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Research Paper

THE DYNAMICS OF GROWTH IN WORLDWIDE SATELLITE COMMUNICATION CAPACITY

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INTRODUCTION

A satellite is an object which has been placed into orbit by human endeavor. Such objects are sometimes called artificial satellites to distinguish them from natural satellites such as the Moon.

The first artificial satellite, Sputnik 1, was launched by the Soviet Union in 1957. By 2010 thousands of satellites have been launched into orbit around the Earth. These originate from more than 50 countries and have used the satellite launching capabilities of ten nations. A few hundred satellites are currently operational, whereas thousands of unused satellites and satellite fragments orbit the Earth as space debris. A few space probes have been placed into orbit around other bodies and become artificial satellites to the Moon, Venus, Mars, Jupiter and Saturn.

Satellites are used for a large number of purposes. Common types include military (spy) and civilian Earth observation satellites, communication satellites, navigation satellites, weather satellites, and research satellites. Space stations and human spacecraft in orbit are also satellites. Satellite orbits vary greatly, depending on the purpose of the satellite, and are classified in a number of ways. Well-known (overlapping) classes include low Earth orbit, polar orbit, and geostationary orbit.

Satellites are usually semi-independent computer controlled systems. Satellite subsystems attend many tasks, such as power generation, thermal control, telemetry, attitude control and orbit control.

HISTORY OF ARTIFICIAL SATELLITES

The first artificial satellite was Sputnik 1, launched by the Soviet Union on October 4 1957, and initiating the Soviet Sputnik program, with Sergei Korolev as chief designer and KerimKerimov as his assistant. This in turn triggered the Space Race between the Soviet Union and the United States.

Sputnik 1 helped to identify the density of high atmospheric layers through measurement of its orbital change and provided data on

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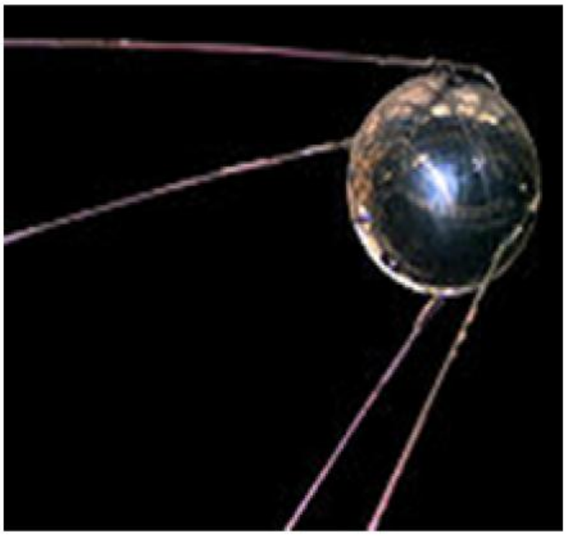
Figure 1: Sputnik 1



radio-signal distribution in the ionosphere. Because the satellite's body was filled with pressurized nitrogen, Sputnik 1 also provided the first opportunity for meteoroid detection, as a loss of internal pressure due to meteoroid penetration of the outer surface would have been evident in the temperature data sent back to Earth. The unanticipated announcement of Sputnik 1's success precipitated the Sputnik crisis in the United States and ignited the so-called Space Race within the Cold War.

Sputnik 2 was launched on November 3, 1957 and carried the first living passenger into orbit, a dog named Laika.

In May, 1946, Project RAND had released the Preliminary Design of a Experimental World-Circling Spaceship, which stated, "A satellite vehicle with appropriate instrumentation can be expected to be one of the most potent scientific tools of the Twentieth Century. The United States had been considering launching orbital satellites since 1945 under the Bureau of Aeronautics of the United States Navy. The United States Air Force's Project RAND eventually released the above report, but did not believe that the satellite was a potential military weapon; rather, they considered it to be a tool for science, politics, and propaganda. In 1954, the Secretary of Defense stated, "I know of no American satellite program."

Following pressure by the American Rocket Society, the National Science Foundation, and the International Geophysical Year, military interest picked up and in early 1955 the Air Force and Navy were working on Project Orbiter, which involved using a Jupiter C rocket to launch a satellite. The project succeeded, and Explorer 1 became the United States' first satellite on January 31, 1958.

In June 1961, three-and-a-half years after the launch of Sputnik 1, the Air Force used resources of the United States Space Surveillance Network to catalog 115 Earth-orbiting satellites.

The largest artificial satellite currently orbiting the Earth is the International Space Station.

FREQUENCY BANDS

Different kinds of satellites use different frequency bands.

- L-Band: 1 to 2 GHz, used by MSS
- S-Band: 2 to 4 GHz, used by MSS, NASA, deep space research
- C-Band: 4 to 8 GHz, used by FSS
- X-Band: 8 to 12.5 GHz, used by FSS and in terrestrial imaging, ex: military and meteorological satellites

- Ku-Band: 12.5 to 18 GHz: used by FSS and BSS (DBS)
- K-Band: 18 to 26.5 GHz: used by FSS and BSS
- Ka-Band: 26.5 to 40 GHz: used by FSS

TYPES

- Anti-Satellite weapons/"Killer Satellites" are satellites that are armed, designed to take out enemy warheads, satellites, other space assets. They may have particle weapons, energy weapons, kinetic weapons, nuclear and/or conventional missiles and/or a combination of these weapons.
- Astronomical satellites are satellites used for observation of distant planets, galaxies, and other outer space objects.
- Biosatellites are satellites designed to carry living organisms, generally for scientific experimentation.
- Communications satellites are satellites stationed in space for the purpose of telecommunications. Modern communications satellites typically use geosynchronous orbits, Molniya orbits or Low Earth orbit.
- Miniaturized satellites are satellites of unusually low weights and small sizes.New classifications are used to categorize these satellites: minisatellite (500-100 kg), microsatellite (below 100 kg), and nanosatellite (below 10 kg).
- Navigational satellites are satellites which use radio time signals transmitted to enable mobile receivers on the ground to determine their exact location. The relatively clear line of sight between the satellites and receivers on the ground, combined with ever-improving electronics, allows satellite navigation systems to measure location to accuracies on the order of a few meters in real time.
- Reconnaissance satellites are Earth observation satellite or communications satellite deployed for military or intelligence applications. Very little is known about the full power of these satellites, as governments who operate them usually keep information pertaining to their reconnaissance satellites classified.
- Earth observation satellites are satellites intended for non-military uses such as environmental monitoring, meteorology, map making, etc. (see especially Earth Observing System).
- Tether satellites are satellites which are connected to another satellite by a thin cable called a tether.
- Weather satellites are primarily used to monitor Earth's weather and climate.

Figure 2: MILSTAR: A Communication Satellite

ORBIT TYPES

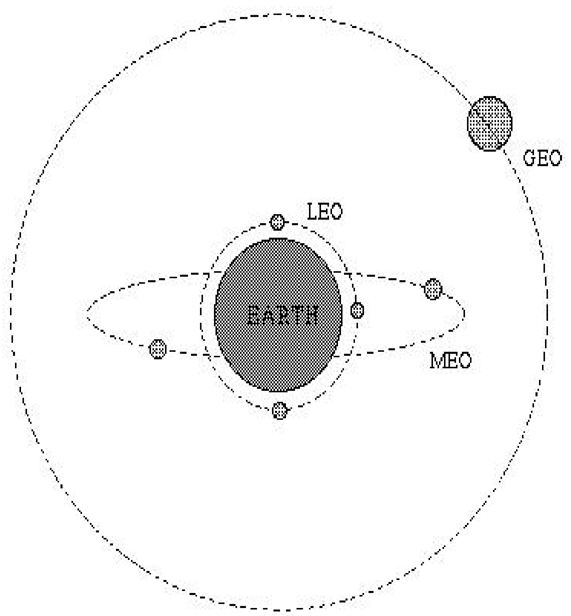
Orbits

- LEO: Low Earth Orbit.
- MEO: Medium Earth Orbit
- GEO: Geostationary Earth Orbit

The commonly used altitude classifications are Low Earth Orbit (LEO), Medium Earth Orbit (MEO) and Geostationary Earth Orbit (GEO). Low Earth orbit is any orbit below 2000 km, and Medium Earth Orbit is any orbit higher than that but still below the altitude for geosynchronous orbit at 35786 km.

Orbits of Satellite

Figure 3: Orbits of Satellite



Low Earth Orbit (LEO)

- LEO satellites are much closer to the earth than GEO satellites, ranging from 500 to 1,500 km above the surface.
- LEO satellites don't stay in fixed position relative to the surface, and are only visible for 15 to 20 minutes each pass

Advantages

1. A LEO satellite's proximity to earth compared to a GEO satellite gives it a better signal strength and less of a time delay, which makes it better for point to point communication.
2. A LEO satellite's smaller area of coverage is less of a waste of bandwidth.

Disadvantages

1. A network of LEO satellites is needed, which can be costly
2. LEO satellites have to compensate for Doppler shifts cause by their relative movement.
3. Atmospheric drag affects LEO satellites, causing gradual orbital deterioration.

Geostationary Earth Orbit (GEO)

- These satellites are in orbit 35,863 km above the earth's surface along the equator.
- Objects in Geostationary orbit revolve around the earth at the same speed as the earth rotates. This means GEO satellites remain in the same position relative to the surface of earth.

Advantages

1. A GEO satellite's distance from earth gives it a large coverage area, almost a fourth of the earth's surface.
2. GEO satellites have a 24 hour view of a particular area.

These factors make it ideal for satellite broadcast and other multipoint applications.

Disadvantages

1. A GEO satellite's distance also cause it to have both a comparatively weak signal and a time delay in the signal, which is bad for point to point communication.
2. GEO satellites, centered above the equator, have difficulty broadcasting signals to near Polar Regions.

- At the Geostationary orbit the satellite covers 42.2% of the earth's surface.
- Theoretically 3 geostationary satellites provide 100% earth coverage.

Medium Earth Orbit (MEO)

- A MEO satellite is in orbit somewhere between 8,000 km and 18,000 km above the earth's surface.
- MEO satellites are similar to LEO satellites in functionality.
- MEO satellites are visible for much longer periods of time than LEO satellites, usually between 2 to 8 hours.
- MEO satellites have a larger coverage area than LEO satellites.

Advantage

1. A MEO satellite's longer duration of visibility and wider footprint means fewer satellites are needed in a MEO network than a LEO network.

Disadvantage

1. A MEO satellite's distance gives it a longer time delay and weaker signal than a LEO satellite, though not as bad as a GEO satellite.

SATELLITE MODULES

The satellite's functional versatility is imbedded within its technical components and its operations characteristics. Looking at the "anatomy" of a typical satellite, one discovers two modules. Note that some novel architectural concepts such as Fractionated Spacecraft somewhat upset this taxonomy.

Spacecraft Bus or Service Module

This bus module consists of the following subsystems:

The Structural Subsystems

The structural subsystem provides the mechanical base structure, shields the satellite from extreme temperature changes and micro-meteorite damage, and controls the satellite's spin functions.

The Telemetry Subsystems (aka Command and Data Handling, C&DH)

The telemetry subsystem monitors the on-board equipment operations, transmits equipment operation data to the earth control station, and receives the earth control station's commands to perform equipment operation adjustments.

The Power Subsystems

The power subsystem consists of solar panels and backup batteries that generate power when the satellite passes into the earth's shadow. Nuclear power sources (Radioisotope thermoelectric generators) have been used in several successful satellite programs including the Nimbus program (1964-1978).

The Thermal Control Subsystems

The thermal control subsystem helps protect electronic equipment from extreme temperatures due to intense sunlight or the lack of sun exposure on different sides of the satellite's body (e.g., Optical Solar Reflector)

The Attitude and Orbit Controlled Control Subsystems

Main Article: Attitude control

The attitude and orbit controlled subsystem consists of small rocket thrusters that keep the satellite in the correct orbital position and keep antennas positioning in the right directions.

Communication Payload: The second major module is the communication payload, which is made up of transponders. Transponders are capable of:

- Receiving uplinked radio signals from earth satellite transmission stations (antennas).
- Amplifying received radio signals
- Sorting the input signals and directing the output signals through input/output signal multiplexers to the proper downlink antennas for retransmission to earth satellite receiving stations (antennas).

CAPACITY ALLOCATION

- FDMA
  - FAMA-FDMA
  - DAMA-FDMA
- TDMA

FDMA

- Satellite frequency is already broken into bands, and is broken in to smaller channels in Frequency Division Multiple Access (FDMA).
- Overall bandwidth within a frequency band is increased due to frequency reuse (a frequency is used by two carriers with orthogonal polarization).
- The number of sub-channels is limited by three factors:
- Thermal noise (too weak a signal will be affected by background noise).
- Intermodulation noise (too strong a signal will cause noise).
- Crosstalk (cause by excessive frequency reusing).
- FDMA can be performed in two ways:

Fixed-Assignment Multiple Accesses (FAMA): The sub-channel assignments are of a fixed allotment. Ideal for broadcast satellite communication.

Demand-Assignment Multiple Accesses (DAMA): The sub-channel allotment changes based on demand. Ideal for point to point communication.

TDMA

- TDMA (Time Division Multiple Access) breaks a transmission into multiple time slots, each one dedicated to a different transmitter.
- TDMA is increasingly becoming more widespread in satellite communication.
- TDMA uses the same techniques (FAMA and DAMA) as FDMA does.

Advantages of TDMA Over FDMA

- Digital equipment used in time division multiplexing is increasingly becoming cheaper.

- There are advantages in digital transmission techniques.

Ex: Error correction.

Lack of intermodulation noise means increased efficiency.

APPLICATIONS

- Amateur radio
  - – Access to OSCAR satellite.
  - – Low earth orbits.
- Internet
  - – High Speed.
  - – Useful for far away places.
- Military
  - – Uses geostationary satellites.
  - – Example: The Defense Satellite Communications System (DSCS).

CONCLUSION

Satellites remain the best utilization used for communications due to their speed and other advantages.