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BROADBAND SATELLITE NETWORKS: STANDARDS, CROSS-LAYER DESIGN, AND QOS IMPROVEMENT

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ABSTRACT

A review of broadband satellite communication networks scenario, standards on broadband satellite networks and the main specifications of standards are provided. Due to the performance of current broadband satellite system is constrained by the layered protocol architecture, typical of both the ISO/OSI reference model and the Internet protocol suite. The cross-layer protocol stack is considered to be a feasible solution. A cross-layer protocol framework is proposed, which contains three pairs of standardization cross-layer interfaces beyond the ISO/OSI layered protocol model, allow for efficiency interactions between different layers. To meet the broadband applications quality of service (QoS) requirements, constraints of resource allocations for broadband satellite networks and the necessity of mappings between QoS requirements and DBA scheme are studied. Meanwhile, an example of DVB-RCS mappings is provided.

Keywords: *Broadband Satellite Communication, Standards, Cross-Layer Design, Qos, Dynamic Bandwidth Allocations*

1. INTRODUCTION

Satellite communications systems are becoming more and more popular for their economy, wide coverage, broadcast and multicast capabilities, and reliability. For rural, underdeveloped regions, and marine areas, satellites are often the only economic means of providing people with communications services and internet access. The upcoming satellite networks will be fully IP-based and support broadband multimedia interactive services, so called broadband multimedia satellite [1]. Different standardization groups like European Telecommunication Standards Institute (ETSI), and International Telecommunication Union (ITU), have started to develop standards and recommendations on broadband satellite communication system.

Meanwhile, to meet the IP-based multimedia services and applications Quality of Service (QoS) requirements, propagation loss of the satellite signal, higher capacity access, and wider service offerings, etc., many technical challenges have to be faced that are constrained by the layered protocol architecture, typical of both the ISO/OSI reference model and the Internet protocol suite [2]. Recently there has been increased interest in protocols for satellite networks that rely on significant interactions between various layers of the network stack [3-4]. The implementation of appropriate cross-layer optimizations framework improves the overall performance of satellite system. The standardization of interactions interfaces between modules of the system and the protocol layers are the basis of the efficient sharing of information [5].

Although, standards define different types of dynamic bandwidth allocation (DBA) scheme that should be treated differently by MAC protocol scheduling process, but undefined specific resource allocation solution. Study on resource allocation algorithm in MF-TDMA satellite systems become a hotspot. However, the constraints of resource allocation are discussed not enough, in processing of algorithm designed. Designers of algorithms often use complex mechanisms to obtain the greater system performance improvement. It may incur significant cost in terms of system architectural and signaling overhead. Therefore, it is necessary to further discuss its constraints.

In addition, the upcoming satellite systems providing both broadband access and broadcast services for users who are exchanging multimedia interactive application, including various voice,

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video, and data applications [6]. Service differentiation and end-to-end QoS requirements have become one of the main features of the broadband satellite communications systems. These systems are challenged to be 'QoS-aware' to efficiently use networks resources. It means that must to ensure efficiency and be able to actively participate in QoS operations. For this situation, the appropriate specifications should be adopted in standards.

The remainder of this paper is organized as follow: a briefly review of broadband satellite networks standards and the main specifications of standards is provided at first. Then, a satellite network protocol framework base on cross-layer design optimizations is proposed. In the cross-layer framework, three pairs of standardization of cross-layer protocol interfaces are defined. Later, the constraints of resource allocations in MF-TDMA satellite networks and QoS requirements mappings are discussed. And an example of DVB-RCS mappings is provided. Finally, conclusions are drawn.

2. BROADBAND SATELLITE COMMUNICATION NETWORKS SCENARIO

The future generation of satellite communication network provides 'high-speed Internet accesses', 'multimedia services' and 'seamless integration between different systems'. Figure 1 shows a broadband satellite communication network scenario, a Geostationary Orbit (GEO) satellite communication network topology with few gateway stations providing connectivity among Internet, corporate network and the LANs. In the space segment, multi-beam technology in Ka-band is used to increase the system capacity in GEO satellite. In the user segment, the satellite terminals aggregate few IP-based applications and they can be connected to the satellite network via return link.

3. STANDARDS ON BROADBAND SATELLITE COMMUNICATION NETWORKS

To meet the challenges for broadband satellite systems, a great deal of standardization work has been conducted, and more work is in progress. Currently, standards in broadband satellite networks include:

（1）ETSI, Broadband Satellite for Multimedia (BSM, ETSI TR 102 603) developed:

1) Air interface specifications for global broadband communications;

2) Multicast architecture; 3) Air interface specification.

（2）ETSI is involved with development of Digital Video Broadcast-Return Channel via Satellite (DVB-RCS, ETSI EN 302 790), Digital Video Broadcasting- Satellite (DVB-S, ETSI EN 300 421), and Digital Video Broadcasting-Satellite- Second Generation (DVB-S2, ETSI EN 302 790) standards for broadband satellite network:

1) Transmission system description;

2) Subsystems specification;

3) Error performance;

4) Reference models for satellite interactive networks in DVB;

5) Return link base-band physical layer specification and multiple access definition;

6) Control and management;

7) Security, identity, encryption.

（3）ETSI has developed the Regenerative Satellite Mesh-A (RSM-A, ETSI TS 102 188, ETSI TS 102 189) standard on:

1) Physical layer specification;

2) MAC/SLC layer specification.

（4）ETSI has developed the Regenerative Satellite Mesh-B (RSM-B, ETSI TS 102 429) standard on:

1) Physical layer specification;

2) Satellite Link Control layer;

3) Connection control protocol;

4) Specific Management Information Base.

（5）International Telecommunication Union Radio Sector (ITU-R) has been working on developing recommendations on:

1) Performance of Enhancements of TCP over Satellite;

2) QoS Architectures and Performance;

3) Reliable Multicast Protocols for Satellites.

（6）Telecommunications Industry Association is involved with development of standards on:

1) IP over Satellite Specifications;

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2) QoS Signaling;

3) Air Interface Specification;

4) DAMA.

Summary above, the existing broadband satellite system standards include: physical layer specification, MAC layer specification and QoS architectures. In particular, the standard organizations define some sub-protocols to meet the multimedia IP-based application demands, such as IP over Satellite Specifications and TCP PEP etc.

Moreover, advanced technologies, such as the multiple frequency-time division multiple access (MF-TDMA), dynamic sub-carrier rate and variable coding and modulation (VCM)/ adaptive coding and modulation (ACM), are employed in broadband satellite standards to adapt to the time-varying in wireless satellite channel and attenuation of Ka-band.

4. STANDARDIZATION OF CROSS-LAYER INTERFACES IN SATELLITE NETWORKS PROTOCOL

It is repeatedly argued that although layered architectures have served well for wired networks, they are not suitable for wireless networks, especially satellite network. Moreover, to meet the broadband services and applications QoS, an efficient cross-layer design beyond the ISO/OSI layered protocol model is necessary. As the packet losses, available bandwidth, and power are particularly critical constrained in the satellite systems.

Figure 2 shows a standardization of cross-layer protocol interfaces design example. For the sake of convenience, cross-layer protocol interfaces can be categorized as follows:

（1）Upper to lower layers interface. For example, delay or priority constraints of the application communicated to the Data link layer to enable the link layer to adapt its Active Queue Management（AQM） mechanisms.

（2）Lower to upper layers interface. For example, queue length in MAC communicated to TCP PEP to enable congestion control in the transport layer; physical layer modulation and coding rate scheme communicated to the link/MAC layer to enable adaptation of allocation algorithm.

There are three pairs of functional entity with cross-layer interface in three layers. The first functional entity pair is the resource management module in MAC layer; the second pair is the QoS management module in network layer; and the third pair is the PEP module in transport layer. Each function modules have the cross-layer interactive interfaces, including to lower layers interface and to upper layers interface, and efficiently information can be shared between layers.

The design of involved cross-layer algorithms including congestion control solutions in transport lay, AQM algorithms, resource management scheme etc. in MAC layer, and channel estimation algorithms in physical layer can base on the cross-layer protocol framework. Meanwhile, invoked mechanisms are provided in the three functional entity pairs, to determine under which system conditions a particular cross-layer algorithm proposal would be invoked.

5. DYNAMIC QOS IMPROVEMENT

On a currently broadband satellite system scenario, multimedia IP-based applications with different performance requirements must be supported. A classification of the different types of applications into user-driven performances is given in 3GPP standard Universal Mobile Telecommunications System (UMTS) where applications are classified depending on their delay sensitivity - Conversational, Stream, Interactive and Background - as well as their packet loss tolerance, reliability requirements, and BER [7], [8]. In order to support the multimedia IP-based applications, various DBA schemes are defined in standards. However, the mapping between the applications QoS parameters and the DBA schemes has not been a clear defined. For this, the specifications of terrestrial broadband access network protocol, such as wimax etc., can be reference. Figure 3 shows an end-to-end QoS scheme, QoS parameters of different layers and DBA schemes of MAC layer mapping should be defined by the system design and target applications. The mapping will affect the resource allocation algorithm, as well as BER and symbol rate in physical layer.

To enhance the performance of multimedia applications in broadband satellite networks, five capacity categories have been proposed in DVB-RCS. These include continuous rate assignment (CRA), rate based dynamic capacity (RBDC), volume based dynamic capacity (VBDC), absolute volume based dynamic capacity (AVBDC), and free capacity assignment (FCA) [9]. Table 1 gives an example of DVB-RCS mappings; the main characteristics of these classes are briefly descripted. Real-time application, such as VoIP, which is

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sensitive to delay and jitter caused by bandwidth insufficiency, is mapped to CRA. The QoS parameters constraints of CRA include maximum sustained rate, maximum latency tolerance, and Jitter tolerance. Streaming applications with the nature of serial video streaming applications, such as broadcast video, video on demand (VoD), etc. in general, they are characterized by a delay tolerance. Therefore, streaming applications are mapped to RBDC, with the QoS parameter constraints of minimum reserved rate, maximum sustained rate, maximum latency tolerance, jitter tolerance, and traffic Priority. Interactive, such as web browsing, is client/server model application. Such application requires a certain amount of throughput, frequently exchange of short packets, and high transmission correctness. Thus, the interactive application is mapped to VBDC, slightly lower than RBDC in the priority level. Background applications require high reliability of the transmission, but the low latency requirements. Therefore, FTP applications are mapped to AVBDC as well as e-mail and low rate applications are mapped to FCA.

6. DYNAMIC BANDWIDTH ALLOCATIONS (DBA) IN MF-TDMA SATELLITE NETWORK

DVB-RCS standard undefined a specific bandwidth allocation algorithm. Meanwhile, the fixed MF-TDMA and the dynamic MF-TDMA (optional) are provided in the DVB-RCS. Therefore, to study the bandwidth allocation algorithm in MF-TDMA satellite network to be the focus.

In general, there are four constraints of the resource allocation for MF-TDMA broadband multimedia satellite communication system: 1) resource allocation for one connection to be limited to a carrier; 2) not overlap in time slot allocation for the same satellite terminal; 3) the same time slot cannot be assigned to two connections; 4) the total number of time slot assigned to a terminal cannot be more than one carrier capacity [10]. The constraint 1) is limited by the current MF-TDMA satellite systems hardware development. To avoid the terminal frequently hopping to bring the high system cost. The constraint 2) is subject to the multi-frequency modulator of the terminal, avoiding the generation of intermodulation interference [11], [12]. The constraints 3) and 4) are in order to avoid the conflicts of resource allocations.

7. CONCLUSIONS

In this paper, an overview of the current broadband satellite standards of different standardization organizations, including ETSI, ITU and Telecommunications Industry Association, is provided. Meanwhile, the status and main content of standards are described. A standardization of cross-layer protocol interfaces design scheme is proposed. The solution contains three cross-layer interfaces beyond the ISO/OSI layered protocol model, allow for efficiency interactions between different layers. Moreover, a discussion on the DBA scheme in MF-TDMA satellite networks and constraints of the resource allocation. And point out that the definition of application QoS requirement and DBA scheme mappings are necessary, an example of DVB-RCS mappings is proposed in this issue.

8. ACKNOWLEDGMENT

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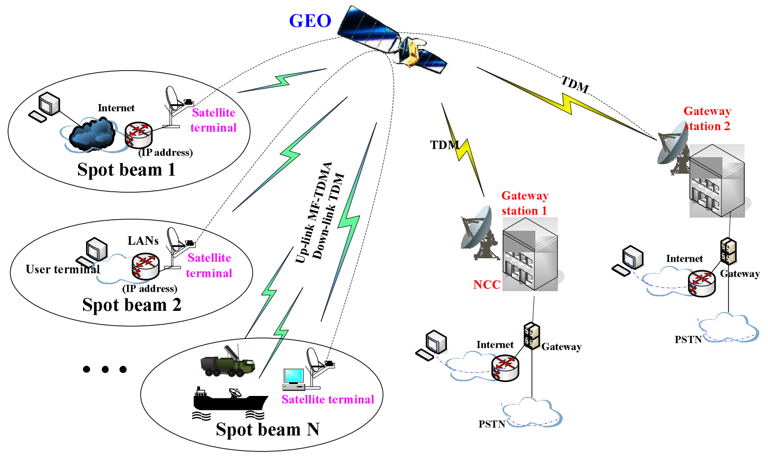

Figure1. Broadband Satellite Communication Network Scenario

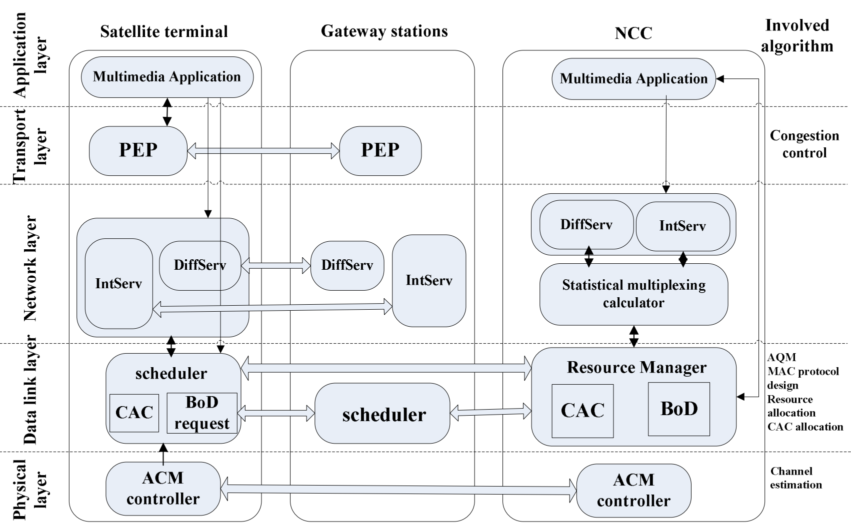

Figure2. Standardization of Cross-layer Protocol Interfaces

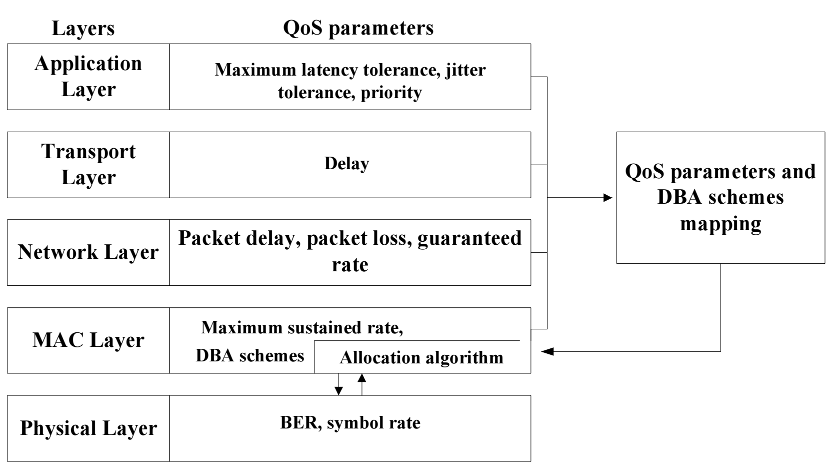

Figure3. End-to-end QoS Scheme

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Table1. Example DVB-RCS QoS Mappings

Requirement	QoS parameters constraints	Application
Constant Bit Rate (CBR)	Maximum sustained rate Maximum latency tolerance Jitter tolerance	VoIP
Bandwidth On-Demand (BoD), Variable Bit Rate (VBR)	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Jitter tolerance Traffic Priority	Streaming video
BoD, VBR	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Jitter tolerance Traffic Priority	Web browsing
BoD, VBR	Minimum reserved rate Maximum sustained rate Maximum latency tolerance Jitter tolerance Traffic Priority	FTP
Best Effort (BE)	Maximum sustained rate Traffic priority	Mail, low rate applications