Guest Editorial
Broadband IP Networks via Satellites—Part I

SATELLITE systems have been an important element of telecommunications networks for many years serving, in particular, long distance telephony, data, and television broadcasting. The involvement of satellite in Internet protocol (IP) networks is a direct result of new trends in global telecommunications, where Internet traffic will hold a dominant share in the total network traffic. The large geographical coverage of the satellite footprint and its unique broadcasting capabilities, as well as its high-capacity channel combined with readily available Ka-band spectrum will retain satellite systems as an irreplaceable part of communications systems, despite the high cost and long development and launching cycle of a satellite system.

This issue of the IEEE JOURNAL ON SELECTED AREAS IN COMMUNICATIONS (J-SAC) is devoted to the numerous research activities toward realization of the global broadband Internet access via satellite networks. The response to our open call-for-papers was overwhelming with high-quality research papers from all around the globe. This has shown great research activities in this important field and justified the needs for this J-SAC issue. After peer review of all submitted papers, we ended with a huge number of good papers and as a result the issue has been divided into two parts. The first part, which is now in your hands, includes 17 high-quality papers describing research results at higher layers of the network. The topics include system architecture, system management, mobility management, multicast, quality-of-service (QoS), routing, and transport protocol techniques. The second part to appear in May 2004 will cover lower layers of the network including link, medium access, and physical layers. Other related topics will be also included.

As the Guest editors of this special issue, we hope that the readers find it interesting and consider it as a useful guide in research and development activities toward realization of the global wireless Internet. We are confident that many of the papers included in this issue will become long-term references for future works in this emerging field.

I. INTRODUCTION

Satellite communications offer clear advantages with respect to cable networks.

- *The architecture is scalable:* a new user can join a satellite communication system by acquiring the necessary technical instrument and no area need be cabled to get the high-speed service. Cabling is not a simple job and adding a customer to the network if he is located remotely is not always possible without heavy technical complications. If a new customer wants to join a satellite network, he should only acquire the necessary tools. There is no problem of scalability in satellite system.
- *The diffusion throughout the land is wide:* a satellite network overcomes simply the geographical obstacles, which will make the installation of a cable network of equivalent quality difficult; moreover the satellite can cover isolated areas. It is sufficient to think of huge continents such as Australia, Africa, America, or countries in Asia and South America, characterized by areas where the population density is so low that the cabling operation cannot be economically justified. Other geographic obstacles characterize other regions: mountains, valleys, and rivers, where either it is extremely difficult to offer a cable service or it is not convenient from the economic viewpoint. The installation of a telecommunication network is made difficult in many regions of the world by natural disasters such as floods and hurricanes, or by wars. In these cases, the only possibility to guarantee telecommunications is represented by satellites.
- *The multicast service is very simple*: as the satellite is inherently a broadcasting tool.

Satellite links are often private lines, unlike submarine and overland networks. The Internet is characterized by heterogeneity both from the point of view of algorithms and management, which is performed by many organizations and providers. A completely private network has the advantage of being managed by few people so to avoid many problems about the property and managing of different portions of the network.

In some situations, satellite is the only choice for broadband communication. For example, recently, many airline companies (e.g., United Airlines and Singapore Airlines) and aircraft makers (e.g., Boeing) started a huge investment for in-flight broadband and cheap Internet access. A recent forecast by Frost and Sullivan estimates that in-flight entertainment alone will be worth $2.7 billion by 2007. Similarly, DirecTV, DirecPC, and broadband Internet for home and small businesses cover a huge market for the Internet access via satellites in order of 1 to a few megabits per second.

Internet has been one the fastest growing technologies within the telecommunications industry in recent years and it is ex-

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pected to continue as the most important technology for years to come. For the future generations of the Internet, broadband access, and QoS are among the most significant issues to be solved.

Which applications may use the Internet's transmission control protocol (TCP)/IP suite? The answer is simple: all the applications that require a reliable (TCP-based) or unreliable user datagram protocol (UDP) transport service over packet-switched communication networks (IP). Anyway this answer does not give any idea about the amount of applications that use the TCP/IP. Some of them are listed below: audio and video streaming, tele-working, video-conference, WEB navigation, database access to retrieve information, tele-medicine (transmission of clinical tests, X-rays, electrocardiograms, magnetic resonance), tele-control (remote control of robots in hazardous environments, remote sensors, systems for tele-manipulation), bank and financial operations, e-commerce for home business, e-commerce for transportation systems goods movements, purchase and delivery, and tele-learning. Most of the applications currently on the market are TCP/IP-based.

Matching applications that use TCP/IP with the advantages offered by satellites is, therefore, important. It is natural to think of TCP/IP-based applications over satellite networks because the widespread diffusion of TCP/IP application makes difficult to think of another protocol architecture nontransparent to the user, dedicated to the satellite links. The problem may be the QoS. All the applications mentioned above require some precise levels of QoS to provide service to the users but the provision of QoS guarantees, which is already a difficult job over terrestrial connections, is a really serious concern over satellite links.

The round-trip delay and the general characteristics (e.g., fading) of the links heavily affect the performance of the protocols at every functional level: physical and data link protocol; IP layer; transport and application protocols. Resource allocation and fading countermeasures are issues of particular importance in this environment. Different from cabled and terrestrial networks for personal communications, satellite channels characteristics vary depending on the weather and the effect of fading that heavily affects the performance of the access system and the whole system.

So, new solutions concerning network architectures and each protocol layer allowing the efficient transport of TCP/IP applications through satellite networks, transparently to the final user, should be the goal.

The first part of this special issue mainly focuses on higher layers of the network. Layer 1 and layer 2 will be the subject of the second part of the same issue, due in May 2004.

II. QoS Over Satellites: Technical Challenges

Providing QoS over satellite networks implies a focus over different functional layers and technical challenges, often related to each other.

A. Applications

The action at the application layer is often fundamental to reduce the traffic load entering the satellite network so to improve the overall quality perceived by the end users. In this view, the paper by Armon and Levy presents the design and performance evaluation of a cache satellite distribution system (CSDS) that selects the documents to be transmitted by the central station to the component proxies and evaluates the benefit of adding a particular proxy to the system. The aim is to forecast future requests and avoid fetching them reducing the overall load. The paper by Celandroni *et al.* proposes an experimental study to act on the video encoding in presence of faded channels.

B. Control Algorithms and Bandwidth Allocation

Control functions are essential to guarantee a certain level of QoS and to improve bandwidth utilization. In particular the following topics are of special interest.

1) Call Admission Control (CAC): Decides whether a new connection request may be accepted or not. It is a powerful tool to guarantee quality because it allows limiting the load entering the network and verifying if enough resources are available to satisfy the requested performance requirements of a new call without penalizing the connections already in progress. In satellite networks, it is often applied in connection with adaptive control strategies to match the dynamic channel status due to weather conditions, as suggested by Alagoz *et al.*

2) Scheduling: Specifies the service policy at a queue within a node (for example, an on-board switch). In practice, scheduling decides the order to be used to pick the packets out of the queue and to transmit them over the channel. It is an important issue because it has a strong impact on different QoS parameters such as delay, jitter, and packet loss. Concepts known in terrestrial networks need to be adapted to the satellite environment as done by del Rio Herrero and Maufroid who present an innovative packet switched transparent processor that retains most of the research performed in optical communication.

3) Flow Control: In some cases, the bit rate entering the network may be ruled according to a congestion notification. Generally, flow control is implemented end-to-end at the transport layer (even if some mechanism are implemented at the application layer, as seen before). Its implementation has a strong effect on the performance of the overall communication and deserves some few words reported shortly in the subsection "Transport Protocol."

4) Routing: Packet routing decisions are often taken with little or no awareness of network status and resource availability. This is not compatible with QoS provision. QoS routing needs to identify end-to-end paths, where there are enough available resources to guarantee performance requirements in terms of metrics such as packet loss, delay, call blocking, number of hops, and reliability, as well as bandwidth optimization. It has a heavy effect on the performance: it is sufficient to think to hybrid satellite/terrestrial networks, LEOs, and spot beam switching.

In more details, Svigelj *et al.* propose a traffic class dependent routing for intersatellite links networks; Sun and Modiano develop routing and scheduling algorithms in LEO environment; and finally, Dai and Chan suggest a unified mathematical framework to match capacity dimension and routing in hybrid networks.

5) Mobility Management: LEO environments are characterized by frequent handover occurrences. Mobility management is topical to guarantee QoS. Tsunoda *et al.* propose to exploit location information to make the mentioned management independent of handovers so reducing update requests and increasing scalability.

C. Security

Satellite networks are particularly sensitive to active intrusions because of their broadcast nature. Moreover, limited on-board processing capabilities make the application of encryption methods difficult. Within this context it is very important to study an efficient key management for encrypted traffic, such as one performed by Howarth *et al.*

D. Transport Protocols

The performance of TCP over satellite links has two main problems: the large delay-bandwidth product and the misinterpretation of channel errors, which are considered as congestion by the TCP. Actions are strictly needed to improve the quality of the communication. Marchese *et al.* present a performance enhancing transport architecture (PETRA), aimed at improving the performance by overcoming the limits imposed by the TCP/IP stack. Karaliopoulos *et al.* investigate TCP interaction with bandwidth on demand (BoD) schemes acting at the medium access control (MAC) layer so generating distinct bearer services over the satellite network. Akan *et al.* suggest a reliable transport protocol called TP-Planet applied over deep-space communication links as interplanetary backbones. Luglio *et al.* consider an evolution of TCP splitting and place a TCP proxy on board the satellite so separating the TCP connection between ground station and satellite. Taleb *et al.* address the TCP efficiency problem over multihop networks from the algorithmic point of view and propose an explicit and fair window adjustment method.

E. Multicast

Even if satellites provide a natural broadcast information distribution, they also introduce additional problems with respect to full terrestrial environments: different channel conditions and data losses for the same multicast group, TCP congestion control problems reported in the previous subsections, low bandwidth, and errored feedback links. In this context, Akyildiz and Fang propose a reliable multicast transport protocol (TCP-Peachtree). Morabito and Palazzo analyze the throughput of TCP-like multicast congestion control in hybrid satellite/terrestrial networks, while Filali *et al.* proposes two different approaches to provide efficient multicast communication over GEO satellite supporting multiple spot-beam, as well as on-board switching, and a new protocol called satellite multicast adaptation protocol (SMAP).

III. CONCLUSION

This special issue is devoted to the numerous research activities toward the generation of the broadband IP via satellite networks. It is aimed at gathering research and progress and at highlighting technical challenges in the field of satellite IP.

The papers included in this issue cover the most important topics in satellite IP communications concerning applications, networking, control algorithms, mobility management, QoS, security, caching, and multicasting.

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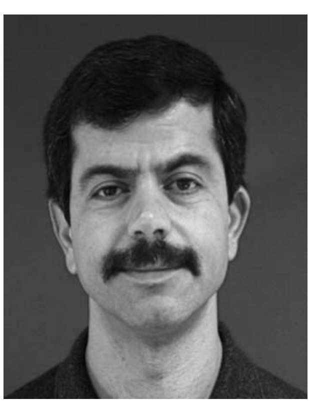

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