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► To cite this version:

Olivier Alphan, Pascal Berthou, Thierry Gayraud, Stéphane Combes. QoS Architecture over DVB-RCS satellite networks in a NGN framework. Globecom 2005, Dec 2005, St Louis, United States. 5p. hal-00356869

HAL Id: hal-00356869

<https://hal.science/hal-00356869>

Submitted on 28 Jan 2009

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QoS Architecture over DVB-RCS satellite networks in a NGN framework

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Abstract—Geostationary satellite networks are currently considered as one of the most promising broadband access network technology for narrowing the digital divide. Though technically attractive and cost effective, the provisioning of end-to-end QoS services in satellite access remains largely undefined. In order to bridge this gap, the European SATIP6 project defines a complete QoS architecture involving Application, Session, Network and Link layers over DVB-S/RCS (Digital Video Broadcasting via Satellite/Return Channel via Satellite) systems which is detailed in this paper. First, a review of DVB-RCS standard approaches to QoS in satellite networks is given. Then we focus on the proposed QoS architecture layer by layer: the MAC layer taking benefits from DVB-RCS dynamic allocation schemes, the IP layer implementing differentiated services and finally two separate solutions, at Application/Session layers, for applications to take advantage of the QoS architecture developed on the satellite segment.

Index Terms—Multimedia Satellite Networks, Quality of Service, SIP

I. INTRODUCTION

The recent standardization of a Return Channel via Satellite [1] and the satellite community efforts in term of interoperability over the last few years stand for major milestones in the development of reliable, efficient and low cost satellite equipments. It leads to quite a positive outcome: geostationary satellite networks are expected to play a decisive role in bridging the existing digital divide through providing broadband access to multimedia services in low terrestrial infrastructure areas.

However, unlike cable or 3GPP access networks, a lot of work on IP over satellite is still needed, in particular connected to Quality of Service (QoS). The next step is obviously to take benefits from DVB-RCS dynamic allocation schemes and IP QoS architectures to cope with the satellite delay and the scarce uplink resources.

For these reasons, the choice was made for the IST SATIP6 [2] project to evaluate and demonstrate key issues of the integration of satellite-based access networks into the Internet (IPv6, QoS, Security, Mobility, Performance Enhancing Proxy and Multicast). In this paper, we'll mainly focus on the design of SATIP6 DVB-S/RCS QoS architecture.

Thus, the organization of this paper articulates around 2 main axes. At first, an overview of DVB-S/RCS system

architectures and standards are outlined in order to clearly position our contribution. Then main features of our DVB-RCS QoS architecture proposal are described layer by layer. At the MAC layer, we put the stress on the bandwidth on demand (BoD) algorithm and its advantages. At the IP Layer, a DiffServ architecture is supported for scalability concerns. And finally, at the application/session layer, two QoS signaling access schemes are proposed to enable most legacy applications to take benefits from the differentiated services on the satellite segment.

II. DVB-S/RCS NETWORKS

A. DVB-S/RCS Architecture

The Satellite network emulation testbed developed in SATIP6 is compliant with the architecture adopted within the ETSI BSM group [3] and the DVB-RCS standards.

The SATIP6 scenario, shown in Figure 1, gives a good overview of next generation satellite networks architecture. It consists in a geostationary satellite network with onboard switching capabilities, Ka MF-TDMA (Multiple Frequency Time Division Multiple Access) uplinks and Ku TDM (Time Division Multiplexed) downlinks. The satellite is regenerative meaning that only a single hop is needed to interconnect two end users. Satellite Terminals (ST) provide single PC or LANs with the access to the network, while Gateways (GWs) allow the connection with Internet core networks. The uplink access from each ST is managed through DVB-RCS interfaces. STs and GWs are boundary devices between the satellite and terrestrial links and play an important role in access to satellite resources and hence in QoS provisioning. Both devices implement IP routing and have an IP interface on the satellite segment, as IP serves as a common denominator between the satellite and terrestrial networks. That is to say that Satellite Network is considered as a special link from a classical network point of view.

Figure 1 depicts the satellite network architecture emulated by the platform. On the left is represented the end-user side of the platform. On the right is shown the provider/enterprise/Internet side of the platform. We distinguish also between the satellite network side (in the middle) and the IP network sides (on left and right ends), interconnected by STs. Inside a spot beam, several channels

are allocated: for the forward DVB-S path, for the return DVB-RCS path, and also a dedicated control channel.

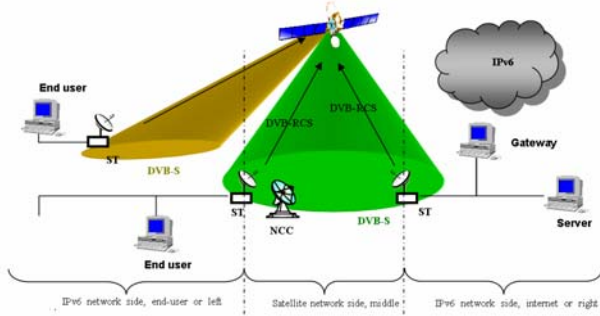


Figure 1 : SATIP6 architecture

Three main components have to be distinguished in the satellite network side (middle): the Satellite Emulator (SE), the Satellite Terminals (ST) and the Network Control Center (NCC)

The role of the different network elements (NCC, ST) is explained in a brief introduction to the main ETSI recommendations related to QoS in satellite. Then an overview of the main contributions provided by the SATIP6 architecture in comparison to current classical DVB-RCS QoS architecture is presented.

B. DVB-RCS standard

Initiated in 1993, the international European DVB Project published, in the end-nineties, a family of digital transmission specifications, based upon MPEG-2 (Motion Picture Expert Group) video compression and transmission techniques. In each specification, data are thus transported within MPEG-2 transport streams (MPEG2-TS) which are identified through DVB Service Information Tables. Adapted for satellite systems, DVB-S defines one of the most widespread formats used for Digital TV over the last years and still nowadays. However, DVB-S Satellite Terminals (ST) can then only receive frames from the satellite. The need for a return link rapidly becomes essential so as to support emerging Internet services via satellite. Two main alternatives, based on DVB-S, can be retained: The UDLR (UniDirectional Link Routing) standard [4] which emulates a cheap bidirectionnal solution through a terrestrial return link and DVB-RCS, published in March 2000, which provides an expensive but full bidirectionnal satellite architecture. Concerning IP encapsulation, various schemes already exist and are still being specified for the forward and return link.

The return link access scheme in DVB-S/RCS systems is MF-TDMA. The return link is segmented into portions of time and frequency ("superframes"), each of which is divided into timeslots ("bursts") of either fixed or variable durations and bandwidths during which STs are able to transmit MPEG2-TS packets or ATM cells. The entire satellite system control, especially STs synchronization and resource allocation, is performed by the NCC. It periodically broadcasts a signaling frame, the TBTP (Terminal Burst Time Plan), which updates

the timeslot allocation within a superframe between every competing ST. This allocation can be dynamically modified on STs demand thanks to a bandwidth on demand protocol called Demand Assignment Multiple Access (DAMA). It supplements the STs with the ability to frequently request capacities that fit their current respective traffic load to the NCC. However the DAMA request/assignment cycle exhibits a non negligible latency and additional delays that cannot always match interactivity requirements of multimedia services. In order to both maximize satellite resource use and meet multimedia requirements, the DVB-RCS norm discriminates ST capacity requests into 4 categories:

- *Continuous Rate Assignment (CRA)*: Fixed slots are assigned in each MF-TDMA frame for the whole duration of a ST connection
- *Rate-Based Dynamic Capacity (RBDC)*: a dynamic rate capacity (in slots/frame) granted in response to explicit ST requests
- *Volume-Based Dynamic Capacity (VBDC)*: a dynamic cumulative volume capacity (in slots), granted in response to explicit ST requests
- *Free Capacity Allocation (FCA)*, which is assigned to STs on an "as available" basis from unused capacity

The standard, after defining separate MAC traffic priority queues (Real-Time, Variable Rate and Jitter-Tolerant priorities), suggests a requesting strategy for each of them, that is to say a relevant mapping between traffic and request categories. Any given ST can be assigned one or a mix of the four capacity types. In general, higher priority classes of service (e.g. IP DiffServ EF and AF classes) are associated with guaranteed capacity (CRA, RBDC), while lower priority classes (e.g. Best Effort) are predominantly given best effort capacity (VBDC, FCA).

However those suggestions are not yet sufficient to seamlessly integrate satellite networks into an end-to-end NGN QoS Architecture. Concerning DAMA algorithms, even though extensive investigations have been carried out to provide QoS in GEO satellite networks [5] in literature, those approaches are not complete since application performance analysis are based on rather approximate resource management procedures not taking into account the combination of capacity requests and network load conditions. Furthermore, most satellite BoD algorithms are proprietary and the little literature found about it is not detailed enough to evaluate realistic algorithm that could be used as references. Besides, the provision of end to end QoS service in satellite network remains largely undefined in comparison with other access network like cable access or 3GPP. Finally, tighter interlayer interactions, especially between IP and MAC, should be specified to provide finer resource management techniques.

One of the aims of the SATIP6 project was to tackle this lack of recommendations through the implementation of a complete DVB-RCS QoS framework including Application layer, IP layer and MAC layer as described in the following section.

III. QoS IN THE SATIP6 SATELLITE SYSTEM

A. SATIP6 QoS Architecture

The QoS management on the return link in the SATIP6 system is split into three resource granularity levels:

- Per-ST (Satellite Level), detailed in Section III.B
- Per-aggregate (DiffServ Level) detailed in Section III.C
- Per-flow (Application/Session Level) detailed in Section III.D

The Figure 2 gives an overview of this QoS architecture within the ST.

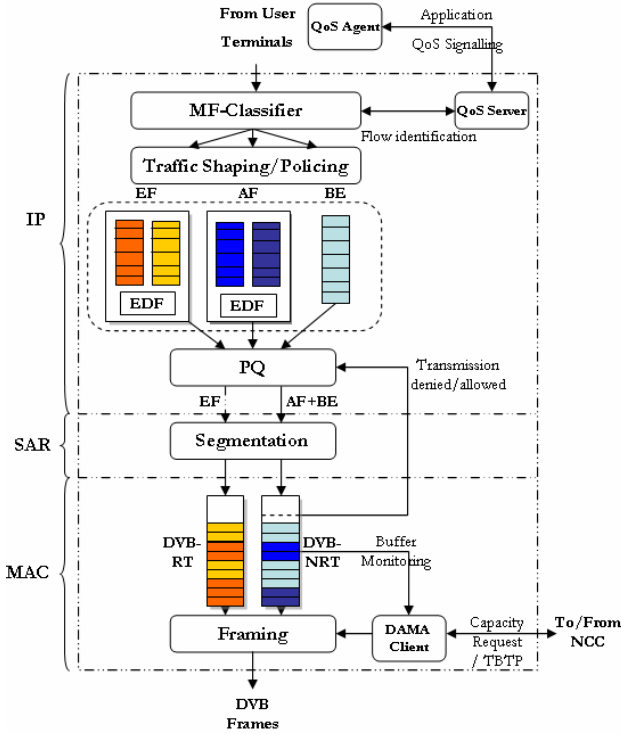


Figure 2 : ST QoS Architecture

B. QoS at DVB-RCS layer

Within the ST MAC Layer, we distinguish between two MAC Classes of Service (CoS), each associated to a specific ATM Permanent Virtual Channel (PVC). The DVB-Real Time (DVB-RT) class benefits from static resource assignment through CRA when the DVB-Non Real Time (DVB-NRT) one relies on a dynamic resource allocation scheme combining VBDC and FCA.

Set at ST logon, capacities granted through CRA remains fixed for the ST connection duration. Therefore, CRA offers the best performance in terms of both delay and jitter but is expensive and might be under-utilized.

Beside this fixed capacity allocation, each ST is able to dynamically request capacities from the remaining uplink resource through an out-of-band signaling. A DAMA client in each ST computes, every superframe, a capacity request on the basis of DVB-NRT queue information and transmits it to the DAMA Server. The DAMA Server within the NCC,

provides the uplink access via two kind of assignments: (i) *Dynamic Capacity Assignments*: the NCC assigns the uplink time-slots based on the VBDC requested capacity; (ii) *Free Capacity Assignments* (FCA): the NCC assigns left over time-slots to the STs based on a predefined fairness criterion. In order to have an estimation about the DAMA request/assignment cycle latency, the time interval between the transmission of a capacity request by the ST and the associated capacity allocation is always superior to the round-trip time (RTT) between the ST and the NCC plus the NCC algorithm runtime. This duration represents the Minimum Scheduling Latency (MSL) and is about 600ms. If we add the sojourn time in a MAC queue and the interval between two consecutive request opportunities, the scheduling latency may reach, in the worst case, up to 1.5s.

The DAMA algorithm has two contrasting objectives: (i) *uplink utilization efficiency*: the STs should be capable of utilizing the whole requested capacity; this means that a proper amount of packets should be accumulated in the MAC queues: in fact, if the buffer is empty when the capacity allocation is received, the unused allocated capacity is wasted; (ii) *DAMA latency*: the MAC layer queue length should be reduced to improve the latency due to the request-assignment cycle. These conflicting targets are the main performance indicators of the DAMA protocol; the SATIP6 DAMA algorithm has a tuning parameter, named *anticipation* and denoted with α , to address this trade off. By properly setting α , the latency introduced by the BoD algorithm can be effectively enhanced and, additionally, FCAs are efficiently exploited to improve the overall performance. For further details, please refer to [6].

Finally, a remarkable advantage of the proposed architecture is that, from the resource management viewpoint, the interface between the IP and the MAC layer is constituted only by a threshold: if the queue length in the MAC NRT buffer is larger than the threshold, the IP layer scheduler is inhibited. The threshold value is set according to a trade-off between BoD algorithm efficiency, which increases with the threshold, and scheduling efficiency, which decreases with the threshold (see [7] for more details).

The next step is to design an IP QoS architecture that will enforce constraints for specific IP traffic categories in order to maximize the utilization of the underlying available time-varying capacity.

C. QoS at IP Layer

NGN is pushing for “full-IP” architecture everywhere, in access and core networks, in order to:

- support end to end services independently from underlying transport-related technologies
- benefit from all existing IP technologies like for instance the exhaustive IP QoS Framework

To achieve a scalable traffic control framework, the choice was made to support DiffServ services in SATIP6 at the IP layer. Thus a Multi-Field classifier separates IP traffic into three main IP categories:

- The *Real-Time IP data category*, associated to DiffServ Expedited Forwarding PHB (Per-Hop Behavior), includes real-time applications with stringent time and bandwidth requirements, such as telephony or video conferencing, and IP signaling which has very stringent delay requirements but which is characterized by low data rates.
- The *Non-Real-Time IP data category*, associated to DiffServ Assured Forwarding PHB, includes traditional Internet applications to be served with a satisfactory level of service, like telnet or HTTP which should be assured small queuing delay though with limited bandwidth.
- The *Best-Effort IP data category* (Peer to Peer, SMTP, FTP) is associated with the traditional service offered by the Internet by default without any specific QoS measures and whose performances are strongly impacted by network congestion states.

The fundamental component of the architecture is the EDF scheduler preceded by token buckets (RC-EDF, Rate-Controlled Earliest Deadline First) which allows fixing an upper bound to queuing delay and a minimum bandwidth for separate IP flows. Namely, the presence of token buckets is a guarantee that each IP flow will receive a minimum bandwidth, given sufficient demand, equal to the relevant token rate, while the EDF scheduler will guarantee to each packet of an IP flow, once suitably regulated by a token bucket to be served within a deadline equal to its associated static parameter.

In Figure 2, the RC-EDF components are regrouped under the block named 'traffic shaping / policing'. The traffic policing and shaping are then realized thanks to single-rate token buckets.

IP Signaling (SIG) traffic, RT (real-time) traffic and NRT (Non-Real-Time) traffic are handled by separate RC-EDF scheduler, while all BE (Best Effort) IP traffic is stored in a single FIFO queue. At last, the three traffic categories are served by a scheduler based on a simple priority queuing (PQ) discipline which respectively maps AF and BE IP classes on the DVB-NRT class and EF on the DVB-RT class.

Finally, to overcome the relative static DiffServ User/Service Provider SLA provisioning, SATIP6 proposes two QoS signaling access schemes which enable most current applications, which do not integrate any QoS features, to take benefits from the satellite DiffServ services.

D. QoS at Application/Session Layer

As said previously, the IP DiffServ architecture is supported by the Satellite Access Network (SAN). Each ST acts as an Ingress Router to the SAN DiffServ domain and therefore implements DiffServ border router functions such as IP flows classification based on multi-field criteria. In order that a data packet, received on the ST router entry point, takes advantage of the services associated to a class, some form of signaling mechanism has to be used.

A mechanism, close to a reservation procedure, has been

chosen for the ST implementation in the SATIP6 project. The stream identification is done by an entity called « QoS Server » running on the ST. When an application has to use one of the available services, it has first to send a 5-uple {source address, source port, destination address, destination port, service identifier} to the QoS Server to identify the stream and the required QoS. This solution can be easily linked to an Admission Control (AC) mechanism which is essential in such an architecture.

Nevertheless, this kind of QoS reservation is seldom supported by today's applications (e.g. they usually do not support RSVP). Next parts will describe two different QoS proxy mechanisms, which are able to perform this task on behalf of the application.

1) A QoS agent for non QoS-aware applications

Very few applications implemented today are aware of the QoS provided by the underlying networks. As the applications are rarely able to define their own requirements, a user-oriented solution allowing any application to take benefits from network services has been defined. The solution proposed in the following is called « QoS Agent ».

Implemented on the user terminal, the « QoS Agent » (Figure 3) waits for application streams, maps them statically or dynamically (using a graphical interface) to the chosen QoS level according to the user's choice and, through interaction with the QoS Server, the ST is configured in order to take the request into account. The user is then able to remotely configure its ST through the QoS Agent, in order that the requested services may be available to any of the applications, during the time they are used.

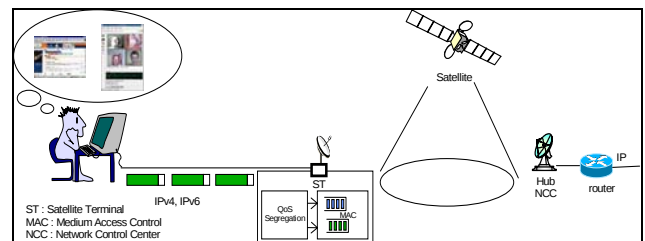


Figure 3 : QoS Agent principle

If resources are not available, the QoS Agent is immediately informed. Using the received information, the QoS Server is able to tag and redirect these packets coming from the user terminal towards the appropriate requested IP service.

2) QoS signaling using a SIP Proxy

The same QoS functions in the ST could also directly be triggered by application servers to avoid user configuration. A SIP [8] Proxy with extended functionalities has been developed in SATIP6 to automate QoS reservations with multimedia applications. SIP (Session Initiation Protocol) should be used by multimedia applications for the session management and codec negotiation. The main functionality of a SIP proxy is to route SIP messages (session establishment for instance) from a SIP entity (an application) to another SIP

entity. If we want the QoS reservation to remain transparent for the application, the enhanced SIP proxy has to extract SDP (Session Description Protocol) [9] descriptions from SIP messages exchanged between caller and callee, translate the parameters of each media in the session in QoS characteristics and manages QoS reservations with the QoS Server on behalf of the application.

The functionalities to be added to the standard SIP proxy are given below:

- a *SDP analyzer* so that the proxy is able to understand the session descriptions defined in SDP format included in SIP messages.
- A *media table* updated at SIP session establishment. Each media is defined by a 4-uple (IP source address, IP destination address, source port, destination port), the kind of media (audio, video...) and the Real-Time Protocol (RTP) profile. The media negotiated by caller and callee are gathered using the Call-ID, which is a unique identifier of the related SIP session.
- A *SDP/DiffServ mapping* from the kind of media (and the codec) to the DiffServ service (and the corresponding peak rate), essential to the QoS module.
- A *QoS module* taking into account the resource reservation corresponding to one media in a SIP session. It manages QoS reservations with the QoS Server.

In addition, the use of intermediate SIP Proxies also allows hiding to legacy SIP applications the satellite propagation delay which is close to SIP retransmission timers. To avoid SIP signaling retransmission on the satellite segment, the proxies will use preferentially UDP on the satellite segment and their SIP timers are appropriately reconfigured to fit to the satellite RTT.

A QoS-Aware SIP proxy is deployed in each user LAN interconnected by the SAN. This distributed architecture is well suited for an access or mesh topology based on a regenerative satellite because it answers the following two concerns:

- *scalability* concerning flow QoS management in user LAN;
- *session establishment delays*: the number of round trips of session and QoS signaling on the satellite link are minimized.

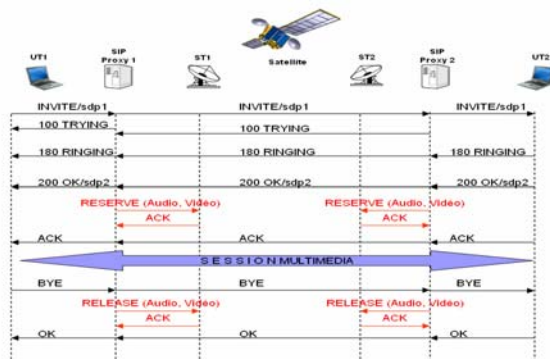


Figure 4 : QoS SIP session establishment

Figure 4 shows a typical session establishment concerning two users starting a videoconference.

Each QoS-Aware SIP proxy captures and translates the SDP description of each media (audio and video) and then sends resource reservations to its related QoS Server.

IV. CONCLUSION

The integration of a satellite access network within Next Generation Networks or QoS enhanced network is a complex matter, which was tackled in IST SATIP6 project. A Satellite Terminal centric (and therefore user centric) architecture, allowing "QoS-Enabled" sessions, was described. This one allows using the traditional DiffServ approach without requiring applications to be able to perform QoS marking on IP packets they generate and without complex application proxies in the Satellite Terminal itself. A QoS Agent, residing on the user's PC or server, allows to dynamically configure the Satellite Terminal classification function based on rules made up by the user or its network administrator. An extension of this approach with an application specific proxy on the user's network has also been shown.

As wireless networks have become increasingly popular, one must be prepared to deliver the last hop with such technologies. Inter-domain QoS architecture then must be deployed to ensure a homogeneous end-to-end QoS over heterogeneous networks.

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