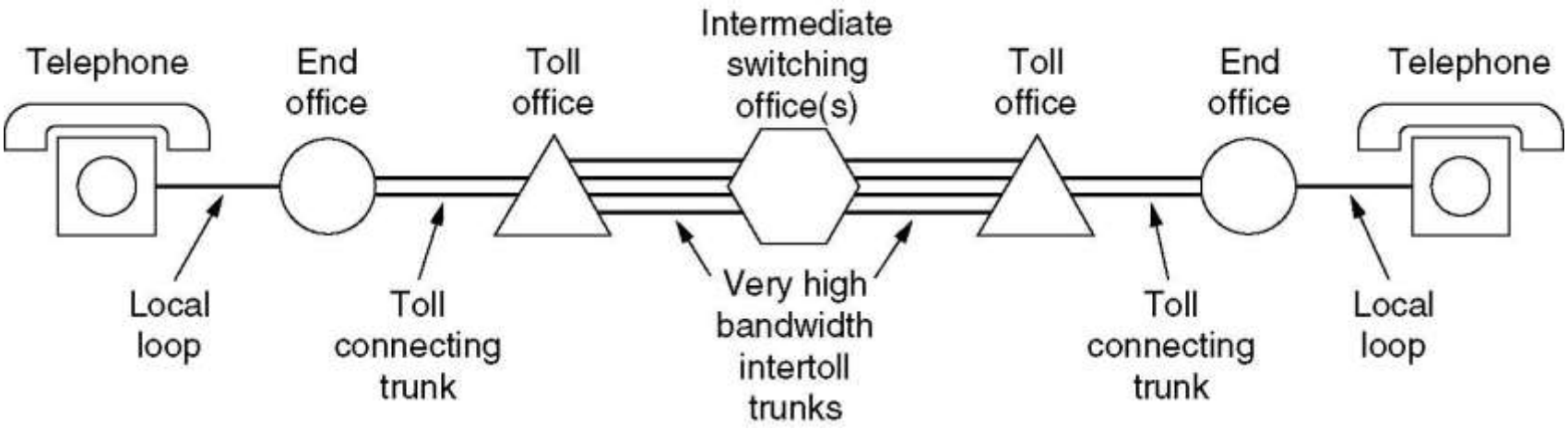
(a) Fully-interconnected network.

(b) Centralized switch.

(c) Two-level hierarchy.

Structure of the Telephone System

A typical circuit route for a medium-distance call.



Components of the Telephone System

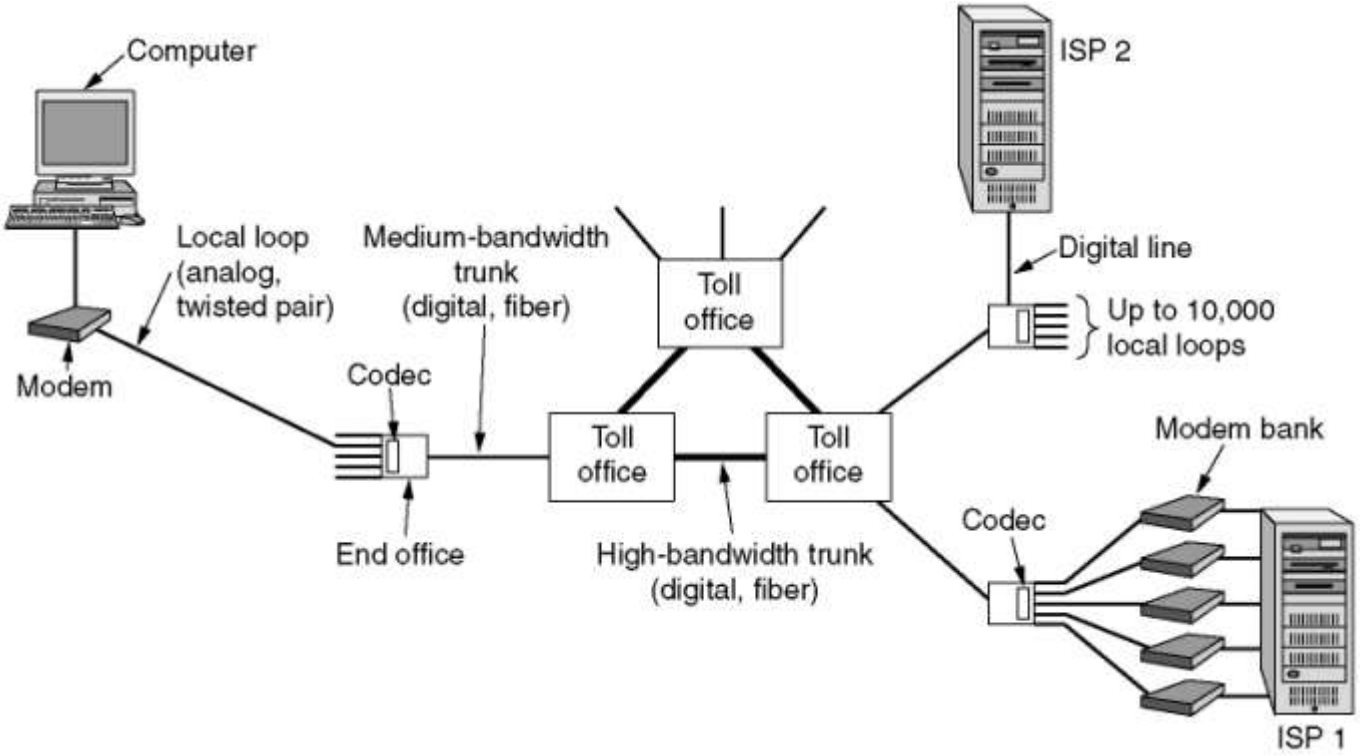
- Local loops
  - Analog twisted pairs going to houses and businesses
- Trunks
  - Digital fiber optics connecting the switching offices
- Switching offices
  - Where calls are moved from one trunk to another

The Local Loop

- Transmission lines suffer from three major problems:
  - Attenuation
  - Delay distortion
  - Noise
- The square waves used in digital signals have a wide frequency spectrum (usually, high frequency) and thus are subject to strong attenuation and delay distortion.

Modems

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



Modems

- The modulation is introduced to solve this problem.
  - Amplitude: two different amplitudes are used to represent 0 and 1.
  - Frequency: different tones are used.
  - Phase: the wave is systematically shifted (45, 135, 225, or 315°).
- A **modem** (modulator-demodulator) is a device that modulates outgoing digital signals to analog signals.

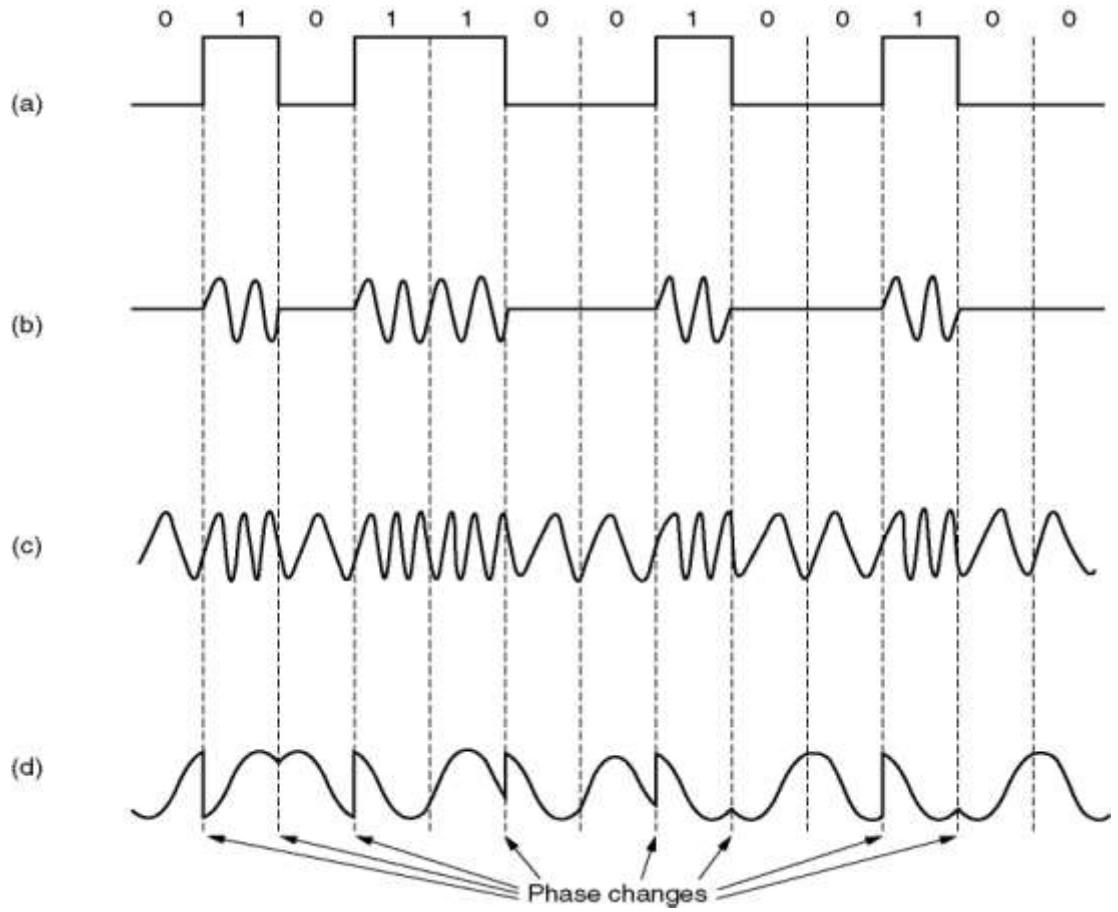
Terms

- Data element, bits, a signal binary 0 or 1
- Data rate, bits per second, the rate at which data elements are transmitted.
- Signal elements/Symbol
- Signal rate or modulation rate, signal elements per second (baud), the rate at which signal elements are transmitted.

Basic Encoding Techniques

- Digital data to analog signal
  - Amplitude-shift keying (ASK)
    - Amplitude difference of carrier frequency
  - Frequency-shift keying (FSK)
    - Frequency difference near carrier frequency
  - Phase-shift keying (PSK)
    - Phase of carrier signal shifted

Modulation of analog signals



(a) A binary signal

(b) Amplitude modulation

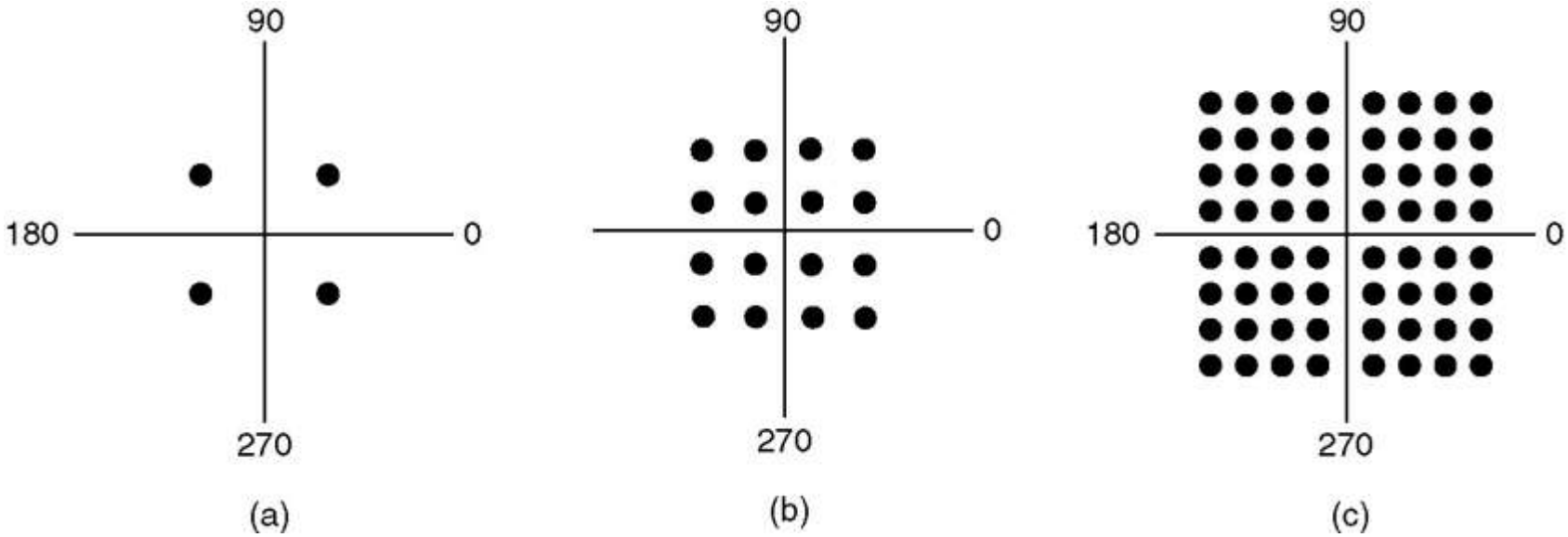
(c) Frequency modulation

(d) Phase modulation

Modems

- The number of samples/symbols per second is measured in **baud**.
- In **quadrature phase-shift keying** (**QPSK**四相/正交相移键控), the four angles, usually out of phase by 90°, are used to transmit 2 bits/symbol. The bit rate is twice the baud rate.
- **QAM-64** (Quadratrue Amplitude Modulation正交幅度调制-64) allows 64 different combinations, so 6 bits can be transmitted per symbol.

Modems



Constellation Diagrams:

(a) QPSK.

(b) QAM-16.

(c) QAM-64.

Modems

- To reduce the chance of an error, standards for higher speeds modems do error correction by adding extra bits to each sample. The schemes are known as **TCM** (**Trellis Coded Modulation**).
- In **V.32**, 14,400 bps is achieved by transmitting 6 data bits and 1 parity bit per sample at 2400 baud. It uses QAM-128.
- In **V.34**, the modem can run at 28,800 bps at 2400 baud with 12 data bits/symbol or 33,600 bps at 2400 baud with 14 data bits/symbol.

Modems

- Why are 56 kbps modems in use?
  - The telephone channel is about 4000 Hz (voice 300 ~ 3400 Hz).
  - The maximum data rate = 2 x 4000 $\log_2 2$ = 8000 sample/sec
  - The number of bits per sample is 8, one for control purpose, allowing 8000 x 7 = 56,000 bit/sec.
- **V.90** provides 33.6 kbps upstream and 56 kbps downstream.
- **V.92** provides 48 kbps upstream.

Modems

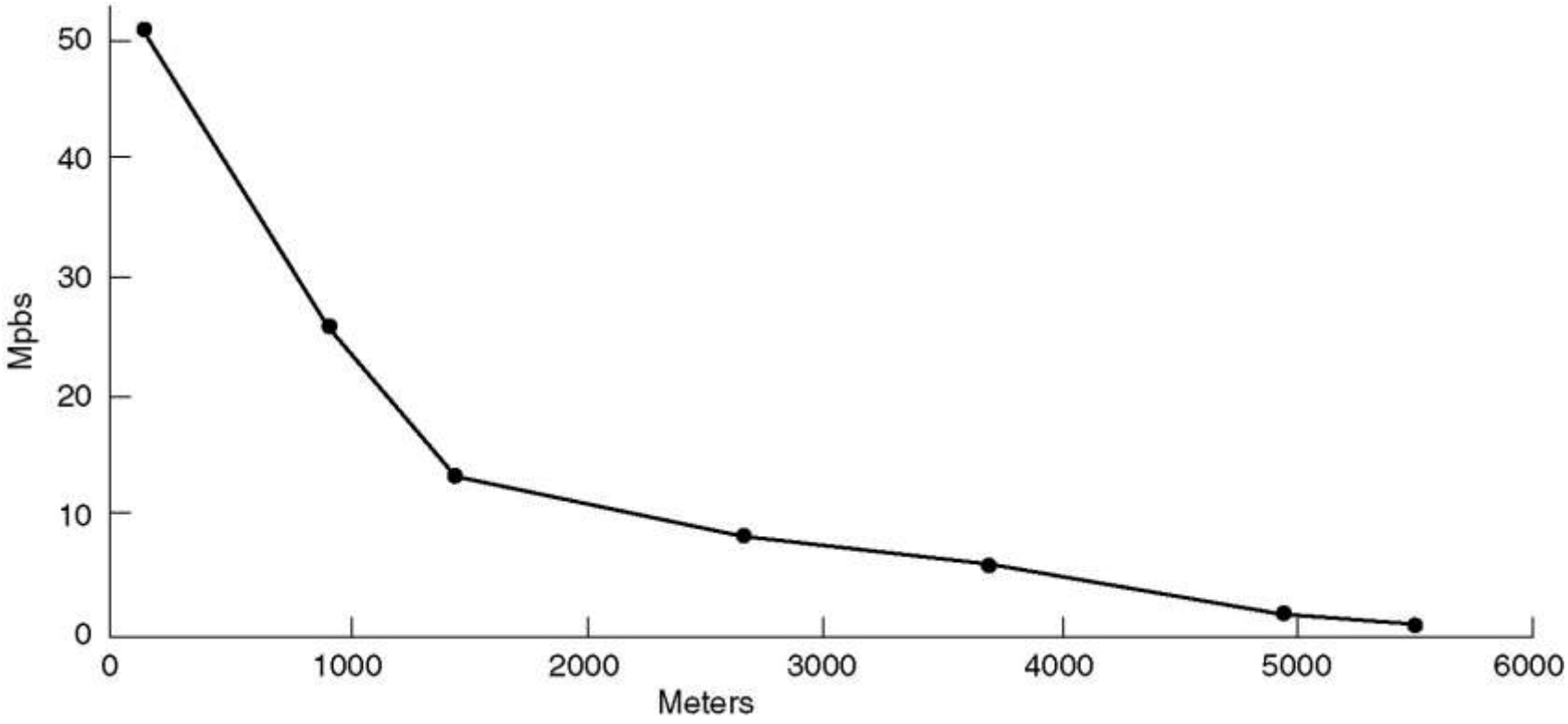
- A connection that allows traffic in both directions simultaneously is called **full duplex**.
- A connection that allows traffic either way, but only one way at a time is called **half duplex**.
- A connection that allows traffic only one way is called **simplex**.

Digital Subscriber Lines (DSL)

- xDSL is made to work by connecting to a different switch instead of the filter that attenuates all frequencies below 300 Hz and above 3400 Hz.
- The xDSL services have been designed with the following goals:
  - They must work over the existing category 3 twisted pair local loops.
  - They must not affect existing telephones and fax machines.
  - They must be faster than 56 kbps.
  - They must be always on.

Digital Subscriber Lines

Bandwidth versus distanced over category 3 UTP for DSL.

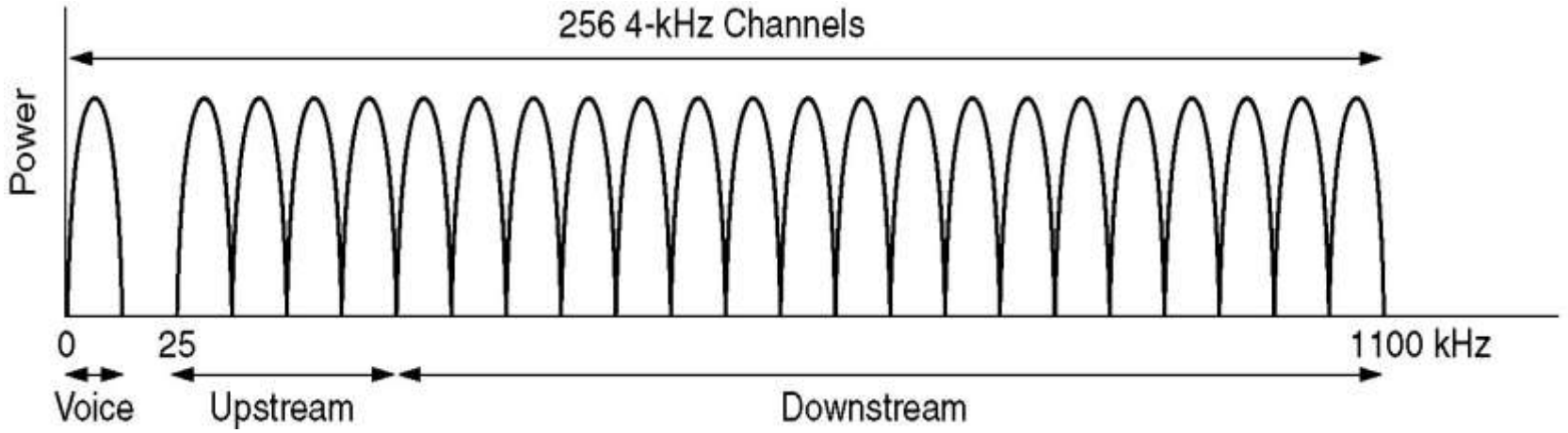


Digital Subscriber Lines (DSL)

- **DMT (Discrete MultiTone**离散多音频) divides the 1.1 MHz spectrum available on the local loop into 256 independent channels of 4312.5 Hz each.
  - Channel 0: POTS
  - Channel 1-5: not used
  - One for upstream and one for downstream control
  - 32 channels for upstream and rest for downstream
- The ADSL standard (ANSI T1.413 and ITU G.992.1) allows speeds of 8 Mbps downstream and 1 Mbps upstream.

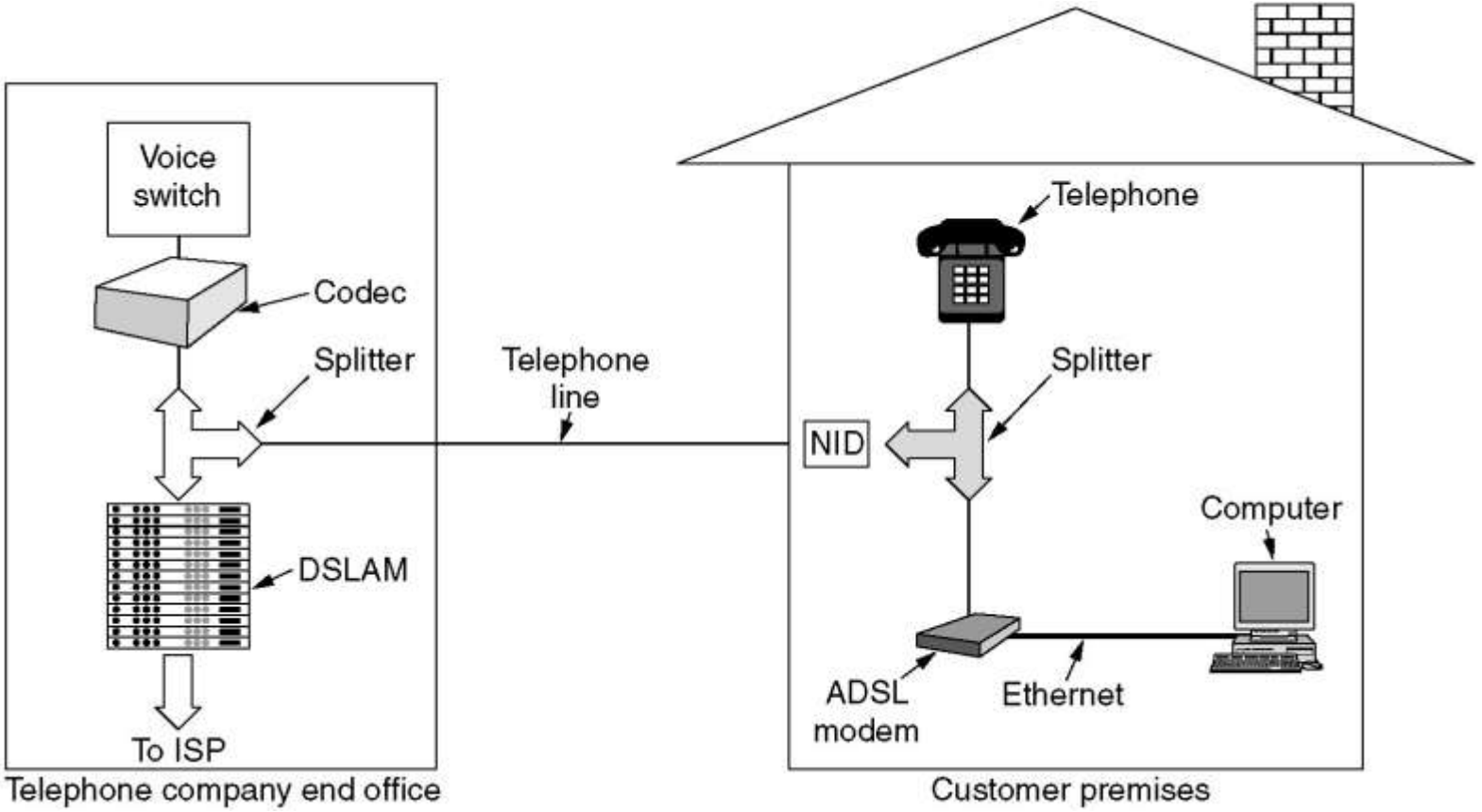
Digital Subscriber Lines

Operation of ADSL using discrete multitone modulation.



Digital Subscriber Lines

A typical ADSL equipment configuration.



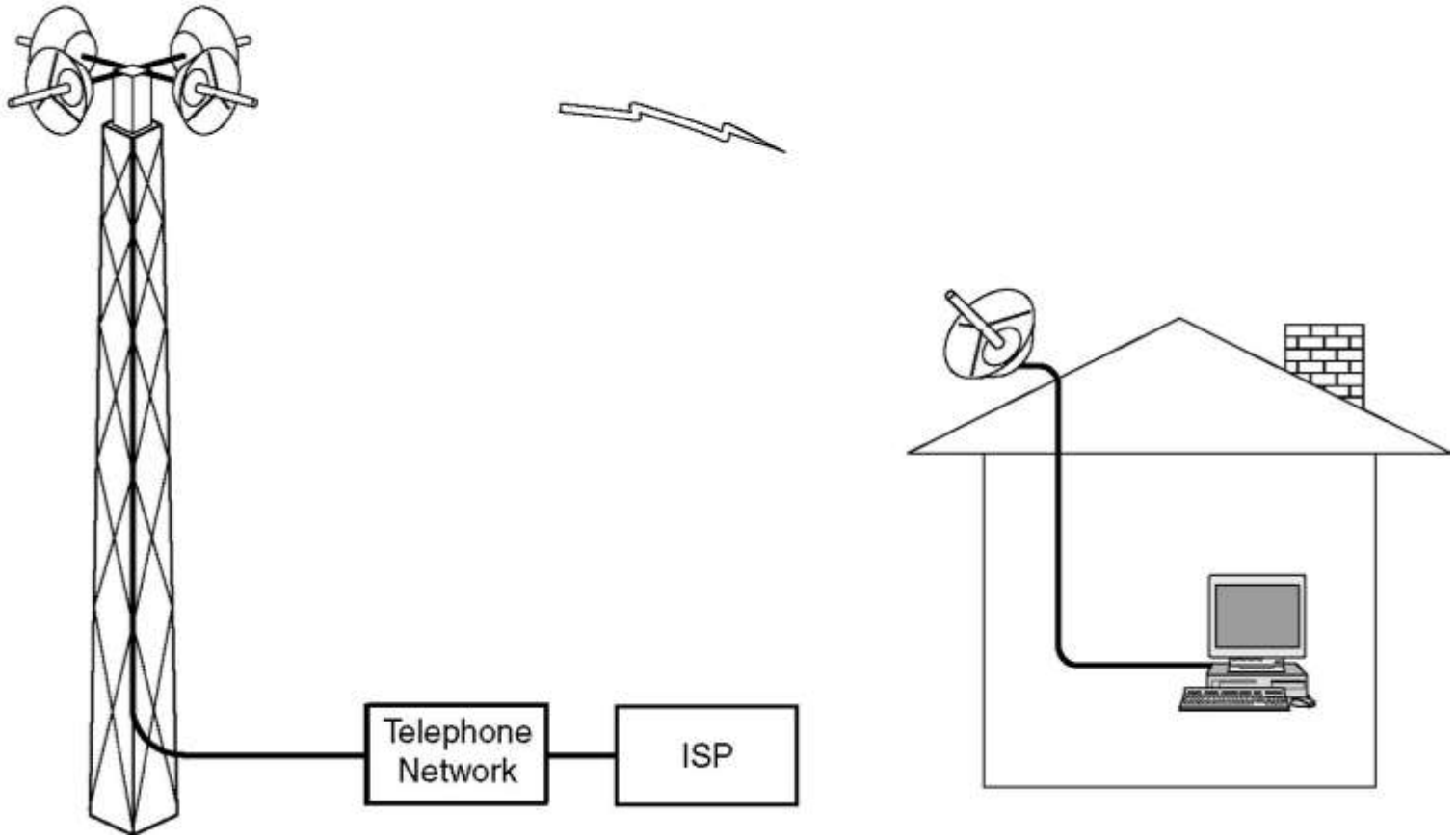
Wireless Local Loops

- Business practice of a long-distance telephone company for the local phone service:
  - It must buy or lease a building for the end office.
  - It must fill the end office with switches.
  - It must run a fiber between the end office and the toll office.
  - It must acquire customer.
- How is the new local phone company to connect customer telephones and computers in the end office?
  - Buy the right to lay the new wires. Costly
  - Buy/lease from other local phone company. Costly
  - Use the **WLL** (**Wireless Local Loop**).

Wireless Local Loops

- A fixed telephone using a wireless local loop is different from a mobile phone in three ways:
  - The wireless local loop customer often wants high-speed Internet connectivity.
  - A directional antenna is needs to be installed.
  - The user does not move.
- **LMDS** (Local Multipoint Distribution System) is a system for broadband microwave wireless transmission direct from a local antenna to homes and businesses within a line-of-sight radius, a solution to the so-called last-mile technology problem of economically bringing high-bandwidth services to users.
- The IEEE 802.16 can be used for wireless local loops standard.

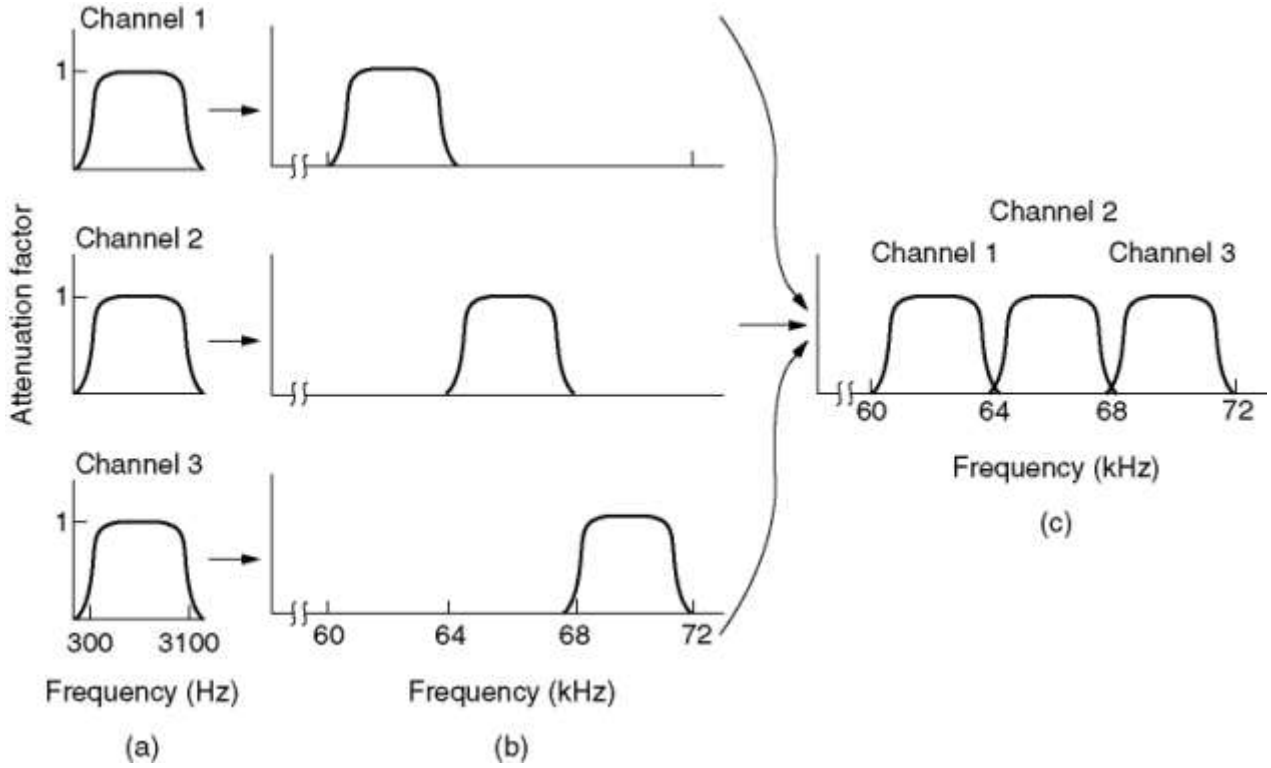
Wireless Local Loops



Trunks and Multiplexing

- Two categories of multiplexing schemes are used to multiplex many conversations over a single physical trunk:
  - In **FDM** (**Frequency Division multiplexing**), the frequency spectrum is divided into frequency bands. For fiber optic channels, **WDM** (**Wavelength Division Multiplexing**) is used.
  - In **TDM** (**Time Division Multiplexing**), the entire bandwidth is used for a chunk of time period.

Frequency Division Multiplexing



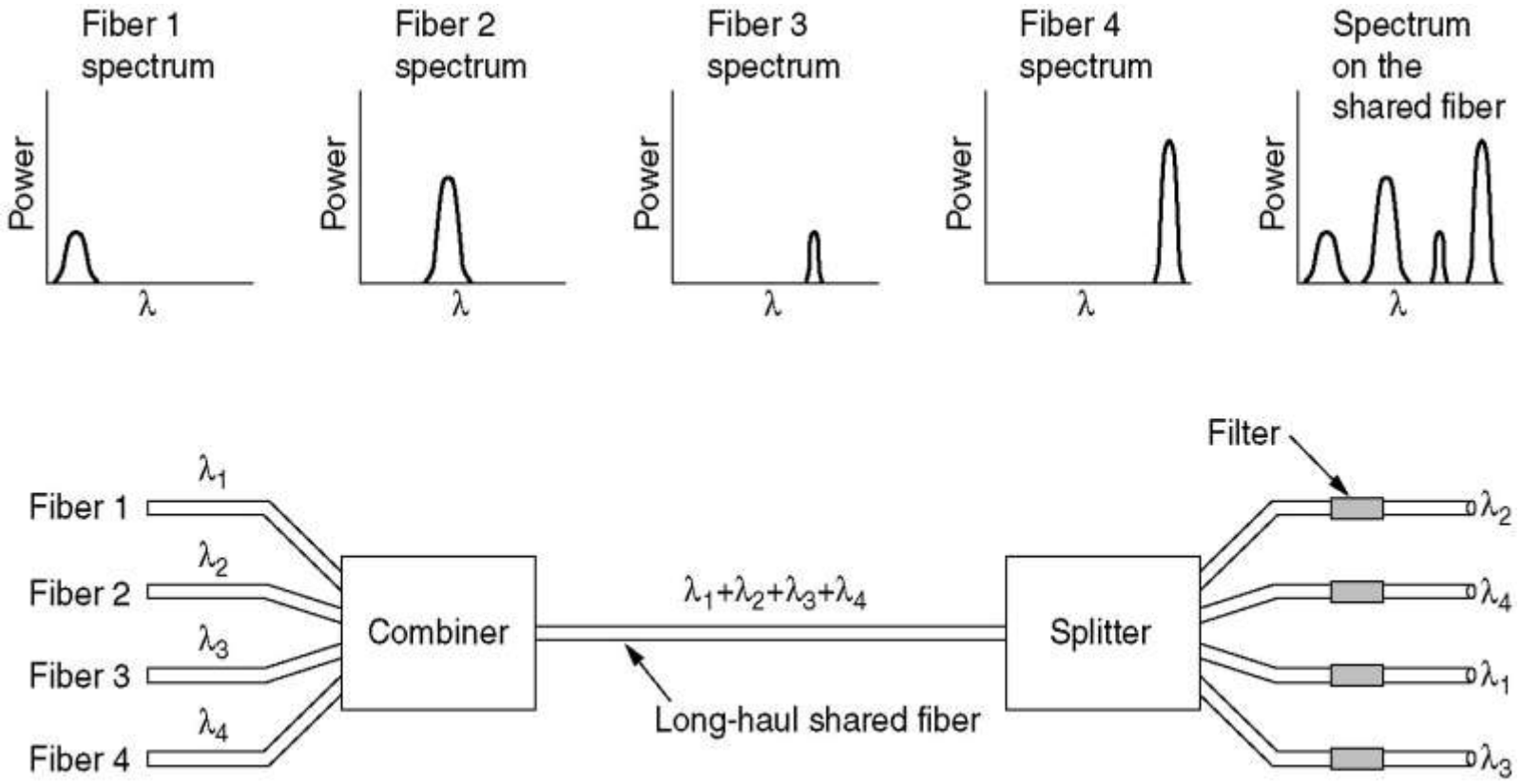
(a) The original bandwidths.

(b) The bandwidths raised in frequency.

(b) The multiplexed channel.

Wavelength Division Multiplexing

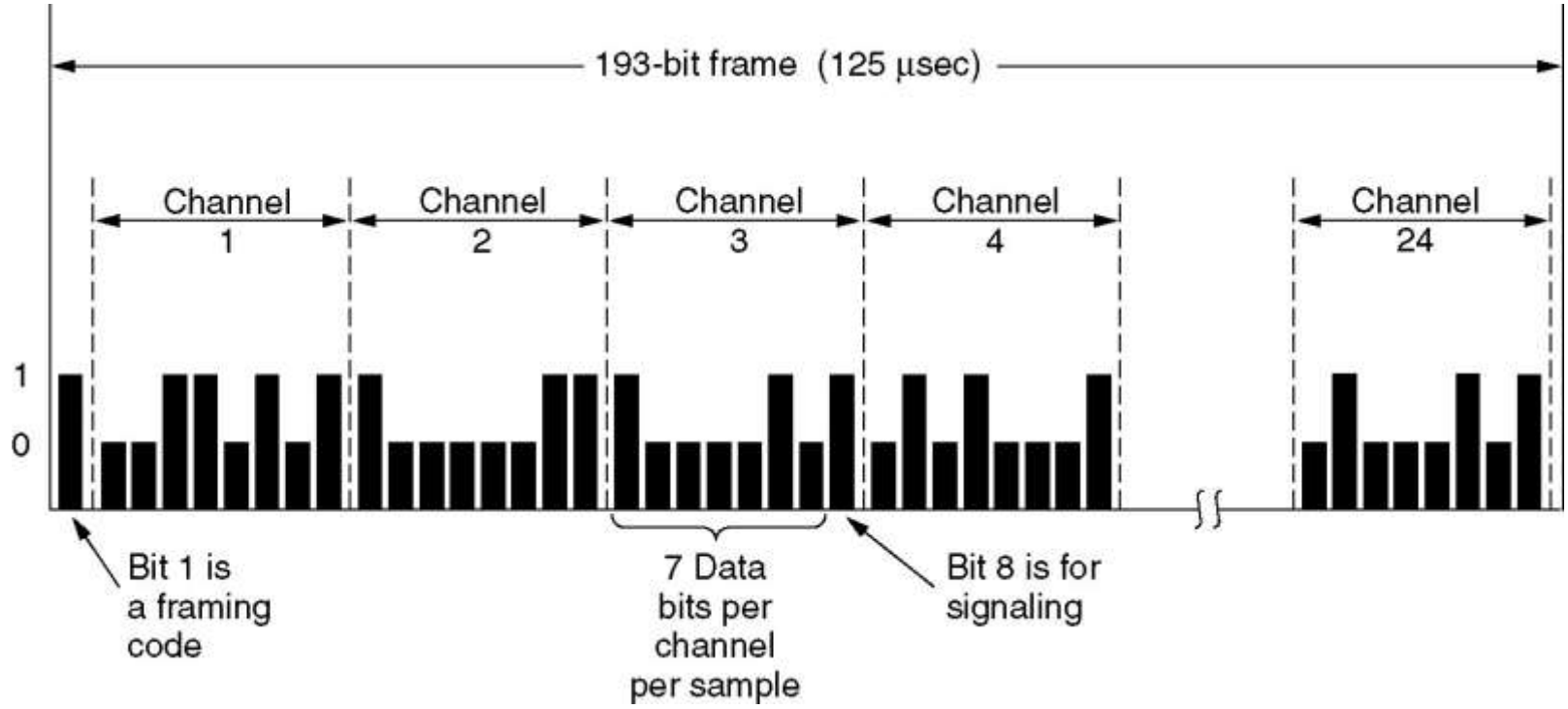
Wavelength division multiplexing.



Time Division Multiplexing

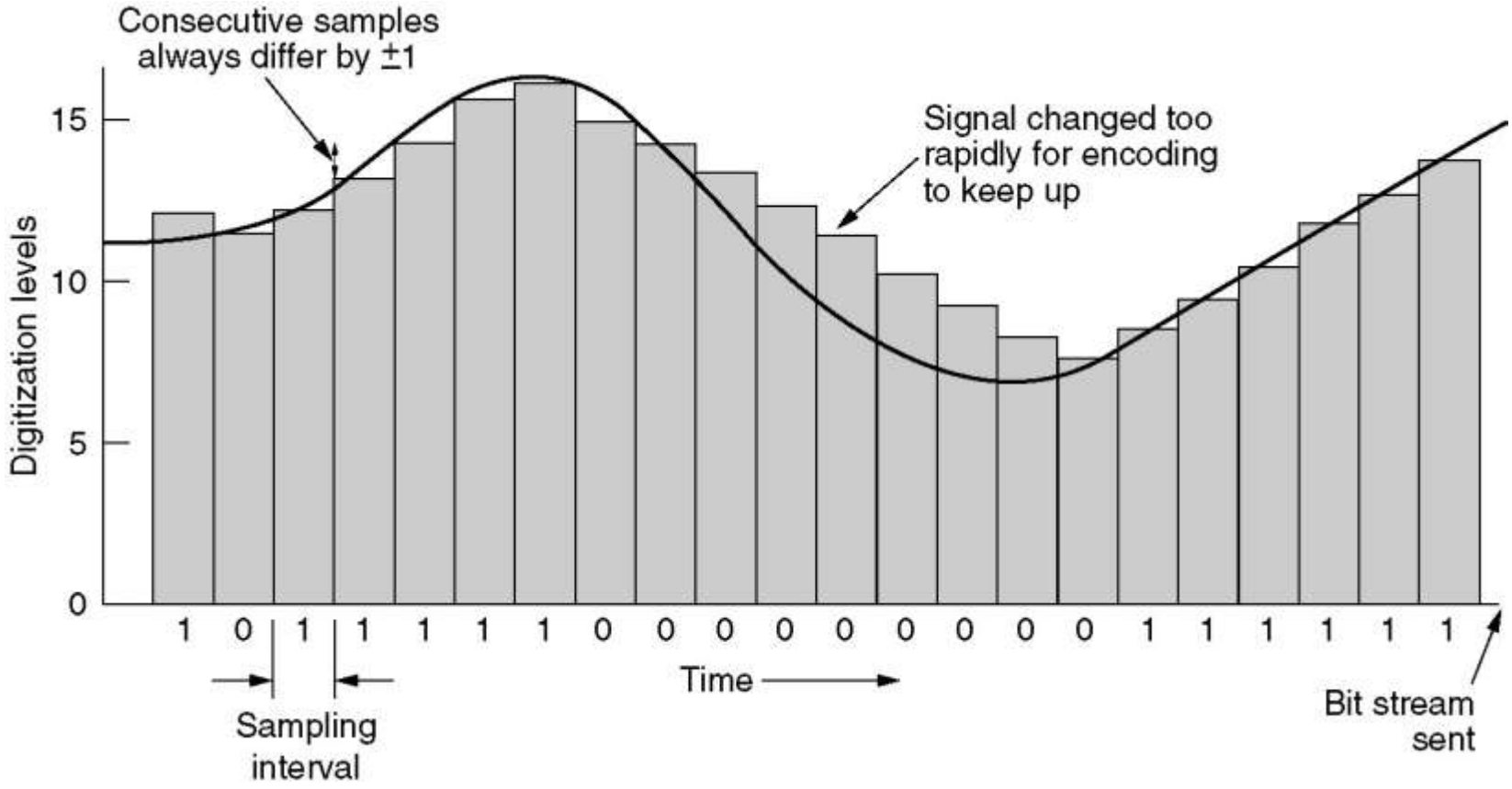
- The analog signals are digitalized by a device called a **codec** (**coder-decoder**) producing a 7 or 8 bit number.
- **PCM** (**Pulse Code Modulation**) is a technique to digitalize analog data.
  - T1 carriers can handle 24 channels multiplexed together. 24 x 8 = 192 bits + 1 bit for framing = 193 bits/frame
  - Since each analog signal must be sampled 8000 times per second, we must repeat this process every 1/8000 sec = 125 microseconds.
  - So, the transfer rate on the T1 carrier is: 193 bits / 0.000125 seconds = 1.544 Mbps.
- **DPCM** (**Differential Plus Code Modulation**) is a method, which consists of outputting the difference between the current value and the previous one, to reduce the number of digitalized bits,

Time Division Multiplexing



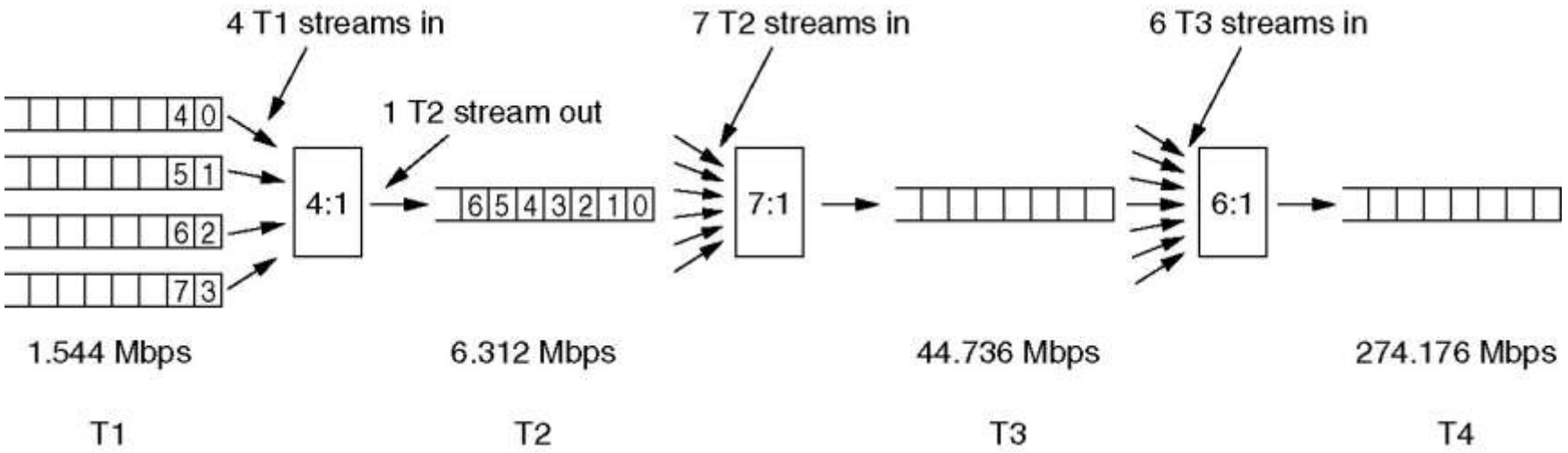
Time Division Multiplexing

Delta modulation.



Time Division Multiplexing

Multiplexing T1 streams into higher carriers.



SONET/SDH

- **SONET (Synchronous Optical NETwork)** is the American National Standards Institute standard for synchronous data transmission on optical media.
- **SDH (Synchronous digital hierarchy)** is the international standard for synchronous data transmission on optical media.
- The goal of SONET:
  - Possible for different carriers
  - Unify the U.S., European, and Japanese digital systems
  - Provide a way to multiplex multiple digital channels
  - Provide support for operations, administration, and maintenance (OAM)

SONET/SDH

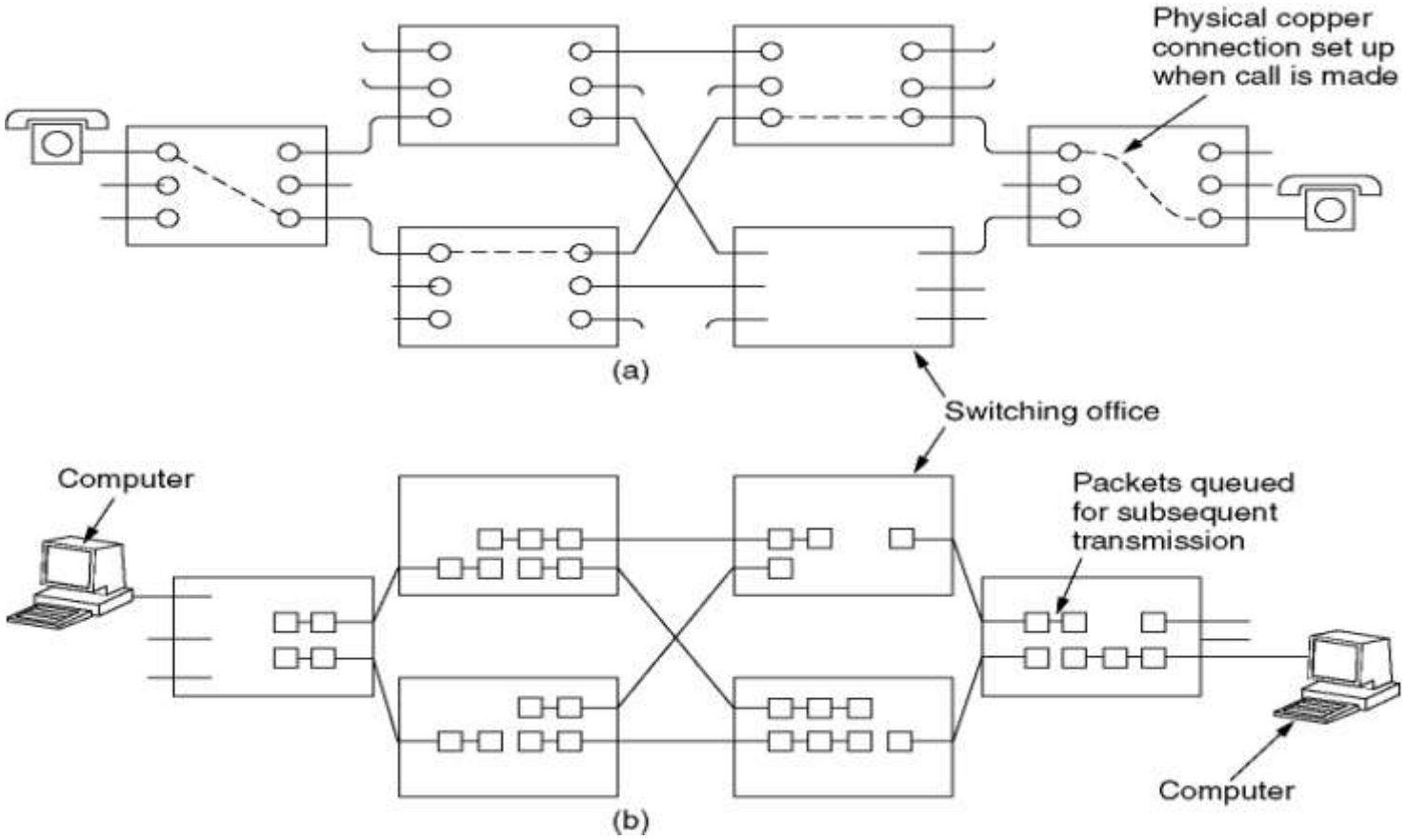
- Synchronous Optical Network (SONET)
  - The full specification is larger than this book.
  - It addresses both the framing and encoding problems.
  - It multiplexes several low-speed links onto one high-speed link.

Switching

- **Circuit switching** – seek out a physical path from sender to receiver. An end-to-end path must be (conceptually) established before data is sent.
- **Message switching** – no path is established in advance. The message is stored in the first switching office and forwarded later one hop at a time.
  - Example: store-and-forward network
  - Problem: No restriction of block size
- **Packet switching** – place a restriction on block size, to allow packets to be buffered in main memory at the switching office.
  - Advantages:

    Well-suited for interactive traffic
    - Improved response time and throughput

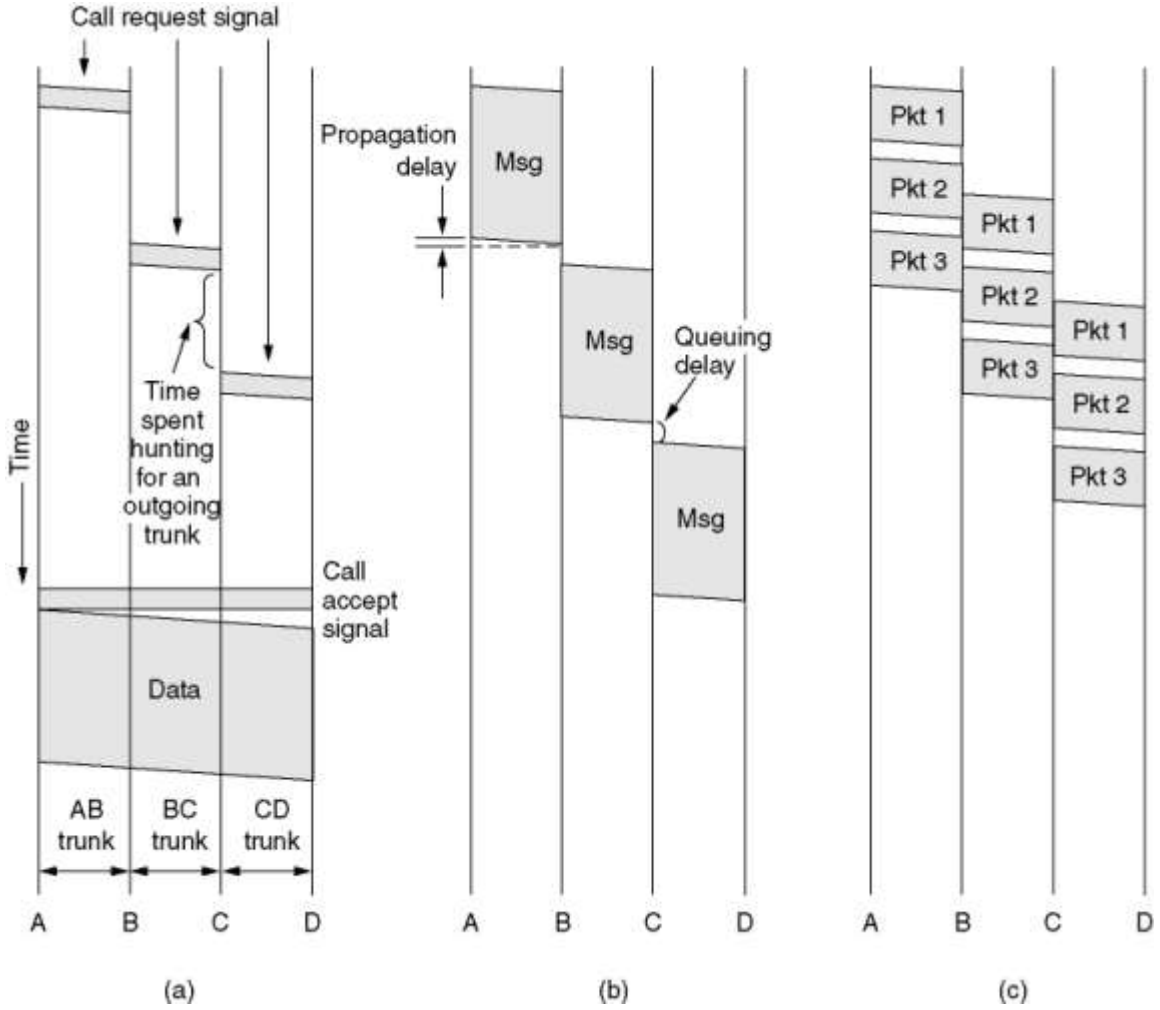
Circuit Switching



(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

Summary

- Public Switched Telephone Networks
- Digital subscriber lines
- Wireless local loops
- Multiplexing
- SONET/SDH
- Switching