An Overview of Major Satellite Systems

N. PANAGIOTARAKIS[*], I. MAGLOGIANNIS[**], G. KORMENTZAS[**]

[*]Horama Marketing & Engineering S.A, Belgian Liaison Office
284, rue Theodore De Cuyper
1200 Brussels, BELGIUM

[**]University of the Aegean
Dept. of Information and Communication Systems,
GR-83200, Karlovassi, GREECE

Abstract: A satellite communication system is distinguished by its global coverage, inherent broadcast capability, ability to support mobility and bandwidth-on-demand flexibility. Taking into account this emerging communication role of the satellite systems, the paper provides an overview of major narrowband GEO, MEO and LEO satellite systems. It presents some typical commercial examples of such satellite systems and discusses their basic features consisting of used frequency bands, supported applications and terminals and critical performance issues.

Key-Words: GEO, LEO, MEO, Narrowband Satellite Systems, Onboard Processing.

1 Introduction

Various wired and wireless technologies are competing for the provision of high-bandwidth access. Flexibility, speed, cost, and time-to-market are major factors affecting the evolution of these technologies. Cable and Digital Subscriber Loops (xDSL) modems are the most promising wired broadband access systems. However, the low flexibility and high installation cost of cable modems and the great dependence of xDSL systems on distance prevent them from achieving significant acceptance and popularity in the domain of broadband services. The wireless broadband access systems are commonly classified, according to their type, as MMDS (Multichannel Multipoint Distribution System) [1], or LMDS (Local Mutlipoint Distribution System) [2]. MMDS systems operate at frequencies lower than 5GHz with coverage areas (cell radius) up to 40km. They are suitable for transmission of video and broadcast services in rural areas. LMDS systems operate at higher frequencies, where large portions of the spectrum are still free. In this case, the coverage area is realized with smaller cells (typically up to a radius of 5km). The extension of this radius usually requires repeaters to be placed in a LOS (Line Of Sight) configuration.

Passing to the satellite systems, their communication role is not to compete with the land-based fixed, wireless or mobile communications systems previously mentioned but to complement them both in a "geographical" sense (where it is impossible or economically unfeasible for the terrestrial systems to provide services coverage) and in a "service complement" sense (satellite delivery is more appropriate and cost efficient for broadcast/ multicast type of services).

The rest paper is organized as follows: Section 2 gives an overview of satellite communication fundamentals. The next Section 3 discusses the major narrowband GEO, MEO and LEO satellite systems. Lastly, Section 4 concludes the paper. An appendix is also included, which tabulates the basic characteristics of current commercial satellite systems.

2 Key Satellite Communication Isuues

A satellite system consists of a space and a ground segment. The space segment is composed of satellites, which may be classified into geostationary earth orbit (GEO) and nongeostationary earth orbit (NGEO) satellite, including middle earth orbit (MEO) and low earth orbit (LEO) satellite, according to the orbit altitude above the earth's surface [3].

The majority of satellites in operation nowadays are GEO. The most significant problem for GEO satellite links is the large propagation delay. The typical value of round-trip delay is 250-280ms, which is undesirable for real-time traffic. The MEO's typical round-trip propagation delay is 110-130ms, while the corresponding delay for a LEO satellite system is 20-25ms, which is comparable to that of a terrestrial link. Since MEO/LEO satellites are closer to the Earth's surface, the necessary antenna size and transmission power level are much smaller. However, the MEO's/LEO's footprint is also much smaller than GEO's. A constellation of a large number of MEO/LEO satellites is necessary for global coverage, while three GEO satellites are sufficient. The lower the obit altitude, the greater the number of satellites required. Note that, for satellites travel at high speeds relative to the Earth's surface, a user may need to be handed off from satellite to satellite as they pass rapidly overhead.

Discussing another critical communication issue, the satellite payload is responsible for the satellite communication functions. Traditional satellites, especially GEOs, serve as bent pipes. They act as repeaters between two communication points on the ground. There is no onboard processing (OBP). Some other satellite systems, allow OBP, including demodulation/remodulation, decoding/recoding, transponder/beam switching, and routing to provide more efficient channel utilization. OBP can support high-capacity intersatellite links (ISLs) connecting two satellites within line of sight. By using a sophisticated constellation with ISLs, connectivity in space without any terrestrial resource is possible [4].

3 The Major Satellite Systems

This section discusses major little LEO and narrowband LEO, MEO and GEO satellite systems. Specifically, individual subsections elaborate on Orbcomm [5], Iridium [6], Globalstar [7], Thuraya [8], ACeS [9] and Inmarsat [10] satellite systems.

3.1 Little LEOs

Little LEO systems aim to complement terrestrial data and mobile radio services. The little LEO satellites usually operate in the VHF band and orbit around earth at heights around 1000km. Their target market segments include transportation and shipping (messaging & location), business travellers (paging – short to medium length e-mail), telemetry and SCADA (Supervisory Control and Data Acquisition) applications support for industry, utilities, environment and agriculture, commercial and residential security, etc. Tailor made terminals (fixed, vehicular, pocket-sized handsets) are offered depending on the type of the served application.

The Orbcomm constitutes a typical example of a little LEO system. The Orbcomm constellation consists of 48 LEO satellites orbiting at 825km. The satellite lifetime is 4 years and the data rate currently supported is up to 2.4kbit/s (the typical rate is 0.3kbit/s).

There are two types of supported terminals. The first enables fixed remote data communications while the other enables mobile, two-way data and messaging communications. Orbocomm's terminal for fixed data applications uses low-cost VHF electronics. The antenna design and small package provide installation flexibility. The terminal for mobile two-way messaging is a hand-held, stand-alone, pocket-sized unit. Typically the unit have an alphanumeric keyboard and small display screen.

3.2 Narrowband LEO, MEO and GEO Systems

3.2.1 Iridium

Iridium system is based on the concept of 66 orbiting satellites in six polar planes giving 11 satellites in each orbit. This configuration aims to ensure that any point on earth is within sight of at least one satellite at any time. The system design is technologically challenging. Iridium employs ISLs, OBP and satellite based switching. These technologies are not yet adequately tested as the majority of other prospective LEO or MEO based mobile satellite systems make use of bent pipe satellites. Each satellite is linked to two others in its plane and two in adjacent planes.

Iridium provides handheld telephony and paging satellite services. The Iridium mobile handsets are significantly larger than their GSM counterparts (three times thicker than many modern GSM phones).

3.2.2 Globalstar

The Globalstar space segment consists of 48 spacecraft in Low Earth Orbit, flying in 8 orbital planes inclined by 52° at an altitude of 1414 km above ground. The goal of Globalstar is to provide services on earth from 70 degrees north latitude to 70 degrees south latitude. This inclination has been chosen to generate the highest satellite density at the latitudes of the highest population density. The spacecraft design life is 7.5 and up to 10 years.

The Globalstar payload comprises transparent passive transponders without OBP or switching. The user segment comprises fixed, mobile and personal dual mode Globalstar/cellular terminals. The satellite transmission is asymmetrical. The asymmetrical links are supported from 100 ground-based gateway earth stations, which relay users' calls into other terrestrial or satellite networks.

The Globalstar system provides satellite-based telephony and SMS services to a broad range of users. Depending on Globalstar service provider policy and infrastructure additional services may include facsimile and data transmission. The typical supported rate for voice is 2.4kbit/s, while the maximum supported data rate is 9.6kbit/s.

3.2.3 Thuraya

The Thuraya mobile satellite system will be the outcome of a regional project built by Boeing Satellite Systems. The project includes the manufacture of two high power geo-synchronous satellites, the launch of the first satellite, the manufacture and the installation of the ground network equipment and the manufacture of nearly a quarter of a million mobile handsets. At the end of the project, Thuraya will cover an area spanning 99 countries that is inhabited by 2.3 billion people. Thuraya's footprint will include the Indian Subcontinent, the Middle East, the Central Asia, the North and Central Africa and the Europe (see Figure 1)

Thuraya's first satellite was launched in October 2000 and commercial services began in a gradual roll out in a number of countries in 2001. Thuraya's system has been adapted for efficient operation in both satellite and GSM environments. It provides high flexibility in managing network resources through a re-programmable satellite payload. Thuraya's satellites have been specially designed to achieve network capacity of about 13,750 telephone channels.

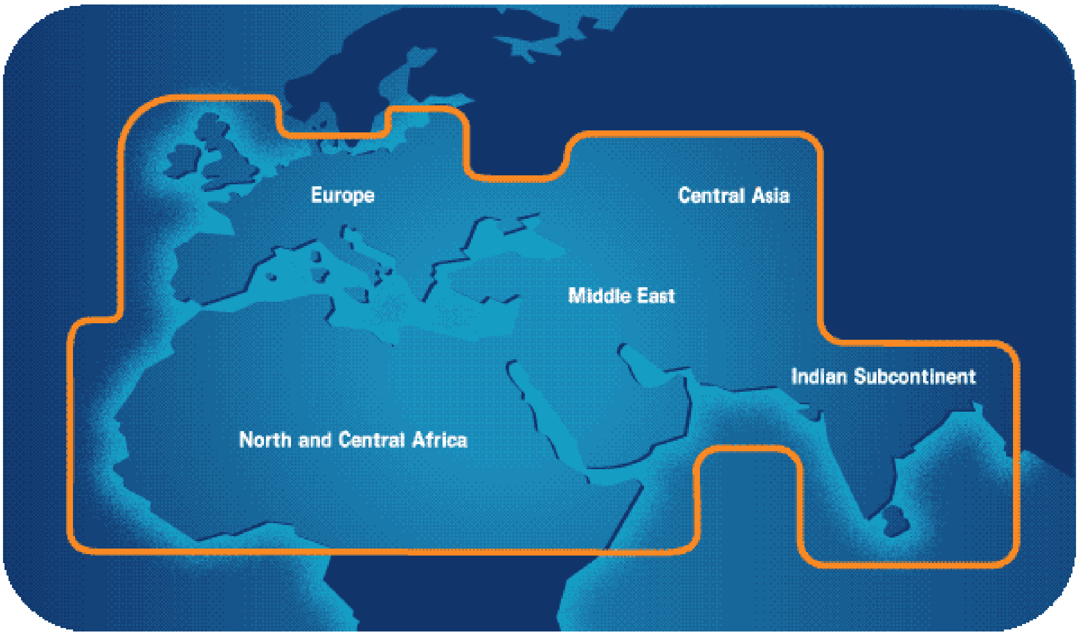

Figure 1. The Thuraya coverage area

Thuraya offers hand-held, vehicular and fixed terminals to cater to the needs of its subscribers. The services include voice (GSM quality), fax (ITU-T G3 at 2.4, 4.8 and 9.6 kbps), data (at 2.4, 4.8 and 9.6 kbps), messaging (GSM short message service) and location determination (within 100 meters accuracy using the Global Positioning System). Thuraya will expand its mobile satellite service portfolio to provide broadband services via Inmarsat (for Inmarsat satellite system see Subsection 3.2.5). The offered broadband services will include the delivery of Internet and Intranet content, e-mail and remote LAN access to Thuraya's coverage area.

3.2.4 ACeS

The Asian Cellular System (AceS) is a GEO regional system quite similar in philosophy and market orientation with Thuraya that covers South East Asia, India, China & Australia. Its first satellite was launched successfully in February 2000 and ACeS offers services in Indonesia and Philippines with plan to do the same in near future in other Asian countries.

3.2.5 Inmarsat

The GEO satellite systems operated by the International Maritime Satellite Organisation (Inmarsat) cover entire ocean surface from latitudes of approximately 70°N to 70°S (see Figure 2). The operational generations of Inmarsat satellites include Inmarsat A, B, C and E.

Inmarsat-A is an analogue mobile satellite communication system approaching the end of its service life. It accommodates voice and 9.6 kbit/s data communications in its standard configuration. A High Speed Data (HSD) option offered by some MES (Mobile Earth Station) manufacturers permits data communications up to 64 kbit/s.

Inmarsat-B constitutes the digital replacement for Inmarsat-A. It supports voice, data, fax and telex. Standard data rate is 9.6kbit/s, while the supported rate for the HSD option is 64kbit/s.

Inmarsat-C is a data store-and-forward messaging system and does not support voice. The data rate is 600bits/s and the maximum message length is 32kB. The system can connect to telex and data networks. It provides a facility for Enhanced Group Calls (EGC), which permits groups of vessels in a geographic area to be simultaneously addressed.

Inmarsat-E includes geostationary satellites and a built-in GPS receiver used mainly for rescuing activities. It offers high positional accuracy and minimal delay between activation and information forwarding to search & rescue authorities.

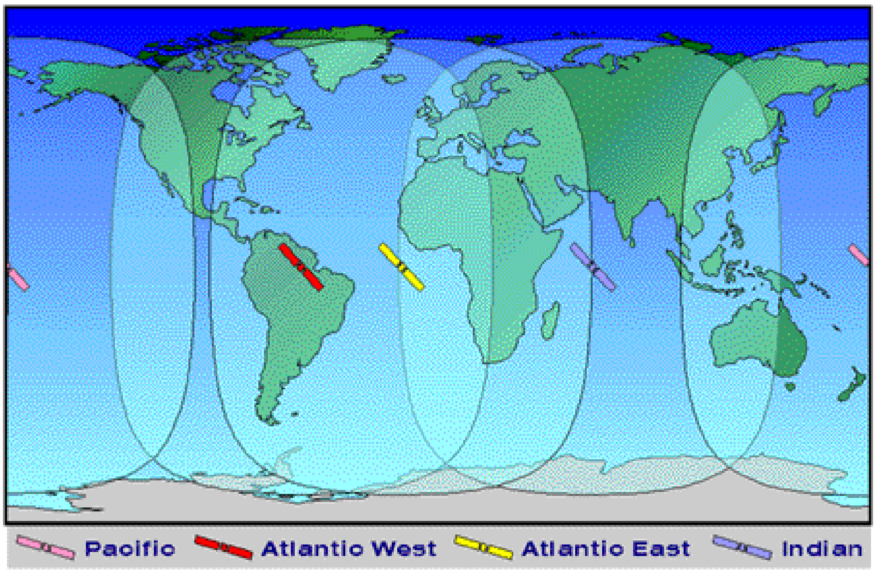

Figure 2. The Inmarsat coverage area

4 Conclusion

Taking into account the emerging communication role of satellite systems, the paper discusses major little LEO (i.e., Orbcomm) and narrowband LEO, MEO and GEO satellite systems (i.e., Iridium, Globalstar, Thuraya, ACeS and Inmarsat). The basic features of these systems are provided in a tutorial way.

References:

[1] R. Rini, and S. Coran, "The FCC's new deal for MMDS",see `http://wirelessvvd.com/newdeal.html.`

[2] D. Bergen, "LMDS wireless multimedia",see `http://www.wirelessvvd.com/LMDSbergen.html.`

[3] Y. Hu and V. Li, "Satellite-Based Internet: A Tutorial", *IEEE Communication Magazine*, pp. 154-162, March 2001.

[4] D. Bem, T. Wieckowski and R. Zielinski, "Broadband Satellite Systems", *IEEE Communications Surveys and Tutorials*, vol. 3, no. 1, pp. 2-15, First Quarter 2000.

[5] Electronically available information in the URL: `http://www.orbcomm.com`

[6] Electronically available information in the URL: `http://www.iridium.com`

[7] Electronically available information in the URL: `http://www.globalstar.com`

[8] Electronically available information in the URL: `http://www.thuraya.com`

[9] Electronically available information in the URL: `http://www.acesinternational.com`

[10] Electronically available information in the URL: `http://www.inmarsat.org`.

Appendix

The following table provides an overview of current satellite systems giving information about their frequency bands, supported applications and typical terminal types/sizes, critical performance issues and commercial examples.

System type	Frequency bands	Applications	Terminal type/size	Critical issues	Examples
Fixed satellite service (GEO)	C and Ku	TV/Video delivery, news gathering, telephony	0.6m and larger fixed earth terminals	Latency/ Noise	Eutelsat HotBird, PanamSat, Intelsat
Direct broadcast satellite (GEO)	Ku	Direct-to-home video/audio	0.3 - 0.6m fixed earth terminals	Latency/ Noise	DirecTV, Echostar, USSB, Astra
Broadband GEO	Ka and Ku	Internet access, voice, video, data, multimedia applications	20cm fixed earth terminals	Latency/ Noise/ Antenna	Cyberstar
Narrowband GEO	L and S	Voice and low-speed data	Fixed or mobile terminals (laptop size)	Latency/ Noise	Inmarsat3, AMSC/TMI
MEOs	L, S, C, X	Personal Communications (Cellular telephony, data, paging, etc.)	Dual mode cellular/satellite phones, fixed phone booths, portable terminals, etc.	Space/Ground segments configuration, orbits	ICO, Ellipso
Broadband LEO	Ka and Ku	Internet access, voice, video, data, videoconferencing, interactive multimedia services	Dual 20cm tracking antennas, fixed	Space/Ground segments configuration, orbits, elevation angle, antenna technology	Teledesic, SkyBridge
Big LEO	L and S	Personal Communications (Cellular telephony, data, paging, etc.)	Dual mode cellular/satellite phones and pagers, fixed phone booth, etc.	Space/Ground segments configuration, orbits,	Iridium, GlobalStar,
Little LEO	Usually VHF	Position location, tracking, messaging	10cm fixed earth terminals	Line of sight, power	OrbComm