Satellite Multimedia Networks and Technical Challenges

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Abstract: **The next generation global communication network infrastructure is designed to be all IP based supporting various heterogeneous core and access technologies for broadband and mobile user applications. In this paper, we discuss the trends of broadband satellite communication networks to meet the emerging aeronautical and fast train applications, and mobile users in providing ubiquitous global coverage. Mobile satellite systems will be fully integrated with wireless networks and terrestrial segments. The technical challenges for future broadband satellite systems will be to insure seamless integration between satellite and wireless systems and without compromising Quality of Service (QoS). We discuss briefly the technical challenges and possible solutions, including a QoS reference model, traffic management, dynamic bandwidth allocation, cross-layer protocol design, Satellite TCP, mobility management, satellite IP security, internetworking and standardization issues to realize heterogeneous networks.**

I. Introduction

The next generation global communication network is designed to be all IP-based supporting heterogeneous core and access technologies for broadband and mobile applications. Fixed, as well as, mobile satellite systems will be fully integrated with future wireless and wired networks. To properly deploy state-of-the-art satellite technologies, several challenges pertaining to provisioning an end-to-end Quality of Service (QoS) and mobility have to be addressed. Emerging applications such as multicast, media streaming, content delivery distribution and broadband access are fueling Internet growth projections. These and other media rich applications require a network infrastructure that offers greater bandwidth and service level guarantees. Residential, small business and enterprise Internet users are already demanding high data rates and high quality of service. 100 Mbps service to home is common in some countries. An outcome of this demand were several access technologies varying from leased line to cable, Digital Subscriber Line (DSL), wireless, optical, and satellite. As the demand for new applications increases, "best effort" service of the Internet will become inadequate and will result in lack of user satisfaction.

In recent years there has been a tremendous growth in mobile communications and new wireless technologies have rapidly emerged. As demand for communication connectivity "anytime, anywhere, and any way" increases, heterogeneous network design trend will grow faster supporting seamless integration. Satellite communication plays a significant role in supporting such architectures through hybrid Satellites/Wired/Wireless infrastructure. The main advantages of Satellite communications offer ubiquitous coverage, bandwidth flexibility, multipoint-multipoint connectivity, and fast service initiation after deployment and reliability.

Traditionally, satellite communication systems have played a significant role in supporting services such as TV broadcasting, digital messaging, enterprise Virtual Private Networks (VPN's), and point-to-point telecommunications and data services. The recent Internet growth has resulted in new generation of applications with higher throughput requirements and communication demands. Service providers, network and Internet access providers are faced with a challenge to meet the higher capacity access to the end user and wider service offerings. Satellite network systems can be optimized to meet new service demands such as aeronautical and mobile applications. However, some of the issues have to be addressed prior to a proper selection of network architecture. For example, trade off studies of the frequency of operation, (Ku, Ka), processing versus non-processing payload, switching (IP, MPLS), QoS mechanisms, type of antennas, network protocols, transport protocols, crosslayer designs, network management, techniques have to be performed to meet the driving applications and requirements.

This paper is organized as follows: Section II introduces a Global Communication Network Scenario and identifies a few applications and requirements. Section II then provides an overview of fixed, mobile current satellite systems and future trends of satellite networks for aeronautical and fast-train applications. Section III presents technical challenges and some of the possible solutions for IP networks, including traffic management; QoS reference model, dynamic bandwidth allocation, crosslayer protocol design, transport protocols, IP security, mobility management, interworking and standards. This paper concludes with some future efforts required for heterogeneous networks providing seamless service.

II. Broadband Satellite Network Systems

This section describes a global network scenario, current satellite systems for fixed and mobile services; and future networking trends for emerging applications with some system examples.

A. Global Communication Network Scenario

One of the key requirements for the emerging "global network" which is a *"network of networks"* is rich connectivity among fixed, as well as, mobile users. Advances in switching and transport technologies have made increases in transmission bandwidth and switching speeds possible, and still more dramatic increases are achievable via optical

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switching. The future generation of communication networks provides "multimedia services", "wireless (cellular and satellite) access to broadband networks", and "seamless roaming among different systems". Figure 1 shows a global communication network scenario providing connectivity among corporate networks, Internet, and the ISPs. The access network technology options can be dial up, cable, DSL, optical, and satellite.

Mobile communications are supported by second generation, digital cellular (Global System for Mobile Communications - GSM) and, data service by Generic Packet Radio Services (GPRS). Third generation systems such as IMT-2000 can provide 2 Mbps and 144 Kbps indoor and vehicular environments. Even fourth and fifth generation systems are being studied to provide data rates 2-20 Mbps and 200-100 Mbps respectively.

Several broadband satellite networks at Ka-band are planned and being developed to provide such global connectivity for both fixed satellite service (FSS) and mobile satellite service (MSS) using Geosynchronous (GSO) and Non-Geosynchronous (NGSO) satellites. Currently GSO satellite networks with Very Small Aperture Terminals (VSATs) at Ku-bands are being used for several credit card verifications, rental cars, and banking applications.

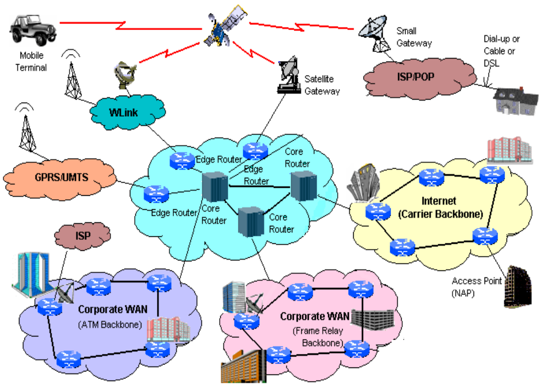


Fig. 1 Global Communication Network Scenario

Development of heterogeneous systems consists of wired and wireless transports to meet the future mobile and high bandwidth applications becomes a challenge.

B. Applications and Requirements

Emerging applications such as multicast media streaming and content delivery distribution are fueling Internet growth projections. In addition, aeronautical applications are gaining momentum to provide broadband and interactive services such as Internet access for inflight office, inflight entertainment and inflight personal communications. Also, demand for multimedia services for passengers in fast trains is increasing.

TABLE 1
FUTURE APPLICATIONS

Broadband	Mobile (Aeronautical/Trains)

• Broadcasting direct to home (DTH)
• Video on Demand
• High Speed Internet Access
• Electronic Messaging
• Multimedia
• Streaming Audio/Video
• Distance Learning
• Tele Medicine
• Video Conferencing
• Games
	• In Flight Office
	  ○ E-mail, Phone, Fax, File Transfer, Video Conferencing
	• In Flight Entertainment
	  ○ E-mail, Gamble, Phone, Live TV
	• Telemedia
	  ○ Video Conferencing, Vital Data Transfer
	• Multimedia & Internet Services for Train Passengers

Future global network infrastructure should support the following requirements.

- ***Data rates***: Applications such as video streaming, media-cast distributions, telemedicine, two-way telephonic education, require rates ranging from a few hundred megabits to several gigabits. Broadband systems have approximately 11-30 Mbps transmission speeds. The target speed for 4G cellular will be around 10-20 Mbps.
- ***Delay***: Real-time applications require a maximum delay of 400 ms and packet transfer delays for other classes of service are even more stringent.
- ***Mobility***: 4G cellular systems will require at least 2 Mbps for moving vehicles.
- ***Wide Coverage***: Next-generation systems must use GSO systems to provide wide coverage. Mobile satellite networks using NGSO cover roaming and handover to other systems.
- ***Scalability***: Network scalability should support large number of users, e.g. a few million, and resources in proportion to the number of users, application scalability providing the necessary QoS levels without performance degradation, i.e. 100,000 users with multimedia service support and QoS level guarantees per system.
- ***Quality of Service***: Application QoS must be supported providing guaranteed bandwidth, delay, and meet a delay jitter, packet loss, and availability requirements.
- ***Security***: User authentication, privacy, encryption, and end-to-end security must be supported.
- ***Multicast***: In addition to unicast, IP multicast service must be provided.
- ***Interoperability***: Standard protocol interoperability must be provided at all levels with interface designs supporting homogeneity of terminals, networks, and user-to-user applications.

C. Current Satellite Networks

C.1 Ka-Band Systems

To meet the broadband application requirements of high-speed data, audio and video streaming, and Internet access, Ka-band systems such as Astrolink (GSO), Spaceway (GSO), Euro Skyway, and Skybridge (NGSO), have been designed and developed [1]. Some of these systems feature data rates ranging from 16 Kbps to as high as 1 Gbps, supporting ATM and IP protocols and global coverage through a large number of spot beams. These systems use on board processing and switching. Skybridge is LEO based and the others used GEO constellation. Typical data rates supported vary from 16 Kbps to 1 Mbps on uplink and 16 Kbps to 155Mbps on downlink. Currently, Spaceway and EuroSkyway are on schedule for operation, whereas the others are either on hold or discontinued due to global economic downturn.

C.2 Mobile Satellite Systems

Three non-geostationary satellite systems, Iridium, Globalstar, and ICO, have been deployed. ICO operates in MEO while Iridium and Globalstar use LEO satellites. Globalstar uses a CDMA for multiple access whereas ICO and Iridium are TDMA based systems. Iridium employs 66 satellites with onboard processing. Currently Iridium is owned by Iridium Satellites Inc. and has a multi-year US Department of Defense (DoD) contract to provide services. Globalstar, does not employ inter-satellite links and a subscriber can gain access to the system only when a satellite is in view, and can also be seen by a gateway earth station. Globalstar has had multiple restructure approaches considered. ICO system is a spin-off from Inmarsat. It has 10 satellites in two inclined circular orbits.

Inmarsat has provided satellite communication services to mobile users since 1981 for data and voice services to maritime, land, and aeronautical users. Inmarsat has 9 successful launches, all of which are still operational. Inmarsat terminals are Standard-A, Standard-B, Standard-M, and Standard-C. *Standard-A* terminals are currently installed around the globe and used in remote locations, disaster situations, or peacekeeping operations. *Standard-B* terminals are used for voice using adaptive predictive coding at 16 Kbps and most terminals can operate at 6.4 Kbps. in a 10 KHz wide channel. *Standard-C* terminals provide data only at 300 bps and are used for low-rate messaging and position reporting.

Inmarsat initially started to provide speech and low data rate services. Currently it provides worldwide spot beam operation in the mobile satellite system (MSS) for paging, navigation, and higher rates to desktop. (See Section II C) Another GEO System for MSS is Thuraya [2] providing GSM and GPRS like services covering Asia and much of Europe.

C.3 Satellite Network Trends

Based on the lessons learned from current systems deployed satellites can only be used economically to provide the niche markets in the areas where cellular and terrestrial become inaccessible, where there are no infrastructures, rural areas, and/or islands.

Full mesh GEO Constellations with on-board processing and switching found to be expensive due to lack of driving applications and the competition from terrestrial systems with fast turn-arounds. Hence, immediate future trend will be to develop satellite network, and to support the mobile and broadband applications with non-regenerative payloads. As the global economy shifts and as per market demands next generation systems can receive the full benefits of processing payloads. Even non-GSO constellations using MEO or even HEO could be successfully operational.

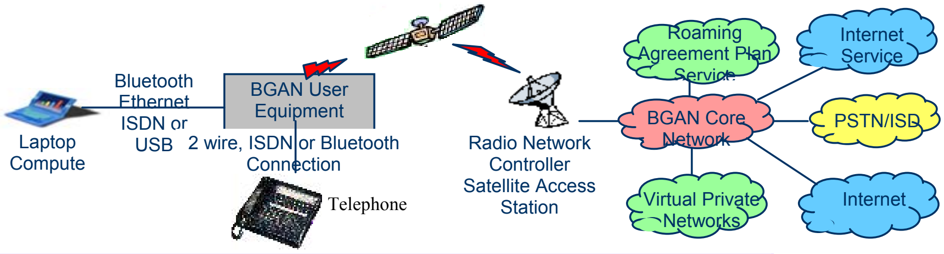
C.3.1 Broadband Satellite Access Network

Broadband access system provides regional coverage and is less complicated than their global or connectivity counterparts. They are usually more cost-effective, less associated technical risk, and regulatory issues. Table 2 provides a partial list of access satellite systems for regional coverage.

TABLE 2
BROADBAND ACCESS SYSTEMS

Services	StarBand	WildBlue	iPStar	Astra-BBI	Cyberstar
Data uplink (Kbps/Mbps)	38-153K	384K-6M	2M	2M	0.5-6M
Data downlink (Kbps/Mbps)	40M	384K-20M	10M	38M	Max. 27M
Coverage Area	US	Americas	Asia	Europe	Multiregional
Market	Consumer	Business/ SME	Consumer & Business	Business	ISPs, Multicast
Antenna Size (M)	1.2	0.8-1.2	0.8-1.2	0.5	--
Frequency Band	Ku	Ka	Ku & Ka	Ku/Ka	Ku, Ka
Satellite	GEO	GEO	GEO	GEO	GEO
Operation scheduled	Nov 2000	TBD	Late 2002	Late 2000	1999-2001

Many of these systems are based on ETSI/Digital Video Broadcasting (DVB-S) standard for forward channel and DVB-return channel via satellite (DVB-RCS) specification for satellite return channel DVB-RCS. Except Wildblue, most of the systems are operational. The DVB-RCS is based on the asymmetry in bandwidth for the broadcasting and return channel. In the forward direction the data rate is typically 40 Mbps in TDM format. The return channel data rate may vary between 144 Kbps and 2 Mbps. To improve the efficiency of system operation DVB-S2 standard is being developed with adaptive coding and modular schemes. [2]



	Inmarsat 2	Inmarsat 3	Inmarsat 4
No. of Satellites	4	4 + 1 spare	3 (inc. 1 spare)
Coverage	Global beam	7 wide spots + 1 Global beam	200 narrow spots + 19 wide spots + Global beam
Mobile Link EIRP	39dBW	49dBW	67dBW
Canalization	4 Channels between 4.5 & 7.3 MHz bandwidth	46 channels between .9 & 2.2MHz bandwidth	630 channels at 200KHz
Satellite dry mass	700kg	1000kg	3000kg
Solar array span	14.5	20.7m	48.0m

Fig. 2 Inmarsat BGAN Architecture

C.3.2 AmerHis - Broadband Access with Onboard Processing

AmerHis, a multimedia satellite network project between European Space Agency and Hispsat at Ku-band is being developed with regenerative multi-spot satellite payload. It employs on-board digital switch and combines both DVB-S, and DVB-RCS providing full cross-connectivity between uplinks and downlinks. [4]

C.3.3 Mobile System: Inmarsat BGAN

Inmarsat will provide Broadband Global Area Network (BGAN) up to 432 Kbps with the introductions of Inmarsat IV Satellites in 2004. Figure 2 provides Inmarsat BGAN architecture. The intended applications include: Internet Access with web browsing, VPN's, video conferencing, file transfer, even access by pocket terminals, PDA's, and notebooks. [5]

C.3.4 Connexion by Boeing-Aeronautical

Figure 3 shows Connexion by Boeing Satellite Network. It has been operational since 2002 in Scandinavian airlines and Lufthansa flights, providing high-speed Internet access using broadband wireless, IEEE 802.11b. It requires installing two antennas on each aircraft, one to receive and the other to transmit. A server and a routing system inside the plane relay signals to and from plug-in-ports at the seat or wireless networking cards in passenger laptops. Japan airlines intend to equip its long-haul fleet with such equipment. [6,7]

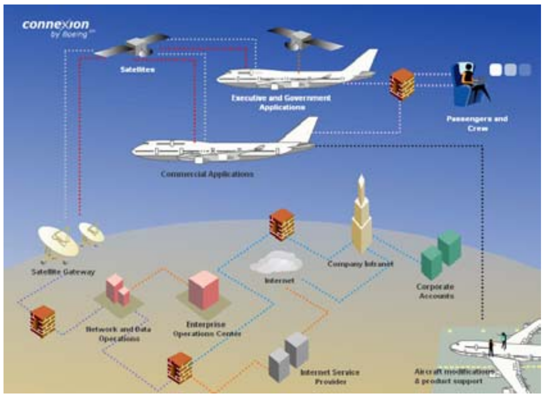


Fig. 3 Connexion by Boeing Broadband Satellite Network

C.3.5 Wireless Cabin for Aeronautical

Currently the European project WirelessCabin aims at providing aircraft passengers and crew members with heterogeneous wireless access solutions for in-flight entertainment, Internet access and mobile/personal communications. Aircraft passengers will be offered the same wireless services for personal and multimedia communications as they are on ground. The most important wireless access technologies are GSM, UMTS with UTRAN air interface, Bluetooth^{TM}, and W-LAN IEEE 802.11. [8]

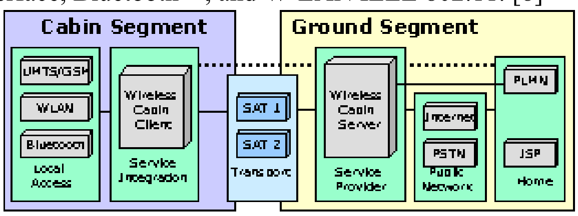


Fig. 4 Wireless Cabin Architecture

C.3.6. Fast Internet for Fast Train Host (FIFTH)

The FIFTH project has been developed to provide multimedia services, mainly Internet access and digital TV, to passengers on high-speed trains. It employs a GEO satellite operating at Ku or Ka Band, and DVB-S Standard. In short term scenarios non-regenerative payload by Atlantic Bird 1 or Hot Bird 6 by Alcatel will be used. In medium and long-term scenarios, on-board processing payload is planned with full connectivity. [9]

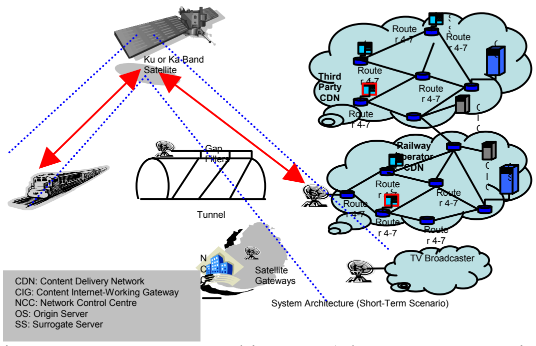


Fig. 5 FIFTH System Architecture (Short Term Scenario)

III. Technical Challenges – Satellite IP

Most of the Systems discussed in Section II are IP based networks. Some of them are planned to have an onboard processing and switching, interfacing with wireless networks for mobile applications. Satellite networks with onboard processing and switching capabilities allow direct interconnecting between satellite terminals and located in any satellite beam. Within a designated service coverage region, network management, onboard switch control, service access, packet routing, and forwarding and/or label switching functions are based within Network Control Center (NCC) which could be terrestrially located. The network control functions could also be shared between ground control and onboard controller. There are many issues for IP based networks and services, in particular, lack of proven robust and scalable standard mechanisms for satellite networks. These include:

- Dynamic allocation of resource optimized for packet loss and delay.
- Assuring that the required end-to-end network performance objectives are achieved.
- Seamless signaling of the desired end-to-end QoS across both the network and interfaces.
- Performance monitoring of IP based networks and services consistent with planning method.
- Rapid and complete restoration of connectivity following server outages or heavy congestion levels.
- Mobility management
- Cross layer protocol engineering methodology.

The following paragraphs describe technical challenges and possible solutions for heterogeneous satellite/wireless/ wired network infrastructure.

A. Traffic Management

Traffic management is required to deliver a negotiated QoS to applications and to control congestion. Thus, critical or real-time application traffic may be given better service at network nodes than less time critical traffic. In addition, congestion must be controlled to avoid performance degradation and congestion collapse that occur when network buffers overflow and packets are lost. The network load should not increase beyond a certain optimal operating point, commonly known as the knee of the delay throughput curves. Beyond this point, increasing the load level on the network results in a remarkable increase in end-to-end delay caused by network congestion and retransmissions. The following are the objectives of traffic management.

- ***Fairness***: Traffic sources should be treated according to some fairness criteria like max-min fairness (with or without minimum guarantees) or proportional fairness. Max-min fairness gives equal (or weighted incase of weighted max-min fairness) shares to sources sharing a common bottleneck.
- ***Efficient Resource Utilization***: Available resources e.g., network buffers, network link bandwidths, processing capabilities, proxy servers, should be efficiently utilized.
- ***Bounded Queuing Delay***: Queuing delay should be small to guarantee low end-to-end delay according to application QoS requirements, and to ensure buffers do not overflow and cause excessive packet loss.
- ***Stability***: Transmission rates of the sources should not fluctuate in steady state.
- ***Fast Transient Response***: Traffic sources should not react rapidly to changing network conditions like sudden congestion.
- ***Scalability***: The traffic management algorithms must be scalable to large number of users.

Possible solution for traffic management for a Satellite IP network exists in extending the concepts, methodologies developed for terrestrial network environment. The real design challenge will be in allocation of the traffic management functions between terminal, gateway, payload, and network control centers for cost effective implementation for connection level and packet level. Many differentiated traffic management methods exist [10]. One of the possible solutions is to use either Integrated Service (IntServ) or Differentiated Services (DiffServ), or even a combination of the two. Even though IntServ is not scalable, but could be possibility for satellite gateways which are not large in number. DiffServ could be employed in the satellite network core router for packet forwarding based on the classification performed at the terminals. Expedited Forwarding (EF) provides low loss delay service using strict admission control at the terminals. Assured Forwarding (AF) provides better than best effort services for more security traffic using multiple queues and drop priorities. [11] addresses the issue of resource management using DiffServ marking for Satellite IP gateways.

Other packet level traffic management functions include policing and shaping with strict leaky bucket algorithms, scheduling, and buffer management. Satellite terminal/gateway routers typically perform classification, marking, shaping, and dropping packets. Packet scheduling disciplines such as Weighted Fair Queuing (WFQ) and buffer management policies including Random Early Detection (RED) and its variants are used to meet the performance bounds throughput, delay, delay variation, packet loss, for guaranteed services.

B. End-to-End QoS Model

QoS mechanisms provide service differentiation and performance measures for Internet applications according to their requirements. Performance assurance addresses bandwidth, loss, delay, and delay variation. Bandwidth is a fundamental resource for satellite communication and its proper allocation determines the system throughput. End-to-end delay is also important for several applications. There are choices to provide the Internet QoS. These are Integrated Services (IntServ), Differentiated Services (DiffServ), and Multiprotocol Label Switching (MPLS). However, the research of application of these QoS framework to broadband satellite network requires supporting IP QoS in a dynamic demand assignment capability environment. Reference [1] provides IP QoS performance objectives and service classification.

A workable QoS architecture must provide a means for specifying performance objectives for different types of packets, as well as, a means of delivering those performance objectives. To give different packets different treatment, the network infrastructure must be capable of distinguishing between packets by means of classification, queuing packets separately as a result of the classification, scheduling packet queues to implement the differential treatments, providing means for measuring, monitoring, and conditioning packet streams to meet requirements of different QoS levels. These can be realized through the implementations of mechanisms in the packet-forwarding path. The number of ways in which a packet can be treated in the forwarding path is limited. Aggregating individual flows according to their common packet forwarding treatment leads to a reduction of state and complexity. The mechanisms of the forwarding path must be amenable to high-speed implementations and easily composable.

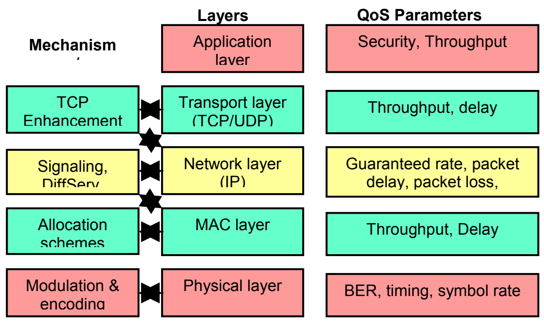


Fig. 6: End-to-End QoS Reference Model

QoS requires the cooperation of all network layers from top-to-bottom, as well as, every network element from end-to-end. At each layer, using efficient technologies and counteracting any factors causing degradation achieve the user performance requirements.

For example, at the physical layer, bandwidth efficient modulation and encoding schemes, such as concatenated coding and adaptive coding, have to be used to improve the BER and power level performance under whether conditions such e.g. rain. Similarly, a superior QoS is achieved providing the guaranteed bandwidth at the link layer by using efficient bandwidth on demand multiple access schemes and studying the interaction of bandwidth allocation mechanisms in the presence of congestion and fading. The provision of a specific bandwidth to be offered by the physical layers to the upper layers implies the existence of a bandwidth allocation scheme that shares the bandwidth available among the different user terminals with different traffic classes. To satisfy the different QoS service level guarantees according to SLAs with DiffServ at the network layer, service classification, marking, queuing, and scheduling functions can be used. Currently, most of the Internet applications use the TCP protocol, and several TCP enhancements exist for satellite environment mitigating the link impairments. Eventually, these QoS parameters have to be mapped to the application QoS as required by the system design and target applications.

C. QoS Parameters

The QoS Parameters are:

- *Delay* is the time for a packet to be transported from the sender to the receiver.
- *Jitter* is the variation in end-to-end transit delay.
- *Bandwidth* is the maximal data transfer rate that can be sustained between two end points.
- *Packet Loss* is defined as the ratio of the number of undelivered packets to the total number of sent packets.
- *Reliability* is the percentage of network availability depending upon the various environmental parameters such as rain.

To achieve an end-to-end QoS in both satellite and/or hybrid satellite/terrestrial networks is a non-trivial problem. However, end-to-end QoS objectives, including security, need considerable research. A successful end-to-end QoS model depends upon the various interfaces at each subsequent lower layer to the upper layers.

D. QoS Provisioning

There are several mechanisms for Provisioning QoS. These are Integrated Services, Differentiated Services and Multi Protocol Label Switching (MPLS).

D.1 Integrated Services (IntServ)

IntServ is a per-flow based QoS framework with dynamic resource reservation. In this, routers need to reserve resources in order to provide quantifiable QoS for specific traffic flows.

Resource Reservation Protocol (RSVP) is the signaling protocol for application to reserve network resources. It adopts a receiver-initiated reservation style, which is designed for a multicast environment and accommodates heterogeneous receiver service needs.

The IntServ architecture adds two service classes to the existing best-effort model – guaranteed service and controlled load service. Guaranteed service provides an upper bound on end-to-end queuing delay and is aimed to support applications with hard real-time requirements. Controlled-load service provides a quality of service to best-effort service in an underutilized network, with almost no loss and delay and is aimed to share the aggregate bandwidth among multiple traffic streams in a controlled way under overload conditions. IntServ can deliver find-grained QoS guarantees by using per-flow resource reservation. Introducing flow-specific states to routers means a fundamental change to the current Internet architecture, especially in the Internet backbone where it will be difficult for the router to maintain a separate queue for each of the hundred thousand flows, which may be present.

D.2 Differentiated Services (DiffServ)

DiffServ has been proposed by IETF with scalability as the main goal. It is a per-aggregate-class based service discrimination framework using packet tagging. Packet tagging uses bits in the packet header to mark a packet for preferential treatment. The type-of-service (TOS) byte is used to mark packets in IPv4. The TOS byte consists of a 3-bit precedence field, 4-bit field indicating requests for minimum delay, maximum throughput, maximum reliability, and minimum cost, and one unused bit. DiffServ redefines this byte as the DS field. Six bits of the DS fields form the DiffServ Code Point (DSCP) and the remaining two bits are unused.

DiffServ uses DSCP to select per-hop behavior (PHB) a packet experiences at each node. A PHB is packet forwarding treatment specified in a relative format compared to other PHBs, such as relative weight for sharing bandwidth or relative priority for dropping. Before a packet enters a DiffServ domain, its DSCP field is marked by the end-host or the first-hop router according to the service quality the packet requires.

DiffServ has two important design principles – pushing complexity to the networks boundary and the separation of policy and supporting mechanisms. Pushing Complexity to network boundary: This is important for the scalability of DiffServ. The network boundary refers to the application hosts, leaf routers and edge routers. Operations can be performed at the fine granularity (operations such as complex packet classification and traffic conditioning) at the network boundary as it has relatively small number of flows. Network core routers have larger number of flows and so should perform fast and simple operations.

Separation of control policy and supporting mechanisms: This is important for the flexibility of DiffServ. DiffServ only defines several PHBs as the basis for QoS provisioning. It leaves the control policy as an issue for further work, which can be changed as needed while the PHBs shold be kept relatively stable. DiffServ has several QoS functions as shown in figure 7. These functions are marking, classification, metering and scheduling.

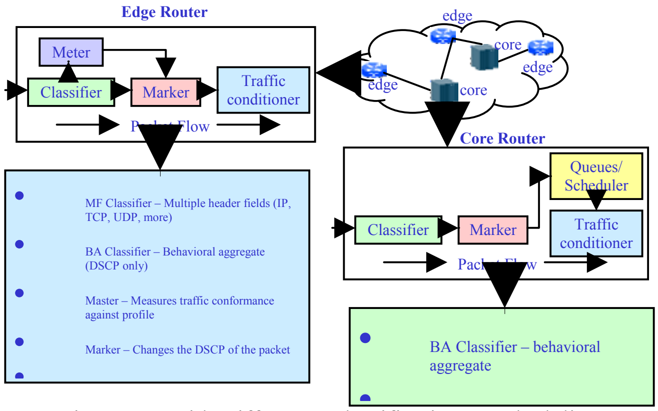


Fig. 7 QoS with DiffServ – Classification & Scheduling

E. Dynamic Bandwidth Allocations

To enhance the performance of the Satellite networks, several demand assignment multiple access to protocols have been proposed [12] using prediction of the bandwidth requirements of the terminals. The network delay and delay filter performance can be improved using such demand assignment algorithms. Dynamic bandwidth allocation studies [13] consider dynamic coding and modulation adapting to link rate and the link quality. The advantages of statistical multiplexing must be taken into account. In addition, for internet access using DVB-RCS, various bandwidth allocation schemes are specified. These include Continuous Rate Assignment (CRA), Rate Based Dynamic Capacity (RBDC), Volume Based Dynamic Capacity (VBDC), and Free Capacity Assignment (FCA). The details can be found in [14]. Some of these concepts and algorithms can be extended to mobile satellite networks.

F. Cross Layer Protocol Design

The fourth generation Communication network incorporates mobility and interface to wireless networks, providing QoS. The terminals are expected to be equipped with multiple wireless network interfaces, including 802.11, Universal Mobile Telecommunication System (UMTS) and Bluetooth. Also, there is a requirement of moving from IPv4 to IPv6 including MIPv6 considering terminal mobility functions. To consider the crosslayer protocol interactions, possible solution is to have a crosslayer protocol design with additional coordination plane in addition to the mobility plane. [15] Figure 7 shows an example of such a crosslayer manager coordinating various interlayer functions. Several issues, such as power vs. delay, power vs. BER, and mobility, TCP performance, handover and satellite link adaptation to fading should be coordinated.

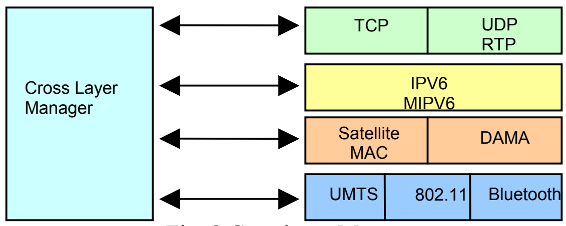


Fig. 8 Crosslayer Manager

G. Transport Protocols

Most of the global and regional satellite network architectures address supporting Internet applications. TCP/IP is the most widely used protocol suite accessing the Internet. The main characteristics of the end-to-end path that affects transport protocols are latency, bandwidth, packet loss due to congestion, and losses due to transmission error links. A number of TCP enhancements have been proposed by the IETF for satellite or large bandwidth delay environment. Excellent surveys on TCP enhancements and their applicability for wireless and satellite networks can be found in [16].

Mostly TCP New Reno, TCP SACK, and TCP Window scaling are being used for satellite environment. A good discussion on TCP is given in Transport Control Protocol TCP: RFC793, and enhancements in RFC2488; and current research in RFC 2760. Other transport protocols include: a) Space Communication Protocol Specification – Transport Protocol (SCPS-TP) CCSDS 714.0-8 Standard b) Stream Controlled Transmissions Protocol (SCTP) RFC 2960 and c) Xpress Transport Control Protocol (XTP). Reference [17] provides a recommendation on TCP enhancements based on several TCP over satellite tests and measurements. A new transport protocol design for satellite links experiencing fading, errors, noise, Doppler shifts, and nomadic behavior could be a challenge in the long run. Recent study [18] shows TCP RSACK , TCK Reno, and TCP Westwood performance for mobile internet access using satellite LEO and GEO Constellations.

H. Mobility Management

LEO satellite networks can provide wireless connectivity while providing short propagation delays. LEO handovers largely effect mobility management. Several mobility management schemes exist which result in large number of binding update requests which affects the scalability of mobility management. Reference [19] introduces a handover independent mobility management scheme for LEO satellite networks. One of the challenges is to design an intelligent mobility management technology to take advantage of the global roaming, and satellite interface in the wireless environment. In a heterogeneous environment new architectures considering location management, hand off management, and mobility management are warranted.

I. Satellite IP Security

The challenge of security in the GEO satellite environment is one of the main issues to be addressed for widespread deployment of satellite IP for multicast and multimedia applications. The main problem is that eavesdropping and active intrusion is much easier than in terrestrial fixed or mobile networks because of the broadcast nature of satellites. In addition, satellite channels experience long delays and high bit error rates, which may cause the loss of security synchronization. This demands a careful evaluation of encryption systems to prevent QoS degradation because of security processing. The IETF provided security standards for the Internet known as IP Security (IPSec), which includes authentication, integrity, confidentiality, and security agreement. [20] The current solution for satellite networks is to use Performance Enhancing Proxies (PEPs) to improve the performance of the Internet Protocols where native performance suffers due to characteristics of satellite links. PEPs represent the “de facto” solution on field for TCP problems over satellite links. In addition, since PEPs need to see inside IP packets, PEPs cannot be used with end-to-end IPSec. Tunneled IPSec should be used with PEPs as the tunnel end points. This requires the PEPs to be trusted by the user. The issue of security is a real challenge to be addressed for global network realization. Solutions such as multilevel security or clear TCP header options should be evaluated.

J. Interworking

One of the challenges is to design interfaces for interworking satellite links with wireless networks, e.g. 4G systems, enabling mobility along with various broadband applications. Significant issues remain to explore the interfaces supporting the required end-to-end QoS levels handover, as well as, link adaptation for aircraft internet use or fast train usage applications.

K.Standards

The following are the current standards activities in the satellite IP networks:
1. International Telecommunication Union Radio Sector (ITU-R) is involved with development of new recommendations on a) Performance of Enhancements of TCP Over Satellite b) QoS Architectures and Performance, and c) Reliable Multicast Protocols for Satellites
2. European Telecommunication Standards Institute (ETSI) ETSI/BSM (Broadband Satellite for Multimedia) developed a) Air interface specifications for global broadband communications b) Multicast architecture) and c) Air Interface specification.
3. ETSI has developed the DVB-S and DVB-RCS for broadband access network, and DVB-S2 Standards.
4. Telecommunications Industry Association has been working on developing standards on a) IP Over Satellite Specifications b) QoS Signaling c) Air Interface Specification and d) DAMA

To meet future application demands the standard organizations require to co-ordinate their activities by liaising, avoiding duplications, and developing relevant standards for the network designers, operators, and implementers.

IV. CONCLUSIONS

This paper provided an overview of the current broadband satellite communications systems for fixed and mobile services. A brief status report on these systems is included. A discussion on the future trends of satellite communication networks for aeronautical applications, fast train passengers, and mobile services resulting in heterogeneous connectivity with a wireless system is given. Various technical challenges and possible solutions for the IP based heterogeneous networks including, traffic management, end-to-end QoS reference model, crosslayer protocol design, bandwidth allocation, security, interworking, and current status of the standards are addressed for a seamless ubiquitous global communication network.

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