Satellite Communications

Basics: How do Satellites Work

- Two Stations on Earth want to communicate through radio broadcast but are too far away to use conventional means.
- The two stations can use a satellite as a relay station for their communication
- One **Earth Station** sends a transmission to the satellite. This is called a **Uplink**.
- The satellite **Transponder** converts the signal and sends it down to the second earth station. This is called a **Downlink**.

Introduction:

- Satellite is a microwave repeater in the space.
- There are about 750 satellite in the space, most of them are used for communication.
- They are:
  - Wide area coverage of the earth’s surface.
  - Transmission delay is about 0.3 sec.
  - Transmission cost is independent of distance.
- It contains several transponders which listens to some portion of spectrum, amplifies the incoming signal and broadcasts it in another frequency to avoid interference with incoming signals.

Overview:

- Satellite technology has progressed tremendously over the last 50 years since Arthur C. Clarke first proposed its idea in 1945 in his article in Wireless World.
- Today, satellite systems can provide a variety of services including broadband communications, audio/video distribution networks, maritime navigation, worldwide customer service and support as well as military command and control.
- Satellite systems are also expected to play an important role in the emerging 4G global infrastructure providing the wide area coverage necessary for the realization of the "Optimally Connected Anywhere, Anytime" vision that drives the growth of modern telecom industry.

- The advantages of satellite communication over terrestrial communication are:
  - The coverage area of a satellite greatly exceeds that of a terrestrial system.
  - Transmission cost of a satellite is independent of the distance from the center of the coverage area.
  - Satellite to Satellite communication is very precise.
  - Higher Bandwidths are available for use.

- The disadvantages of satellite communication:
  - Launching satellites into orbit is costly.
  - Satellite bandwidth is gradually becoming used up.
  - There is a larger propagation delay in satellite communication than in terrestrial communication.

Geostationary Earth Orbit Satellites:

In 1945, the science fiction writer Arthur C. Clarke calculated that a satellite at an altitude of 35,800 km in a circular equatorial orbit would appear to remain motionless in the sky. so it would not need to be tracked. He went on to describe a complete communication system that used these (manned) geostationary satellites, including the orbits, solar panels, radio frequencies, and launch procedures. Unfortunately, he concluded that satellites were impractical due to the impossibility of putting power-hungry, fragile, vacuum tube amplifiers into orbit, so he never pursued this idea further, although he wrote some science fiction stories about it.

SATELLITE COMMUNICATION

The invention of the transistor changed all that, and the first artificial communication satellite, Telstar, was launched in July 1962. Since then, communication satellites have become a multibillion dollar business and the only aspect of outer space that has become highly profitable. These high-flying satellites are often called GEO (Geostationary Earth Orbit) satellites.

With current technology, it is unwise to have geostationary satellites spaced much closer than 2 degrees in the 360-degree equatorial plane, to avoid interference. With a spacing of 2 degrees, there can only be 360/2 = 180 of these satellites in the sky at once. However, each transponder can use multiple frequencies and polarizations to increase the available bandwidth.

SATELLITE COMMUNICATION

Modem satellites can be quite large, weighing up to 4000 kg and consuming several kilowatts of electric power produced by the solar panels. The effects of solar, lunar, and planetary gravity tend to move them away from their assigned orbit slots and orientations, an effect countered by on-board rocket motors. **This fine-tuning activity is called station keeping.** However, when the fuel for the motors has been exhausted, typically in about 10 years, the satellite drifts and tumbles helplessly, so it has to be turned off. Eventually, the orbit decays and the satellite reenters the atmosphere and burns up or occasionally crashes to earth.

Orbit slots are not the only bone of contention. Frequencies are, too, because the downlink transmissions interfere with existing microwave users. Consequently, ITU has allocated certain frequency bands to satellite users. The C band was the first to be designated for commercial satellite traffic. Two frequency ranges are assigned in it, the lower one for downlink traffic (from the satellite) and the upper one for uplink traffic (to the satellite). To allow traffic to go both ways at the same time, two channels are required, one going each way. These bands are already overcrowded because they are also used by the common carriers for terrestrial microwave links. The L and S bands were added by international agreement in 2000. However, they are narrow and crowded.

SATELLITE COMMUNICATION

DEPARTMENT OF COMPUTER SCIENCE, SARDAR PATEL UNIVERSITY, V. V. NAGAR.

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

The next highest band available to commercial telecommunication carriers is the Ku (K under) band. This band is not (yet) congested, and at these frequencies, satellites can be spaced as close as 1 degree. However, another problem exists: rain. Water is an excellent absorber of these short microwaves. Fortunately, heavy storms are usually localized, so using several widely separated ground stations instead of just one circumvents the problem but at the price of extra antennas, extra cables, and extra electronics to enable rapid switching between stations.

Bandwidth has also been allocated in the Ka (K above) band for commercial. satellite traffic, but the equipment needed to use it is still expensive. In addition to these commercial bands, many government and military bands also exist.

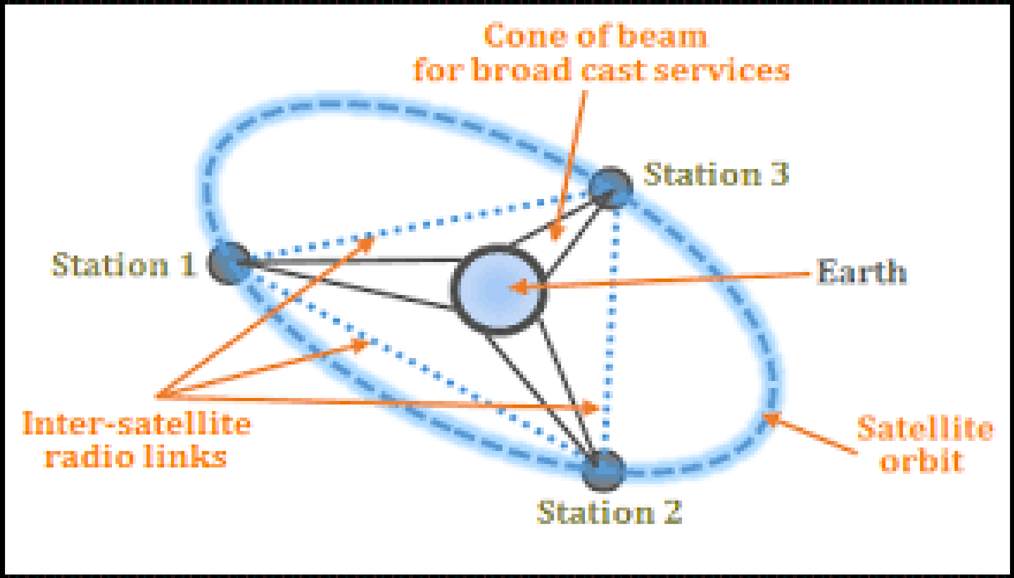
SATELLITE COMMUNICATION

A modern satellite has around 40 transponders, each with an 80-MHz band-width. Usually, each transponder operates as a bent pipe, but recent satellites have some on-board processing capacity, allowing more sophisticated operation: In the earliest satellites, the division of the transponders into channels was static: the bandwidth was simply split up into fixed frequency bands. Nowadays, each transponder beam is divided into time slots, with various users taking turns.

In satellite communications, FOOT PRINT means portion of the Earth's surface over which a satellite antenna delivers a specified amount of signal power .

The first geostationary satellites had a single spatial beam that illuminated about 1/3 of the earth's surface, called its footprint. Each satellite is equipped with multiple antennas and multiple transponders. Each downward beam can be focused on a small geographical area, so multiple upward and downward transmissions can take place simultaneously. Typically, these so-called spot beams are elliptically shaped, and can be as small as a few hundred km in diameter. A communication satellite for the United States typically has one wide. beam for the contiguous 48 states.

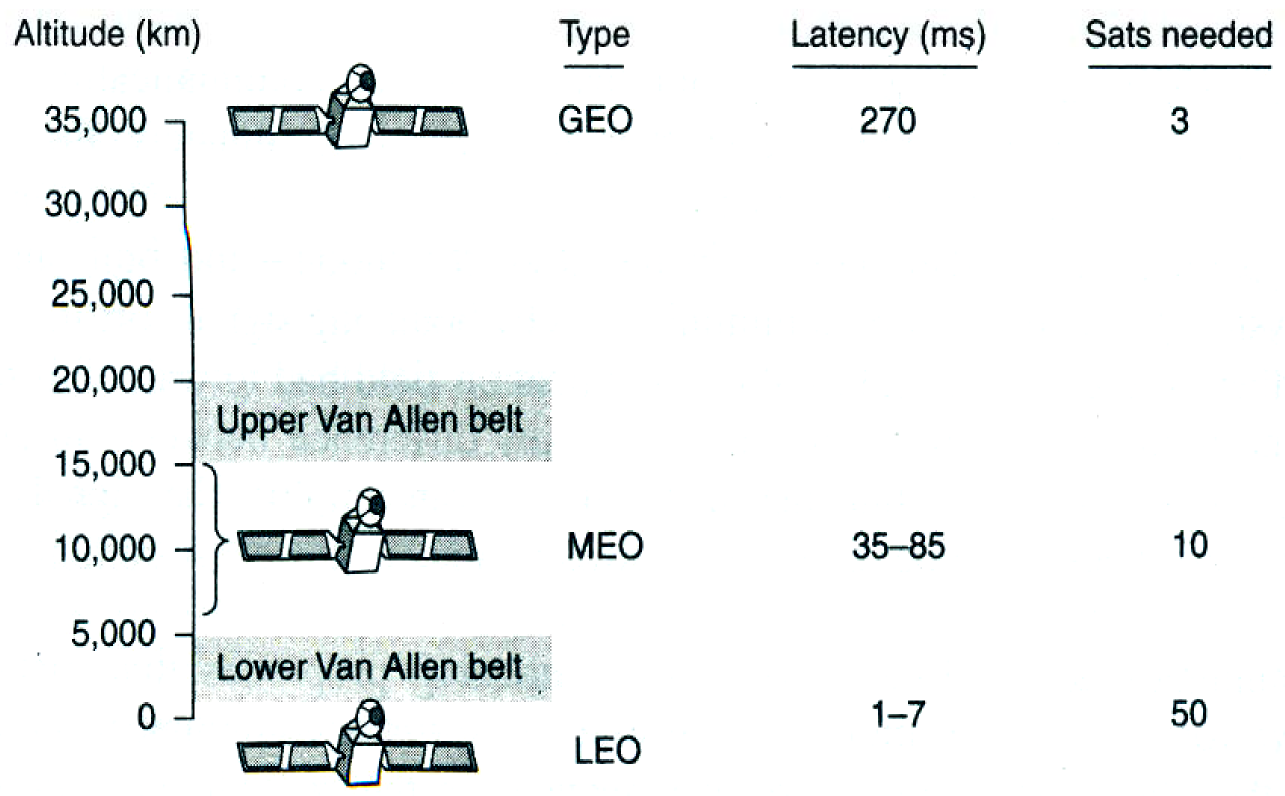
SATELLITE COMMUNICATION



A new development in the communication satellite world is the development of low-cost microstations, sometimes called VSATs (Very Small Aperture Terminals). These tiny terminals have 1-meter or smaller antennas and can put out about 1 watt of power. The uplink is generally good for 19.2 kbps, but the downlink is more often 512 kbps or more. Direct broadcast satellite television uses this technology for one-way transmission.

SATELLITE COMMUNICATION

DEPARTMENT OF COMPUTER SCIENCE, SARDAR PATEL UNIVERSITY, V. V. NAGAR.



Communication satellites and some of their properties, including altitude above the earth, round-trip delay time, and number of satellites needed for global coverage.

SATELLITE COMMUNICATION

An important property of satellites is that they are inherently broadcast media. It does not cost more to send a message to thousands of stations within a transponder's footprint than it does to send to one. For some applications, this property is very useful. For example, one could imagine a satellite broadcasting popular Web pages to the caches of a large number of computers spread over a wide area. Even when broadcasting can be simulated with point-to-point lines, satellite broadcasting may be much cheaper. On the other hand, from a security and privacy point of view, satellites are a complete disaster: everybody can hear everything. Encryption is essential when security is required.

SATELLITE COMMUNICATION

Satellites also have the property that the cost of transmitting a message is independent of the distance traversed. A call across the ocean costs no more to service than a call across the street. Satellites also have excellent error rates and can be deployed almost instantly, a major consideration for military communication.

Medium-Earth Orbit Satellites :

At much lower altitudes, between the two Van Allen belts, we find the MEO (Medium-Earth Orbit) satellites. As viewed from the earth, these drift slowly in longitude, taking something like 6 hours to circle the earth. Accordingly, they must be tracked as they move through the sky. Because they are lower than the GEOs, they have a smaller footprint on the ground and require less powerful transmitters to reach them. Currently they are not used for telecommunications, so we will not examine them further here. The 24 GPS (Global Positioning System) satellites orbiting at about 18,000 km are examples of MEO satellites.

Low-Earth Orbit Satellites :

Moving down in altitude, we come to the LEO (Low-Earth Orbit) satellites. Due to their rapid motion, large numbers of them are needed for a complete system. On the other hand, because the satellites are so close to the earth, the ground stations do not need much power, and the round-trip delay is only a few milliseconds. Here, we will examine three examples, two aimed at voice communication and one aimed at Internet service.

Iridium :

As mentioned above, for the first 30 years of the satellite era, low-orbit satellites were rarely used because they zip into and out of view so quickly. In 1990, Motorola broke new ground by filing an application asking for permission to launch 77 low-orbit satellites for the Iridium project (element 77 is iridium). The plan was later revised to use only 66 satellites, so the project should have been renamed Dysprosium (element 66), but that probably sounded too much like a disease. The idea was that as soon as one satellite went out of view, another would replace it. This proposal set off a feeding frenzy among other communication companies. All of a sudden, everyone wanted to launch a chain of low-orbit satellites.

SATELLITE COMMUNICATION

After seven years of cobbling together partners and financing, the partners launched the Iridium satellites in 1997. Communication service began in November 1998. Unfortunately, the commercial demand for large, heavy satellite telephones was negligible because the mobile phone network had grown spectacularly since 1990. The satellites and other assets (worth $5 billion) were subsequently purchased by an investor for $25 million at a kind of extraterrestrial garage sale. The Iridium service was restarted in March 2001.

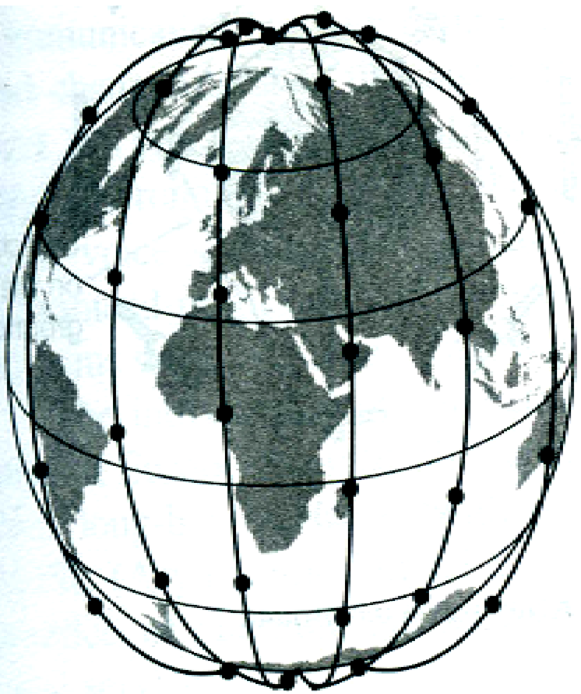
SATELLITE COMMUNICATION

Iridium's business was (and is) providing worldwide telecommunication service using hand-held devices that communicate directly with the Iridium satellites. It provides voice, data, paging, fax, and navigation service everywhere on land, sea, and air. Customers include the maritime, aviation, and oil exploration industries, as well as people traveling in parts of the world lacking a telecommunications infrastructure (e.g., deserts, mountains, jungles, and some Third World countries).

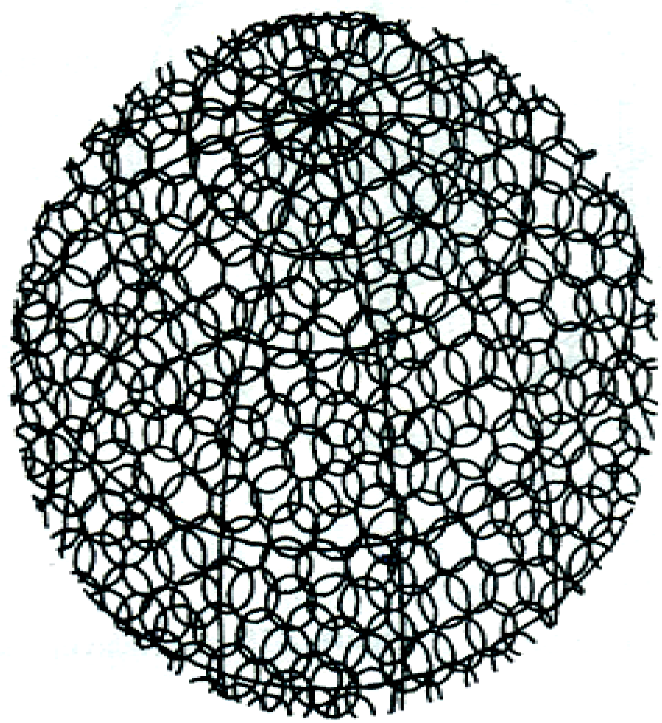
SATELLITE COMMUNICATION

The Iridium satellites are positioned at an altitude of 750 km, in circular polar orbits. They are arranged in north-south necklaces, with one satellite every 32 degrees of latitude. With six satellite necklaces, the entire earth is covered, as suggested by figure-A. People not knowing much about chemistry can think of this arrangement as a very, very big dysprosium atom, with the earth as the nucleus and the satellites as the electrons.

SATELLITE COMMUNICATION



(a)



(b)

(a) The Iridium satellites form six necklaces around the earth
(b) 1628 moving cells cover the earth

SATELLITE COMMUNICATION

Each satellite has a maximum of 48 cells (spot beams), with a total of 1628 cells over the surface of the earth, as shown in Figure (b). Each satellite has a capacity of 3840 channels, or 253,440 in all. Some of these are used for paging and navigation, while others are used for data and voice.

An interesting property of Iridium is that communication between distant customers takes place in space, with one satellite relaying data to the next one, as *illustrated in figure (c)*. Here we see a caller at the North Pole contacting a satellite directly overhead. The call is relayed via other satellites and finally sent down to the callee at the South Pole.

Globalstar :

An alternative design to Iridium is Globalstar. It is based on 48 LEO satellites but uses a different switching scheme than that of Iridium. Whereas Iridium relays calls from satellite to satellite, which requires sophisticated switching equipment in the satellites, Globalstar uses a traditional bent-pipe design. The call originating at the North Pole is sent back to earth and picked up by the large ground station at Santa's Workshop. The call is then routed via a terrestrial network to the ground station nearest the callee and delivered by a bent-pipe connection as shown. The advantage of this scheme is that it puts much of the complexity on the ground, where it is easier to manage.

Also, the use of large ground station antennas that can put out a powerful signal and receive a weak one means that lower-powered telephones can be used. After all, the telephone puts out only a few milliwatts of power, so the signal that gets back to the ground station is fairly weak, even after having been amplified by the satellite.

Teledesic :

Iridium is targeted at telephone users located in odd places. Next example, Teledesic, is targeted at bandwidth-hungry Internet users all over the world. It was conceived in 1990 by mobile phone pioneer Craig McCaw and Microsoft founder Bill Gates, who was unhappy with the snail's pace at which the world's telephone companies were providing high bandwidth to computer users. The goal of the Teledesic system is to provide millions of concurrent Internet users with an uplink of as much as 100 Mbps and a downlink of up to 720 Mbps using a small, fixed, VSAT-type antenna, completely bypassing the telephone sys-tem. To telephone companies, this is pie-in-the-sky.

SATELLITE COMMUNICATION

The original design was for a system consisting of 288 small-footprint satellites arranged in 12 planes just below the lower Van Allen belt at an altitlide of 1350 kms. This was later changed to 30 satellites with larger footprints. Transmission occurs in the relatively uncrowded and high-bandwidth Ka band. The system is packet-switched in space, with each satellite capable of routing packets to its neighboring satellites. When a user needs bandwidth to send packets, it is requested and assigned dynamically in about 50 msec. The system is scheduled to go live in 2005 if all goes as planned.