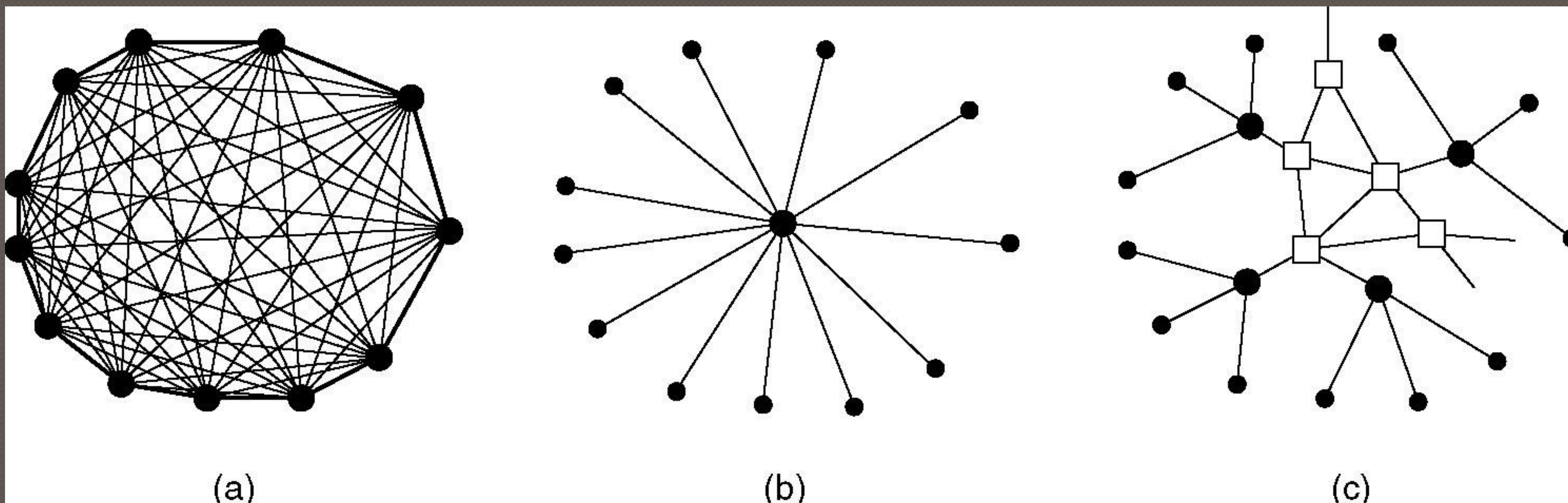
Chapter 2

The Physical Layer

Existing Transmission Systems and Media

- Guided:
  - Twisted pairs
  - Coaxial cables
  - Fiber optics
- Unguided:
  - Radio
  - Microwave
  - Infrared and Millimeter Waves
  - Lightwave
- Public Switched Telephone System
- The Mobile Television System
- The Cable Television

Structure of the Telephone System



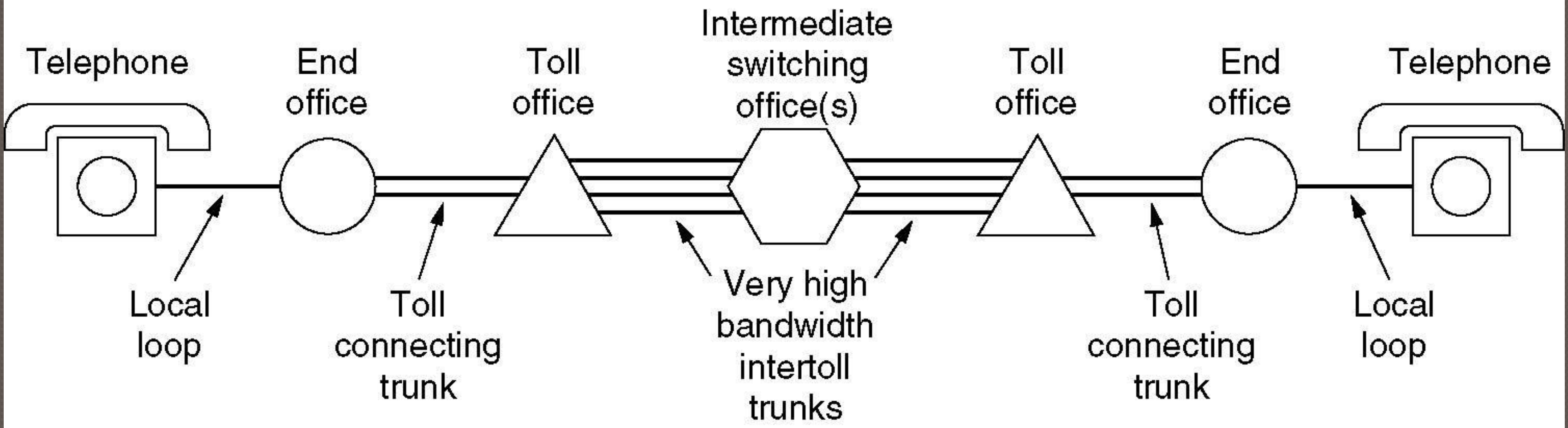
(a) Fully-interconnected network.
(b) Centralized switch.
(c) Two-level hierarchy.

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

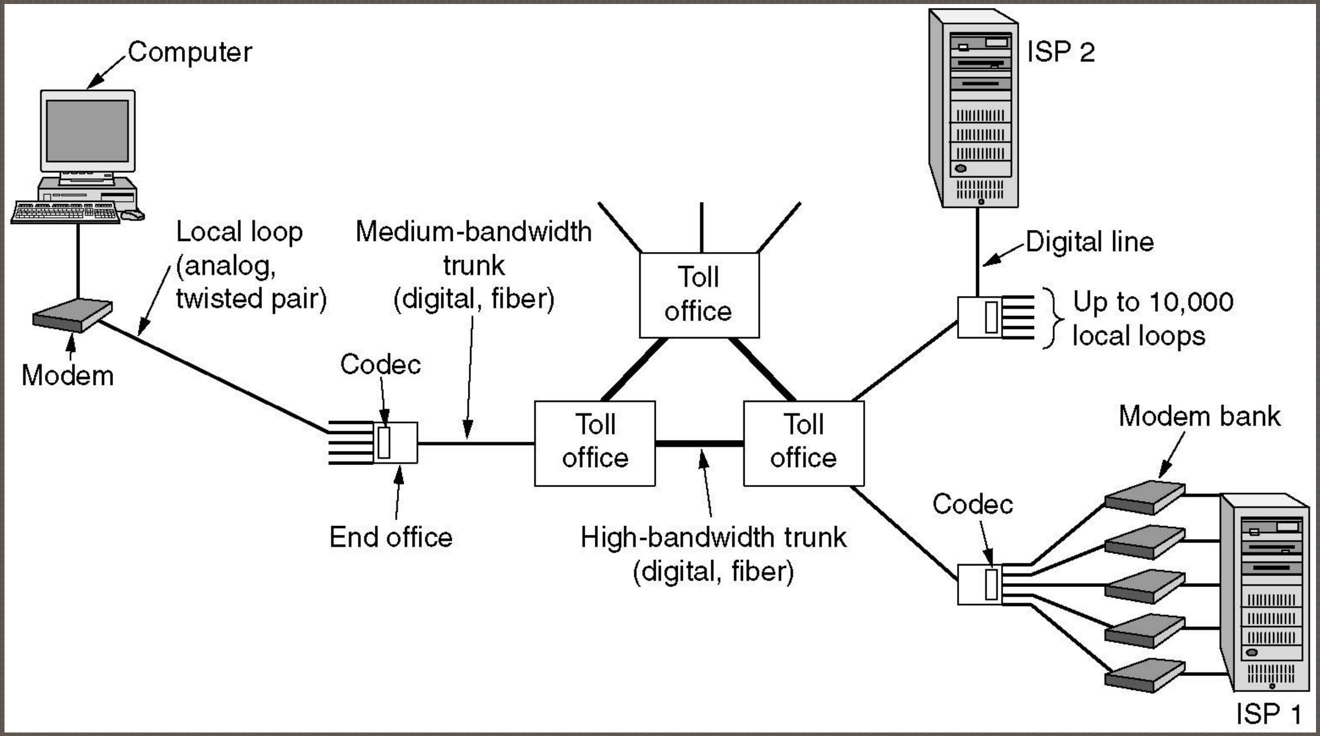
Structure of the Telephone System

A typical circuit route for a medium-distance call.

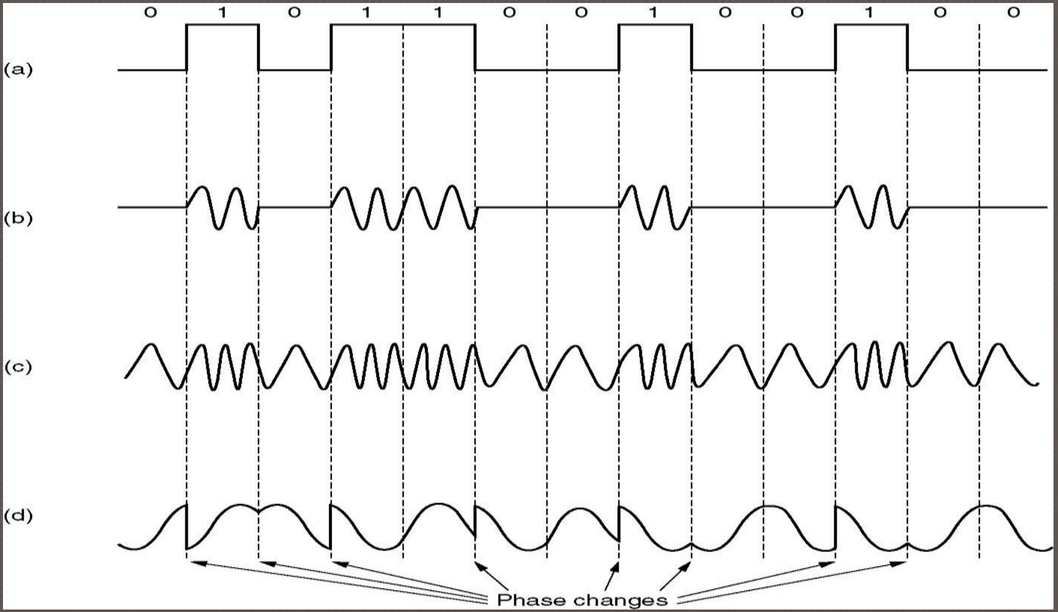


The Local Loop: Modems, ADSL, and Wireless

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



Modems



(a) A binary signal
(b) Amplitude modulation

(c) Frequency modulation
(d) Phase modulation

- shift at uniformly spaced intervals –
  - e.g.0 and 180 degree

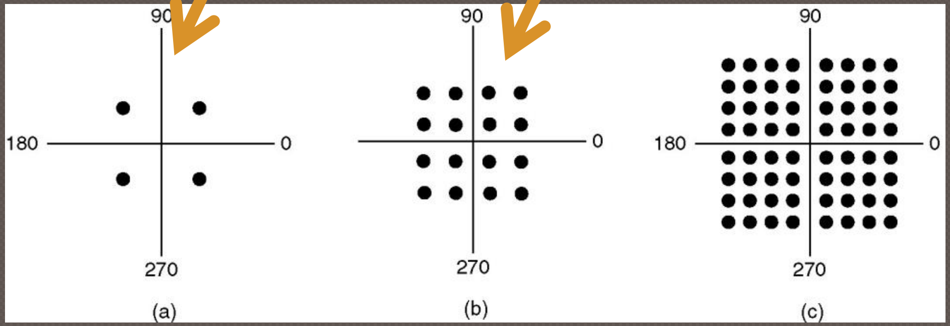
Problems in Transmission Lines

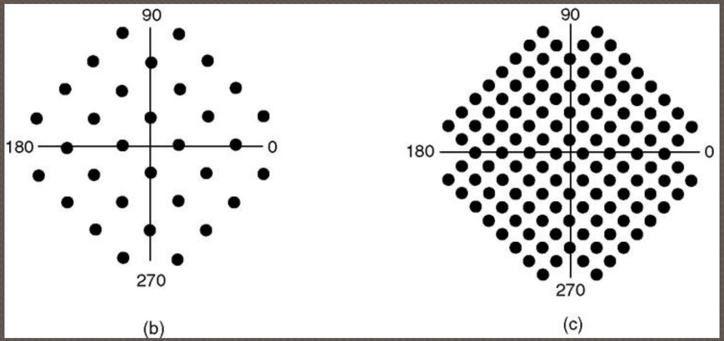
- Attenuation - The loss of energy as the signal propagates outward
  - Loss expressed in db per km
  - The energy lost depends on the frequency.
    - Each Fourier component is attenuated by a different amount which results in a different spectrum at the receiver
- Delay Distortion -
  - The Fourier components propagate at different speed in the wire – this leads to distortion
- Noise – unwanted energy from sources other than the transmittal
  - Thermal noise is caused by random motion of the electrons and is unavoidable
  - Crosstalk – inductive coupling between two close wires
  - Impulse noise – spike of energy on the power line (wipes out bits in digital)

1 amplitude
4 phases
2 bits per symbol
4800 bps on a
2400 baud line

4 amplitudes and 4 phases
(i.e. $16=2^4$ combinations)
4 bits to transmit a symbol
9600 bps on a 2400 baud line
(i.e. 2400 x 4)

Modems (2)





(a) QPSK (Quadrature Phase Shift Keying)
(b) QAM-16.
(c) QAM-64.

(a) V.32 for 9600 bps.
(b) V32 bis for 14,400 bps.

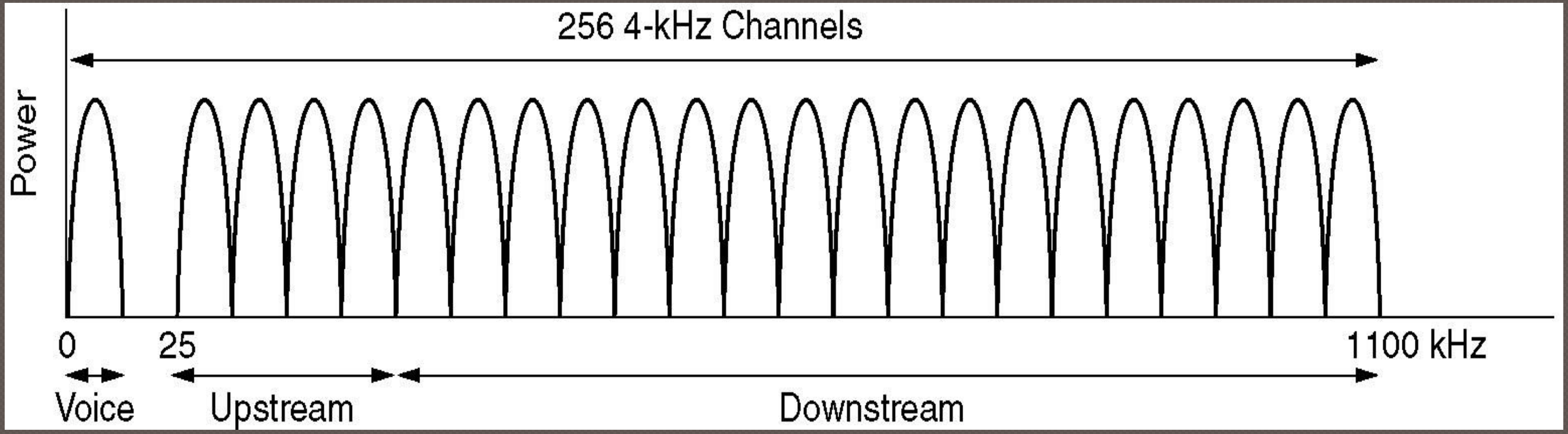
Amplitude = Distance to the origin
Baud = number of samples per second – ONE symbol sent per baud

Example: 3000 Hz, no more than 6000 sample/sec (by Nyquist)
- In reality no more than 2400 sample/sec are used

If 0 volt for 0 and 1 volt for 1 is used the bit rate in a 2400 baud line is 2400 bps
If 0,1,2,3 volts are used , every symbol consists of 2 bits so the bit rate in a 2400 baud line is 4800 bps

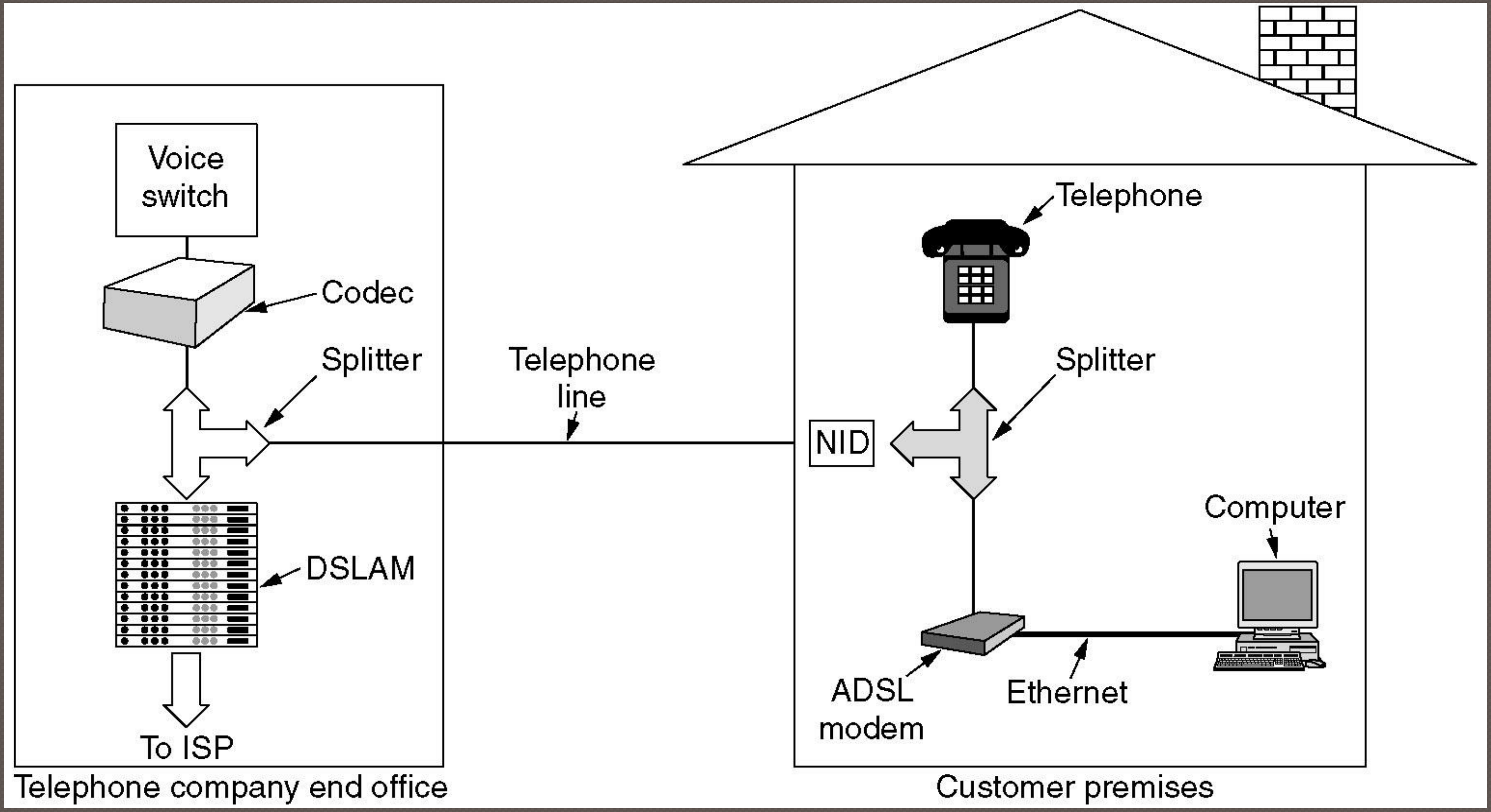
ADSL Digital Subscriber Lines

- Operation of ADSL using Discrete MultiTone (DMT) modulation.
  - Division in channels – more use for downstream than upstream
  - Low channels for voice (telephone)



Digital Subscriber Lines

A typical ADSL equipment configuration.

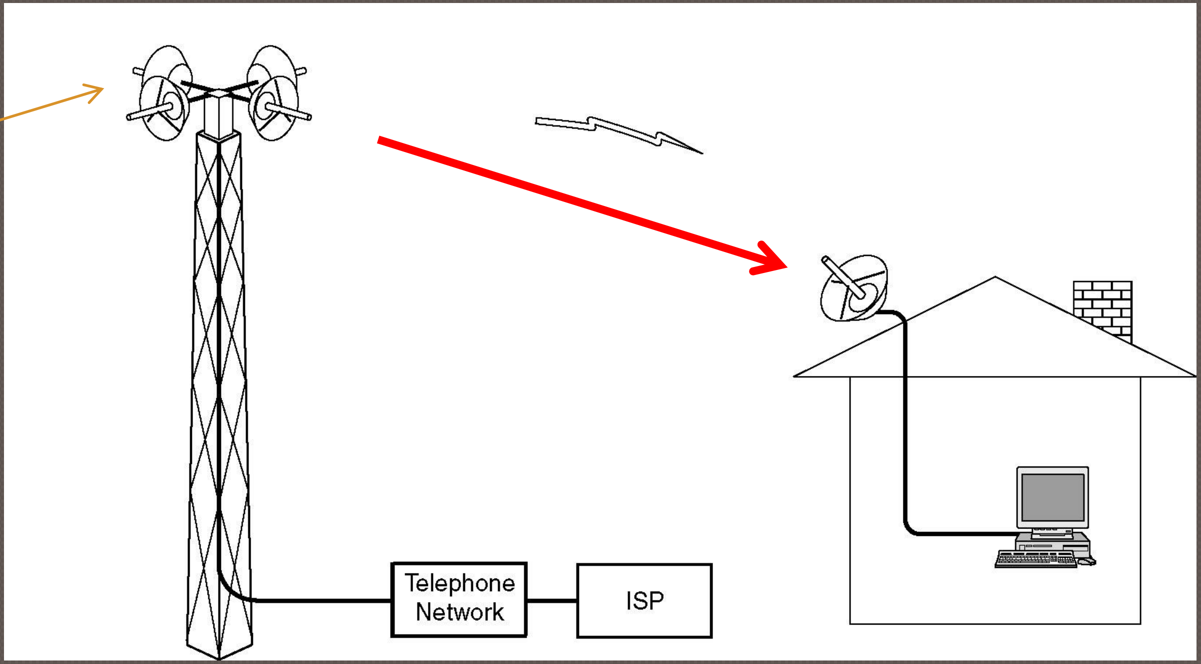


Wireless Local Loops

Use of millimeter wave at frequency of 28-31 GHz in US and 40 Hz in Europe

- Small range of 2-5 km – require antenna
- Signal travels on a straight line (obstacles are a problem)
- Disturbed by rain – 9000 users per sector

Antenna with 4 sectors

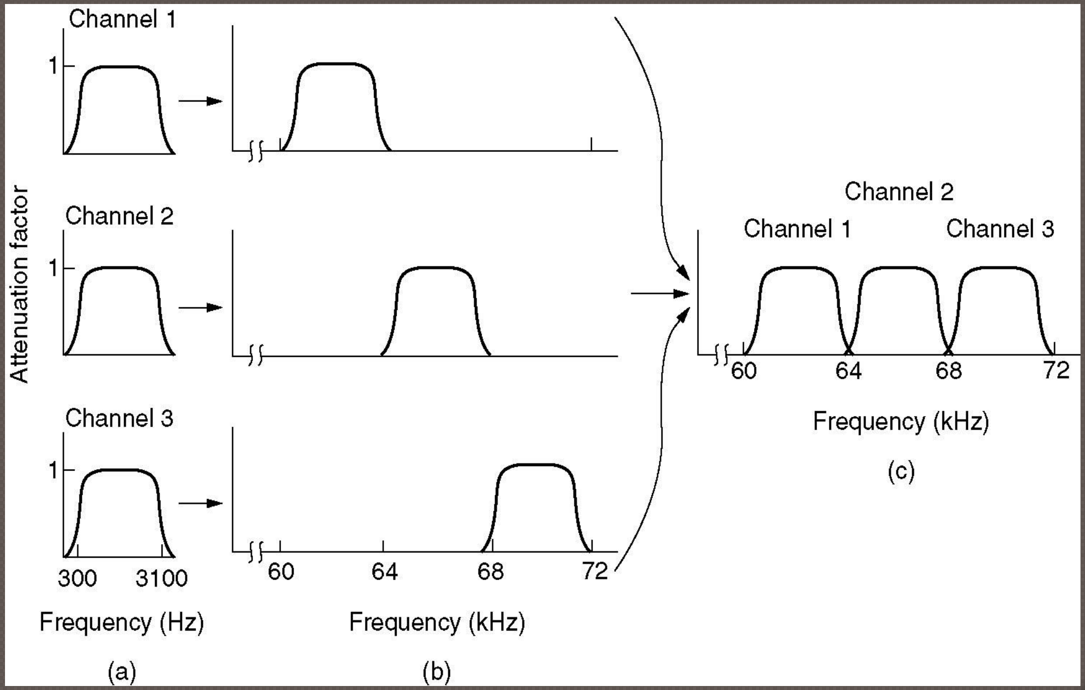


Architecture of an LMDS system.

(Local Multipoint Distribution Service)

Frequency Division Multiplexing

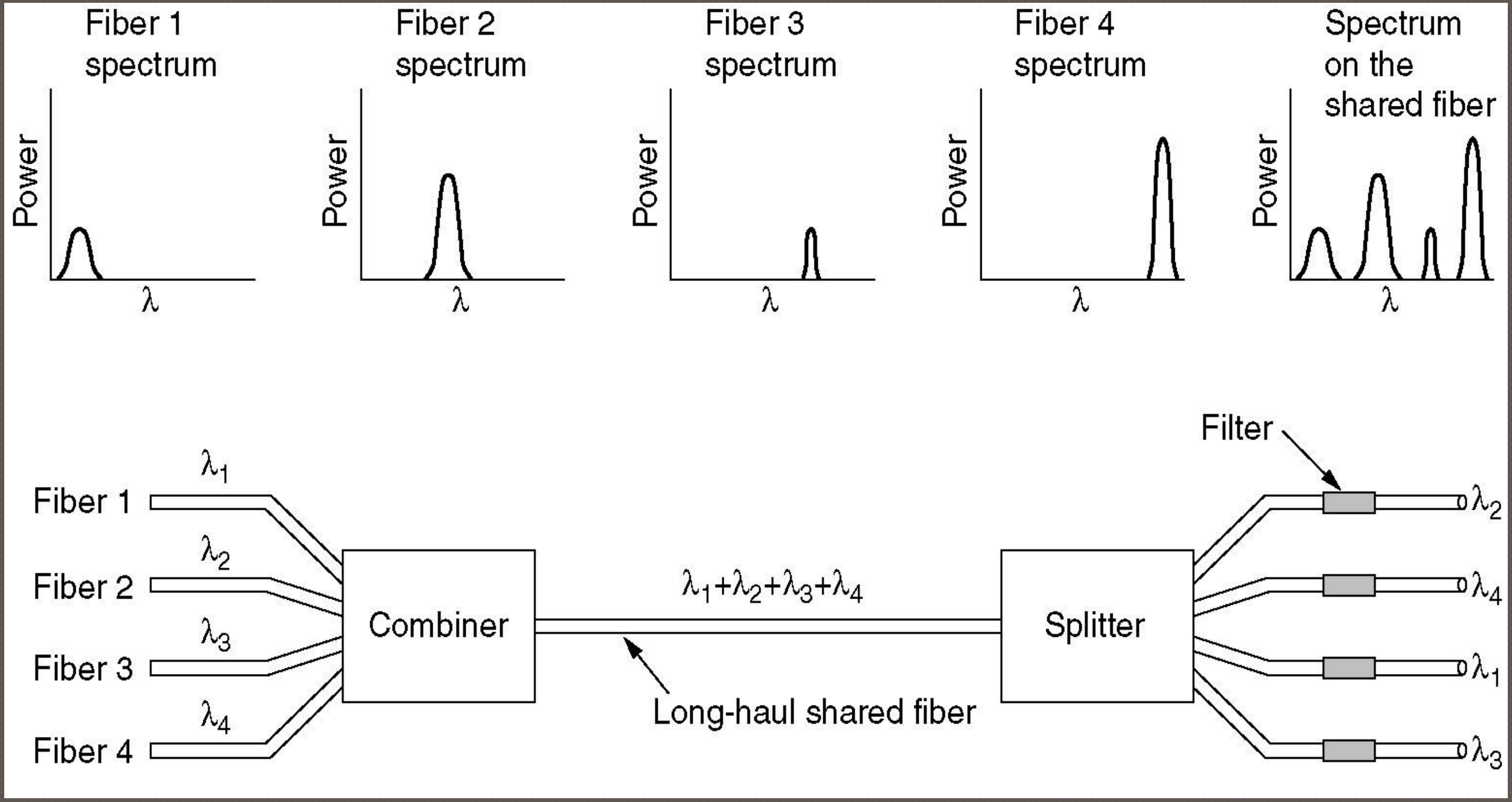
- Many conversations on one physical media
- Good technique over copper wire
  - requires analog circuitry
  - not amenable to being done by a computer



(a) The original bandwidths.
(b) The bandwidths raised in frequency.
(b) The multiplexed channel.

Wavelength Division Multiplexing

Good technique over fibers.



Time Division Multiplexing

TDM can only be used for digital data

- Analog signal is digitized by a codec
  - The method is called PCM (Pulse Code Modulation)
  - Codec makes 8000 samples per sec (125μsec) on a 4kHz telephone line

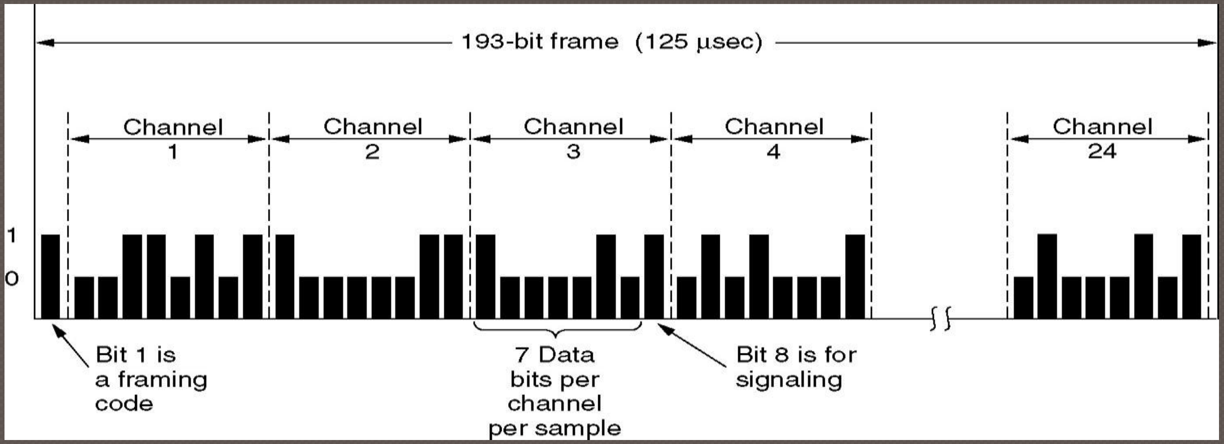
TDM in US is achieved using T1 (more precisely DS1 and a carrier T1)

- In T1 the PCM are produced in a round-robin fashion by a single codec

Digital Signal 1 (DS1) and T1

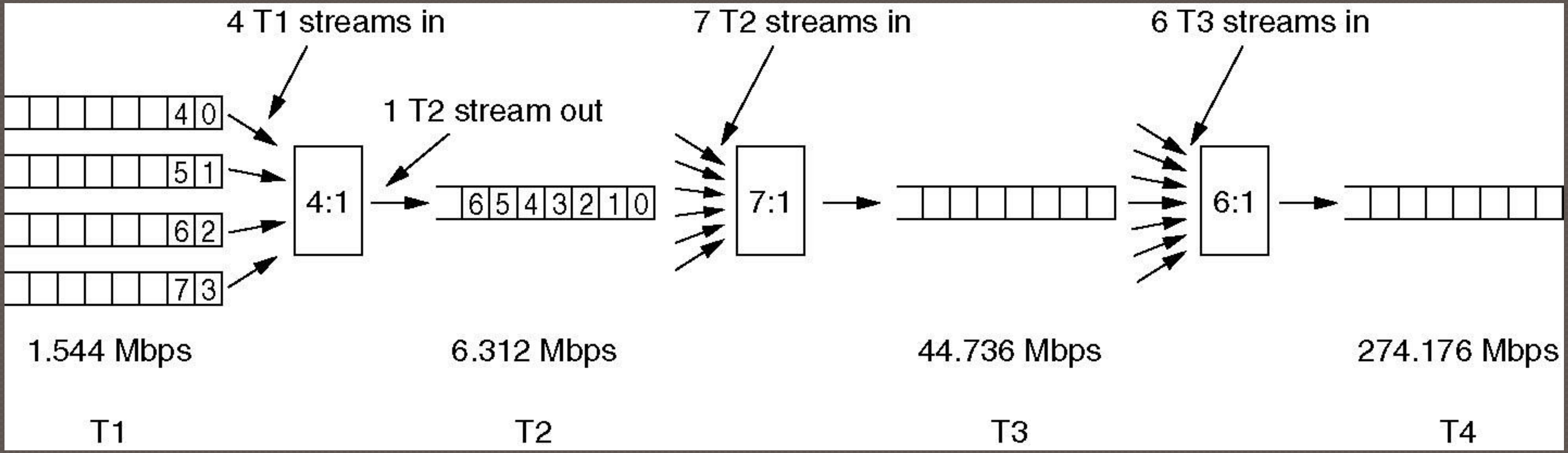
- 24 8-bit channels (also known as timeslots)
- each channel is a 64 kbit/s multiplexed carrier circuit
- full-duplex circuit
- bandwidth = 1.536 Mbit/s
- sampling 8000 times per second.
- 8 kbit/s of overhead from the one framing bit for synchron.

$$\left(8\,\frac{\text{bits}}{\text{channel}} \times 24\,\frac{\text{channels}}{\text{frame}} + 1\,\frac{\text{framing bit}}{\text{frame}}\right) \times 8000\,\frac{\text{frames}}{\text{second}} = 1544000\,\frac{\text{bits}}{\text{second}} = 1.544\,\frac{\text{Mbit}}{\text{second}}.$$

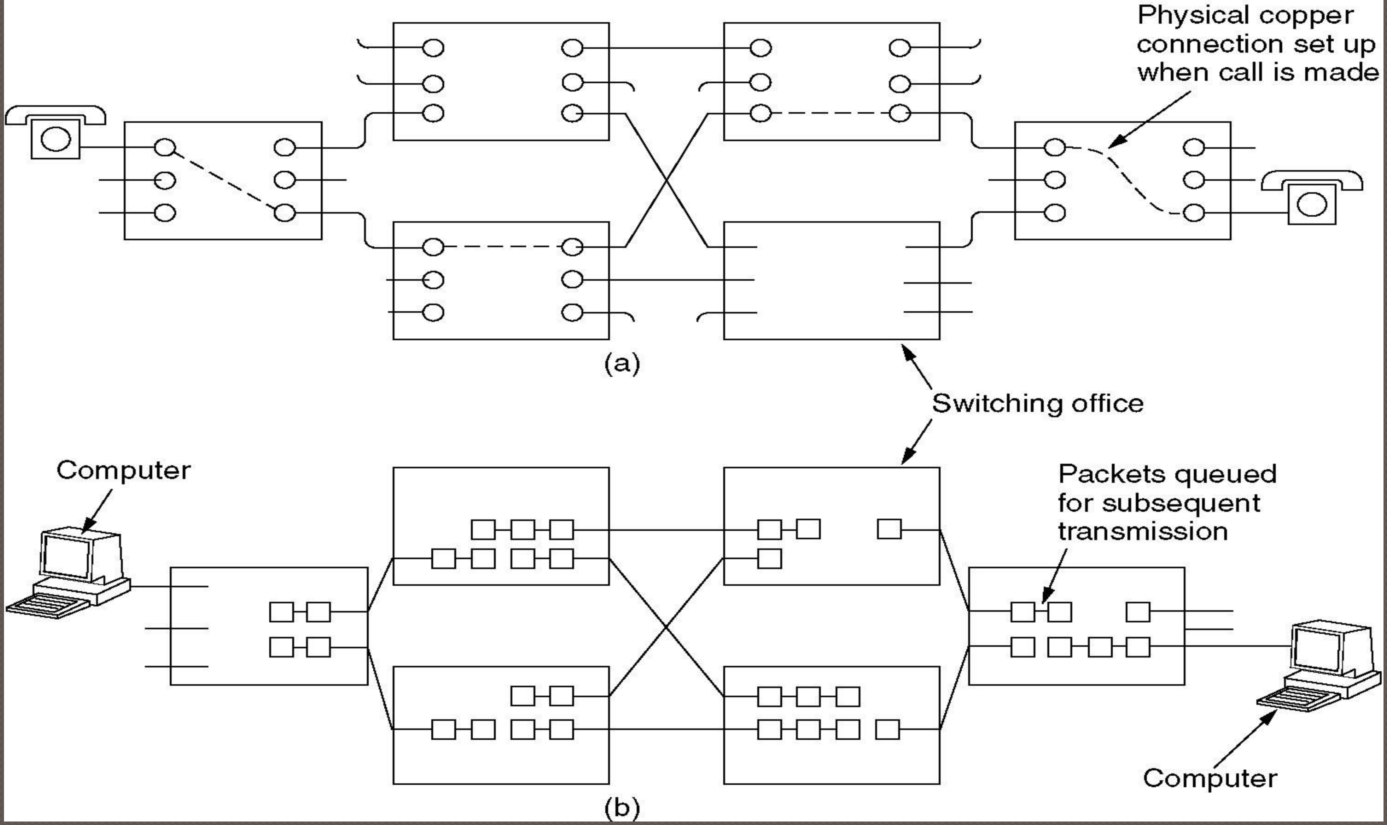


Time Division Multiplexing

Multiplexing T1 streams into higher carriers.



Circuit and Packet Switching

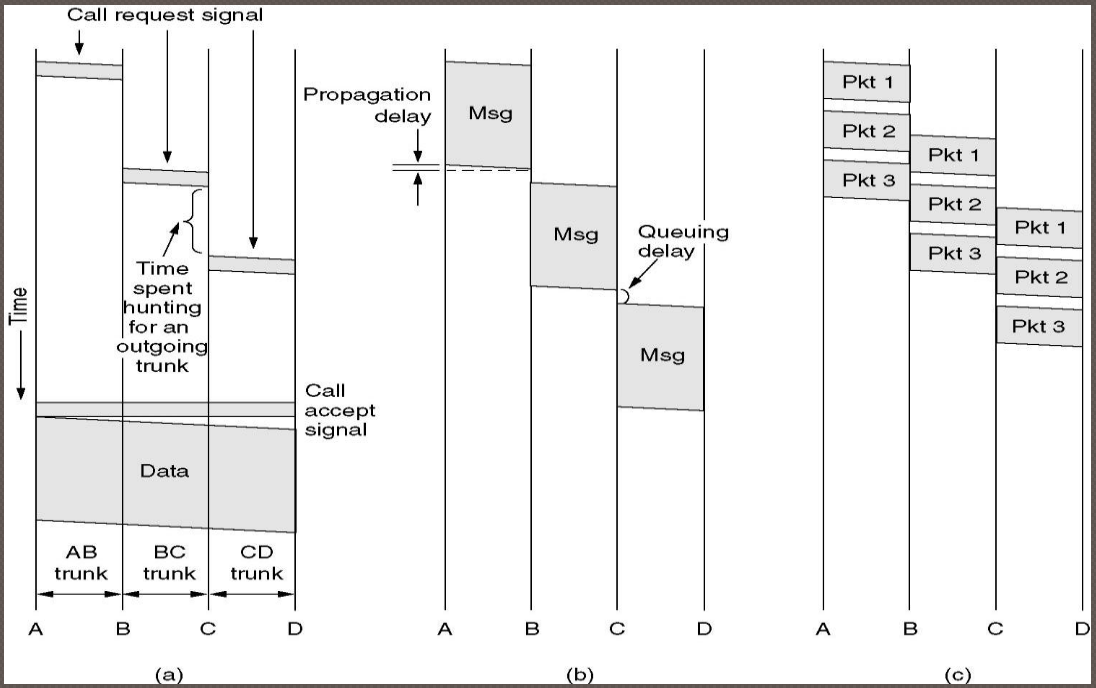


(a) Circuit switching.
(b) Packet switching.

Packet vs. Circuit 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

Message Switching



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

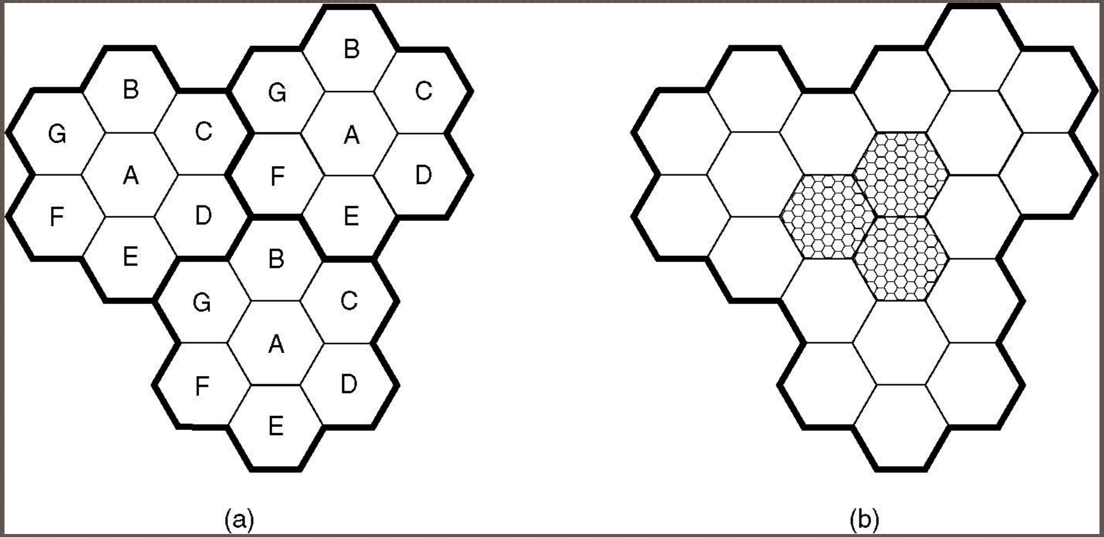
The Mobile Telephone System

- First-Generation Mobile Phones: Analog Voice
  - AMPS
- Second-Generation Mobile Phones: Digital Voice
  - D-AMPS, GSM, CDMA
- Third-Generation Mobile Phones: Digital Voice and Data
  - Broadband CDMA

Advanced Mobile Phone System (AMPS)

Handoff: acquire a new base station

- soft: tone both frequency at the same time (no loss of continuity)
    - 1st and 2nd generation devices CANNOT do this
- hard: old base drops the call, new base acquire it (chance of cut)

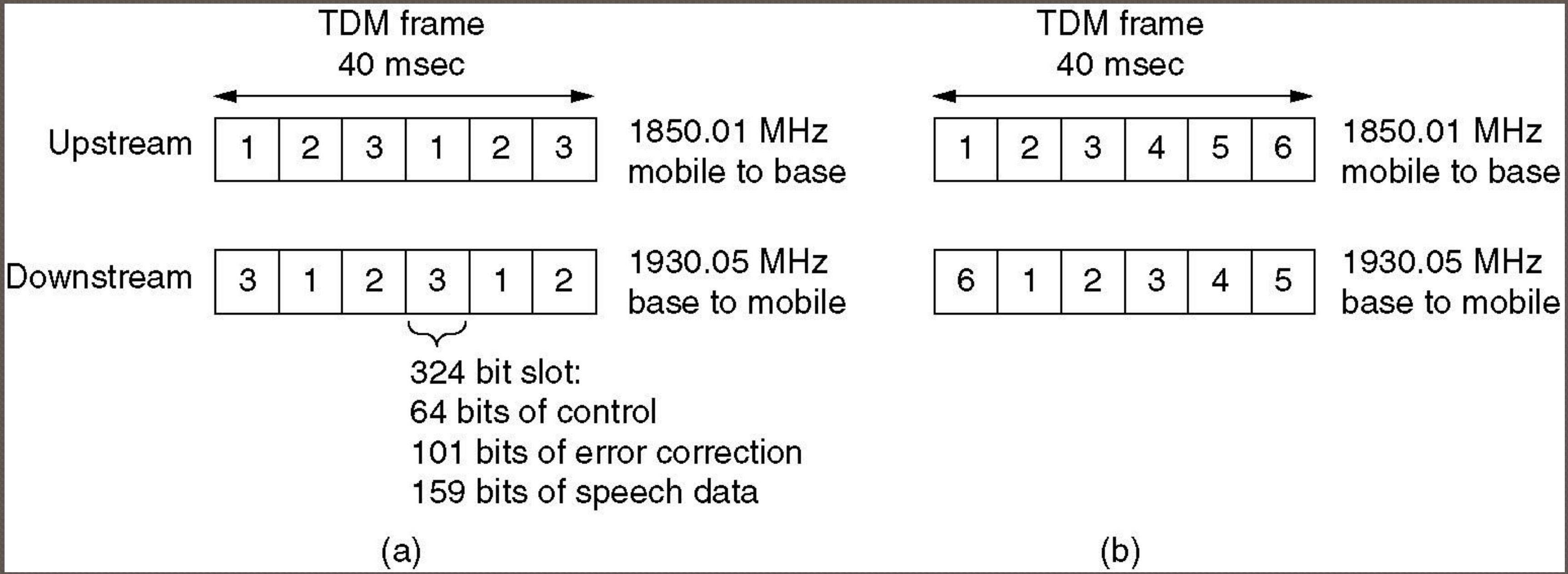


(a) Frequencies are not reused in adjacent cells.
(b) To add more users, smaller cells (microcells) can be used.

AMPS Channels

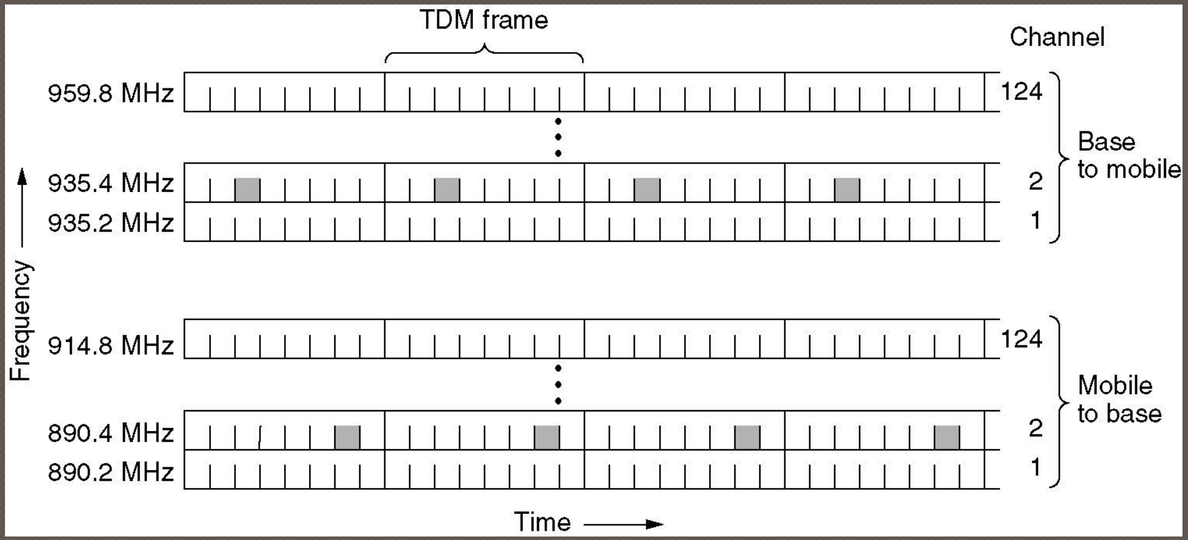
- AMPS uses FDM to separate the channels
- 832 channels full-duplex made of 2 simplex channels
  - 832 transmitting simplex from 824-849 MHz
  - 832 receiving simplex from 869 to 894 MHz
  - 30 kHz per channel
- They are divided into four categories:
  - Control (base to mobile) to manage the system
  - 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 MobileCommunications



- Used in Europe
- 124 frequency channels
  - each uses an 8-slots TDM system

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 + C	S_2 = (−2 0 0 0 +2 +2 0 −2)
1 0 — —	A + $\overline{\text{B}}$	S_3 = (0 0 −2 +2 0 −2 0 +2)
1 0 1 —	A + $\overline{\text{B}}$ + 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 + $\overline{\text{C}}$ + 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)

Binary chips are
pair wise orthogonal
i.e.
for channels X and Y
XY = 0
but
XX = YY = 1

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

Third-Generation Mobile Phones: Digital Voice and Data

Basic services an IMT-2000 network should provide

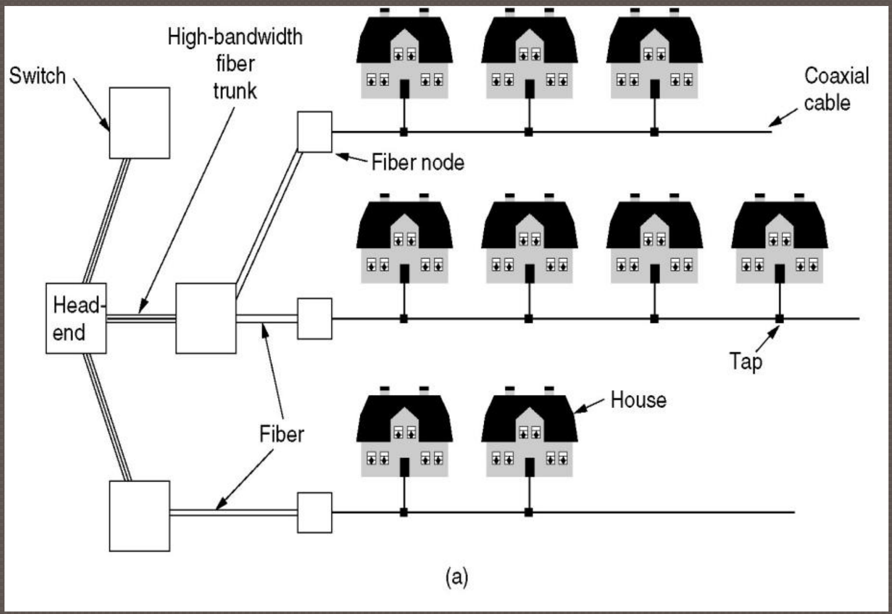
- High-quality voice transmission
- Messaging (replace e-mail, fax, SMS, chat, etc.)
- Multimedia (music, videos, films, TV, etc.)
- Internet access (web surfing, w/multimedia.)

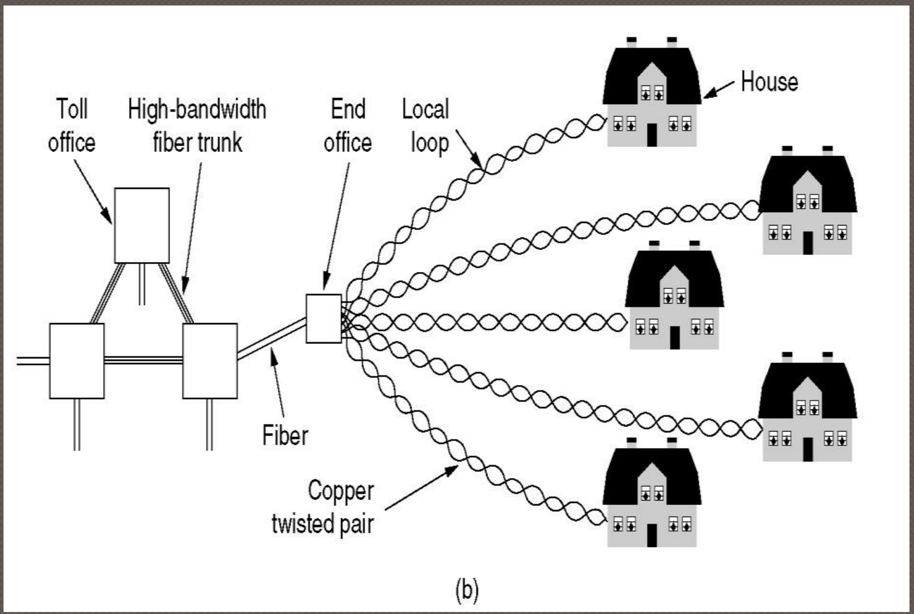
Cable Television

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

Internet over Television Cable

Internet over Telephone

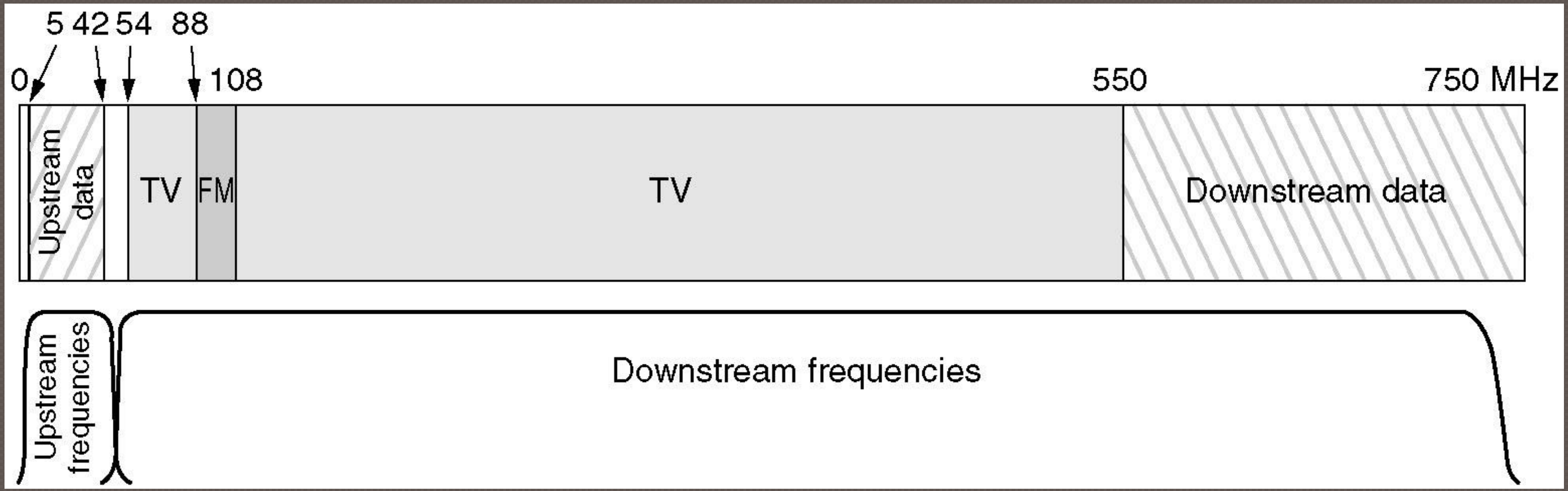




Cable television

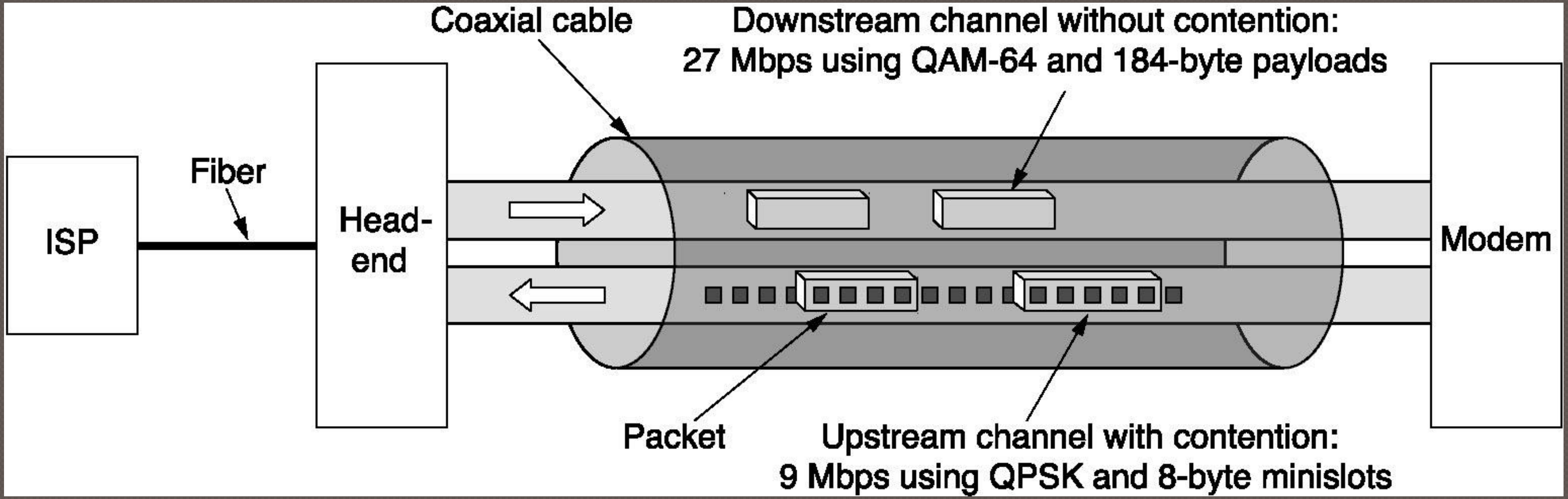
The fixed telephone system

Spectrum Allocation



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

Cable Modems



Typical upstream and downstream channels in US.

- Name of standard modem:
  - DOCSIS (Data Over Cable Service Interface Specification)

ADSL vs. Cable

Item	ADSL	Cable
Media	Twisted pairs	Coax
Media Capacity	Smaller	Larger
Use of Capacity	Small part used for voice	Large part used for television
Bandwidth	1Mbps downstream 256 kbps upstream	Unclaimed
Capacity availability	Full (due to point-to-point connection)	Depends on people active at the moment
Security	More secure	Less secure
Service Availability	No, if user distant from end office	No, if cable not offered – distance not an issue
Choice of ISP offer	Yes	No/Sometimes

Summary

- Physical limitation determine bandwidth
  - Nyquist (noiseless) and Shannon (noisy)
- Transmission media is guided or unguided
  - Guided: twisted pairs, coax, fiber optics
  - Unguided: radio, microwaves, infrareds, laser
- Telephone system components
  - Local loops (analogs), trunks and switches
  - ADSL speeds up to 50 Mbps by dividing the local loop into many channels and modulating each one separately

Summary (2)

- Local loops are analogs
  - ADSL speeds up to 50 Mbps by dividing the local loop into many channels and modulating each one separately
- Trunks are digital
  - Are multiplexed in FDM, TDM and WDM
  - Both Circuit Switching and Packet witching are important
- Mobile Phone
  - 1st generation
    - Analog
    - Dominated by AMPS
  - 2nd generation
    - Digital
    - D-AMP, GMS and CMDA available
  - 3rd generation
    - Digital and broadband CMDA

Summary (3)

- Cable Television
  - Evolved from community antenna to hybrid fiber coax
  - Offers high bandwidth
  - Actual bandwidth depends on currently active users what they are doing