

QoS and QoE Evaluation of Web-browsing Over an SI-SAP-Enabled DVB-S2/RCS System

Tomaso de Cola
DLR–German Aerospace Center
Institute for Communications and
Navigation
82234 Wessling, Germany
tomaso.decola@dlr.de

Mario Marchese, Marco Cello
University of Genoa,
Department of
Telecommunication, Electronic,
Electrical Engineering and Naval
Architecture,
Via Opera Pia 13
16145, Genova, Italy
mario.marchese@unige.it,
marco.cello@unige.it

Maurizio Mongelli
National Research Council of
Italy Institute of Electronics,
Computer and
Telecommunication Engineering
Via De Marini, 6
16149 Genova Italy
maurizio.mongelli@ieiit.cnr.it

Abstract—The SI-SAP protocol interface, defined in the framework of the ETSI BSM architecture, has the function of logically separating the Satellite Dependent (SD) from Satellite Independent (SI) layers, thus enabling the implementation of powerful vertical QoS mapping strategies. The paper analyses the use of the SI-SAP interface over DVB-S2/RCS technology in particular with respect to QoS functionalities and proves the performance benefits introduced by the SI-SAP interface in terms of QoS and QoE of Web-browsing by means of a satellite emulator developed to this aim.

Keywords— ETSI BSM, SI-SAP, DVB-RCS, QoS, MOS

I. INTRODUCTION

The penetration of satellite communication into everyday life is continuously increasing, thus broadening the range of services that were traditionally limited to TV broadcasting [1] [2]. Actually, current satellite services also encompass lottery networks, banking and financial applications, GSM backhauling, governance and defense, and mobility applications. Furthermore, media distribution is performed in terms of IPTV and, in general, IP-based applications are the baseline for present and future services.

From a standardization point of view, the advent of DVB-S and -S2 [3] has been recognized as a suitable candidate for more efficient satellite communications, also thanks to the deployment of ACM (Adaptive Coding and Modulation) available in the second version of the standard. Quite different is the market penetration of DVB-RCS [4], where terminals still implement proprietary solutions. To this regard, the glue to unify all possible manufacturers solutions and make them interwork is to provide an hardware abstraction layer working on top of the satellite technology.

This concept is actually provided by the ETSI BSM (Broadband Satellite Multimedia) architecture [5], built on the Satellite Independent-Service Access Point (SI-SAP) interface, responsible for logically separating the functionalities of higher layers (application, transport and network) from lower layers

(data link and physical), defined as Satellite Independent (SI) and Dependent (SD) layers, respectively. In more detail, this interface allows the interaction between SI and SD layers by means of specific primitives aimed at providing the tools for achieving a cross-layer architecture [6], in terms of QoS and multicast management.

This paper focuses on the main characteristics of a DVB-S2/RCS architecture implementing the SI-SAP interface with particular attention on the QoS management. The performance assessment of the SI-SAP interface potentials is carried out by means of a dedicate satellite system emulator, where all functionalities of a DVB-S2/RCS standard are implemented. In particular, the impact of QoS management in terms of quantitative and qualitative metrics (QoS and QoE) is investigated.

The remainder of this paper is structured as follows. Section II describes the main elements of the SI-SAP interface, whereas the integration of its QoS function into a DVB-S2/RCS system is discussed in Section III. Performance analysis is then addressed in the second part of the paper: Section IV briefly presents the emulation tool and Section V presents the results of the testing campaign. Finally Section VI draws the conclusions about the conducted study and gives an outlook about possible extensions of this work.

II. SI-SAP INTERFACE: ESSENTIALS

SI-SAP [7] defines an abstract interface between SI and SD layers. It is responsible for separating the implementation of the protocol functions provided at SI and SD layers; e.g., it is in charge of separating the IPv4(or IPv6) at SI protocol layer from DVB-RCS/S2 (or other satellite technology standard) at SD protocol layer. Hence, the implementation of different SI and SD services is independent one from another and the related mapping functionalities are provided by the SI-SAP interface. The list of standardized [7] SI-SAP primitives is summarized in Table I, where the different actions at User (U-), Control (C-) and Management (M-) planes are detailed.

Primitives' name is structured according to the usual OSI nomenclature.

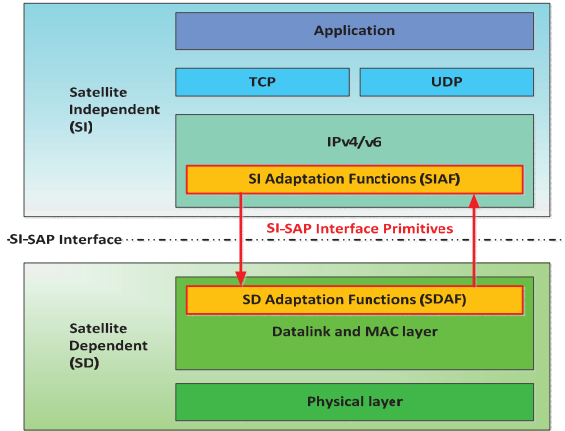


Figure 1. ETSI BSM architecture implementing the SI-SAP interface

TABLE I. U-, C- AND M-PLANE SERVICES AND CORRESPONDING SI-SAP PRIMITIVES [7]

U-plane services		
Service	Description	Primitives
Data Transfer	Submission of data from SI to the SD layer for transmission to peer destination; and receipt of data from the SD layers by that peer. This service can be used for both unicast and multicast data transfer.	SI-U-UNITDATA-req SI-U-UNITDATA-ind
C-plane services		
Service	Description	Primitives
Resource Reservation	A mechanism to open, modify and close SD layer queues for use by the SI layer as well as a mechanism to confirm (reject) the received request used by the SD layer.	SI-C-QUEUE_OPEN-req, -cfm SI-C-QUEUE_MODIFY-req, -cfm SI-C-QUEUE_CLOSE-req, -cfm SI-C-QUEUE_MODIFY-ind, -res SI-C-QUEUE_CLOSE-ind, -res SI-C-QUEUE_STATUS-ind, -res
Group Receive	A mechanism to activate and configure the SD layer to receive a requested multicast service	SI-C-RGROUP_OPEN-req, -cfm SI-C-RGROUP_CLOSE-req, -cfm
Address Resolution	A mechanism to perform the mapping between SI and SD addresses	SI-C-AR_QUERY-req, -cfm SI-C-AR_INFO-ind, -res
M-plane services		
Service	Description	Primitives
None	No M-plane services are defined	

The primitives are generated by the Satellite Independent Adaptation Function (SIAF) and Satellite Dependent Adaptation Function (SDAF), implemented in the SI and SD layers respectively. SIAF is responsible for adapting all the functionalities implemented at the network layer (i.e. resource reservation, multicast and addressing) so that they can be mapped into the underlying layers. SDAF implements adaptation functions on resource reservation, address

resolution, and group multicast membership requests generated at the SD layer and mapped onto specific SI-SAP primitives by SIAF. More precisely, SDAF translates SI-SAP primitives into SD specific primitives in order to assign the requested physical resources to the IP traffic (unicast or multicast) coming from the SI layer.

The overall ETSI BSM architecture is depicted in Figure 1. A fundamental concept for achieving a QoS-enabled ETSI BSM architecture is the Queue identifier (QID) [7]. It identifies the queues implemented at the SD layers, thus implicitly linking lower layer resources' reservation to IP layer QoS requests. QID is composed of 24 bits and must be included in all U-plane primitives (i.e., in every SI-U-UNITDATA-req), in order for the SD protocol layer to correctly forward each data traffic to the proper SD queues.

III. APPLICATION OF SI-SAP CONCEPTS IN DVB-RCS SYSTEMS

The implementation of the SI-SAP interface in a DVB-S2/RCS system implies some re-engineering of the interface actually provided between IP and DVB-RCS layers in order to efficiently incorporate SIAF and SDAF modules and properly interwork with the SI-SAP primitives. Particular attention is here dedicated to the resource reservation functionalities, which are actually the main focus of the paper. Certainly, the implementation of address resolution and multicast management primitives imply some modifications of the DVB-RCS/S2 interface towards IP, which are not detailed here for brevity.

A. QoS Management

Quality of service is managed by means of the DiffServ architecture, which consist in a number of dedicated functionalities distributed across the layers. The IP layer is mainly responsible for performing metering, shaping and classification of the input IP flows. On the other hand, the DVB-RCS/S2 layer essentially implements the resource allocation schemes, which actually consists in the actual bandwidth allocation, the scheduling and QoS mapping from IP classes into DVB ones. In this respect, the use of the QoS primitives provided by the SI-SAP interface [11] allow a direct association between IP and DVB-RCS queues, achieved through the concept of QID.

In more detail, the service level agreements (SLAs) and the related specifications (SLses) to be applied to each IP flow are encoded in QID specification (QIDSPEC). Each QID can offer a defined type of service for the transfer of IP packets to the DVB-RCS layer in the integrated ETSI BSM-DVB architecture. In particular, a given QID is univocally associated to DVB-RCS queues and used for all data flows aggregated in that queue. Hence, the QID works as a label logically appended to IP streams, whose transport is signalled by means of SI-U-UNITDATA-req primitives.

QIDs are locally handled by the Satellite Terminal QID Resource Manager (STQRM), implemented in the SDAF module. The STQRM receives QID allocation requests from the IP resource manager (BSM QoS Manager) implemented in the SIAF and starts the resource reservation request by

interacting with the resource request manager implemented in the DVB-RCS layer. Another important aspect is how QoS requests contained in the SI-SAP primitives are translated into resource allocations actions at the DVB-RCS layer. In the case of the proposed ETSI BSM-DVB integrated architecture, this task corresponds to mapping QID onto corresponding MAC aggregates, based on the QoS guarantees (QIDSPEC) specified during the creation of a new QID (SI-C-QUEUE_OPEN-req). On the other hand, the IP manager is responsible for associating DSCPs to specific QID, through different mapping strategies. In this way, it is possible to 1) keep the implementation of QoS models in IP and DVB completely independent and 2) to perform dynamic QoS management by means of real-time queue aggregation/de-aggregation thanks to the QID functions (i.e. primitives SI-C-QUEUE_MODIFY-req and -ind). The overall resource allocation mapping, which includes DiffServ, QID and DVB parameters can be found in [12].

B. Data Transfer

Transport of data messages over the SI-SAP interfaces is carried out by the SI-U-UNITDATA primitives, which allow SIAF and SDAF modules to exchange IP datagrams. Hence, the adaptation of the frame format from IP to DVB-RCS is directly performed at the SD layer. In particular, DVB-RCS standard mandates the use of ATM cells, although most recent implementations support the use of MPEG cells, resulting in the implementation of the MPE protocol as encapsulation format.

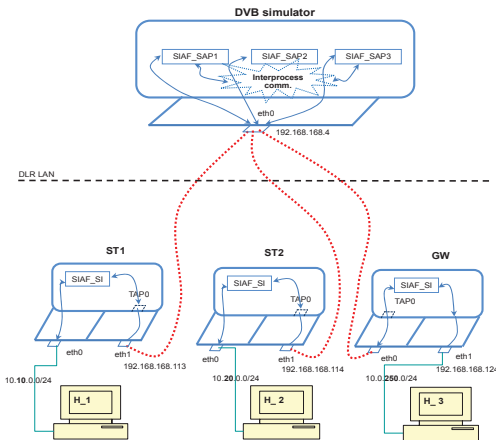


Figure 2. SI-SAP emulator.

IV. SI-SAP EMULATOR

Figure 2 summarizes the structure of the emulation system, developed in the framework of the “Emulator for an ETSI BSM Compliant SI-SAP Interface” project, funded by the European Space Agency (ESA).

The emulator is composed of regular Linux PCs. SIAF and SDAF parts are implemented independently. The “SIAF_SI” sw modules are responsible for the SIAF primitives (Fig. 1)

and are located in different machines, which also make use of Kernel functionalities for the processing, addressing and routing of IP datagrams. Since SIAF and SDAF are implemented separately, the system actually implements the concept of “external” SI-SAP, whereby the related SI-SAP primitives cannot be simply realised as function calls but have to be transported in specific messages actually exchanged by SIAF and SDAF modules. To this end, additional headers to specify SIAF primitives are added by the SIAF_SI modules before sending information (original IP data, plus SIAF primitives) to the “DVB simulator” machine. This machine is in turn responsible for implementing the main functionalities of a DVB-S2/RCS system, in terms of resource allocation, ModCod assignment and data encapsulation together with the management of SDAF primitives. The “SIAF_SAP” sw modules build and interface to read SIAF primitives and write appropriate responses in terms of SDAF primitives. Those modules act before sending/receiving IP datagrams to/from the DVB layer.

The communication between SIAF_SI and SIAF_SAP modules is obtained by regular TCP/IP sockets and can be deployed over a LAN (as depicted in Fig. 3) or over the Internet, thus enabling a distributed implementation of the emulator. To this aim, the sockets are routed over a virtual network of TAPs, whose internal communication is depicted in red in Figure 3, which is in turn made transparent to the “real” SI-SAP system. The emulation system of Figure 3 implements two satellite terminals (STs) and one Gateway (GW) to which three hosts are attached.

V. WEB-BROWSING TESTS

A. Web-Browsing HTML Application

An HTTP server is installed on the host connected to the GW and a client software is installed on the host connected to the ST. The client software tests the network and server performance by sending HTTP requests. The performance metric under investigation is the time to complete each single page download. The inherent service level agreement is reported in Table II.

TABLE II. SERVICE LEVEL AGREEMENT ACCORDING TO [13].

Application	Degree of symmetry	Typical data rates	Key performance parameters and target values		
			One-way delay	Delay variation (jitter) [2]	Information Loss
Web-browsing HTML	Primarily one-way	N/A	< 2 s/page (*, **)	N.A	0
* For these applications "One-way delay" means the time to complete the download of a specific web page (Web-browsing HTML application) or the time to complete a SSH command (Remote Login SSH).					
** It is important to highlight that performance targets for “Web-browsing HTML” were proposed in 2001 and they can be considered now overestimated for cable networks, but reasonable for satellite environments.					

B. Network configuration

Bandwidth allocation. Each application is firstly evaluated in Best Effort (BE) modality, which means the satellite channel may not be able to provide the required target rate of the application. Then, a bandwidth allocation is provided, denoted by “rate[...] + x_i%” (i={ssh, web, audio, video, videoconf}), which means a given bandwidth is allocated in order to support QoS.

Round Trip Time and Bit Error Rate. The satellite delay is coherent with a GEO environment, thus leading to Round Trip Times (RTTs) in the order of 500ms. The Bit Error Rate (BER) at the satellite physical layer follows time-series traces obtained from real data.

Mean Opinion Score (MOS). The MOS is obtained by the unanimity of opinions of 6 different persons. The score can be: ‘bad’, ‘acceptable’, ‘good’ or ‘very good’. Detailed descriptions are anyway provided when specific comments are worth to be noted. It is evaluated by using the Firefox web browser, which implements http compression and pipelining of TCP.

C. Browsing

An Apache HTTP server was installed on GW side. Three web pages were prepared: ~/low.html, only text, 10 Kbytes, ~/medium.html, with low resolution images, ~305 Kbytes and ~/high.html, with high resolution images, ~1.4 Mbytes.

Apache JMeter was installed on the hosts. JMeter allows performance monitoring of download operations of web pages; it highlights the web page downloading time (the “One-way delay” SLA metric of interest, reported below). The next table describes the tests in more details.

The “X.html navigation” notation means that tests were done with a HTML web page (~/“X”.html) whose size corresponds to the mentioned low/medium/high cases. “Mixed navigation” means web browsing is performed on a sequence of low/medium/high pages. More specifically, the mixed navigation is obtained using the low-, medium- and high- size pages by setting (on JMeter) three different users accessing the pages in parallel; the allocations are as in the high case. It consists of navigating on all the pages above by changing from one page to another one, also when one (the high, in particular) has not finished the downloading of the images.

D. Best effort and bandwidth allocation

The Best Effort (BE) rate is set according to the throughput generated by the web server as follows. The web throughput was firstly measured (with Wireshark) for low-, medium- and high-size web pages: 1) in the presence of background traffic: 36.4 kbps on low, 310 kbps on medium, 656 kbps on high (in forward link, FL, direction), 2) without background traffic (reduced by a factor of 100): 42 kbps on low, 330 kbps on medium, 718 kbps on high.

Those values may have fluctuations due to internal statistics of the simulator mainly related to the background traffic and fading events on the channel. Then the BE rate was set to the measured throughput (without background traffic), divided by a factor of 2 (and then allocated to the Forward Link (FL)

because the server is at the GW). The bandwidth allocation is on the other hand the exact measured throughput (without background traffic). Concerning the return link (RL), the FL rate is divided by a factor of 2 and allocated to the RL.

The overall test configuration is shown in Table IV.

E. Accuracy of the delay measures

Using JMeter, each test is sampled over 10 repetitions (whose overall average and deviation are reported); JMeter does not use parallelization of TCP connections inside a web page. JMeter also does not make use of any http compression like other web browsers (e.g., Firefox uses gzip on text). For those reasons, the performance delay measured by JMeter is higher than the one of other browsers. Each repetition of the transmission with JMeter contains the handshakes to open and close the connection (the regular TCP three-way handshake when establishing the connection).

F. Ideal delay

The ideal delay, whose values are reported with the ‘(ideal)’ notation in the table, is the size of the page divided by the allocated rate, the actual delay may be lower than the ideal when more slots are actually allocated on the channel by the DVB resource allocator (it happens when few resources are requested, first case only) or it is typically higher than the ideal due to TCP congestion control.

TABLE III. TESTS ON WEB-BROWSING.

#	Characteristics	Bandwidth allocation
1	low.html	BestEffort
2	low.html	rateWebBrowsing + x%
3	medium.html	BestEffort
4	medium.html	rateWebBrowsing + x%
5	high.html	BestEffort
6	high.html	rateWebBrowsing + x%
7	mixed	BestEffort
8	mixed	rateWebBrowsing + x%

G. Discussion

The results of the conducted testing campaign are summarized in Table IV.

Overall, the perceived quality of web-browsing is acceptable in BE conditions and almost good in case of bandwidth allocation, also with respect to the high-size page.

The bandwidth allocation strictly depends on the measured throughput during web-browsing, the inherent values are evidenced in bold in the table (in the mixed case, the bandwidth allocation is the same as in the high case). Such a throughput depends on the size of the page. For this reason, in general conditions, some overprovisioning for bandwidth allocation should be provided, for example with respect to the measured throughput of the largest web-page among the ones really used. In the test #2, for instance, there is no improvement

with the bandwidth allocation due to the low size of the webpage being transferred.

VI. FINAL REMARKS AND CONCLUSIONS

The paper focused on the application of the BSM SI-SAP standard to a DVB-S2/RCS system. In this respect, performance assessment of the SI-SAP interface functions has been carried out by means of an emulation system, capable to implement all the needed functionalities in terms of SI-SAP primitives, IP, and DVB-S2/RCS functionalities, in particular with respect to the QoS management. The conducted analysis was around the performance benefits that web-browsing application can receive when dynamic QoS management, enabled by the SI-SAP primitives, is implemented.

Future work concerns the extension of the presented study so as to include a larger range of applications, in order to better characterise the application data usually transiting over satellite networks. In particular, application such as remote login SSH, audio and video streaming and videoconference will be taken into account.

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TABLE IV. WEB-BROWSING RESULTS.

Test	Test Characteristics	One way delay / (ideal) [ms]	MOS
1	low.html navigation (Best Effort, BE rate=21 kbps)	Avg: 3264 Dev: 639 / (3809)	fast web access, very good
2	low.html navigation with bw allocation 42 kbps	Avg: 2117 Dev: 94 / (1904)	fast, very good
3	medium.html navigation (BE rate=155 kbps)	Avg: 21695 Dev: 135 / (15690)	no so fast, but good
4	medium.html navigation with bw allocation 330 kbps	Avg: 15935 Dev: 59 / (7369)	no so fast, but good (a little improvement over the previous case)
5	high.html navigation (BE rate=359 kbps)	Avg: 41320 Dev: 178 / (30529)	slow, annoying
6	high.html navigation with bw allocation 718 kbps	Avg: 27721 Dev: 563 / (15264)	almost good
7	mixed navigation (BE rate=359 kbps)	Avg_low: 4637 Dev_low: 2744, Avg_medium: 30059 Dev_medium: 3939, Avg_high: 47552 Dev_high: 3662	navigation is not so fast, sometimes slow (with high page), but acceptable
8	mixed navigation with bw allocation 718 kbps	Avg_low: 2750 Dev_low: 661, Avg_medium: 17869 Dev_medium: 1058, Avg_high: 29686 Dev_high: 1344	acceptable, also with the high page