Dallo Spazio alla Rete

Un Cloud di dati e servizi

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Un Cloud di dati e servizi

La cosa più bella che possiamo sperimentare è il mistero; è la fonte di ogni vera arte e di ogni vera scienza

Albert Einstein

La collana raccoglie opere relative alla comunicazione e alla tecnologia via satellite, allo sviluppo di nuove piattaforme satellitari multi fascio, alla interconnessione tra il satellite e la rete di comunicazione terrestre 5G, agli sviluppi tecnologici e di servizio con la continua evoluzione della banda larga spaziale. Le ricerche si concentrano sui sistemi di telecomunicazione e osservazione della terra sia per satelliti GEO (orbita geostazionaria a 36.000 Km) sia per satelliti MEO (su orbite tra 10.000 e 20.000 Km) che per satelliti LEO (orbite basse tra i 500 e gli 800 Km). Le tecnologie studiate possono essere sia a radiofrequenza che ottiche per le interconnessioni spazio–terra e spazio–spazio (Inter Satellite Links ISL). Lo sviluppo dei servizi con l'integrazione dello spazio con la rete 5G costituisce una rete cloud nello spazio accessibile a tutti gli utenti.

Web content

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Chapter 1

Satellite technology fundamentals

Communication satellites, whether in geostationary Earth orbit (GEO) or non-GEO, provide an effective platform to relay radio signals between points on the ground. The users who employ these signals enjoy a broad spectrum of telecommunication services on the ground, at sea, and in the air. In recent years, such systems have become practical to the point where a typical household can have its own satellite dish. That dish can receive a broad range of television programming and provide broadband access to the Internet. These satellite systems compete directly in some markets with the more established broadcasting media, including over-the-air TV and cable TV, and with high-speed Internet access services like digital subscriber line (DSL) and cable modems.

In addition, GEO and non–GEO satellites will continue to offer unique benefits for users on the go with such mobile services as twoway voice and data, and digital audio broadcasting. The accelerated installation of undersea fiber optics that accompanied the Internet and telecom boom of the late 1990s put more capacity into service than markets could quickly absorb.

Curiously, these new operators claimed that satellites were obsolescent. Quite to the contrary, satellite communication continues to play an increasing role in backbone networks that extend globally. Just how well we employ satellites to compete in markets depends on our ability to identify, develop, and manage the associated networks and applications.Satellite communication applications can establish a solid business for companies that know how to work out the details to satisfy customer needs.

1.1. Evolution of Satellite Technology and Applications

Communication satellites, whether in geostationary Earth orbit (GEO) or non-GEO, provide an effective platform to relay radio signals between points on the ground. The users who employ these signals enjoy a broad spectrum of telecommunication services on the ground, at sea, and in the air.

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Curiously, these new operators claimed that satellites were obsolescent. Quite to the contrary, satellite communication continues to play an increasing role in backbone networks that extend globally. Just how well we employ satellites to compete in markets depends on our ability to identify, develop, and manage the associated networks and applications.

To this end, this Training shows how satellite technology can meet a variety of human needs, the ultimate measure of its effectiveness. These have progressed significantly since the late 1980s; however, the basic principles remain the same.

Satellite communication applications extend throughout human activity—both occupational and recreational. Many large companies have built their communications foundations on satellite services such as cable TV, direct-to-home broadcasting satellite (DBS), private data networks, information distribution, maritime communications, and remote monitoring.

For others, satellites have become a hidden asset by providing a reliable communications infrastructure. In the public and military sectors, satellite applications are extremely effective in situations where terrestrial lines and portable radio transceivers are not available or ineffective for a variety of reasons.

The composition of satellite communication markets has changed over the years. Initially, the primary use was to extend the worldwide telephony net. In the 1980s, video transmission established itself as the hottest application, with data communications gaining an important second place position. Voice services are no longer the principal application in industrialized countries but retain their value in rural environments and in the international telecommunications field.

Special purpose voice applications like mobile telephone and emergency communications continue to expand. The very fact that high-capacity fiber optic systems exist in many countries and extend to major cities worldwide makes satellite applications that much more important as a supplementary and backup medium.

Satellites are enjoying rapid adoption in regions where fixed installations are impractical. For example, ships at sea no longer employ the Morse code because of the success of the Inmarsat system. And people who live in remote areas use satellite dishes rather than large VHF antenna arrays to receive television programming. Satellite operators, which are the organizations that own and operate satellites, must attract a significant quantity of users to succeed as a business.

The fixed ground antennas that become aligned with a given satellite or constellation create synergy and establish a "real estate value" for the orbit position. Some of the key success factors include the following:

– The best orbit positions (for GEO) or orbital constellation (for non-GEO).

- The right coverage footprint to reach portions of the ground where users exist or would expect to appear.
- Service in the best frequency bands to correspond to the availability of low-cost user terminal equipment.
- Satellite performance in terms of downlink radiated power and uplink receive sensitivity.
- Service from major Earth stations (also called teleports) for access to the terrestrial infrastructure, particularly the Public-Switched Telephone Network (PSTN), the Internet, and the fiber backbone.
- Sufficient funding to get the system started and operating at least through a cash-flow break-even point.

Optimum footprint and technical performance allow a satellite to garner an attractive collection of markets. Importantly, these do not necessarily need to be known with precision when the satellite is launched because new users and applications can start service at any time during the operating lifetime of the satellite (typically 15 years). Anywhere within the footprint, a new application can be introduced quickly once ground antennas are installed. This provides what is called high operating leverage—a factor not usually associated with buried telecom assets such as fiber optic cables and wireless towers.

In the case of cable TV, access is everything because the ground antenna is, in turn, connected to households where cable services are consumed and paid for. DBS delivers direct access to subscribers, bypassing cable systems.

Satellite operators, who invest in the satellites and make capacity available to their customers, generally prefer that users own their own Earth stations. This is because installing antennas and associated indoor electronics is costly for satellite service providers. Once working, this investment must be maintained and upgraded to meet evolving needs.

But a typical small Earth station is no more complex than a cellular telephone or VCR. As a result of strong competition for new subscribers, DBS have to subsidize receiver purchases. Larger Earth stations such as TV uplinks and international telephone gateways are certainly not a consumer item, so it is common for several users to share a large facility in the form of a teleport.

User organizations in the public and private sectors that wish to develop their own unique satellite networks have a wide array of tools and technologies at their disposal (which are reviewed in detail in this book).

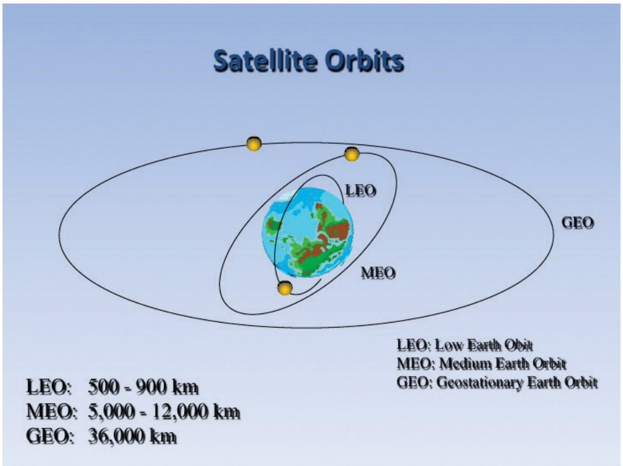
Satellite communications reduce entry barriers for many information industry applications. As a first step, a well-constructed business plan based on the use of existing satellites could be attractive to investors. The history of commercial satellite communications includes some fascinating startup services that took advantage of the relatively low cost of entry.

Satellite communication applications can establish a solid business for companies that know how to work out the details to satisfy customer needs. A stellar example is the mobile satellite service business pioneered by Inmarsat. Through a conservatively managed strategy, Inmarsat has driven its service from initially providing ship-to-shore communications to being the main source of emergency and temporary communications on land.

1.2. Satellite Network Fundamentals

Every satellite application achieves its effectiveness by building on the strengths of the satellite link. A satellite is capable of performing as a microwave repeater for Earth stations that are located within its coverage area, determined by the altitude of the satellite and the design of its antenna system. The arrangement of three basic orbit configurations is shown in Figure 1.

A GEO satellite can cover nearly one third of the Earth's surface, with the exception of the polar regions. This includes more than 99% of the world's population and economic activity (see Figure 2).



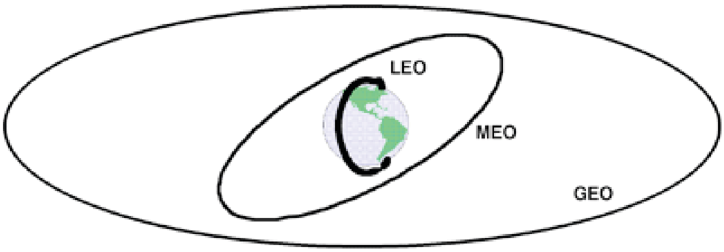


Figure 1. Arrangement of three basic orbit configurations.

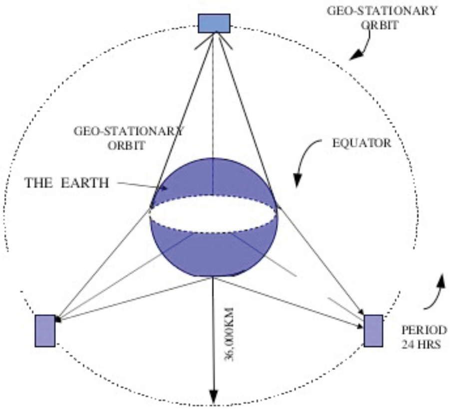


Figure 2. GEO satellite Coverages.

The low Earth orbit (LEO) and medium Earth orbit (MEO) approaches require more satellites to achieve this level of coverage. Due to the fact that non-GEO satellites move in relation to the surface of the Earth, a full complement of satellites (called a constellation) must be operating to provide continuous, unbroken service.

The trade-off here is that the GEO satellites, being more distant, incur a longer path length to Earth stations, while the LEO systems promise short paths not unlike those of terrestrial systems. The path length (see Figure 3) introduces a propagation delay since radio signals travel at the speed of light.

This is illustrated in Figure 4, which is a plot of orbit period and propagation delay for various altitudes. Depending on the nature of the service, the increased delay of MEO and GEO orbits may impose some degradation on quality or throughput. The extent to which this materially affects the acceptability of the service depends on many factors, such as the degree of interactivity, the delay of other components of the end-to-end system, and the protocols used to coordinate information transfer and error recovery.

Three LEO systems have been put in operation: Orbcomm, Iridium, and Globalstar. Orbcomm was designed for two-way messaging service, while Iridium and Globalstar (see Figure 5) were designed for mobile telephony. Early advertising for Iridium suggested that with one of their handheld phones, you

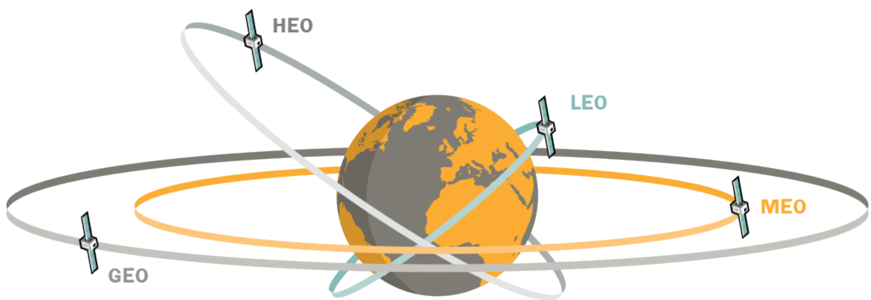


Figure 3. GEO, MEO and LEO altitude.

could be reached anywhere in the world. This would be the case only if you remained out of doors with a clear view of the sky from horizon to horizon.

Globalstar had a slightly less ambitious claim that its service was cheaper than that of Iridium. While these systems could deliver services, all have resulted in financial failures for their investors. The non-GEO system was subsequently dropped to MEO constellation.

As microwaves, the signals transmitted between the satellite and Earth stations propagate along line-of-sight paths and experience free-space loss that increases as the square of the distance.

Actual assignments to satellites and Earth stations are further restricted in order to permit different services (and the associated user community) to share this valuable resource. In addition to microwaves, laser systems continue to be under evaluation.

Rather than being simple repeaters, laser links require modulated coherent light sources and demodulating receivers that include mutually tracking telescopes. So far, commercial laser links are not in use, but there is interest in them principally to al-

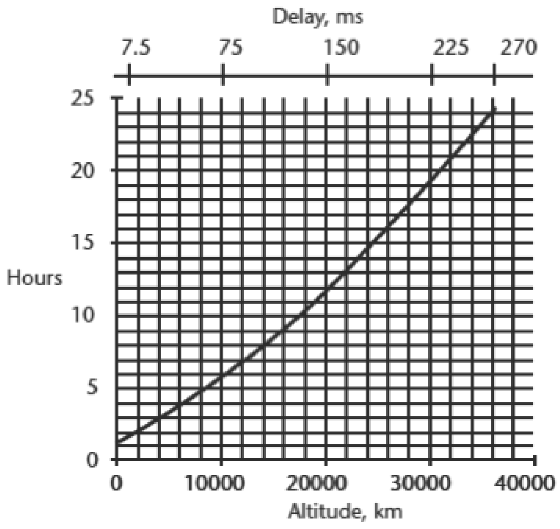


Figure 4. Plot of orbit period and propagation delay for various altitudes.

low direct connections between satellites named intersatellite links or cross links.

Applications are delivered through a network architecture that falls into one of three categories: point-to-point (mesh), point-to-multipoint (broadcast), and multipoint interactive (VSAT). Mesh-type networks mirror the telephone network. They allow Earth stations to communicate directly with each other on a one-to-one basis. To make this possible, each Earth station in the network must have sufficient transmit and receive performance to exchange information with its least effective partner.

Generally, all such Earth stations have similar antennas and transmitter systems, so their network is completely balanced. Links between pairs of stations can be operated on a full-time basis for the transfer of broadband information like TV or multiplexed voice and data. Alternatively, links can be established only when needed to transfer information, either by user scheduling (reservation system) or on demand (demand-assignment system).

A broadcast of information by the satellite is more efficient than terrestrial arrangements using copper wires, fiber optic

		Globalstar	IRIDIUM
Constellation	# Satellites	48	66
	Orbit/Inclination	Circ/52°	Circ/86.4°
	# Planes	8	6
	Altitude (km)	1401	785
Frequency	Mobile User		
	Uplink (GHz) Downlink (GHz)	1.610-1.6265 2.4835-2.500	1.616-1.6265 1.616-1.6265
	Gateway Terminal		
	Uplink (GHz) Downlink (GHz)	C-band C-band	27.5-30.0 18.8-20.2
Connectivity	FDX Circuits/Sat	2800	3840
	Average Satellite Connection Time	10-12 min.	9 min.
	Min Elevation Angle	10°	8.2°

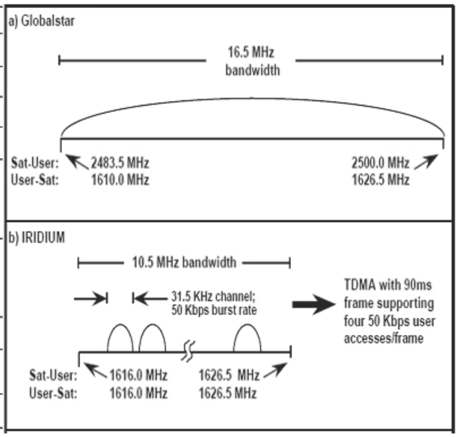


Figure 5. Iridium and Globalstar performances.

cables, or multiple wireless stations. By taking advantage of the broadcast capability of a GEO satellite, the point-tomultipoint network supports the distribution of information from a source (the hub/uplink Earth station) to a potentially very large number of users of that information (the remote Earth stations, also called receive-only terminals). Any application that uses this basic feature will usually find that a GEO satellite is its most effective delivery vehicle to reach a national audience.

Many applications employ two-way links, which may or may not use the broadcast feature. The application of the VSAT to interactive data communication applications has proven successful in many lines of business and more recently to the public. A Hub and spoke network using VSATs can be compared to almost any terrestrial wide-area network topology that is designed to accomplish the same result. This is because the satellite provides the common point of connection for the network, eliminating the requirement for a separate physical link between the hub and each remote point.

Other interactive applications can employ point-to-point links to mimic the telephone network, although this tends to be favored for rural and mobile services. The incoming generation of satellite and ground equipment, which involves very low-cost VSATs, is reducing barriers to mass market satellite networks.

The degree to which satellite communications is superior to terrestrial alternatives depends on many interrelated factors. Experience has shown that the following features tend to give satellite communication an advantage in appropriate applications:

- Wide area coverage of a country, region, or continent.
- Wide bandwidth available throughout.
- Independent of terrestrial infrastructure.
- Rapid installation of ground network.
- Low cost per added site.
- Uniform service characteristics.
- Total service from a single provider.
- Mobile/wireless communication, independent of location.

While satellite communications will probably never overtake terrestrial communications on a major scale, these strengths can produce very effective niches in the marketplace. Once the satellite operator has placed the satellite into service, a network can easily be installed and managed by a single organization. This is possible on a national or regional basis (including global using at least three GEO satellites).

The frequency allocations at C-, Ku-, and Ka-bands offer effective bandwidths of 1 GHz or more per satellite, facilitating a range of broadband services that are not constrained by local infrastructure considerations. Satellites that employ L- and S- bands constrain bandwidth to less than 100 MHz but may propagate signals that bend around obstacles and penetrate non-metallic structures.

Regardless of the band, the satellite delivers the same consistent set of services at costs that are potentially lower than those of fixed terrestrial systems. For the long term, the ability to serve mobile stations and provide communications instantly are features that offer strength in a changing world.

Originally, Earth stations were large, expensive, and located in rural areas so as not to interfere with terrestrial microwave systems that operate in the same frequency bands. These massive structures had to use wideband terrestrial links to reach the closest city. Current emphasis is on customer premise Earth stations—simple, reliable, low cost. Home receiving systems for DTH service are also low in cost and quite inconspicuous.

The current generation of low-cost VSATs introduced since 2002 encourage greater use of bidirectional data communications via satellite. As terminals have shrunk in size, satellites have grown in power and sophistication. Some satellites serve specialized markets such as GEO mobile satellites that connect directly with specially designed handheld phones.

1.3. International Regulations

The reader might query the purpose and need for international regulations. This emerges as the international community realizes that the radiofrequency spectrum and the geostationary satellite orbit are two finite natural resources available to humans. Each of these resources has the unique property of being conserved if it is used properly and wasted if it is not used properly. To conserve the precious commodity, certain requirements need to be fulfilled, as follows:

- The first essential requirement for the orderly use of the frequency spectrum is the division of the spectrum into separate parts (referred to as bands), where each of bands can be utilized by one or more communication services.
- The second essential step is the division of the world into regions. In this regard, the world has been divided into three distinct regions: Region 1, Region 2, and Region 3. as shown inFigure 6.
- The third is the application of preestablished regulatory procedures for the use of frequencies by stations in the

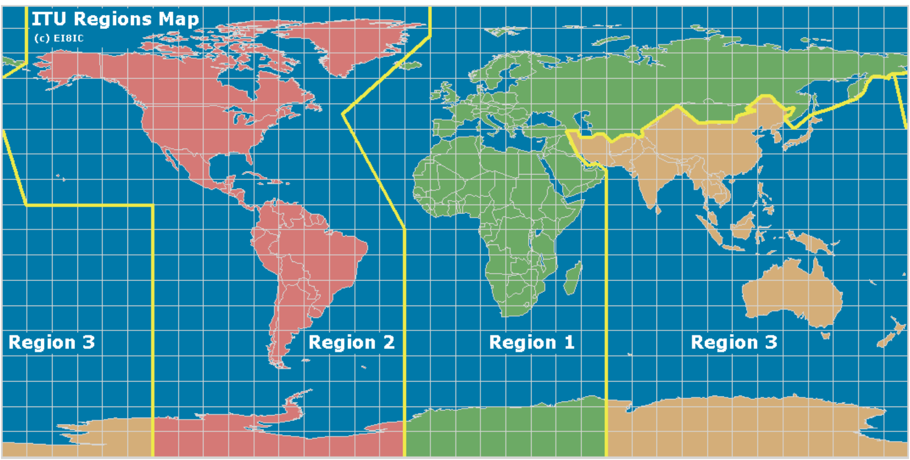


Figure 6. ITU Regions.