# Computer Networks Protocols

Adrian Sergiu DARABANT

Lecture 3

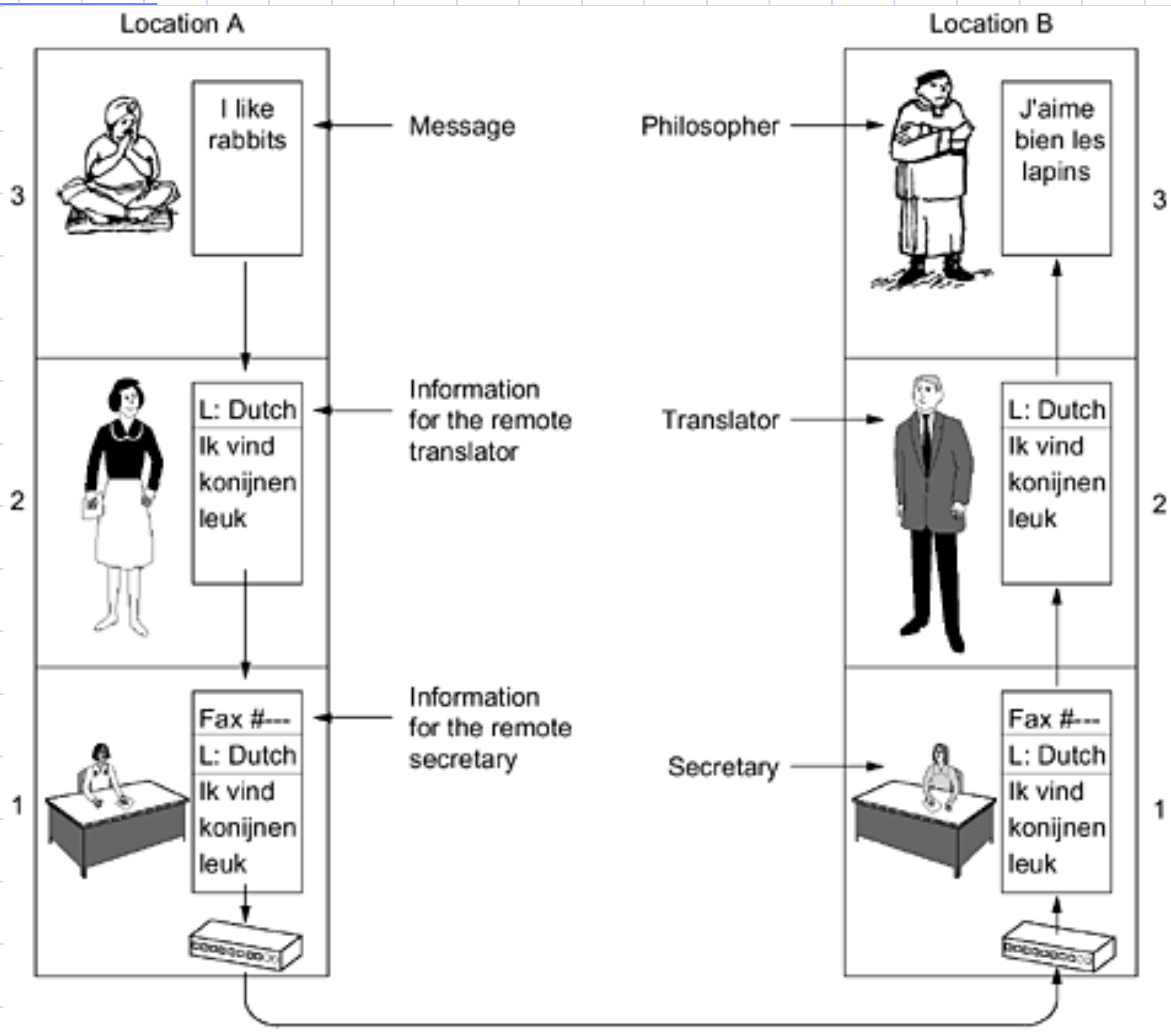
# Protocol

- Agreement about communication
- Specifies
  - Format of the messages
  - Meaning of the messages
  - Rules of exchange
  - Procedures for handling problems (errors)

# Need for protocols

- Hardware is low-level
- Problems that can occur
  - Bits corrupted or destroyed
  - Entire packet lost
  - Packet is duplicated
  - Packets delivered out of order
  - Flow control

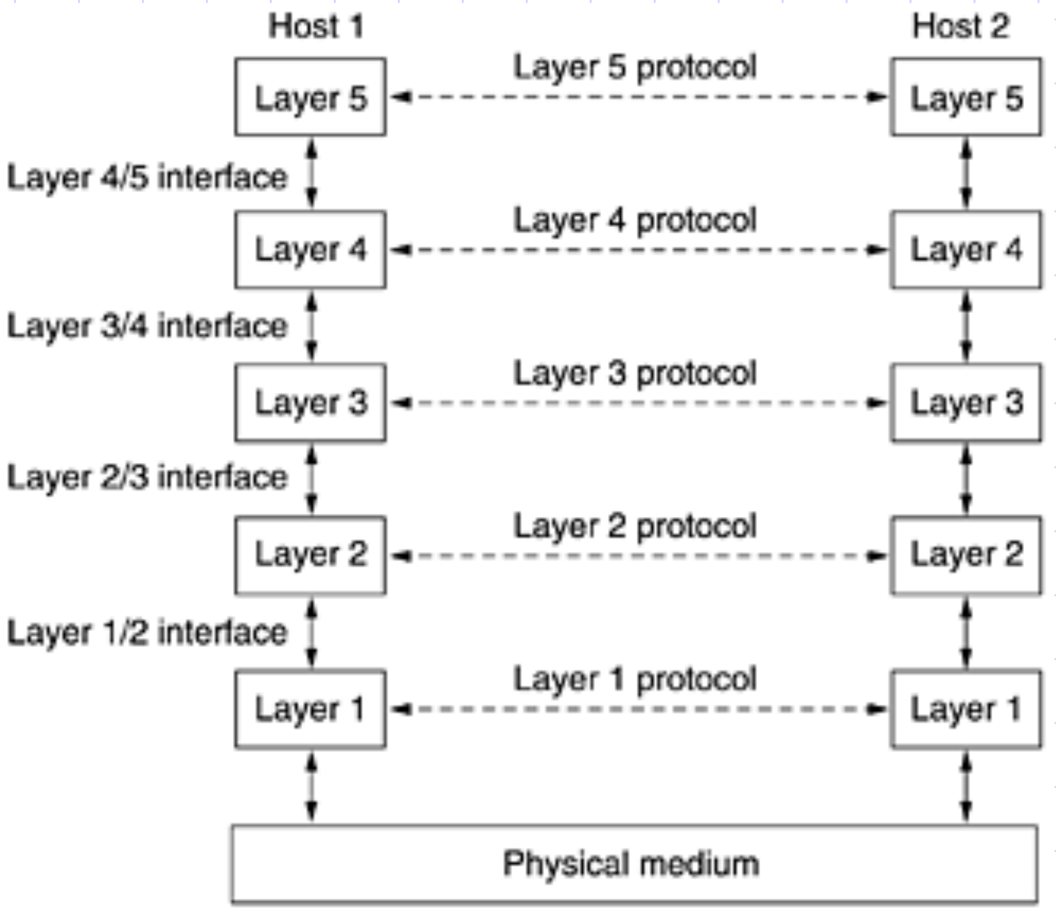
# Exemple of layered communication



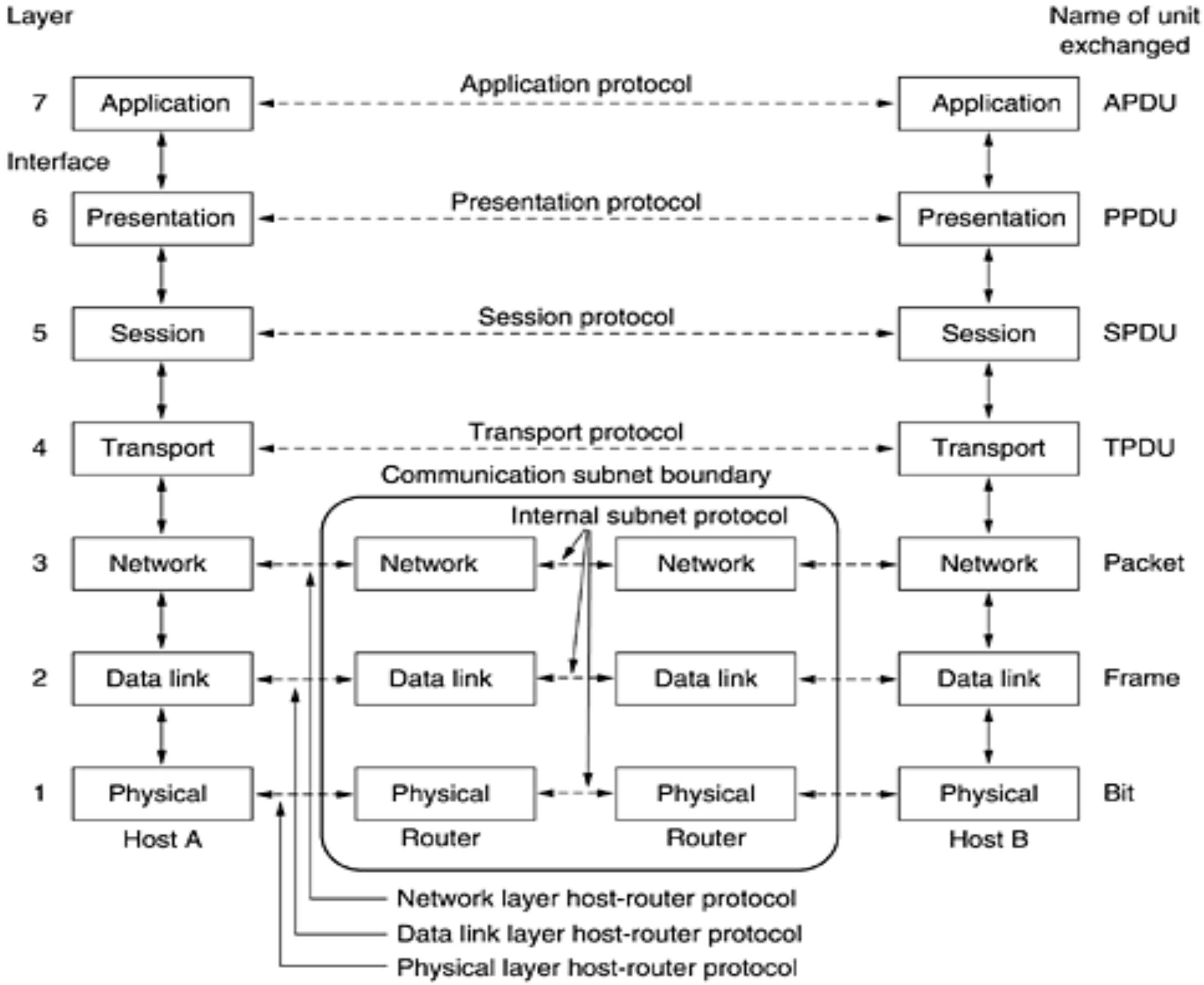
# Protocol Hierarchies

- Networks organised as stacks of layers
  - Reduce complexity
  - Each layer offers services to higher layers
- Equivalent to data abstraction
- Network architecture = a set of layers and procotols

# Layers, protocols, interfaces



# The OSI Reference Model




**A**ll **P**eople **S**eem **T**o **N**eed **D**ata **P**rocessing

# Principles of the OSI model

1. A layer should be created where a different abstraction is needed.
2. Each layer should perform a well-defined function.
3. The function of each layer should be chosen with an eye toward defining internationally standardized protocols.
4. The layer boundaries should be chosen to minimize the information flow across the interfaces.
5. The number of layers should be large enough that distinct functions need not be thrown together in the same layer out of necessity and small enough that the architecture does not become unwieldy.

# The Physical Layer

- Raw bits over a communication channel
- Data representation
  - 1–how many volts ?; 0 – how many volts ?
- 1 bit – How many nanoseconds ?
- Bidirectional simultaneous transmission?
- Electrical, mechanical, timing interfaces

# Data Link layer

- Turn the raw transmission into an error free communication line
- Sets data in ***frames***=thousands of bytes
- Traffic regulation (flow control)
- Access to the medium in broadcast shared coomunication lines

# The Network Layer

- Controls the operation of a subnet
- How packets are routed from source to destination
- Quality of service – congestion control
- Fragmentation and inter-network problems

# The Transport Layer

- Accept data from upper layers and splits it into packets (small units)
- Ensure that packets arrive correctly to the other end
- Type of service: error free PtoP, preserve order or not, guarantees delivery or not, broadcast
- True end-to-end layer

# The Session Layer

- Allows for establishing sessions
- Session
  - Dialog control
  - Token management
  - Synchronization

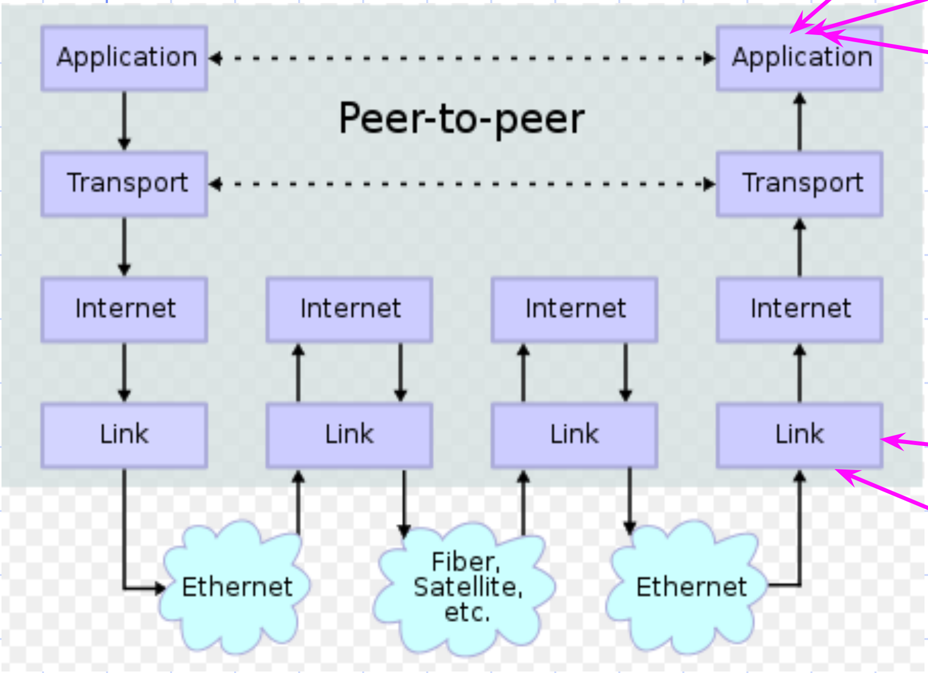
# The Presentation Layer

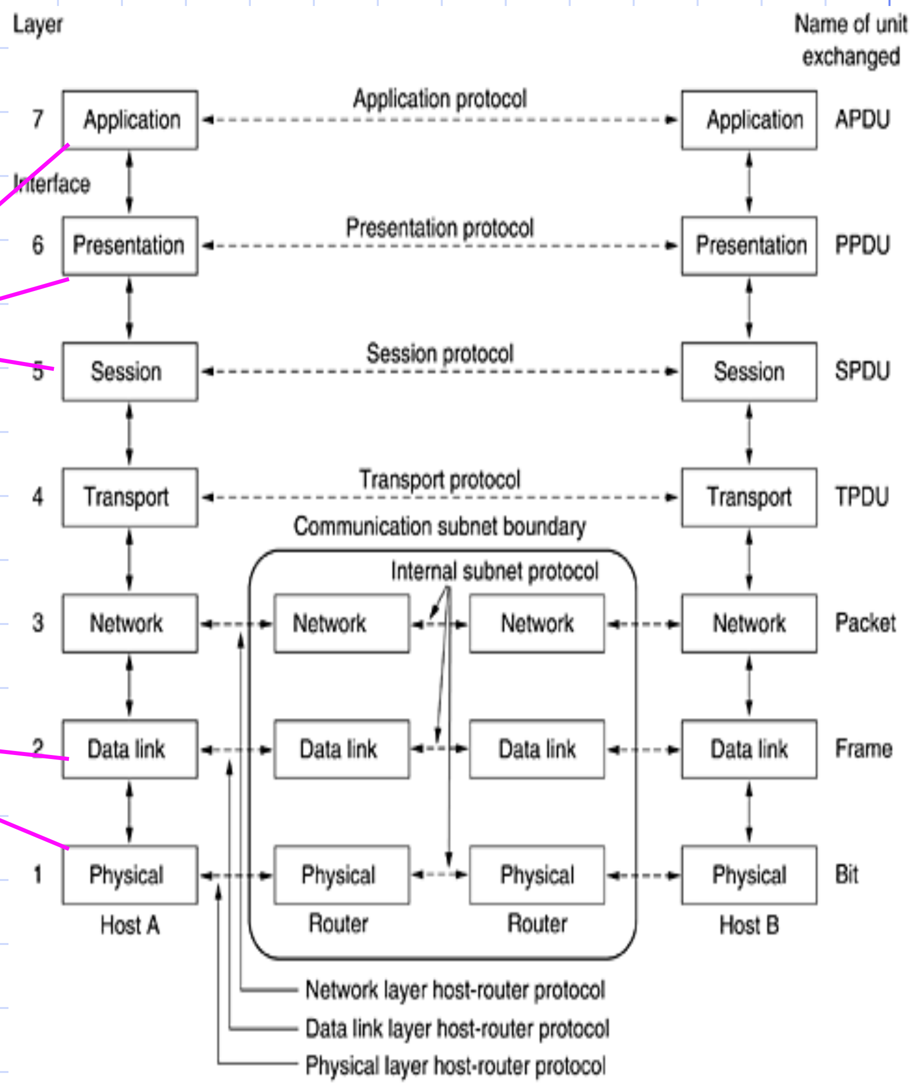
- Syntax and semantics of data
- Abstract data definitions/ encoding for information exchange between heterogeneous systems
- Standard encoding “on the wire”
- Exchange unit – record type

# The Application Layer

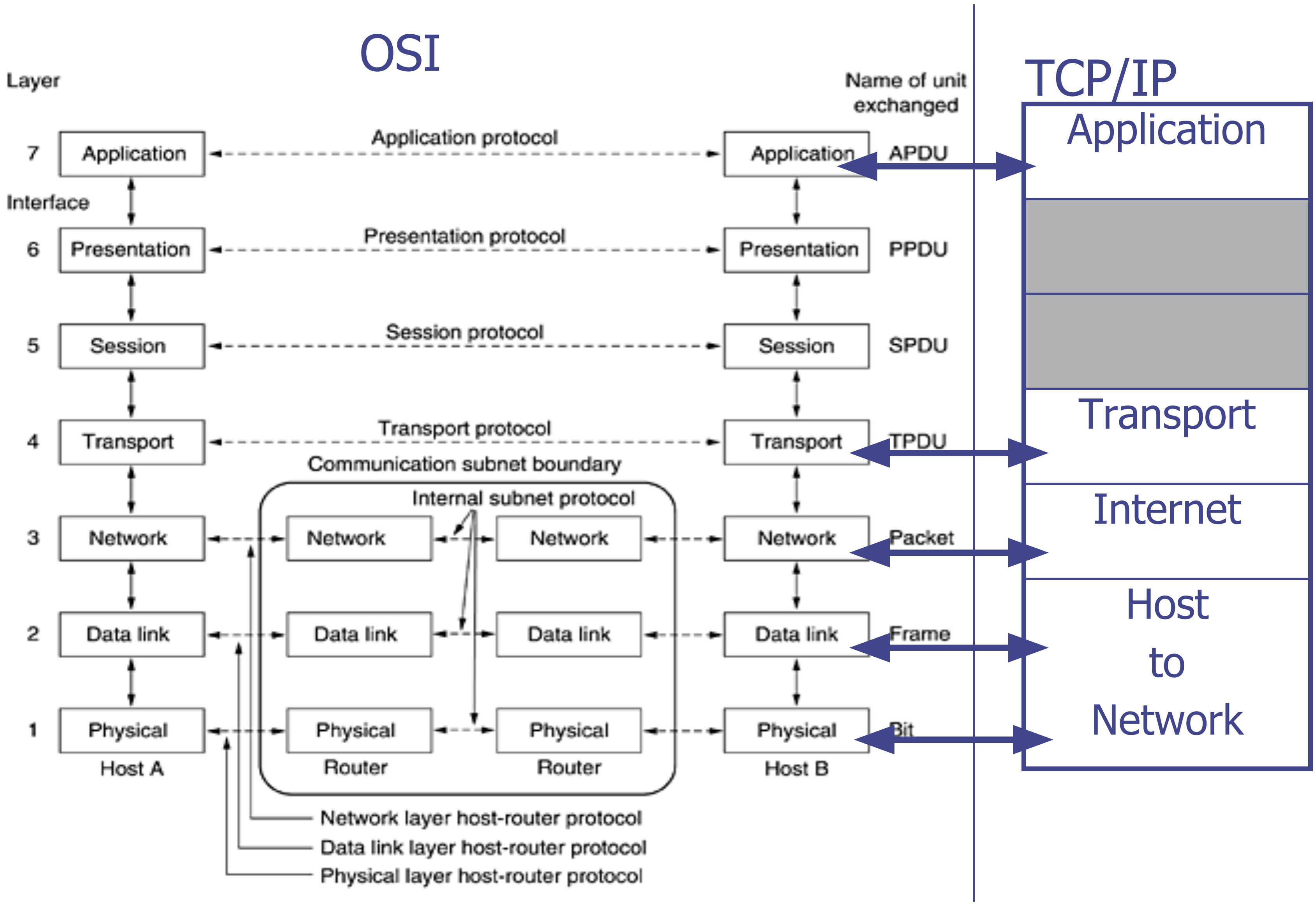
- Protocols needed by users:
  - HTTP - www
  - FTP – file exchange
  - TELNET – remote command
  - SSH – remote command
  - SMTP – mail exchange

# TCP/IP Reference Model

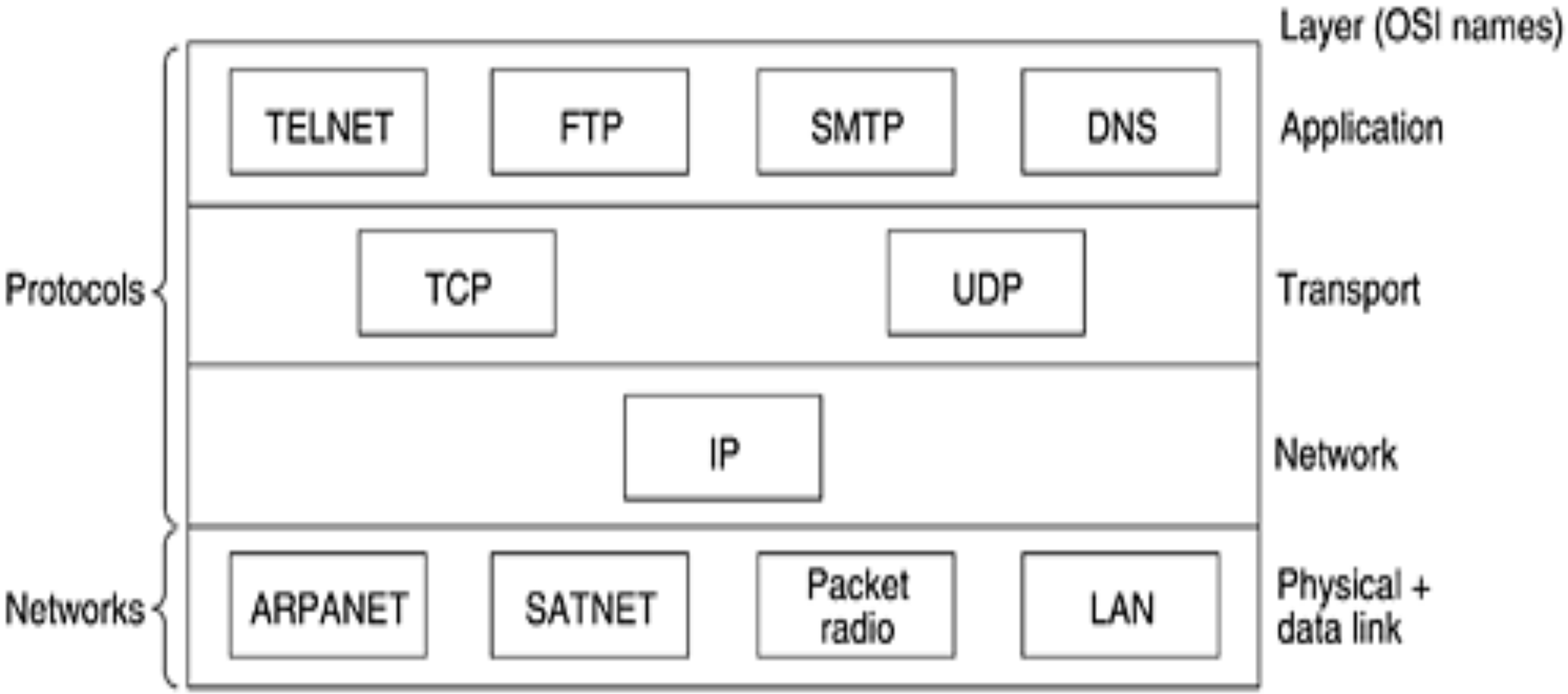


# OSI Model vs TCP/IP Model



# Protocols in the TCP/IP Model



# Network Standardization

- Europe 1865 – ITU- International Telecommunication Union
  1. Radiocommunications Sector (ITU-R).
  2. Telecommunications Standardization Sector (ITU-T).
  3. Development Sector (ITU-D)
- USA – **ISO/ANSI** – establishing standards
  - ISO is a member of ITU-T
- USA – NIST (National Institute of Standards and Technology) – issues standards for the US gov. (except DOD)
- WorldWide IEEE (Institute of Electrical and Electronics Engineers) – standardization groups.

# IEEE Standards

| Number | Topic |
|---|---|
| 802.1 | Overview of architecture of LANs |
| 802.2 | Logical link control (hibernating) |
| 802.3 | Ethernet (*) |
| 802.4 | Token ring (hibernating) |
| … | |
| 802.11 | Wireless LANs (*) |
| 802.13 | Nobody wanted it (unlucky number) ☺ |
| 802.15 | Personal area networks (Bluetooth) |
| 802.16 | Broadband wireless |

# ARPANET Standards

- 1983 – IAB (Internet Architecture Board) – watch over ARPANET – DoD.
- Proposals = Request for Comments (RFC) –http://www.ietf.org/rfc
- RFC=>standard stages:
  - Ideea completely explained in a RFC =>*Proposed Standard*
  - A working implementation => *Draft Standard*
  - Everything OK => RFC=>*Internet Standard*
- There are over 3000 RFCs. (ex:FTP RFC775, RFC959)

# Theoretical Bases for Data Comm

- Jean Baptiste Fourier => Fourier decomposition (Fourier Series)

$$g(t) = \frac{1}{2}c + \sum_{n=1}^{\infty} a_n \sin(2\pi nft) + \sum_{n=1}^{\infty} b_n \cos(2\pi nft)$$

For g(t) periodic of period T. $a_n$, $b_n$ amplitutes of the *n-th* harmonic. f=1/T – fundamental frequency

$$a_n = \frac{2}{T}\int_0^T g(t)\sin(2\pi nft)dt \quad b_n = \frac{2}{T}\int_0^T g(t)\cos(2\pi nft)dt \quad c = \frac{2}{T}\int_0^T g(t)dt$$

# Signal Energy & Loss

$$\sqrt{a_n^2 + b_n^2}$$

Direct proportional with the transmitted signal energy at the corresponding freq

Any signal transmission occurs with power loss.

Fourier coef are not affected proportionally by the power loss => signal amplitude is distorted

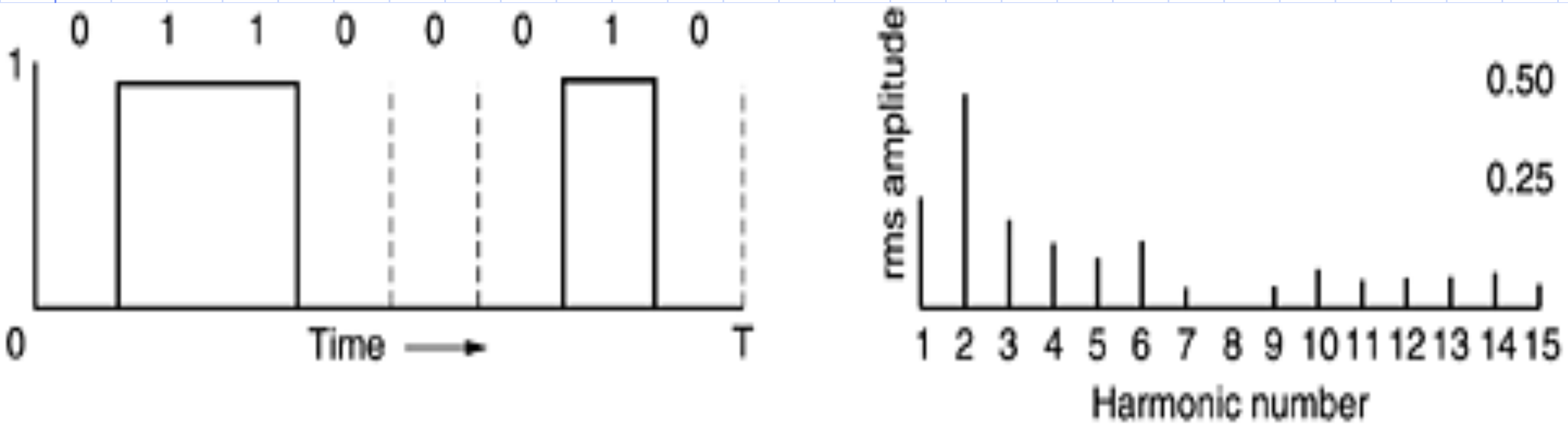
Frequencies : **0-$F_{max}$ =>**the amplitutdes are undiminished – above they are attenuated.

# Medium Bandwidth

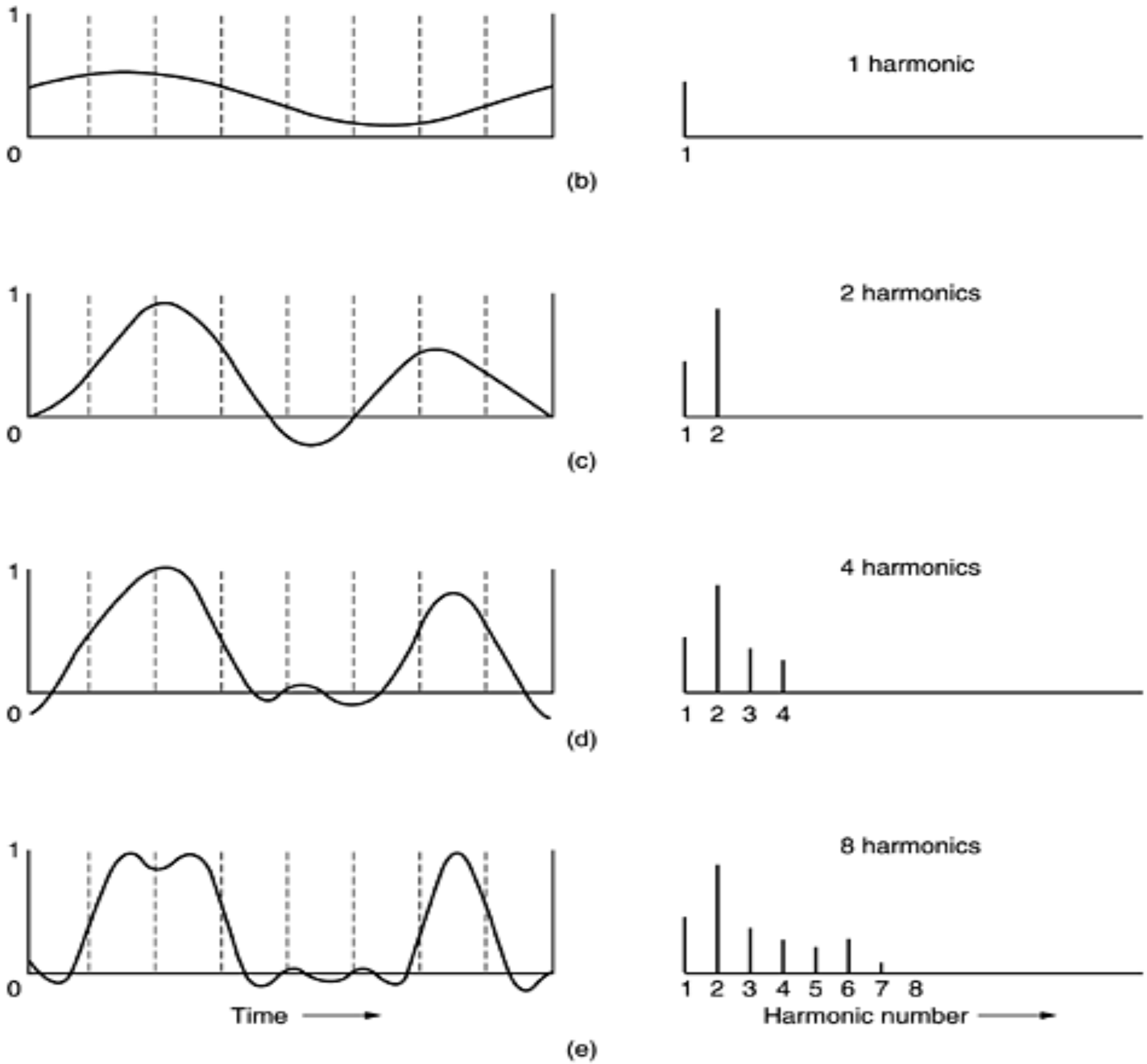
- The range of frequencies for a given media for which the signal Is not strongly attenuated = BANDWIDTH
- Bandwidth – is a physical property of the transmission medium.
- Bandwidth = *valid* frequency spectrum.

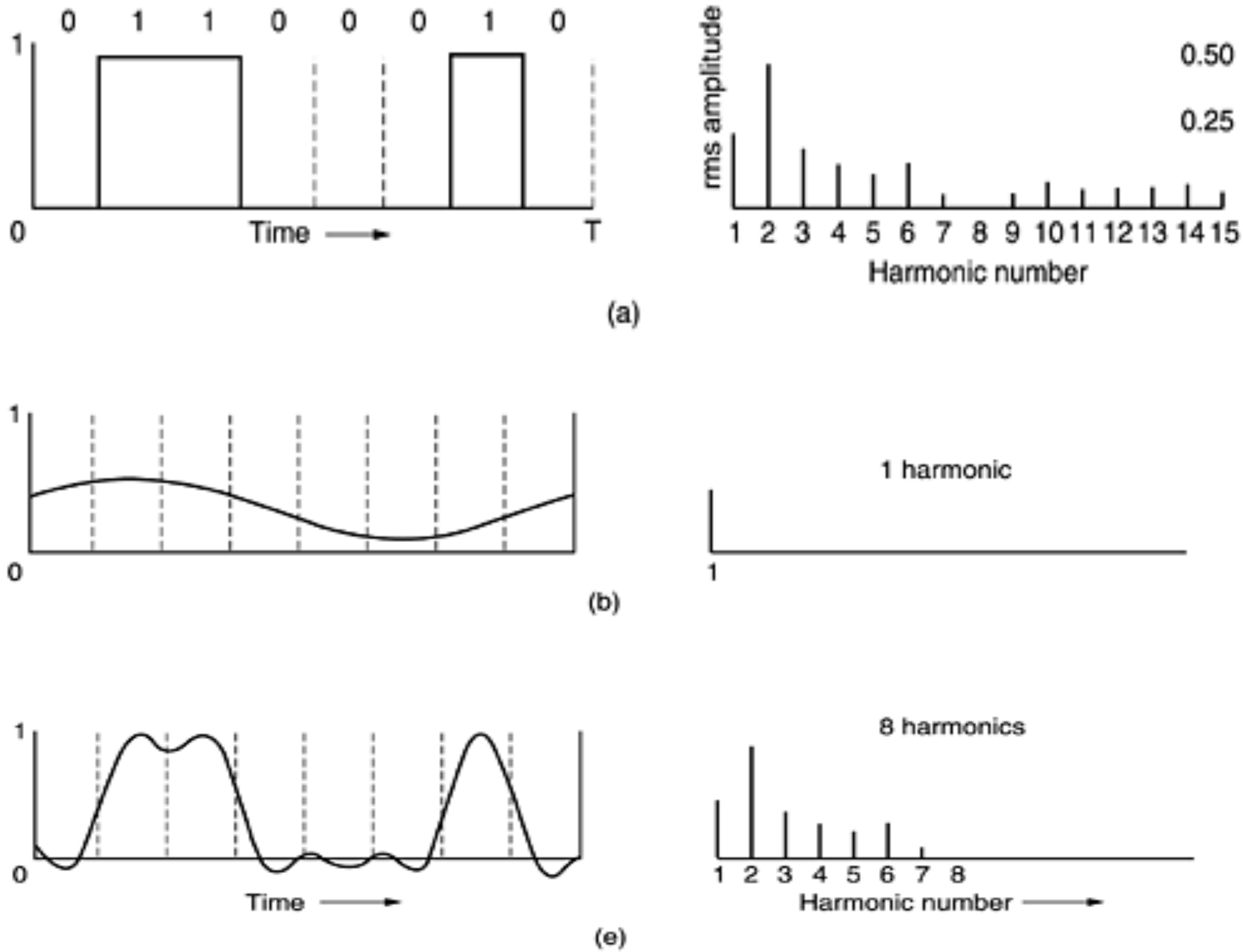
# Bandwidth-Limited Signals

Character 'b' = 01100010 – to be transmitted
The root mean square coefficients (bellow)



(a)


1 harmonic
(b)
2 harmonics
(c)
4 harmonics
(d)
8 harmonics
Time
Harmonic number
(e)



0 1 1 0 0 0 1 0
1
0
Time
T
rms amplitude
0.50
0.25
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
Harmonic number
1
0
1 harmonic
1
1
0
Time
8 harmonics
1 2 3 4 5 6 7 8
Harmonic number


(a) (b) (e)

# Bandwidth – example

Speed: **b** bits/sec - 1 bit at a time=>

=>Time required to transfer 8 bits T:= 8/b sec,
=>Freq of first harmonic: b/8 Hz.

Ordinary tel line bandwidth: 3000 Hz=3 kHz.

=>Highest harmonic no: 3000/(b/8)=24000/b.

# Bandwidth example 3kHz tel line

| Bps | T(msec) | 1st harmonic (Hz) | # Harmonics sent |
|---|---|---|---|
| 300 | 26.67 | 37.5 | 80 |
| 600 | 13.33 | 75 | 40 |
| 1200 | 6.67 | 150 | 20 |
| 2400 | 3.33 | 300 | 10 |
| 4800 | 1.67 | 600 | 5 |
| 9600 | 0.83 | 1200 | 2 |
| 19200 | 0.42 | 2400 | 1 |
| 38400 | 0.21 | 4800 | 0 |

# Bandwidth vs Data Rate

- 1924 Henri Nyquist –relation between bandwidth and data rate in a noiseless channel **(throughput):**

Nyquist Theorem:(bandwidth/data rate equiv)
A data signal on a medium with *H* Hz bandwidth can be reconstructed by making 2H samples/sec.
For a signal of *V* discrete levels:
***Maximum data rate***=$\mathbf{2H \log_2 V}$ bits/sec.

3 kHz channel (binary signals) => max_data_rate=6000 bps
throughput $=2*3000 \log_2 2 = 6000$ bps.

# Throughput in a noisy channel

- S – the signal power; N – the noise power

=> S/N **the signal to noise ratio**.

- Signal to noise (decibels) 1 dB = 10 $\log_{10}$ S/N.

Ex: S/N = 10 => 10 dB; S/N =100 => 20 dB, etc

Shannon's Theorem (throughput on a noisy channel)

The maximum throughput of a noisy channel of bandwidth *H* with a signal to noisy ratio of S/N is:

***Maximum throughput* = H $\mathbf{\log_2(1+S/N)}$** bps.

**Ex:** tel line Bandwidth=3kHz; S/N=30 dB =>

Max throughput = 3000 * $\log_2(1+1000)$ =~ 30.000 bps = 28.8 kbps

# Bottom Line

- Nyquist’s theorem means finding a way to encode more bits per cycle improves the data rate
- Shannon’s theorem means that no amount of clever engineering can overcome the fundamental physical limits of a real transmission system.

# Transmission Media Categories

- Guided Transmission Media
- Wireless Transmission Media
- Communication Satellites
- The Public Switched Telephone Line (PSTN)
- The Mobile Telephone System
- Cable Television

# Guided Transmission Media

1. **Magnetic Media**

Ultrium tape =100GB. A box 60x60x60 holds 1000 tapes =>200 Tbytes=1600 Tbits.

A box can be delivered in 24H anywhere in USA => throughput: 1600 Tbits/86400 sec = <u>19 Gbps !!!</u>

<u>CONCLUSION:</u>

Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway ☺

# Guided Media

2. **Twisted Pair/ Unshielded TP (UTP)**

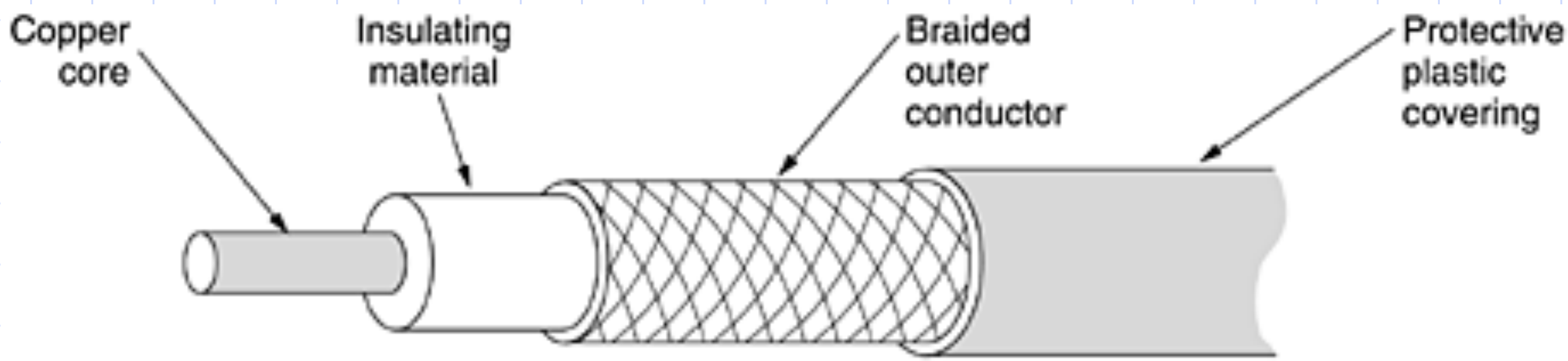
- classic telephone lines – 2 wires
  - Category 3 (a) – 16MHz
  - Category 5 (b) – 100 MHz
  - Category 6 – 250 MHz
  - Category 7 – 600 MHz

Throughput : a few Mbit/sec - Gbits.

# Guided Media

3. **Coaxial Cable**

Bandwidth ~ 1 GHz (better shielding)



# Guided Media

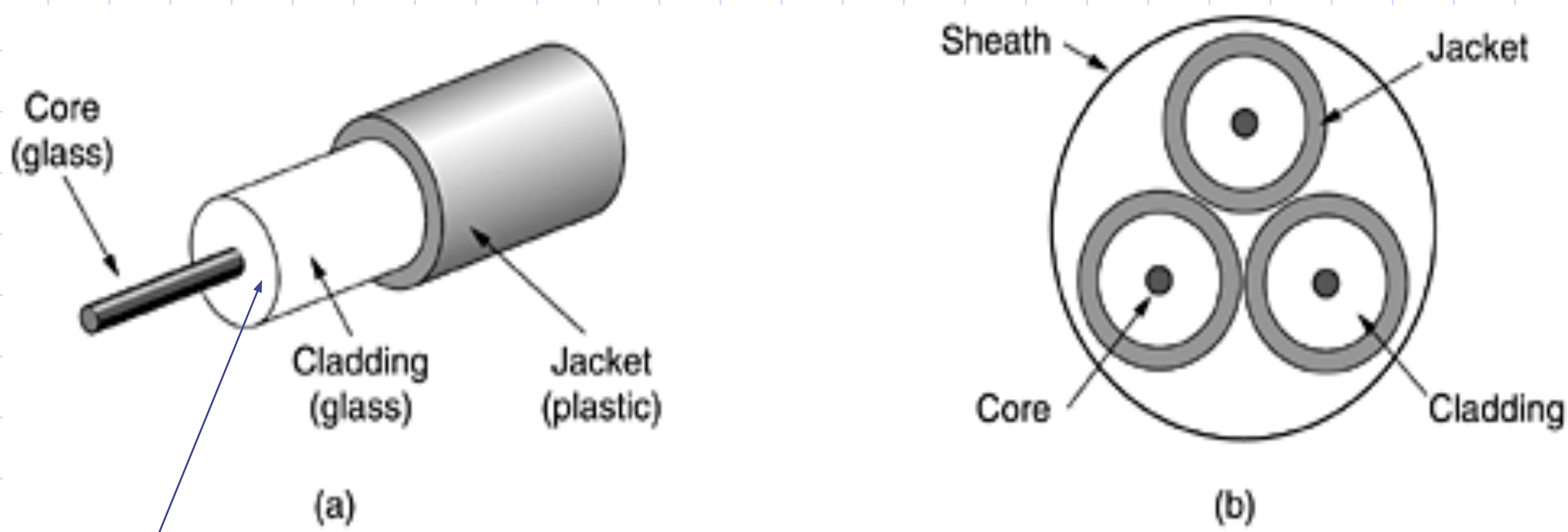
4. **Fiber Optics**

Technology:

- Light source
- Transmission media
- Detector

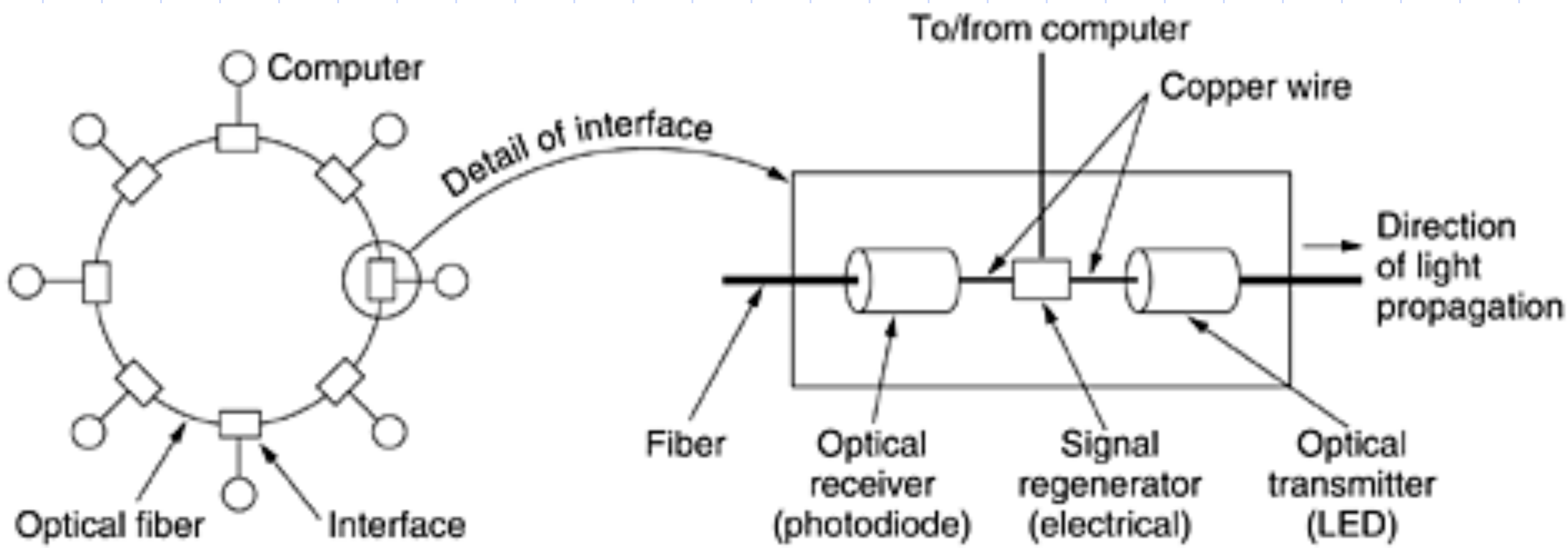
- Problems: refraction (light escaping from the fiber) – Solution – critical angle.
- Types:
  - Multi-mode fiber
  - Single-mode fiber

# Fiber optics - continued



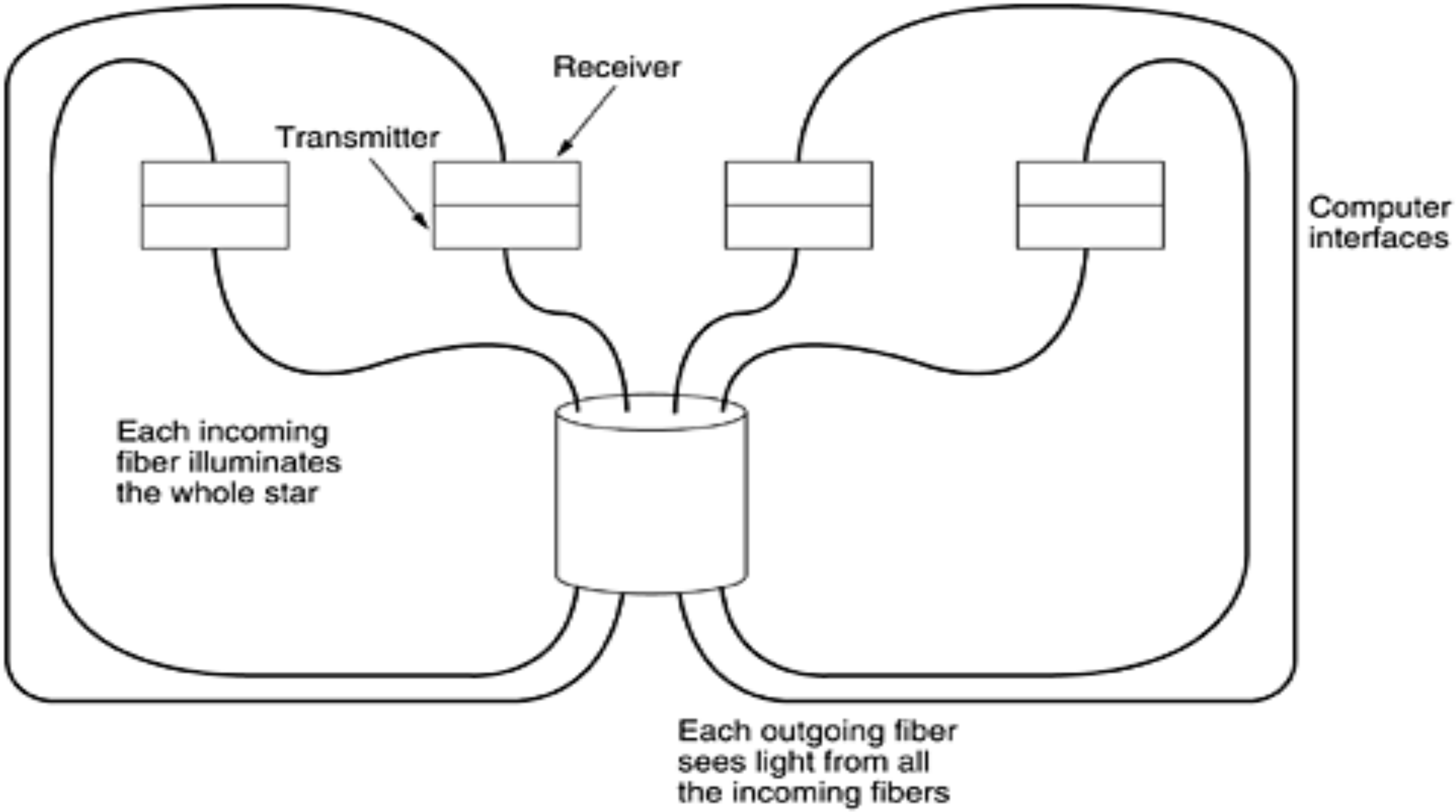

Lower refraction index

# Fiber Optic Equipments




Active repeater

# Fiber optics - Equipments



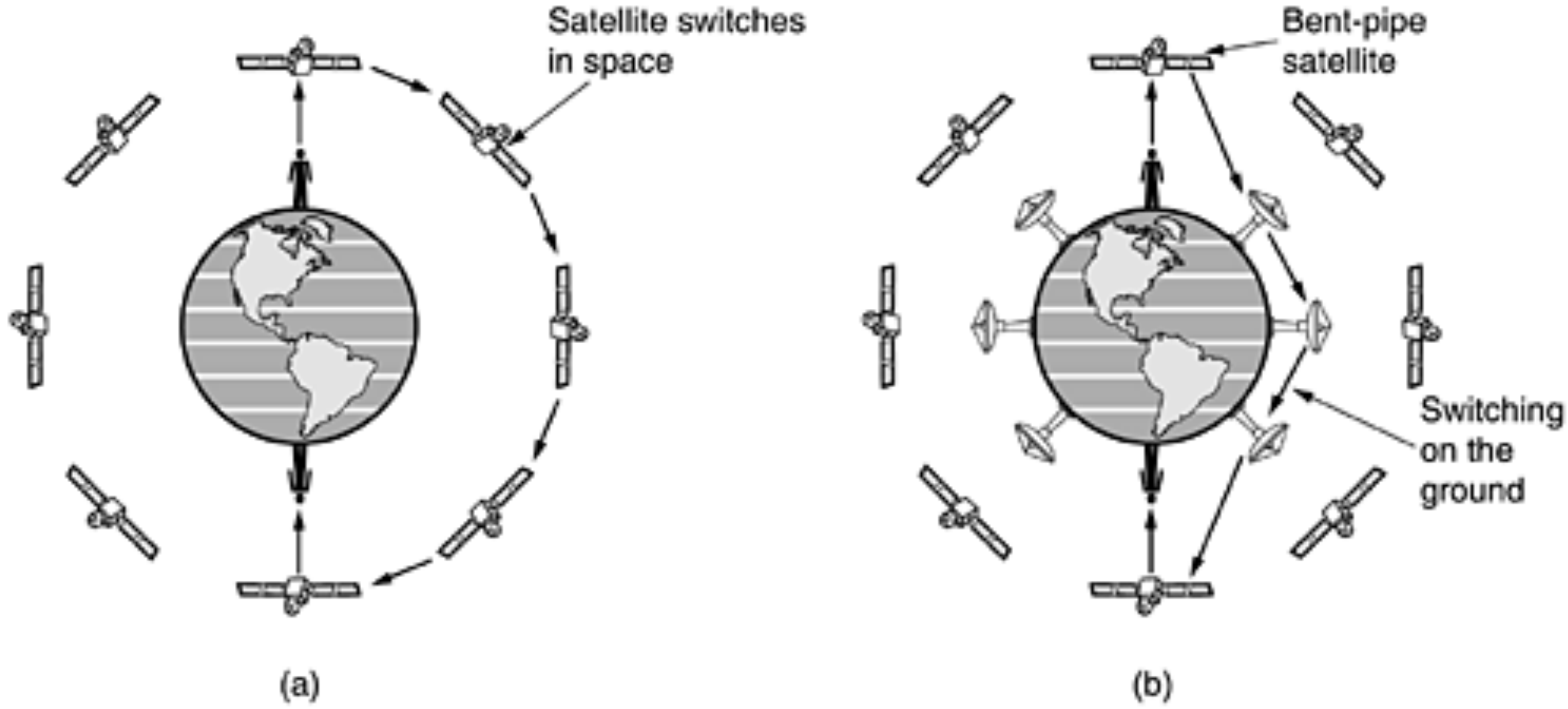

Passive repeater

# Wireless Transmission

- Uses Electromagnetic pulses to send signals.
- Two transmission policies:
  - Frequency hopping spread spectrum- FHSS
  - Direct sequence spread spectrum – DSSS

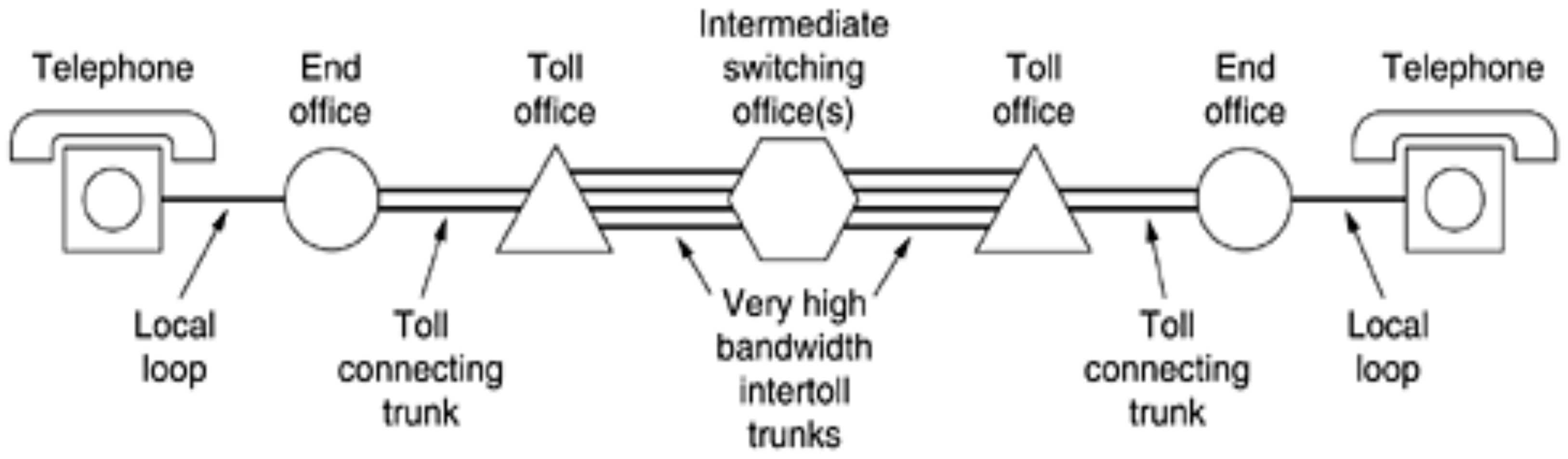
- FHSS – discovered and introduced by Heddy Lamarr – an austrian born actrice (Czech movie Extase – 1933) .

# Communication Satellites

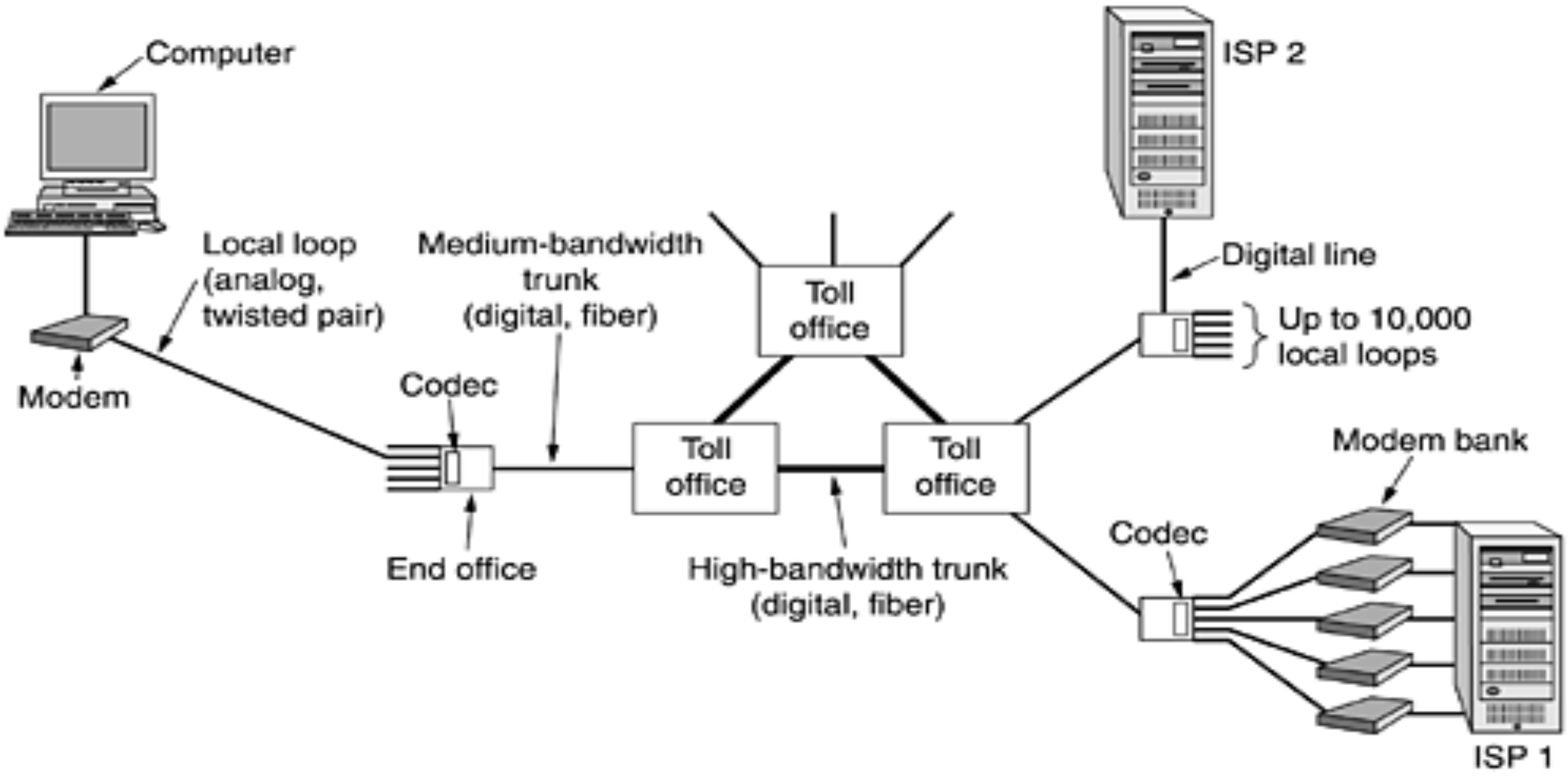



More – read chapter 2 – Computer Networks

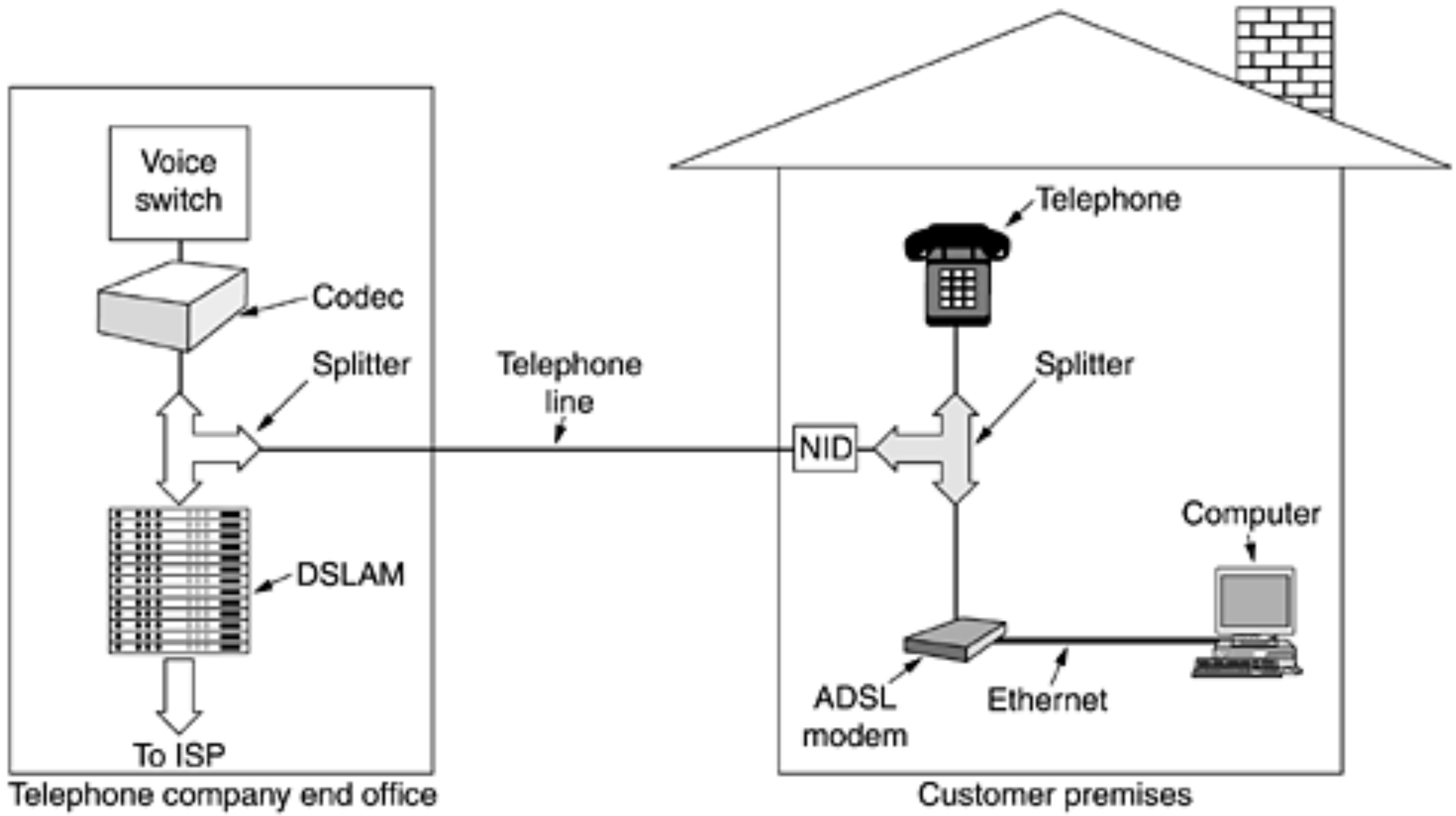
# The PSTN system



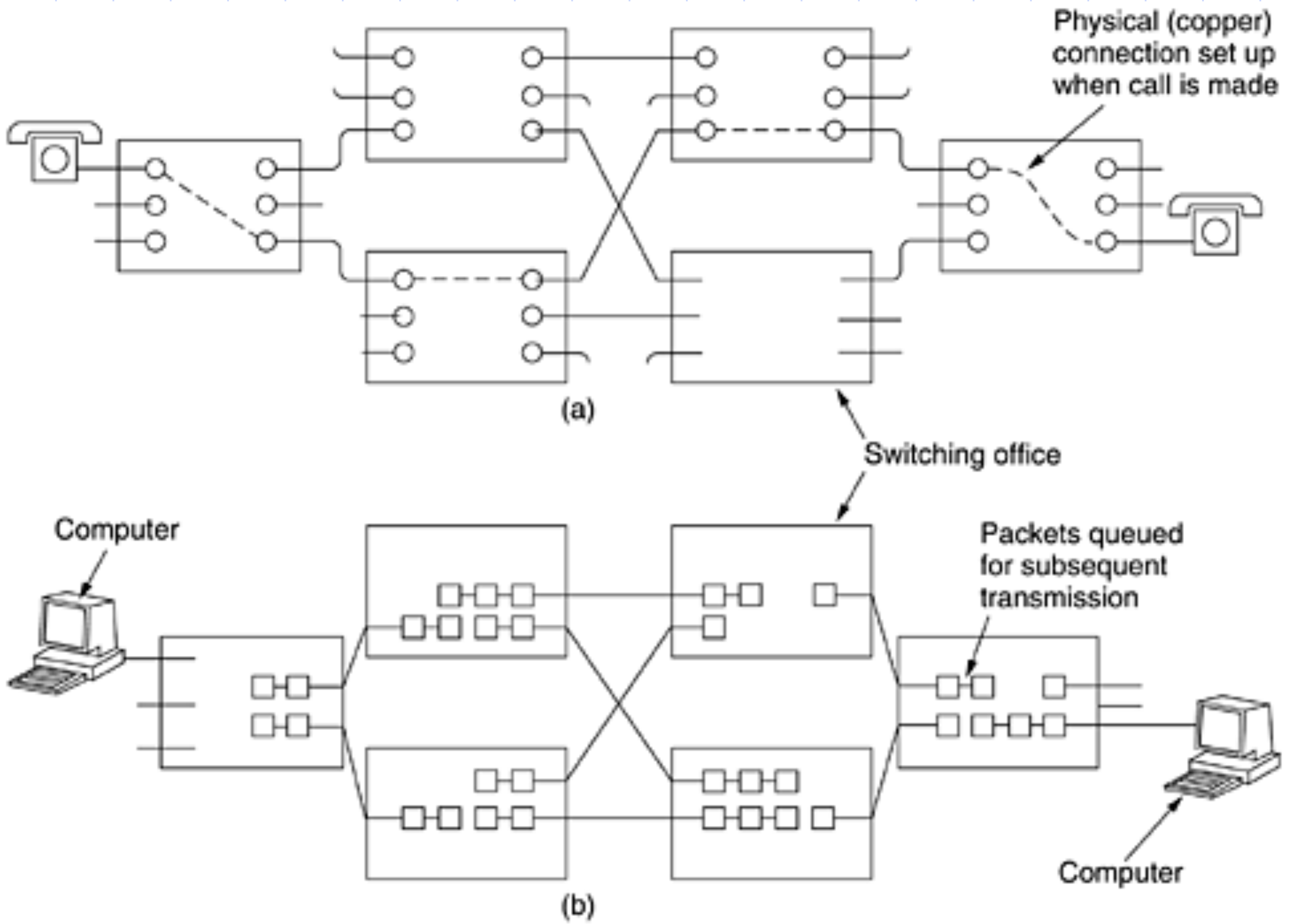
# The PSTN System



# PSTN – Asymmetric DSL



# Circuit switching/packet switching

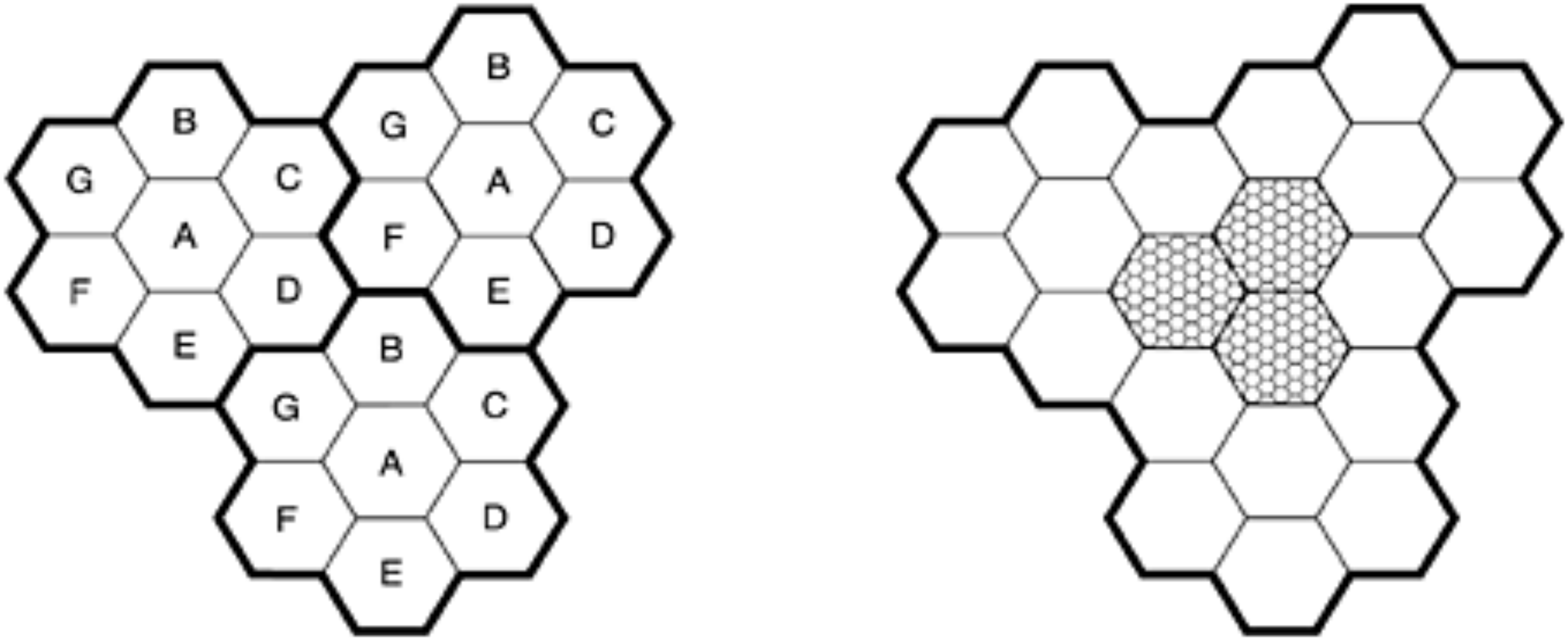


# The mobile phone system

- Analog voice
- Digital voice
- Digital voice and Data

Differences between USA and Europe.

# The mobile telephone system

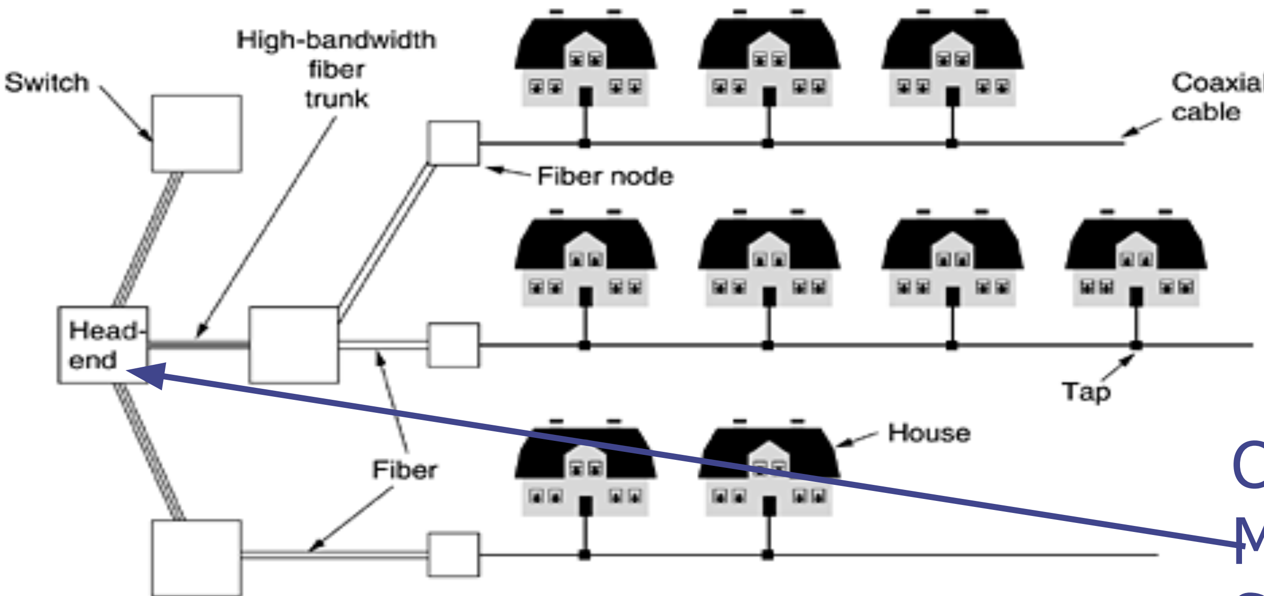



(a) (b)

In each cell - **MTSO** (Mobile Telephone Switching Office)

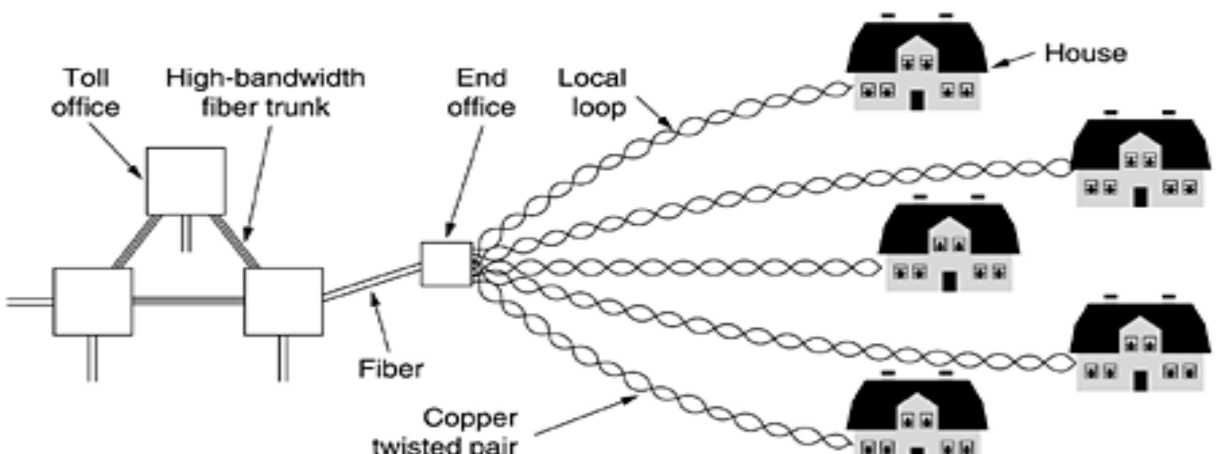
MTSO-MTSO links – packet switched

# Cable Television Systems



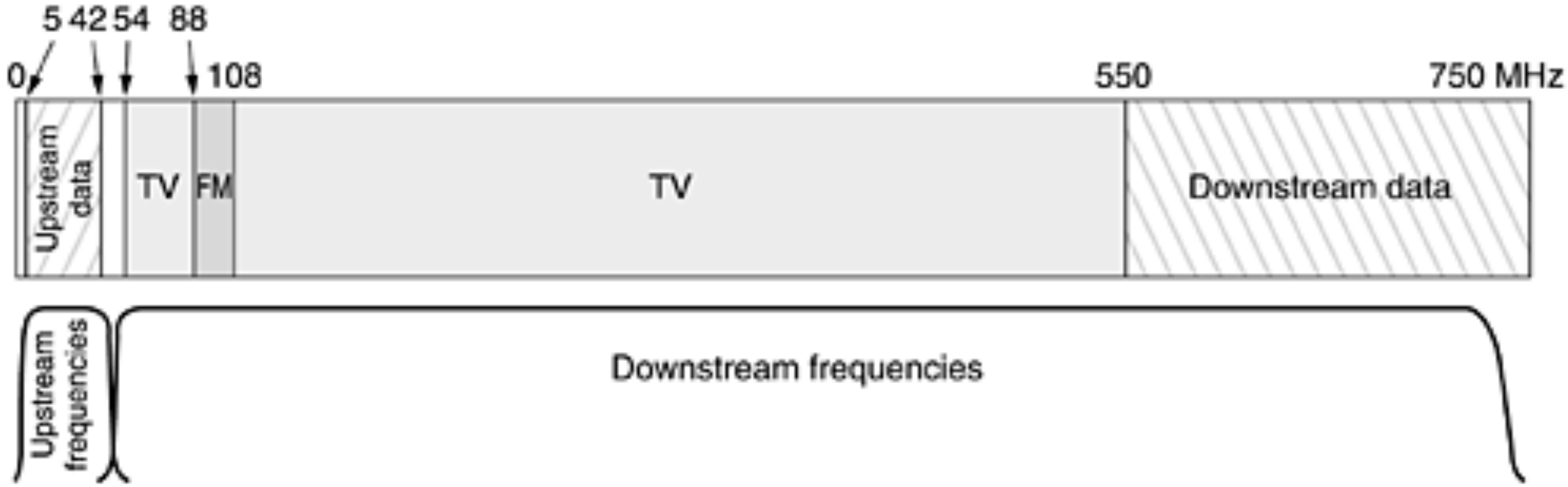

(a)

CMTS (Cable Modem Termination System)




(b)

# Cable Television for Internet



# Material Readings

- Chapters: 1 and 2 from Computer Networks (A. Tanenbaum)