A NEW THRESHOLD SWITCHING SCHEME FOR A DVB-RCS MOBILE RETURN LINK IN A TERRESTRIAL RAILWAY SCENARIO

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Abstract. *The new standard for DVB-RCS includes guidelines for mobile user in the market of aircraft, maritime and terrestrial transportation. The standard proposed by ETSI suggests the possibility of using a continuous carrier operation mode in the return channel, beside the classical MF-TDMA mode for better adapting the satellite bandwidth to the new requests of mobile users. It can be important a mechanism for switching between these modalities, in order to exploit in a better way the satellite resources. In this paper a proposal of a novel switching mechanism is presented. Simulation campaigns are carried out in order to validate the proposal algorithm considering different user application distributions. Simulation results proof the goodness of the proposal and provide some guidelines to the satellite operators that want to adopt in their satellite system this hybrid mode called by ETSI standard "Basic Mode".*

Keywords

DVB-RCS, MF-TDMA, return link, SCPC, switching mechanism.

1. Introduction

The new standard for Digital Video Broadcasting with Return Channel Satellite (DVB-RCS) includes guidelines for mobile user (DVB-RCS+M) in the market of aircraft, maritime and terrestrial [1], [2], [3]. These studies have also shown one of the most important characteristics of the satellite terminals installed in airplanes, ships and trains, that is, the management of aggregate and dynamic traffic pattern generated from a relatively high number of end-users that represent the passengers of the transportation vector. This requires a very dynamic capacity allocation mechanism in order to optimize the satellite capacity by using Single Channel Per Carrier (SCPC) with high aggregate traffic volume and Multi Frequency – Time Division Multiple Access (MF-TDMA) for bursty traffic pattern. The design of scalable and multimedia satellite systems integrated with terrestrial networks is an important issue to realize the convergence and the ubiquity of communication. Such as shown in [4], [5], [6], [7], [8], [9], [10] scalable architecture, Quality of Service (QoS) mechanisms and interworking functions become essentials for a convergence among broadband satellite networks and IP backbone. At this purpose a switching mechanism is an important feature to be considered in satellite communications. In this work, the return link of DVB-RCS+M has been analyzed and, in particular, the attention has been focused on the dual uplink management suggested by the standard. The railway environment has been chosen as reference scenario, therefore mobile terminals are considered to be mounted on trains where the end-users are the passengers accessing to applications like HTTP, FTP and Video Conference. The models used for traffic representation are shown in order to highlight the impact of the traffic on the resource management. An algorithm to perform the switching between the two modalities (MF-TDMA and continuous carrier – SCPC) has been proposed which is able to guarantee the required constraints (latency, data rate, etc.) to these applications. The proposed algorithm, called Threshold Basic Switching Algorithm (TBSA), is based on a threshold-crossing behavior. This modality allows the mobile terminal to send the information either in MF-TDMA or SCPC depending on the traffic demand. The TBSA controls the switching from MF-TDMA to SCPC mode based on the capacity request operated by the mobile terminal. Therefore, the switching from the SCPC to the MF-TDMA is done on the basis of the mobile terminal throughput (aggregate traffic volume). Section 2 introduces the existing related work; section 3 presents the DVB-RCS+M scenario, the return link structure and traffic models. The algorithm is presented in section 4; performance evaluation and conclusions are summarized, respectively, in section 5 and section 6.

2. Related Works

DVB-RCS+M systems need to operate in diverse mobile propagation environments in terms of speed, acceleration, and geometry. Three main types of scenarios have been identified as the primary target for DVB-RCS+M systems: maritime, aeronautical and railway. In [11] authors presents an overview of the DVB-RCS system addressing mobile scenarios. It analyses the challenges linked to the mobility support and it summarizes some of techniques to cope with those challenges. The focus of this article will be on the technical solutions analyzed within the framework of ESA studies and, in particular, they show the DVB-RCS+M traffic aggregation. Satellite terminals installed in airplanes, ships and trains have to manage and aggregate traffic from a relatively high number of end-users. Such Return Channel Satellite Terminal (RCST) may have a sufficient number of users behind them that the physical-layer bandwidth efficiency gain of continuous-carrier operation outweighs the loss of flexibility of the classical MF-TDMA. Therefore, the use of continuous carriers in the return link has been adopted as an optional feature in DVB-RCS+M systems; in particular, for RCST's with substantial traffic aggregation such as those serving trains, cruise ships and wide-body commercial aircrafts. In [12] rate-based dynamic allocations are investigated in SCPC based network architectures. Key advantages and limitations of SCPC-based implementations are discussed and quantitative comparisons between dynamic SCPC and TDMA architecture are provided, showing that under realistic conditions, the dynamic SCPC approach reduces the required return link bandwidth by greater than 40%. In [13], author, chairman of Technical Module – Return Channel Satellite (TM-RCS), shows the advantages and enhancements of DVB-RCS2 in respect of version1. One of the characteristics that is listed is the continuous carrier return link mode, that aids to a better management of satellites.

3. DVB-RCS+M, Return Channel Structure and Traffic Models

The DVB-RCS+M system architecture (see Fig. 1) is based on the standard for fixed terminals composed of a DVB-RCS satellite, RCST terminals, the Gateway (GTW) and the Network Control Centre (NCC).

Fig. 1: The DVB-RCS mobile scenario.

The forward channel (from GTW to the terminals) is compliant with DVB-S2 standard, while, the return channel (from the terminals to the GTW) uses the DVB-RCS standard with the extension for mobile scenarios [1], [2]. The NCC is responsible of managing the resource allocation for the terminals and the GTW of managing the traffic queues. The NCC has the responsibility of processing the Capacity Requests (CRs) that come from RCST and, on the basis of these requests, it assigns resources through the Terminal Burst Time Plan (TBTP) table. In some case NCC and GTW are in the same device called HUB. The RCSTs are transportation vectors represented in the considered scenario by trains whose passengers using applications generate traffic on return channel.

3.1. Return Channel Structure

In this paper, the considered return link is divided in two portions, one managed in a classical MF-TDMA mode with a frame as reported in the standard and the other in SCPC, also called continuous carrier operation, that uses a very short frame size (4 kbit). In DVB-RCS systems, the resource allocation policy is based on the so-called Bandwidth on Demand (BoD). In the SCPC case, the use of continuous carriers in the return link has been adopted in order to exploit a simple and robust access mechanism for mobile DVB-RCS networks, in particular, for RCS Terminals with substantial traffic aggregation, like terminals represented by transportation vectors such as trains, ships and airplanes. In particular, the standard proposes two modalities in which a RCST terminal can work: one is called “Basic RCST mode” and the other one is called “Enhanced RCST mode” [1], [2]. In the reference mobile scenario, the traffic pattern is dynamic, depending on the number of users accessing the network. The provisions in the standard are therefore designed to support a hybrid architecture that retains all the characteristics of a DVB-RCS network, while adding continuous carrier operation in the return link as an overlay.

3.2. Return Link Dynamic Resource Control

In the DVB-RCS standard, terminals can use two signaling methods to forward capacity requests to the NCC:

- **Mini slot method.** The capacity request message is carried in the Satellite Access Control (SAC) field of a dedicated SYNChronization burst, used for synchronization maintenance purposes and sent about once every second (normally it is used a period of 32 frames). A SYNC burst can carry up to four different capacity requests. This mechanism is called Out Band Request (OBR).
- **Prefix method.** A capacity request is piggy-backed onto a traffic burst (it is inserted in a SAC field, appended as a header of the MPEG

payload). One capacity request per traffic burst can be transmitted. This mechanism is called In Band Process (IBR).

DVB-RCS standard makes provision for both mechanisms, IBR and OBR. The IBR is associated with the prefix method and with the Data Unit Labeling Method (DULM), while OBR is associated with the mini-slot method that relies on SYNC burst. Normally, the prefix method (IBR) is used combined with the mini-slot method (OBR) with the SYNC. The SYNC slots are primarily assigned to an ST in order to perform CR and for synchronization needs, typically one slot SYNC every 32 frames (1440 ms at 45 ms frame duration). The role of the OBR is therefore merely to speed up the initial access to return link capacity. In the following figure (Fig. 3) it is shown the time diagram of the request of capacity performed by a RCST terminal to the satellite system. In this work it has been implemented the OBR modality, the IBR is reserved for future work. Dynamic resource control consists in assignment of resources (slots) to terminals based on their requests and limit values negotiated/set during connection establishment. The assignments are conditioned by the availability of resources (capacity) within defined return channels (as per system connectivity).

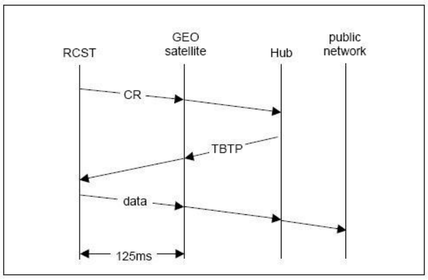

Fig. 2: Time diagram of CR request.

The assignment is the responsibility of the MAC Scheduler, which implements a Demand-Assignment Multiple Access (DAMA) protocol. The MAC Scheduler is located on the NCC terminal. The uplink scheduling consists of processes taking place in the Scheduler and in terminals, namely:

- calculation of capacity requests in terminals (once a RCST is logged it continuously monitors bandwidth related parameters, e.g. RCST queue lengths and queue input rates),
- transmission of capacity requests to the Scheduler (request signalling),
- calculation of capacity assignment to terminals,
- allocation (placement) of the assigned capacity,
- generation and transmission of TBTPs carrying the allocations to terminals.

3.3. IP Encapsulation and Data Link Layer

The RCST and the HUB protocol stacks are represented in Fig. 3. Within the RCST, IP packets are encapsulated in MPEG2-TS packets like the HUB. Then these MPEG2-TS packets are encapsulated inside DVB-RCS slot in the Return Link and DVB-S2 frame in the Forward Link. In the work scenario a RCST with connected a certain number of users has been considered that can generate three types of traffic, HTTP, FTP and Video Conference traffic.

3.4. Traffic Models

In order to simulate a more realistic scenario and to get realistic and valid results, a set of real traffics (shaped realistically) have been considered in this work. All that

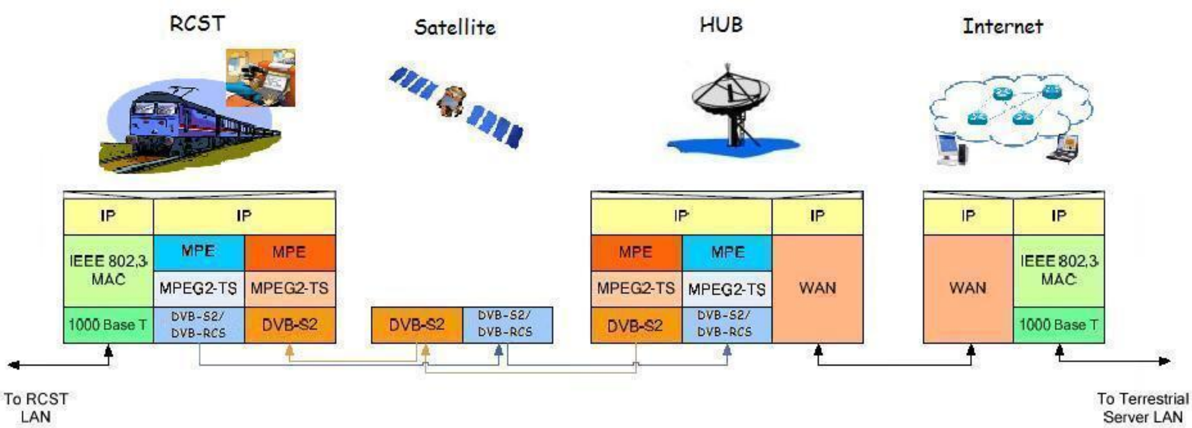

Fig. 3: The DVB-RCS+M scenario protocol stack.

in order to provide some guidelines to the satellite operators that want better utilize their satellite resource and meet the new users request in terms of service and quality of communication. For the simulations two different kinds of non-RT traffic (HTTP, FTP) and one kind of RT traffic (Video Conference) have been modeled on IP layer. HTTP traffic is modeled as an ON/OFF source with the ON state corresponding to the request and download of the objects and the OFF state corresponding to the inactive time. In this work the implementation is based on a work of the Communications Technology Laboratory of Intel Corporation of the 2007 [14]. According to [15], an ESA project concerning on Broadband on the Train, an FTP file transfer can be modeled like a web session with only one web request. The implementation in this work has been done creating a software model for the generation of a single HTML document, that is a HTTP page with the main object and a certain number of embedded object that have a size bigger from the HTTP case. The traffic generation for the Video Conference consists of two parts. First the arrival of a video session and second the behavior of the video source itself. The arrival of the Video Conference sessions is modeled with a Poisson distribution, the duration of a session as an exponential distributed random variable. The video source itself is modeled as a discrete time Markovian arrival process according to [16], [17].

4. Switching Mechanism for the Return Link

The switching mechanism proposed in this paper is a threshold algorithm that regulates the moving of a RCST from a MF-TDMA to a SCPC modality and vice versa. The proposed algorithm is composed of two parts. In the first part, if the RCST terminal is in a MF-TDMA mode, the proposed mechanism controls the capacity request performed by the terminal for the Rate Based Dynamic Capacity (RBDC) queue in order to decide if it is better to switch the RCST to a SCPC mode. The choice of performing the control only on RBDC queue has been done in order to better satisfy the QoS in the considered applications. In this work the Video Conference traffic has been mapped in the RBDC category and the HTTP and FTP traffics have been mapped in the Volume Based Dynamic Capacity (VBDC) category. This in order to give more priority to the video traffic that has more stringent constraints (end-to-end delay, jitter, etc.). In a given time window *wnd*, the mechanism verifies if the capacity request is higher than a certain threshold *thr*, previously empirically estimated through a specific campaign of simulations: in order to choose right values of *thr* and *wnd*, many observations of end-2-end delays and queue lengths have been made. After the preliminary simulations we stated that a value of *thr* equals to two times the value of maximum RBDC request and a value of *wnd* equals to 4 seconds lead the system to best results. If the capacity request is greater than *thr* for the overall time window *wnd*, then the NCC sends a Terminal Information Message (TIM) toward the RCST allowing it to the continuous carrier mode. The second part previews that, if the terminal is in a SCPC mode, the mechanism controls, on a periodical basis, the throughput of the specific terminal in order to state if there is a waste of bandwidth that would make more efficient the MF-TDMA mode in order to exploit the dynamic capacity request. The NCC performs a control now based on the throughput of the mobile terminal. If the throughput is lower than a threshold, evaluated through simulations, for a fixed time interval, the NCC sends a TIM message toward the RCST that it will switch from SCPC to MF-TDMA modality. For more details see [17]. In this work no ACM mechanism has been considered.

A return link continuous transmission can use a very short frame size. This very short frame is an extension of DVB-S2 and shall follow the provisions of [18]. Physical layer framing shall be in accordance with clause 5.5 of [18], except that the last slot in each frame shall contain *k* information-carrying symbols, so that the total number of such symbols in the frame, i.e., excluding the physical layer header and pilots, is 90×S+k. The remaining 90-k symbols in the last slot of each frame shall be filled with pilot symbols. The total number of symbols in each frame, including physical layer header and pilots, thus becomes $90*(S+2)+P\lfloor (S-1)/16 \rfloor$, where P=36, S is the number of symbols (see [1]) and $\lfloor x \rfloor$ denotes the largest integer not greater than *x*. For the case of QPSK that is the modulation considered in this work the value *S* is 22 and the value *k* is 68. For more details see [1].

5. Performance Evaluation

The simulations have been performed considering three types of applications that a passenger of a train can use during his travel, such as HTTP, FTP, and Video Conference. For more details on simulation campaigns see [17].

Tab.1: Simulation parameters.

Total Capacity	10 MHz		
MF-TDMA Capacity (%)	100, 90, 85, 80, 75		
SCPC Capacity (%)	0, 10, 15, 20, 25		
Carrier MF-TDMA	500 kHz		
Carrier SCPC	500 kHz		
ES/N0	5,2 dB		
FEC MF-TDMA	2/3		
FEC SCPC	3/4		
Continuous Carrier size	4 kbit		
Modulation	QPSK		
# Mobile Terminal (RCST)	20, 22, 24, 26, 28, 30		
# User	1, 2, 3, 4, 5, 10, 20, 35, 50		
	HTTP	**FTP**	**Video**
Scenario 1	70 %	20 %	10 %
Scenario 2	**60 %**	**25 %**	**15 %**

In this paper a new simulation scenario, called Scenario 2, is presented in order to verify the goodness of the proposed algorithm in this satellite platform under different traffic repartition. This scenario previews a traffic distribution as shown in Tab. 1, 60 % of HTTP, 25 % of FTP and 15 % of Video Conference. Also, in this scenario a simulative campaign for finding the better capacity distribution between TDMA and SCPC has been performed.

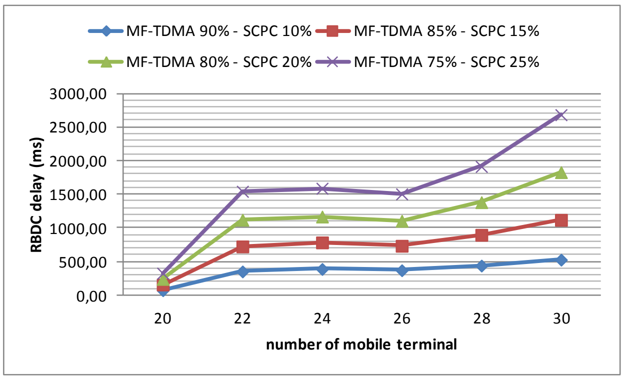

Fig. 4: RBDC delay comparison between classical MF-TDMA system and TBSA algorithm varying capacity percentage.

The results show that the better distribution is that books the 90 % of capacity to TDMA and 10 % to the SCPC mode as it is shown in the following figures. The parameters considered for the simulations are reported in the Tab. 1. In order to make a fair comparison between the two modalities SCPC and MF-TDMA the correct parameters have been chosen. It is important that the obtained Eb/N_0 is the same for the two modalities because the satellite terminals have to be able to get the signal with their antenna system. The considerations reported in this paper are qualitative analysis; impact of QoS is not investigated, it will be done in future works. Different number of mobile terminals has been considered, from 20 to 30 in order to load the system from 100 % to 150 % (20 terminals, considering a 500 kHz carrier, result in a 10 MHz of total bandwidth).

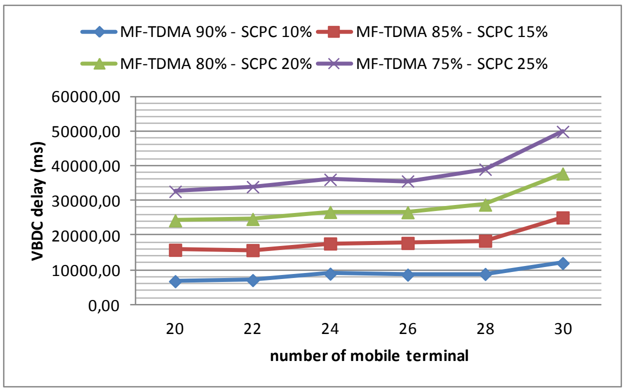

Fig. 5: VBDC delay comparison between classical MF-TDMA system and TBSA algorithm varying capacity percentage.

The scenario previews a small number of Video Conference applications in respect of the other applications given that they represent the most demanding application in terms of traffic. The graphics reported in this section show a comparison between classical MF-TDMA mechanism and the TBSA algorithm varying the percentage of satellite resource dedicated to the two modalities. As it is possible to observe in Fig. 4 the comparison is made on RBDC delay.

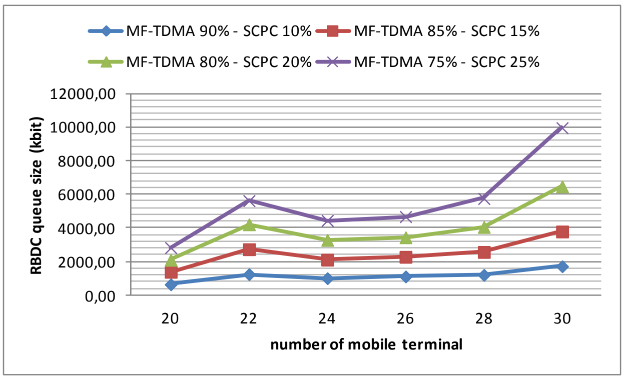

Fig. 6: RBDC queue size comparison between classical MF-TDMA system and TBSA algorithm varying capacity percentage.

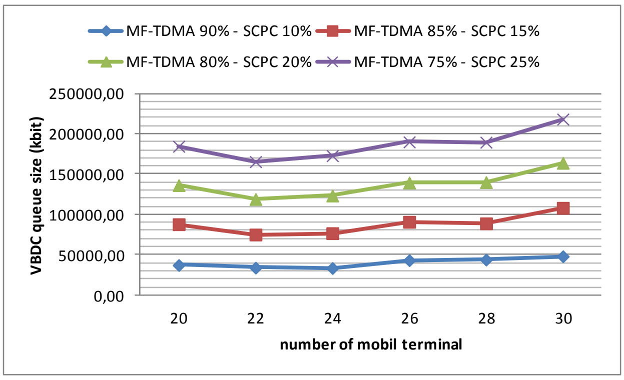

Fig. 7: VBDC queue size comparison between classical MF-TDMA system and TBSA algorithm varying capacity percentage.

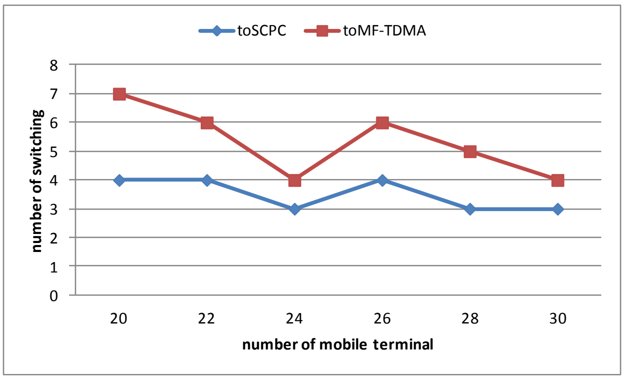

Fig. 8: Number of switch between two modalities considering 90 % MF-TDMA and 10 % TBSA.

The combination of 90 % MF-TDMA and 10 % SCPC results to be the best resource repartition. Also Fig. 5 shows the same result for VBDC traffic about the delay parameter. Figure 6 and Fig. 7 show, instead, the comparison as regard the queue size parameter. How it is possible to observe also in this case the better capacity repartition results that previews 90 % MF-TDMA and 10 % SCPC. At last, the graphic of switching number performed by the system between the two modalities is shown (Fig. 8). It is possible to make a consideration concerning the signaling overhead introduced in the system by the TBSA algorithm but it is possible to note that the average number of switching is not high and, then, not a lot of overhead is introduced in the system with the use of the TBSA switching algorithm. This behavior confirms that the proposed algorithm is able to reduce delay and queue size for the traffic in the system maintaining low the overhead due to the signaling between NCC and RCST terminals.

6. Conclusion

This paper presents a study on the DVB-RCS+M return channel. As suggested by standard, the return channel can operate beyond the classical MF-TDMA in a continuous carrier mode in order to better exploit the satellite resource in a mobile scenario. In this work an algorithm for the switching between two modalities MF-TDMA and SCPC has been proposed called Threshold Basic Switching Algorithm (TBSA). This algorithm meets the requirements imposed by the applications considered in the analysis. It is based on threshold behavior and on the Basic RCST mode that is one of the two modalities suggested by the standard. The Basic RCST mode allows the mobile terminals to send the information either in MF-TDMA or in SCPC mode but not simultaneously. The simulation campaigns have been made considering different traffic scenario in order to better verify the goodness of proposal algorithm. In particular, in this paper the simulation made for scenario called scenario 2 are shown in order to test the system with a different application traffic repartition between the users and RCSTs. The TBSA provides a switching mode capable of better exploiting the system resource (better efficiency in term of delay and queue size). Lower delay means better QoS provided by the network to the end users, reduced queue size means better resource management which is translated in a saving in capacity. Thanks to this proposal, the system is able to handle a greater number of mobile terminals while satisfying the QoS required by the users.

References

[1] ETSI EN 301 790 V1.5.1. *Interaction channel for Satellite Distribution Systems*. Sophia Antipolis Cedex: ETSI, 2009.

[2] ETSI TR 101 790 V.1.4.1. *Guidelines for the Implementation and Usage of the DVB Interaction Channel for Satellite Distribution Systems*. Sophia Antipolis Cedex: ETSI, 2009.

[3] TROPEA, M., F. DE RANGO and S. MARANO. Current Issues and Future Trend: DVB-RCS Satellite Systems. *IEEE Aerospace and Electronic Systems Magazine*. 2009, vol. 24, iss. 9, pp. 15-22. ISSN 0885-8985. DOI: 10.1109/MAES.2009.5282285.

[4] MOLINARO, A., F. DE RANGO, S. MARANO and M. TROPEA A Scalable Framework for End-to-End QoS Assurance in IP-Oriented Terrestrial-GEO Satellite Networks. *IEEE Aerospace and Electronic Systems Magazine*. 2005, vol. 43, iss. 4, pp. 130-137. ISSN 0163-6804. DOI: 10.1109/MCOM.2005.1421916.

[5] DE RANGO, F., M. TROPEA and S. MARANO. Integrated Services on High Altitude Platform: Receiver Driven Smart Selection of HAP-Geo Satellite Wireless Access Segment and Performance Evaluation. *International Journal of Wireless Information Networks*. 2006, vol. 13, iss. 1, pp. 77-94. ISSN 1068-9605.

[6] DE RANGO, F., M. TROPEA, A. F. SANTAMARIA and S. MARANO. An enhanced QoS CBT multicast routing protocol based on Genetic Algorithm in a hybrid HAP–Satellite system. *Computer Communications*. 2007, vol. 30, iss. 16, 3126–3143. ISSN 0140-3664. DOI: 10.1016/j.comcom.2007.05.058.

[7] DE RANGO, F., M. TROPEA, P. FAZIO and S. MARANO. Call Admission Control for Aggregate MPEG-2 Traffic Over Multimedia Geo-Satellite Networks. *IEEE Transactions on Broadcasting*. 2008, vol. 54, iss. 3, pp. 612-622. ISSN 0018-9316. DOI: 10.1109/TBC.2008.2002716.

[8] DE RANGO, F., M. TROPEA, A. F. SANTAMARIA and S. MARANO. Multicast QoS Core-Based Tree Routing Protocol and Genetic Algorithm Over an HAP-Satellite Architecture. *IEEE Transaction on Vehicular Technology*. 2009, vol. 58, iss. 8, pp 4447–4461. ISSN 0018-9545. DOI: 10.1109/TVT.2009.2019281.

[9] DE RANGO, F., P. FAZIO and S. MARANO. Utility-based predictive services for adaptive wireless networks with mobile hosts. *IEEE Transactions on Vehicular Technology*. 2009, vol. 58, iss. 3, pp. 1415-1428. ISSN 0018-9545. DOI: 10.1109/TVT.2008.924989.

[10] DE RANGO, F., M. TROPEA, P. FAZIO and S. MARANO. Call admission control with statistical multiplexing for aggregate MPEG traffic in a DVB-RCS satellite network. In: *IEEE Global Telecommunications Conference, 2005. GLOBECOM '05*. St. Louis: IEEE, 2005, pp. 3231-3236. ISBN 0-7803-9414-3. DOI: 10.1109/GLOCOM.2005.1578372.

[11] ALAMANAC, A. B., P. M. L. CHAN, L. DUQUERROY, Y. HU, G. GALLINARO, W. GUO and D. MIGNOLO. DVB-RCS goes mobile: Challenges and technical solutions. *International Journal Satellite Communications Networking*. 2010, vol. 28, iss. 3-4, pp.137-155. ISSN 1542-0973. DOI: 10.1002/sat.946.

[12] M. DALE, Dynamic Bandwidth Allocation in SCPC-based satellite networks. In proceeding of: Military Communications Conference (MILCOM). DOI: 10.1109/MILCOM.2008. 4753479. Publication Year: 2008, Page(s): 1-6.

[13] SKINNEMOEN, H. A New Powerful Platform: 2nd Generation DVB Interactive Satellite System. In: *DVB* [online]. Issue 37. 2011. Available at: http://www.dvb.org.

[14] LEE, J. J. and M. GUPTA. A New Traffic Model for Current User Web Browsing Behavior. In: *Intel Corporation* [online]. 2007. Available at: http://blogs.intel.com/intellabs.

[15] Preparation for Internet to Trains Initiative: Broadband on Trains, Analysis of the Opportunity and Development Roadmap. In: *ESA project* [online]. 2008. Available at: http://telecom.esa.int/telecom/www/object/index.cfm?fobjectid=24283.

[16] ANDREADIS, A. a G. GIAMBENE. *Protocols for High-Efficiency Wireless Networks*. Dordrecht: Kluwer Academic Publishers, 2003. ISBN 978-1-4020-7326-7.

[17] TROPEA, M., A. BOLEA-ALAMANAC, D. MIGNOLO, F. DE RANGO and S. MARANO. Mac scheme For Hybrid Return Link in a DVB-RCS+M Railway Scenario. In: *27th International Communications Satellite Systems Conference (ICSSC 2009)*. Edinburgh: IEEE, 2009, pp. 214-218. ISBN 978-1-84919-132-6. DOI: 10.1049/cp.2009.1168.

[18] ETSI EN 302 307 V1.3.1. *Digital Video Broadcasting (DVB); Second generation framing structure, channel coding and modulation systems for Broadcasting, Interactive Services, News Gathering and other broadband satellite applications (DVB-S2)*. Sophia Antipolis Cedex: ETSI, 2012.

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