First and perhaps foremost, next-generation mobile telecommunications systems must provide universal access for a wide range of services, such as those supported by fixed networks, using personal and mobile terminals.

Standardization activities are addressing the definition of a Universal Mobile Telecommunications System (UMTS), as the European Telecommunications Standards Institute (ETSI) calls it, or the International Mobile Telecommunications 2000 (IMT2000) system, as the International Telecommunication Union (ITU) calls it, which will serve as the platform for new multimedia services.

Moreover, as evidenced in the past four Ka Band Utilization conferences (see http://kaconf.grc.nasa.gov), researchers are working to implement high-capacity systems based on geostationary constellations using high-frequency bands. (See also the special issue on this topic in IEEE Journal on Selected Areas on Communications, Vol. 17, No. 2, Feb. 1999.) In the new systems implementation, the satellite component will be the key to ensure that users have real global coverage, including maritime and aeronautical users (see the sidebar "Multimedia via Satellite").

Satellite role evolution

Satellite systems have evolved from providing connections among different national networks to offering access directly to users on both fixed networks with small terminals (very small aperture terminal, or VSAT, networks) and mobile networks for a restricted set of services (such as messaging or low data-rate voice), using handheld terminals as in the case of Iridium and Globalstar, operating as stand-alone systems.

As we enter the fifth decade of satellite communications, the challenge will consist of setting up systems to ensure global mobility with multimedia capability. Also, data rates and quality of service should be as similar as possible to terrestrial fixed networks in a real integrated scenario both with fixed and landmobile systems.

Candidate constellations

The possible constellations for satellite systems include geostationary earth orbit (GEO), highly elliptical orbit (HEO), medium earth orbit (MEO), and low earth orbit (LEO).

Geostationary earth orbit systems can get global coverage with a small number of satellites (at least three), but are demanding in terms of link dimensioning and round-trip delay due to the long distance (~36,000 km). They provide time-invariant coverage with a low elevation angle at medium and high latitudes, where in fact a large population resides and large traffic demand is expected. Handover and Doppler effects are minimized for landmobile and maritime users, and may not be so critical for aeronautical users. Spectral efficiency is not high at low frequency but it can be meaningfully improved by working at the Ka band (20/30 GHz) or extremely high frequency (EHF), which is 40 GHz and beyond. The geostationary earth orbit systems show low complexity.

Highly elliptical orbit systems, with two or three satellites in elliptical orbits (63.4-degree inclination), suit multiregional coverage by offering a good elevation angle at medium and high latitudes. They are critical in terms of link dimensioning and round-trip delay. Handover among satellites occurs at every submultiple of the rotation period. Doppler and zoom effects—resulting from the relative motion of the satellite with respect to a fixed point on earth—represent a critical problem requiring compensation. Highly elliptical orbit systems show a medium complexity.

Medium-earth orbit systems, composed by about ten satellites in medium (~10,000-km orbital height) circular orbits, allow global coverage with a relatively small number of medium-sized satellites. They suffer from Doppler effects and satellite handover.

Low-earth orbit systems—with several small satellites in low (400- to 1,000-km orbital height),
Multimedia via Satellite
Margaret Weatherford

Satellite networks already offer mobile telephone and paging services globally, but consumers want global multimedia. Companies want their widely scattered employees to videoconference and exchange multimedia data. Teachers in far-flung schools want to bring the Internet to their classrooms. Physicians separated by continents want to confer over X-rays. And universities want to offer interactive learning to students at the ends of the earth. Given this mandate for broadband satellite connectivity, some communications and satellite companies have adapted existing systems to provide services now; others, investing in the future, are striking out in new directions.

Using existing networks
Several companies have developed equipment to provide high-speed, broadband Internet access via existing satellite networks. For example, Hughes Network Systems’ DirecPC uses the same satellites as its DirecTV service to deliver Internet data to home computer users at 400 Kbps. Helius Inc. combines DirecPC with a Satellite Router that provides satellite Internet access and IP multicasting to LANs at 3 Mbps. Similarly, Logic Innovations and InfoGlobal have combined technologies to deliver Internet connectivity and other IP-based services at 2 Mbps on the unused bandwidth of a digital TV broadcast from a geostationary earth orbit (GEO) satellite network.

These systems exist now, but all three depend on terrestrial return channels, limiting upstream data rates.

New satellites, new frequencies
To enable high-speed multimedia communication in both directions, some companies are launching new constellations of GEO satellites. Others have chosen low earth orbit (LEO) satellites, because their lower altitudes mean much shorter round-trip times for data. Further advantages are low demands of link dimensioning and the possibility of small satellites.

GEOs
Italsat is the first regenerative Ka-band system providing high-capacity links for the public telephone network.

Meanwhile, NASA operates the only nonmilitary Ka-band GEO satellite over the Western Hemisphere, the Advanced Communications Technology Satellite. Through June 2000, US companies can use ACTS to experiment with high data rates and Internet protocols. Raytheon’s Applications Development Center, for example, has established a two-way link through the satellite using ATM protocols. The system simultaneously supports LAN-to-WAN connectivity at greater than 700 Kbps, videoconferencing at 512 Kbps, ISDN at 192 Kbps, and dual 64-Kbps telephony.

In Europe, the Alenia Aerospazio Space Division of the Finmeccanica Group has planned EuroSkyWay, a cluster of five Ka-band GEO satellites. EuroSkyWay will overcome the long latency inherent in TCP/IP for GEO satellites through a proprietary system based on ATM. Choosing downlink data rates between 16 Kbps and 32.768 Mbps to suit their applications, customers will pay according to bandwidth use. The user’s terminal type determines the uplink data rate: 160 Kbps for laptop, 512 Kbps for standard, and 2 Mbps for high-capacity terminals. With a first launch scheduled for 2001, EuroSkyWay will initially cover Europe and adjacent countries; later phases will add Africa and West Asia.

GEOs complemented by LEOs
Hughes Network Systems, which already operates DirecPC, has begun work on Spaceway, a bandwidth-on-demand system with uplink rates between 16 Kbps and 6 Mbps. Hughes will first deploy a network of Ka-band GEO satellites and then add an LEO-satellite constellation to increase Spaceway’s network capability in high-traffic areas. Hughes ultimately plans an integrated worldwide system; Spaceway will begin North American operations, with two GEO satellites and an in-orbit spare, in 2002.

LEOs alone
Rather than adapting protocols to grapple with high-latency GEOs, some companies have turned to LEOs. SkyBridge, originally conceived by Alcatel and now under the aegis of several international partners, will offer interactive multimedia services beginning in 2001. With a constellation of 80 LEO satellites, SkyBridge will eventually have the capacity to serve 20 million users worldwide and offer downstream speeds in multiples of 20 Mbps and return links in multiples of 2 Mbps. SkyBridge differs from other two-way broadband satellite projects in that it will use Ku-band instead of Ka-band frequencies.

Teledesic’s Internet in the Sky is the most massive satellite constellation on the drawing table. Its 288 LEO satellites, orbiting at altitudes below 1,400 km and using Ka-band frequencies, will make multimedia services available to nearly everyone. Data rates will be 64 Mbps on the downlink and 2 Mbps on the uplink for standard terminals, and 64 Mbps both ways for broadband terminals. All terminals will support standard network protocols including IP, ISDN, and ATM. Teledesic expects to begin service in 2004.

circular orbits—at first glance look like the most suitable and best candidate, if targeting small and low-power terminals due to the low demanding link dimensioning. Thanks to the possibility of implementing frequency reuse techniques efficiently, good spectral efficiency can be achieved.
Low-earth orbit systems can provide the same minimum elevation angle at all latitudes. However, they have a high degree of complexity due to the large number of satellites required and to the management of frequent handovers.

Predicting UMTS requirements

Looking at the traffic forecasts for UMTS, we can see that satellites will be relevant in multimedia scenarios in terms of the number of potential users, of expected capacity, and of required bandwidth until the year 2010.

Researchers have considered two types of terminals and traffic—hand-held terminals for low data-rate services and larger terminals for multimedia services.

Figures 1, 2, and 3 show the numbers in terms of users, traffic, and spectrum foreseen world-wide for the years 2005 and 2010. Figure 4 shows the expected bandwidth demand in Europe for both terrestrial and satellite components in 2005 and 2010, while Figure 5 shows the evolution in terms of percentage. These figures show that the role of the satellite component is expected to grow slightly between 2005 and 2010.

Spectrum for mobile satellite services

The World Radiocommunication Conference (see http://www.itu.int/itudoc/itu-r/wrc/wrc-97/index.html) established that bands 1885 to 2025 MHz and 2110 to 2200 MHz were intended for the IMT2000 system.

A further possibility is to use higher frequency bands around 20 to 30 GHz and 40 to 50 GHz. In fact, 100 MHz are allocated in ITU Regions 1 and 3 (20.1- to 20.2-GHz downlink; 29.9- to 30.0-GHz uplink) while 500 MHz are allocated in ITU Region 2 (19.7- to 20.2-GHz downlink; 29.5- to 30.0-GHz uplink). In addition, 1 GHz (39.5 to 40.5 GHz) is allocated in the downlink, shared with terrestrial fixed and mobile services, and 43.5 to 47.0 GHz is allocated shared with terrestrial mobile, radionavigation, and radionavigation-satellite service.
Technical aspects

Although features for next-generation systems have been established, many critical technical issues remain, including the following:

- Services identification. Satellite networks can provide a wide range of services (videoconferencing, Web browsing, e-mail, telemedicine, and so on) that fixed networks currently provide. For example, in this issue Franchi et al. discuss Inmarsat’s services. In addition, others have conducted demonstrations with Ka band systems, including Holzbock and Senninger in this issue.

- Payload key technologies. To improve payload performance, the use of on-board processing (OBP) capabilities based on digital signal processing techniques are well accepted nowadays, having already been tested. The use of multibeam antennas and steerable beam technology enables more efficient coverage and alleviates user terminal requirements. The intersatellite link (ISL) allows interconnection among different units, realizing a real network in the space. Marinelli and Giubilei deal with these aspects in this issue.

- Spectral efficiency and interference. One of the most limiting factors for satellite systems is achieving spectral efficiency—providing coverage as similar as possible to terrestrial cellular systems. Although using the frequency reuse technique in cellular-like systems reduces the needed bandwidth, it introduces co-channel interference as the frequency reuse factor is higher. For satellite systems, adopting multispot coverage proves even more critical than for landmobile systems. The beam-to-beam interference level depends only on the angular separation between two beams using the same frequency, and the orography doesn’t mitigate this impairment.

- Radio access. One open issue concerns selecting the radio access scheme. In the frame of the UMTS/IMT2000 standardization process several proposals have been submitted, mostly based on code-division multiple access, or CDMA (see http://www.itu.int/imt/2_rad_dev/index.html). In the case of Ka band systems, time-division multiple access (TDMA) is preferred in some cases.

- Channel impairments. A critical aspect involves communication channel impairments. When mobility is introduced, the time variability proves more critical, and phenomena such as shadowing arise. If a frequency beyond 10 GHz is used, tropospheric attenuation must also be considered.

- User terminals. To get maximum market penetrability and real integration between terrestrial and satellite segments, the terminal must be as inexpensive, small, and power efficient as possible. The goal is to have the same terminal connect transparently to one of the two system components.

- Spectrum use. The history of wireless communications has so far demonstrated the need to explore and use even higher frequencies to satisfy traffic requirements. As shown in this issue, the Ka band is well accepted. Exploring the EHF band in both the lower portion (40 to 50 GHz)—which Motorola plans to use in its MStar system—and the higher portion (90 GHz) will open new possibilities in the next few years.

- Evolutionary constellations. Starting from the classical constellations as described in the previous section, new and hybrid concepts could synthesize the advantages of different configurations targeting even more capillary coverage with high data-rate capabilities and performances.

- Integration. Integration between terrestrial and satellite components and between fixed and mobile networks represents a key issue. Of course, the integration can be pursued at dif-
different levels (terminal, services, network, and so on), each implying different technological requirements and constraints. Searching the maximum number of common elements between the components can facilitate this process. The intersegment handover procedure represents a critical issue (see http://www.euroskyway.alespazio.it/accord.htm).

Network architecture and protocols. Network aspects are perhaps the most relevant, aiming to adapt protocols and procedures peculiar (and well assessed) to the fixed networks and to the interconnection among different networks. Three articles in this issue cover this topic, one on UMTS (Delli Priscoli) and the other two on a Ka-band system (Blefari-Melazzi and Reali and Iera et al.).

Conclusions

The expectation of the importance that mobile multimedia communications will assume is also witnessed by the effort that international organizations like Inmarsat, the European Space Agency (ESA), and the European Union (EU) are dedicating to their development.

As the articles in this issue show, researchers have identified and solved most of the main problems associated with satellite systems. However, much work lies ahead to finalize specifications and set up systems and services.

References


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