ECE 453 – Introduction to Computer Networks

Lecture 3 – Physical Layer II

1

Physical Layer

- Services – transmit bits from sender to receiver.
- Transmission media
  - Guided: twisted pair, coax, fiber
  - Unguided (wireless): radio, microwave, infrared
- Examples of communication networks
  - Public switched telephone system
  - Cable television
  - Mobile telephone system

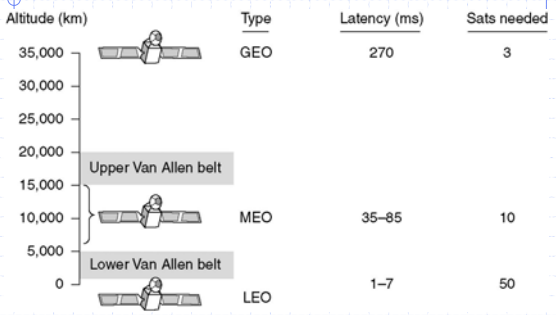
2

Communication Satellites

- Big microwave repeater in the sky
- Bent pipe
  - Incoming signal (upward beam) → transponders → amplification → rebroadcast (downward beam)
- Where to put satellites (orbital slot)?
  - Orbital period (Kepler's law)
  - Van Allen belts
- Which b/w to use (b/w slot)?
- Footprint and spot beam

3

Different Satellites



4

Principal Satellite Bands by ITU

Band	Downlink	Uplink	Bandwidth	Problems
L	1.5 GHz	1.6 GHz	15 MHz	Low bandwidth; crowded
S	1.9 GHz	2.2 GHz	70 MHz	Low bandwidth; crowded
C	4.0 GHz	6.0 GHz	500 MHz	Terrestrial interference
Ku	11 GHz	14 GHz	500 MHz	Rain
Ka	20 GHz	30 GHz	3500 MHz	Rain, equipment cost

5

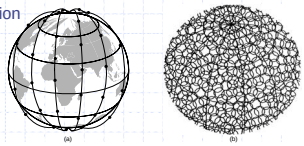
A Comparison

	GEO (Geostationary)	MEO (Medium-Earth Orbit)	LEO (Low-Earth Orbit)
Altitude	35,800 km	18,000 km	750 km
Orbital period	24 hrs	6 hrs	90 mins
RTT	270 ms	35-85ms	1-7ms
Recent development	VSAT 1962, Telstar		Iridium 1990 (66) Globalstar (48) Teledesic 2005 (30)
Application	Satellite TV	24 GPS	Internet, data, voice, paging, navigation

6

Low-Earth Orbit Satellites - Iridium

- Motorola's Iridium project (1990)
  - Launch 77 LEO's → 66
- Altitude: 750 km
  - six necklaces around the earth
  - 1628 moving cells cover the earth
  - One satellite every 32 degrees of latitude
- Application
  - Targeted at satellite telephone users in odd spaces
  - Data, voice, paging, navigation



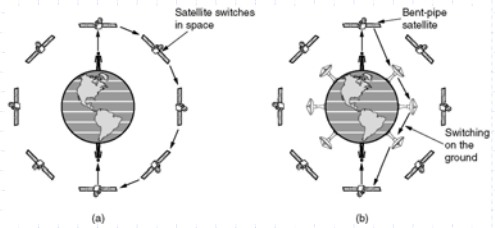
LEO - Teledesic

- Targeted at bandwidth hungry Internet users
- Year 2005
- 30 satellites
- Ka band
- Packet-switching in space
- Uplink: 100 Mbps, downlink: 720 Mbps

8

LEO - Globalstar

- (a) Relaying in space.
- (b) Relaying on the ground.



9

Satellite vs. Fibers

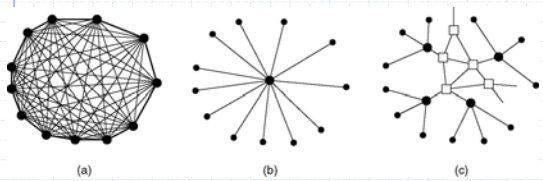
10

Public Switched Telephone System

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

11

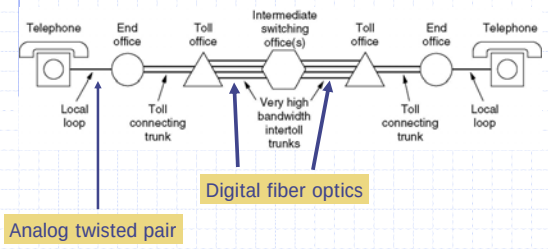
Structure of the Telephone System



(a) Fully-interconnected network (1876)
(b) Centralized switch (1878)
(c) Two-level hierarchy.

12

Structure of the Telephone System (2)

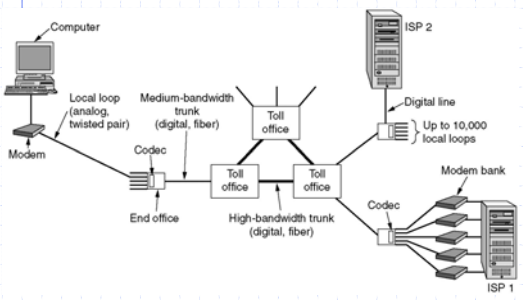


Digital fiber optics

Analog twisted pair

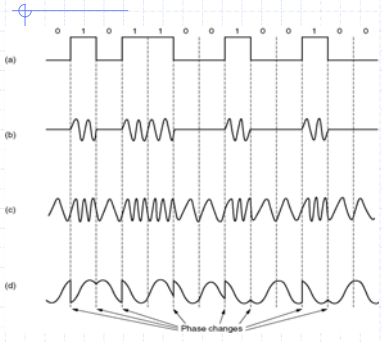
13

The Local Loop: Modems, ADSL, and Wireless



14

Modems - Modulation

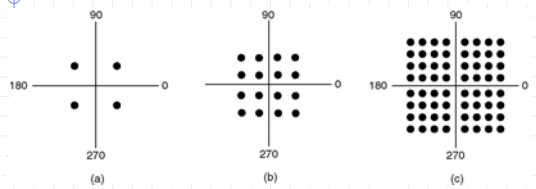


Sampling rate: 2400 baud line

Number of samples per second

15

Modems - Constellation Diagrams

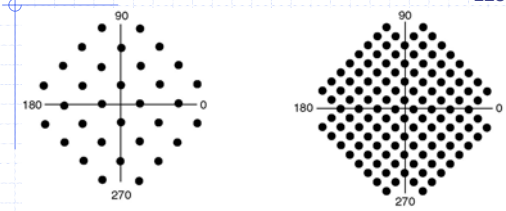


(a) QPSK.
(b) QAM-16.
(c) QAM-64.

16

Modems – With Error Correction

128 pts



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

17

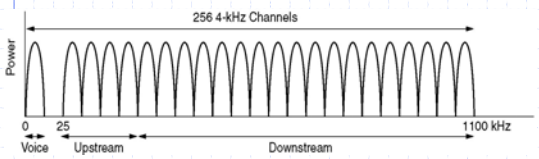
Theoretical Limits - Modem

- V.34: 28,800 bps (12 bits/sample)
- V.34 bis: 33,600bps (14 bits/sample)

- Why does standard modem stop at 33.6kbps? Theoretical limit 35kbps
- 56 kbps downstream (why 56 kbps?)

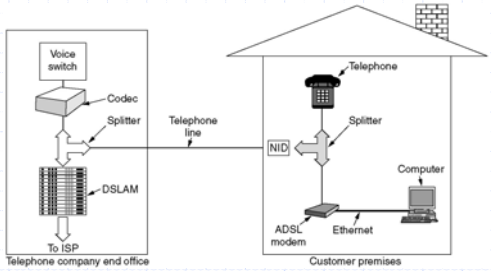
18

Digital Subscriber Lines



19

Digital Subscriber Lines (2)



20

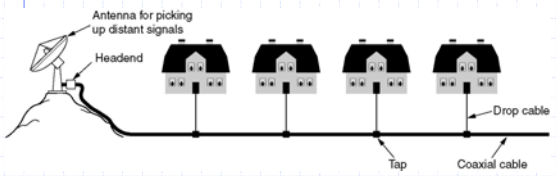
Cable Television

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

21

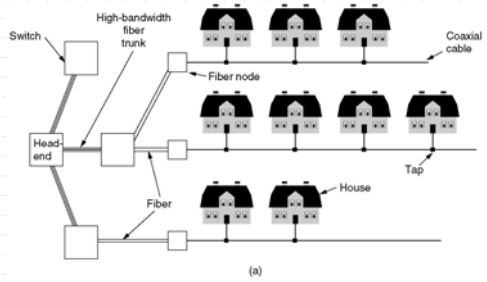
Community Antenna Television

An early cable television system.



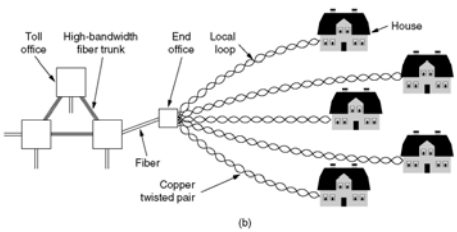
22

Internet over Cable



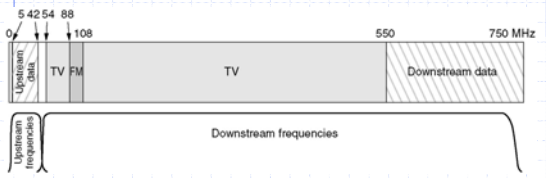
23

Internet over Telephone Line



24

Spectrum Allocation



25

Comparison

- DSL (1M – 10Mbps) (FDM)
  - Asymmetric digital subscriber line
  - High-speed downstream channel (Download): 50kHz ~ 1MHz, 8M
  - Medium-speed upstream channel (Upload): 4kHz ~ 50kHz, 1M
  - Traditional telephone line: 0 ~ 4kHz
- Cable Modem (HFC) (1M – 10Mbps)
  - Use cable (cable company becomes ISP)

26

The Mobile Telephone System

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

27

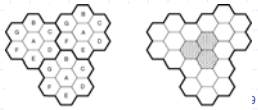
Mobile Telephone System

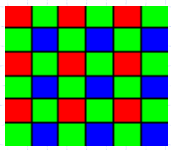
- US
  - The first system is mandated by the gov.
  - Digital generation: incompatible
  - Phone number (mixed) (pay for incoming call)
- Europe
  - Different countries have their own system
  - Digital generation: GSM
  - Special area code (caller pays)
  - Prepaid card
  - No monthly charge

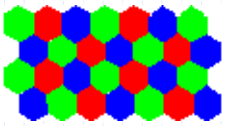
28

1st Generation – AMPS (Advanced Mobile Phone System)

- Bell Lab (1982)
- Frequency reuse in nearby cells
- Base station – radio relay
- MTSO (mobile telephone switching office)
- Handoff (300 ms)
- Each cell: 10-20 km







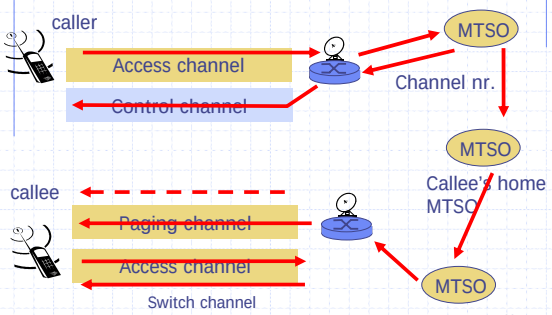
30

AMPS - Channel Categories

- 832 full-duplex channels
  - 824 – 849 MHz simplex channels
  - 869-894 MHz simplex channels
  - Each simplex channel 30 kHz wide
- The channels are divided into four categories:
  - Control (base to mobile) to manage the system (21)
  - 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

31

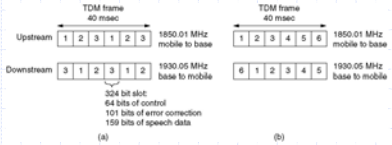
AMPS – Call Management



32

2nd Generation – D-AMPS

- Channel b/w: 30kHz
- Handset-side digitization and compression
  - 3 users share a freq. Pair (TDM)
  - Each pair supports 25 frames/sec
  - Each frame is divided into 6 time slots

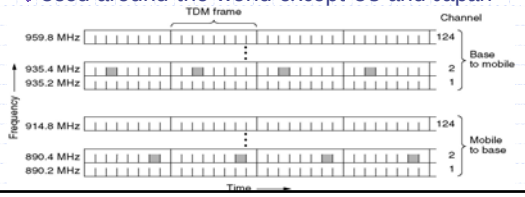


- MAHO (Mobile Assisted HandOff)

33

2nd Generation - GSM

- Channel b/w: 200 kHz (FDM)
  - 890.2MHz – 959.8MHz
  - 124 pairs of simplex channels
- Hold 8 users in each channel (TDM)
- Used around the world except US and Japan



2nd Generation - CDMA

- Neither FDM nor TDM is used
- CDM (code division multiplexing)
- B/w used: 1.25MHz
- Each bit time is subdivided into m "**chips**"
- Each station is assigned a unique m-bit code as a "**chip sequence**"
- Normally, 64 or 128 chips per bit

35

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 + B	S_3 = (0 0 –2 +2 0 –2 0 +2)
1 0 1 –	A + 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 + $\bar{C}$ + 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)

36

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.)
  - IMT – International Mobile Telecommunication
- Proposals
  - W-CDMA (Ericsson) (5MHz) → UMTS
  - CDMA2000 (Qualcomm) (5MHz)

37