Satellites, Telcos, Modems, and Valentine’s Day

CS158a
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Outline

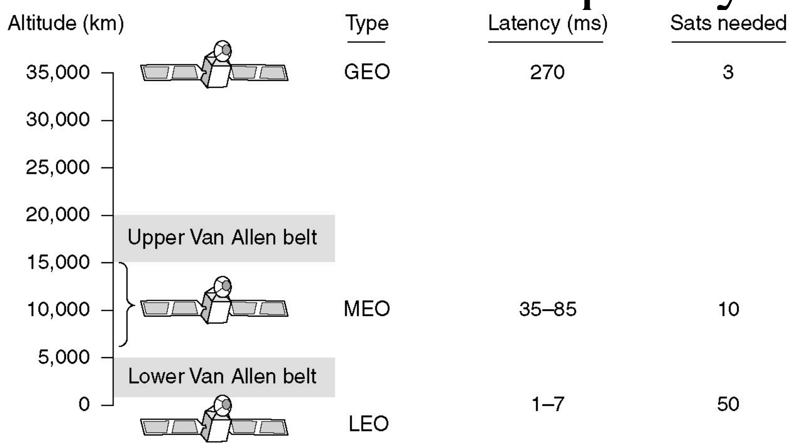
- Satellites
- Telephone system

Communication Satellites

- In the 1950 and 1960 various attempts were made to create long distance communication systems by bouncing signals off weather balloon.
- A system which bounced signals off moon was used by the Navy for ship to shore communication.
- Aside: The Apollo program left reflectors on moon for lasers to be able to target for length of day measurements. These are still in use. So we really did go to the moon.
- Unlike the moon, artificial satellites can amplify the communication signals.
- A communication satellite is essentially a few tons microwave repeater. It has several **transponders** that listen to a portion of the spectrum, which is then rebroadcast at another frequency downward. This is called a **bent pipe.** Power comes from solar panels.
- Because microwave has a shorter wavelength then radio, one can focus the uplink beam tightly getting the signal mainly to the satellite.
- The higher a satellite is the longer its orbit period will be. A **geostationary satellite** is one with a 24 hour period so that it always stays over the same part of the earth. (Invented by Arthur C. Clarke)

More on Communication Satellites

- Solar, lunar, and planetary gravity tend to knock a satellite out of orbit. This is counteracted by **station keeping** activities on the satellite (firing small rockets).
- When the fuel for these rockets runs out, the satellite tends to crash. So a satellite can last about 10 years in service.
- Allowed orbital slots of satellites are allocated by the ITU.
- The following are common orbital distances and microwave frequency bands are used by satellites:



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

More on Satellites

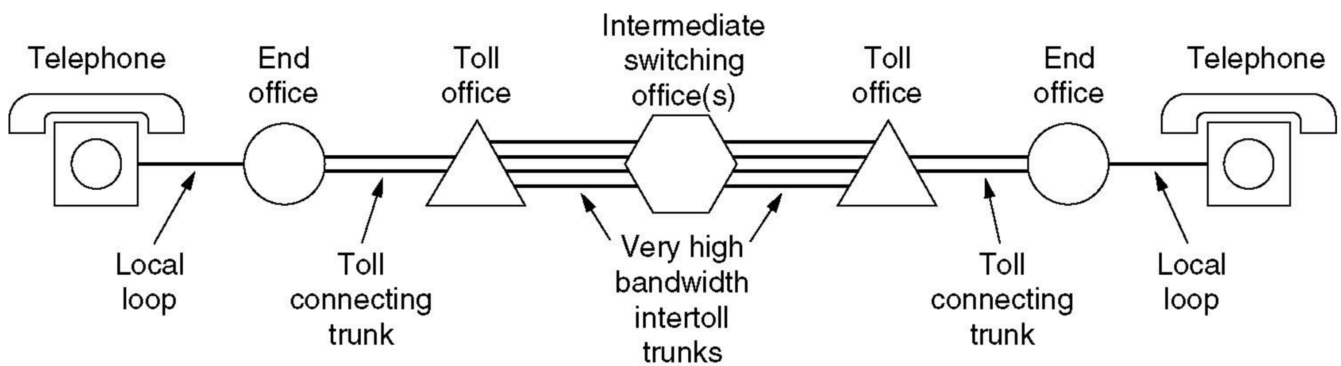
- Early satellites had a single downlink that hit a large fraction of the Earth's surface.
- Nowadays, satellites can have multiple beams each of which can be more focused on a geographic region: For example, one for lower 48 states, one for Hawaii, and one for Alaska.
- Very Small Aperture Terminals (VSAT, are small (1m or less) dishes which can be used to communicate with a satellite. They get about 19.2kbps up, and 512kbps down.
- Here are some example satellite systems for each altitude range:
  - **Geostationary Earth Orbit (GEO)** -- are often used for TV. For example, Canada's Anik satellites
  - **Medium Earth Orbit (MEO)** -- the 24 satellites of the global positioning system are MEO satellites.
  - **Low Earth Orbit (LEO)** -- Iridium, a Motorola-developed, failed satellite phone service using satellite relays; Globalstar, a bent-pipe phone satellite service; and Teledesic, a satellite-VSAT internet service are examples of LEO satellites.

Satellites versus Fiber

- Satellite does not offer as much bandwidth as fiber.
- As the telephone industry became deregulated, the price of fiber networks also became cheaper.
- Nevertheless, for airborne, sea, and remote settings satellite might be all that is available.
- Positioning and imaging can be done on a worldwide scale with satellite and this is not possible with cell-phone positioning systems.
- Also for things like TV or where it is useful to broadcast to lots of people at once, satellite is still very competitive.

Public Switched Telephone Network (PSTN)

- The telephone was patented in 1876 by Alexander Bell.
- You can go see early phones in Baddeck, Nova Scotia (Bell's summer home), near where I grew up.
- Phones were immediately popular and it soon became obvious that if you wanted to connect n phones in all possible ways, that you didn't want to maintain $O(n^2)$ wires.
- The rough way a cross-country phone call got routed at least until AT&T broke up looked like:



- For shorter distance calls you might not go through all of these steps

Major Components of the Telephone System

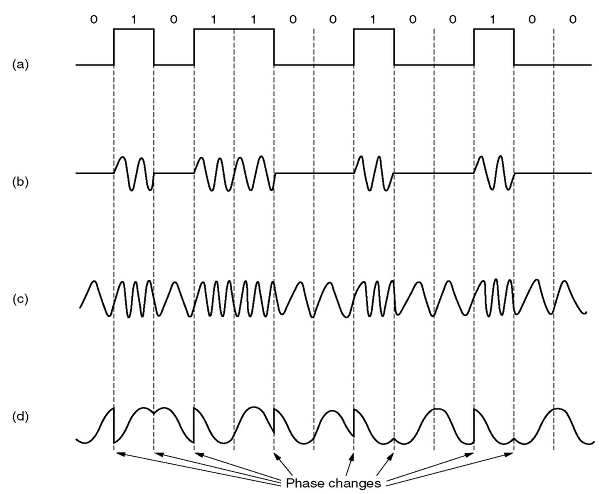
- **Local loops**
  - Analog twisted pairs connecting houses and businesses (1 to 10km) to **end offices**. There are 22,000 of these end offices in the US.
  - Each end office typically connects to several Toll Offices which in turn connect to several intermediate switching offices.
- **Trunks**
  - Digital fiber optics (sometimes also coax) connecting the switching offices and toll offices.
- **Switching offices**
  - Where calls are moved from one trunk to another

Analog Data Transmission

- We are now going to discuss how the phone system work and how it can be used to send computer data.
- An end office can have up to 10,000 local loops, numbered 0000-9999.
- It used to be that the three digit number after the area code exactly corresponded to the end office.
- Until recently, computers connected to ISPs via dial-up using a device called a modem to convert data to analog form to be sent over the local loop. The modem would place a phone call tot the ISP and then start sending data.
- An ISP might live on the other end of this phone call and have a bank of modems each connected to a different local loop.
- Analog signaling consisted of varying the voltage level of the line with time to represent an information stream.
- Analog signaling suffers from three major problems:
  - attenuation -- loss of power
  - distortion -- caused by speed difference in components of signal
  - noise -- unwanted energy on the line (for example, thermal source of energy)

Modems

- Digital signals require a wide frequency spectrum and so are unsuitable for a low bandwith 3kHz channel.
- So AC rather than DC signaling is used.
- A sine carrier wave is used, and either its amplitude, frequency or phase are modulated (the device that does this is called a modem:

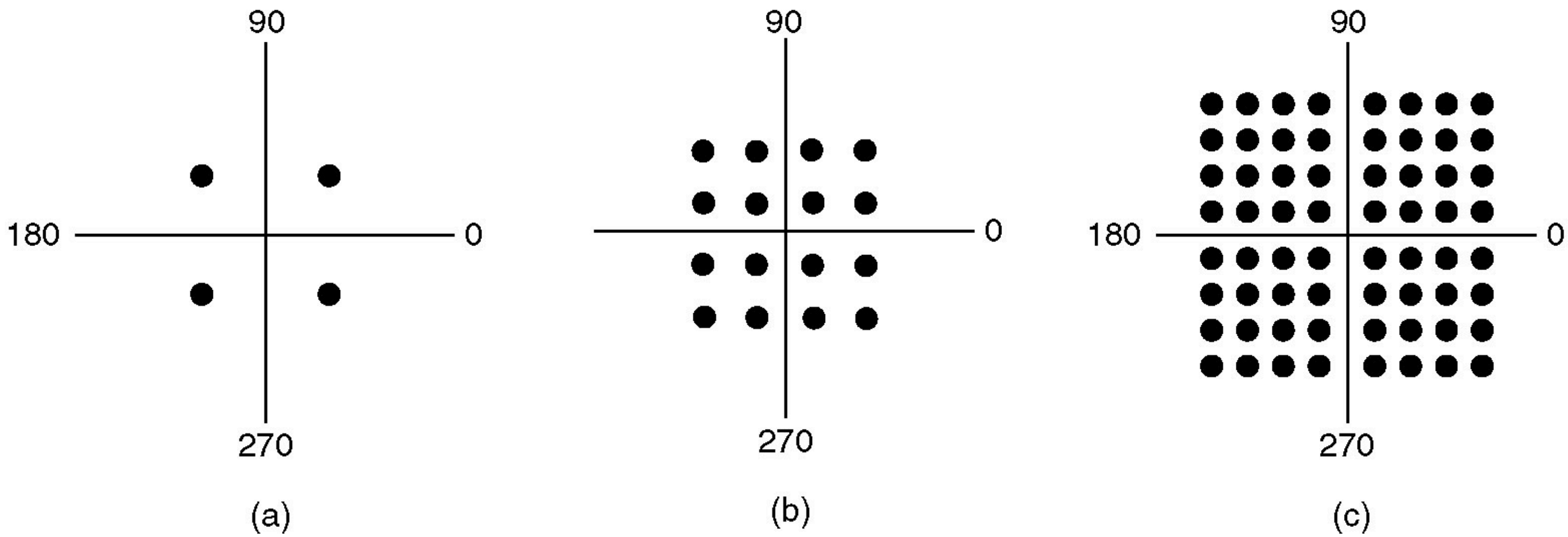


(a) A binary signal (b) Amplitude modulation (c) requency modulation (d) Phase modulation

More on Modems

- In the example of phase modulation on the last slide only the two angles of 0 and 180 degrees were used. Typically, one uses more angles.
- From Nyquist, we know there is no point in sampling a 3kHz line more than 6000 times second.
- **Baud** is the number of samples /second.
- Most modems sample 2400 baud and focus on getting more bits/sample. During each baud one symbol is sent. But a symbol might be made up on more than one voltage/phase shift so you can get higher than 2400bps.
- Four symbols with phase shifting is called **QPSK** (quadrature phase shift keying).
- All modern modems use a combination of the different modulation techniques to transmit multiple bits/baud.
- Often a dot pattern is used to represent combinations of voltages and amplitudes. (quadrature amplitude modulation)

Examples of Quadrature Amplitude Modulation



(a) QPSK.

(b) QAM-16.

(c) QAM-64.