Satellite Systems for Multimedia and Internet Traffic

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Abstract

Satellite networks handle Internet and multimedia traffic at C- and Ku- bands today, while a new generation of systems is being developed at Ka-band. Present satellite systems provide high-speed ISP backbone connectivity and two-way Internet accesses. Future Ka-band systems are primarily targeted for business and home users with low-cost fixed user terminals. Satellite links are also used for interconnecting remote networks as well as some semi-fixed and mobile networks/ applications. This paper provides an overview of the present and planned satellite systems/ services, and addresses the key related RF and antenna technology issues.

Introduction

Multimedia and Internet services, consisting of data, voice and video, represent a key growth engine for the satellite service industry today. Internet and other data services are already contributing more than 70% of new business revenues for some of the major satellite operators. The share of internet traffic via satellites is expected to grow as new service applications emerge and as the number of internet users grows from its present estimate of 160 million to a projected 500 million by 2005 and in excess of a billion users by the year 2010. The new multimedia service applications for home or business users include high-speed Internet access, e-commerce, home shopping, telecommuting, telemedicine, distance education and learning, teleconferencing and other voice, data, and image based communications services. According to a study published by Euroconsult, an estimated 10.5 Gigabit/s of Internet traffic (equivalent to 8.5 GHz bandwidth) was carried by communications satellites in mid-year 2000 [1]. The study also pointed out that approximately 90% of this total traffic represented Internet backbone 'trunking' traffic. This is attributed to high bandwidth access provided by satellite networks to many areas where terrestrial infrastructure is not available and also to overcome growing congestion of the existing terrestrial networks in the developing countries. Because of wide area regional and global coverage, satellite networks are well suited to provide connectivity to remote/ inaccessible regions or areas where terrestrial infrastructure has been damaged.

An important and rapidly growing application of satellite communications systems, is providing two-way 'access' between enterprises and corporate users for their virtual private networks (VPNs). These networks provide high speed connection to Internet Service Providers (ISPs), provide content management and Intranet expansion. This capitalizes on the ability of satellite networks to provide a global reach and very flexible bandwidth-on-demand capabilities. Satellite channels are accessible from any earth station in a satellite's coverage area. These features, coupled with the multipoint/ broadcast capabilities inherent in satellite links, highlight an important role for satellite communications in the evolving information superhighway. Internet multicasting/ broadcasting applications include 'edgecasting' of content for caching (storage) at the ISP point of presence (PoP), and streamed media to cable headends, broadband wireless providers, and wired Digital subscriber Loop (DSL) service providers. A system concept [2] for satellite based multimedia services is shown in Figure 1. This paper provides a summary of presently available and planned multimedia satellite services primarily at Ku- and Ka- bands and addresses associated RF and antenna technology issues and challenges for the satellites and ground terminals.

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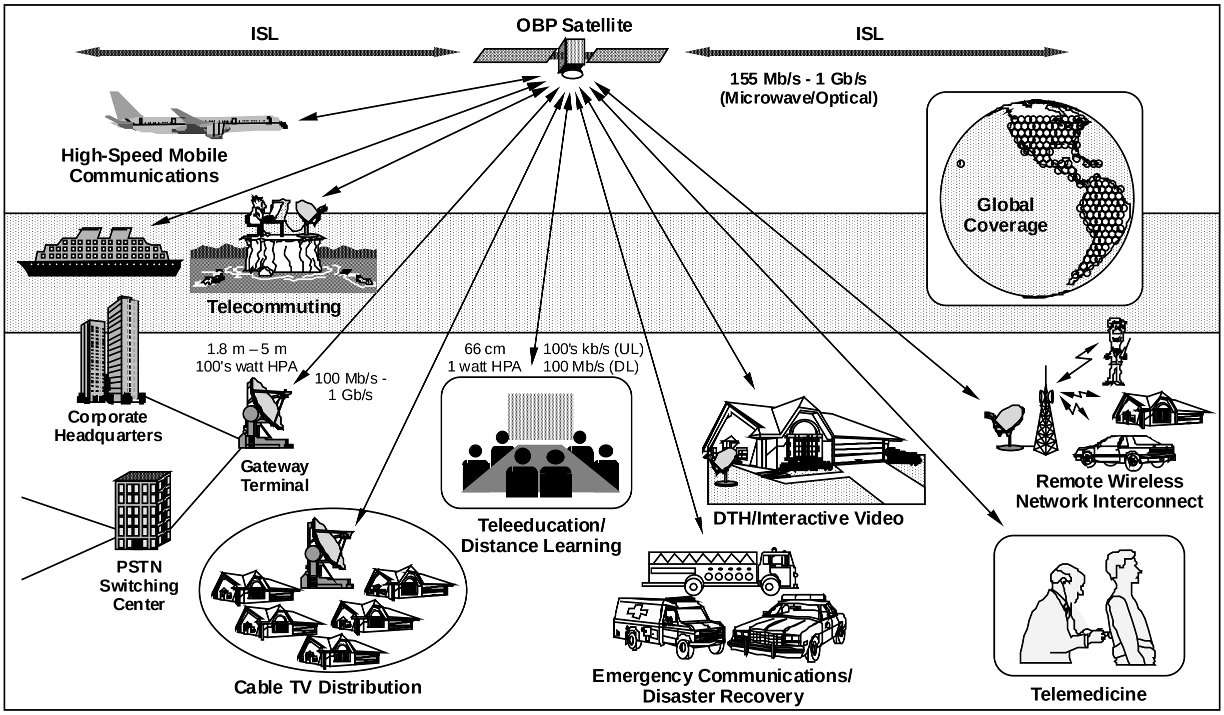

OBP – On-Board Processing; **UL,DL – Up-link, Down-link**
ISL- Intersatellite Link; **HPA – High Power Amplifier**

Figure 1 : Multimedia System Concept (T. Inukai- LMGT ; Ref [2])

Multimedia Satellite Systems

All major satellite operators have announced multimedia service offerings primarily at Ku-band using their existing or planned geostationary (GSO) satellites [3]-[4]. SkyBridge LLC of Washington, DC (subsidiary of Alcatel) plans to offer Ku-band non-geostationary orbit (NGSO) services with 80 low earth orbit (LEO) satellites [5]. SES Astra [4] on the other hand has a hybrid Ku- (Receive) and Ka-band (return transmit channel) system for its multimedia offerings. Inmarsat plans to offer 144 kbps mobile services using Thuraya regional mobile satellites in 2002, followed by 432 kbps IP services with the launch of Inmarsat 4 in 2004. Newly acquired ICO Global Systems is expected to be a key player and a competitor in this market using their Medium Earth Orbit (MEO) satellites. There are several proposed Ka-Band systems, which are under advanced stages of development for broadband multimedia services. This paper will focus on the Ku-/C- and Ka-band broadband fixed satellite services (FSS).

GSO Ku-/C- Band High Speed Services:

Existing international and large regional satellite operators such as INTELSAT, PanAmsat, New Skies, Eutelsat and Cyberstar offer high speed services at Ku- and C-bands using their existing satellite assets. New European entrants include Europestar, a joint venture between Alcatel Spacecom (France) and Loral Space and Communications (US). High speed data services for internet backbone interconnections are being implemented with single carrier per channel (SCPC) streams at rates up to 155 Mbps (e.g. New skies – IPsys Direct, Europestar). In addition, links between internet backbone and a customer's PoP are made using Digital Video Broadcast (DBV) satellite service standard for shared data rates up to 45 Mbps (e.g. PanAmsat-SPOTbyte, New skies – IPsys Premier). Ku- (or Ka-band) Return Channel-by-Satellite (DVB-RCS) standards are also under development and test (e.g. SES Astra) for return path. Multi frequency TDMA (MF-TDMA) has been adopted by several operators including INTELSAT and Eutelsat as part of their service offerings to provide bandwidth-on-demand capability, in which terminals communicate with all other terminals (full-mesh connectivity) but use satellite capacity on an as-needed basis. In MF-TDMA, since each transmitter only transmits a single carrier at a time, with QPSK modulation, it is possible to operate the transmitters close to saturation.

These systems exploit one of the unique advantages of satellite networks in that the satellite offers a shared bandwidth resource, which is available to many users spread over a large geographical area on earth. Presently, each of these platforms is capable of providing variable data rates up to 2 Mbps. Higher data rates are expected with deployment of higher capacity satellites with higher EIRP multiple beams in the 2004 time frame. One of the important considerations for seamless integration of satellite and terrestrial networks is that the transmission delay and channel fading should not degrade the quality of service (QoS). To overcome interoperability problems new standards and techniques have been developed for satellite systems [6]. Specific technologies include dynamic adaptive coding, data compression, Transmission Control Protocol (TCP) proxy to enable TCP/IP based applications in the presence of delays associated with geosynchronous satellites, bandwidth-on-demand and traffic management.

Ku-band systems operate at up-link transmit frequencies of 14.0 – 14.5 GHz and down link receive frequencies of 10.95 – 12.75 GHz, whereas C-band systems operate at up-link frequencies of 5.85-6.425 GHz and down-link frequencies between 3.4-4.2 GHz or 4.5-4.8 GHz. Receive and transmit frequencies vary between different satellite systems because of international frequency allocations and local coordination in the same coverage area. Ku-band antenna sizes are typically 1.8 meters whereas C-band antennas tend to be 2.4 meters or even 3.7 meters depending upon the regional or global coverage available. Depending on the satellite Effective Isotropic Radiated Power (EIRP) and transmission data rates, the RF power requirements at Ku-band can be up to 16W and at C-band up to 20 or 40 W for hubless 'mesh' connectivity. For system configurations with a large hub, the transmit power level is reduced to between 2 to 5 W. These systems operating in a star connectivity require double-hop operation for communications between the user terminals. One of major barriers to market penetration of these systems has been relatively high cost of RF equipment. Most of the RF transmit/receive equipment was developed for SCPC operation and provides 70 or 140 MHz IF bandwidth. This presents a limitation in fully exploiting the bandwidth on demand capability by transponder hopping of the carriers using MF-TDMA over the full 500 MHz satellite band. An L-band IF inter facility link (IFL) between indoor unit (IDU) and out door unit (ODU) results in better bandwidth performance and significantly reduces the cost of RF equipment. Several cost reduction issues related to the ODU include: developing integrated low-cost high-power solid-state power amplifiers, and use of a single IFL connection between the IDU and the ODU with multiplexed DC power and Monitoring/Control (M&C) signals. Use of integrated GaAs MMIC modules could result in more uniform gain and gain-variations with temperature. Manufacturing process improvements would result in cost reductions of ODUs for quantity production.

Ka-Band Multimedia Satellite Systems

Existing satellite operators including INTELSAT, PanAmsat, and Eutelsat plan to offer Ka-band services by augmenting their existing satellites in orbit with Ku-/Ka-band transponders in future satellites or by launching new Ka-band satellites. Of the several Ka-band systems [7] proposed in the 1995-1997 time frame, GSO satellite systems under implementation include Astrolink (Lockheed Martin), Spaceway (Hughes Networks), Wildblue (formerly iSky). The NGSO Ka-band system, initially proposed by Teledesic with 288 satellites, may undergo revisions because of its merger with ICO system. All of these systems use the allocated 500 MHz bandwidth (29.5 – 30.0 GHz for uplink and 19.7-20.2 GHz for downlink) for FSS. Additional Ka-band frequency allocations are available between 28.35–28.6GHz and 29.0-29.5 GHz for uplink and 18.55-18.8 GHz an 19.2-19.7 GHz for down-link, which may require coordination with local multipoint distribution services (LMDS) and mobile services feeder links.

Most of the systems use a large number of narrow spot beams covering the whole service to deliver high (50-60 dBW) EIRP to the user terminals. Multiple beam antenna designs present a significant design challenge. A single reflector with a large number of feeds or multiple reflectors with a combination of narrow and wide spot beams may be used. A number of fixed spot beams make the design simpler. However, use of a small number of hopping or scanning beams using phased array antenna [8] provides an attractive alternative. The hopping beam approach provides efficient satellite resource utilization by assigning each beam with different dwell timings over the major traffic area and thin traffic areas. For a large number of beams, and large number of frequency re-uses, co- and cross-polarization interference becomes a major issue.

A majority of Ka-band systems employ a combination of frequency division and time division multiple access (FDMA/TDMA) techniques for uplink data rates between 64 kbps to 10 Mbps. Use of 'bent pipe' connectivity results in simpler payload designs. However, use of satellite switched time division multiple access (SS-TDMA) and on-board demodulation and remodulation results in more efficient use of the spacecraft capacity. Implementation of these systems using GaAs MMIC technology [9] has already been demonstrated. Use of base band switching allows more flexible interconnections between all users and allows transmission link design to be optimized based on the user traffic volume. More advanced satellite payloads use on-board packet switching for packet-by-packet routing.

One of the key requirements for all these systems is use of a low cost Ka-band user terminal capable of providing uplink variable data rates up to 1 Mbps. These terminals use a small aperture antenna extending from 60 cm – 1.2 m for specific applications with typical sizes of 90 cm. The transmit power requirements are between 2–10 W. Use of low-cost, low-power consuming RF integrated circuits (RFICs), on-chip and off-chip power combining techniques, and availability of low cost frequency sources would help meet the user terminal cost targets of US$2000-$5000.

Conclusions

Communications satellites are already playing an important role in transport of multimedia and internet traffic with data rates of 64kbps to 155 Mbps. These services are presently being offered using Ku- and C-band transponders. A number of broadband Ka-band satellite systems are under development that would be deployed by 2005 and significantly increase the data rates. RF and antenna technologies are critical to cost reduction of the Ku- and Ka-band user terminals.

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