MAC LAYER QOS MECHANISMS FOR A GEOSTATIONARY SATELLITE NETWORK

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Abstract- An efficient resource management is crucial in supporting multimedia traffic in satellite networks. To this, Dynamic Bandwidth Allocation Capabilities mechanisms can be exploited to deliver the required QoS while optimising the bandwidth utilization. This paper just deals with the design of innovative algorithms for scheduling and sending the resource requests queued on a EuroSkyWay [1,2] satellite terminal to a Traffic Resource Manager (TRM). The effectiveness of the defined mechanisms has been evaluated through computer simulations. Particularly, by considering different mixes of MPEG-2 traffic and HTTP traffic, the *Average Waiting Time* (AWT) of the requests and their *Losses Percentage* have been calculated and compared with those ones obtained using algorithms proposed in MAC layer EuroSkyWay specifications.

KEYWORDS: **Satellite, Ka-band, QoS, MAC, DBAC, Scheduling, Performance**

I. INTRODUCTION

The near future will be characterized by a deep integration between IT and TLC worlds to make Internet a global multi-service network environment built on both wired and wireless technologies.

In this scenario, an important wireless technology is based on satellites which are very attractive for a number of reasons: ubiquitous communications, high-bandwidth availability, a natural support for broadcast/multicast transmissions. However, an efficient resource management is mandatory in order to support multimedia traffic in satellite networks. An accurate design of a Medium Access Control (MAC) protocol which exploits Dynamic Bandwidth Allocation Capability (DBAC) mechanisms can play a key role in delivering the required QoS levels while optimising the bandwidth utilization.

This paper reports the results of an activity in the framework of EuroSkyWay (ESW), a research program that aims at implementing a satellite-based platform for the provision of a number of services, among which Internet services. Particularly, innovative algorithms for scheduling and sending the resource requests queued in an ESW Satellite Terminal (SaT) to a Traffic Resource Manager (TRM) have been defined.

By considering different mixes of MPEG-2 traffic and HTTP traffic, the *Average Waiting Time* (AWT) of the requests and their *Losses Percentage* have been calculated through computer simulations using Network Simulator v2 tool [3]. The simulation results showed the effectiveness of the designed mechanisms compared with those ones proposed in MAC layer ESW specifications.

The rest of the paper is organized as follows. EuroSkyWay network is briefly introduced in Section II. The proposed MAC Layer QoS schemes are described in Section III. Section IV reports the simulation model. The simulation results are discussed in Section V. Finally, conclusions and areas of future research are provided in Section VI.

II. EUROSKYWAY NETWORK

EuroSkyWay network (Fig.1) is an ATM-like satellite platform that offers broadband connectivity services.

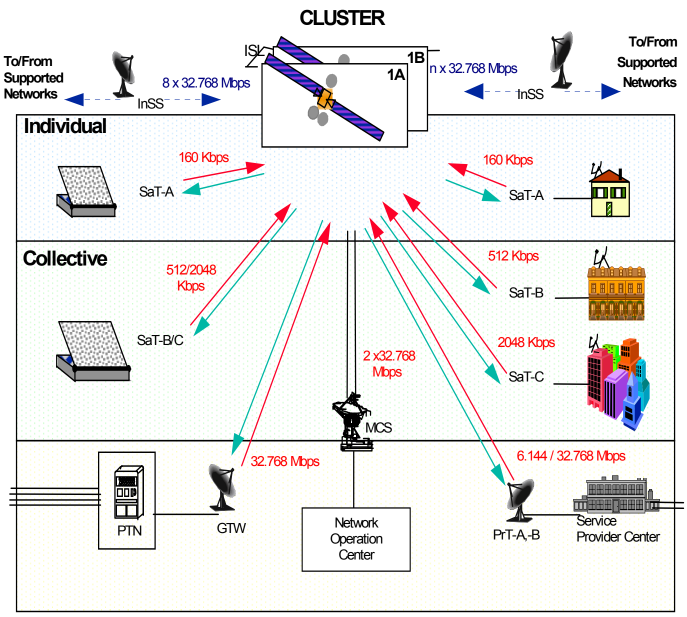

Fig.1 ESW network

Four service categories, called A, B, C, D and roughly corresponding, respectively, to CBR, rt-VBR, nrt-VBR, ABR/UBR ATM service classes, are supported.

Resources are statically allocated to ESW connections pertaining to A service class. On the contrary, resource management for B, C and D classes is based on a DBAC mechanism: whenever an ESW SaT needs transmission resources, a capacity request message is sent to a

Traffic Resource Manager (TRM) running on board the satellite (Fig. 2). A number of Resource Request Channels (RRC), shared by all SaTs belonging to the same Service Carrier Group, are used to carry Out of Band Capacity Request (OBCR) messages: an OBCR message will be formatted by a Resource Manager (RM) on the SaT whenever resources previously allocated to a connection are expired. Capacity request messages can be also sent by In-Band Capacity Requests (IBCR): the amount of requested resources is inserted in the header of a data ESW cell.

Resource Grant Channels (RGC) are used to carry Capacity Assignment Messages (CAMs) and Capacity Confirmation Messages (CCMs). CAMs and CCMs are generated by the TRM as answers, respectively, to OBCR and IBCR messages.

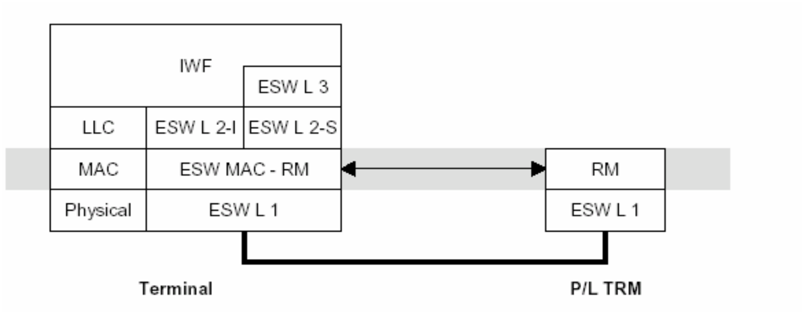

Fig. 2 Resource Management Protocol Stack

III. Proposed MAC Layer QoS Mechanisms

The research activity summarized in this paper focused on two ESW architecture MAC layer mechanisms which are very crucial in satisfying QoS parameters required by connections, that is, the scheduling of OBCR messages queued in SaTs and the scheme to be used for accessing to RRCs in order to send to TRM OBCR messages.

ESW MAC layer specifications propose a classical priority queuing discipline for the scheduling of OBCR messages. Particularly, the priority level associated to an OBCR message corresponds to the priority level of ESW connection for which the message has been generated.

With regard to the MAC protocol for accessing RRCs, ESW specifications simply consider Slotted Aloha.

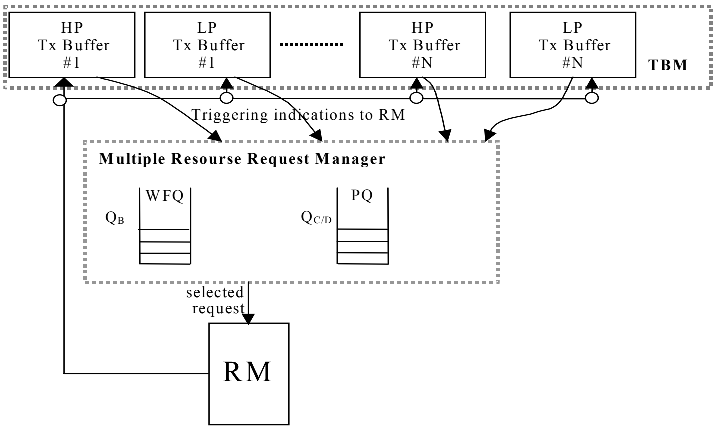

Fig. 3 Resource Requests Scheduling Scheme

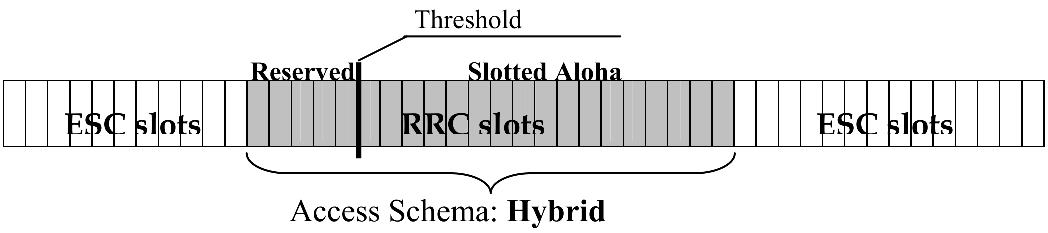

Fig. 4 Uplink Channel Access Scheme

In this work an innovative scheduling scheme has been defined (Fig.3): a queue Q_B, served according to Weighted Fair Queuing (WFQ) policy, stores the OBCR messages pertaining to class B connections; another queue, $Q_{C/D}$, served according to Priority queuing policy, stores the OBCR messages associated to classes C and D connections. In order to guarantee the QoS required by the class B connections while not significantly reducing the QoS offered to class C connections, the scheduler, called Multiple Resource Request Manager, switches from queue Q_B to queue $Q_{C/D}$ after it has served a given number of Q_B elements.

Fig.4 refers to the other mechanism considered, that designed for controlling the access to the RRC time slots: a number of slots are reserved to each active terminal and the remaining slots are accessed according to Slotted Aloha protocol. Of course, reserved slots will be used by giving the highest priority to OBCR messages generated for class B connections and the lowest priority to those associated to class D connections.

The performance analysis aimed at identifying the best distribution between reserved and Slotted Aloha RRCs by varying the “movable boundary” (Fig.4): all or the most of the class B resources requests have to be successfully allocated into the RRCs while ensuring uplink frame utilization as high as possible. The proposed uplink channel schema has been evaluated by comparing its performance with those got by adopting a pure Slotted Aloha access schema.

IV. SIMULATION MODEL

The blocks of simulation model used to evaluate the effectiveness of the designed MAC layer algorithms compared with those ones proposed in MAC layer ESW specifications are represented in Fig. 5. , where a satellite terminal sends to TRM the resource request messages, in band or out of band, in order to satisfy the QoS requirements associated to active connections. This work aimed at showing that the proposed schemes can improve QoS support in terms of bandwidth and delay considering different mixes of multimedia traffics. The following assumptions have been made:

- there are only two types of traffic (MPEG-2 and HTTP, respectively, corresponding to B and D ESW service classes);
- all traffic is already admitted to the network;
- satellite channel is bit error free.

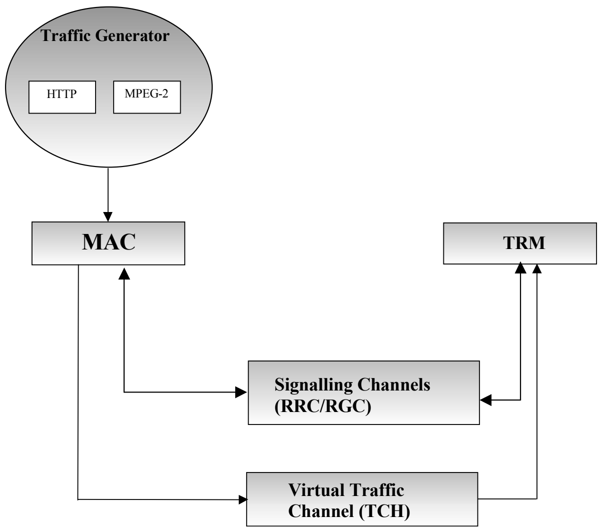

Fig. 5 Simulation Model

Using the Network Simulator v2 (ns2) tool [3], the effects of adopting the proposed scheme have been evaluated in terms of the *Average Waiting Time* (AWT) of the requests and their *Losses Percentage*.

All the results of the simulations are characterised by a 95% confidence interval whose maximum relative error is equal to 5%. Finally, Table 1 summarises the values related to the main parameters of the simulation model.

Parameter		Value
SaT bit rate		2048 Kbps
Scenario	MPEG2	Mean Data Rate: 64 Kbps Peak data Rate: 2048 Kbps
	HTTP	Mean Data Rate: 16 Kbps Peak data Rate: 2048 Kbps
Round Trip Time (SaT-TRM)		265 ms
Number of RRC slots		25, 50, 75
Number of connections		20, 15, 16
Number of class D connections (N_H)		15, 5, 8
Collision probability		0.63
Number of SaT belonging to the same Carrier Group, handled by TRM (N_{SaT})		90

Tab. 1 Simulation Parameters values

V. SIMULATION RESULTS

In order to evaluate the effectiveness of the designed MAC layer algorithms, the following metrics have been considered: resource requests *Average Waiting Time* (AWT) on terminal; *percentage* of *resource requests discarded* due to limited Up-Link (U/L) channel capacity.

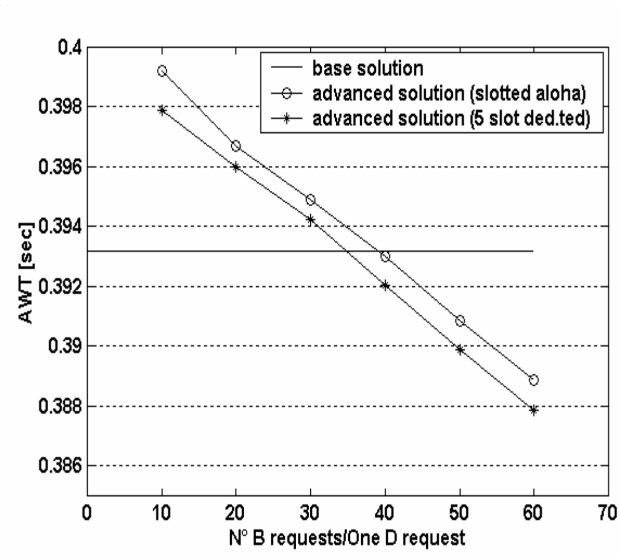

Fig.6 Class B Requests AWT

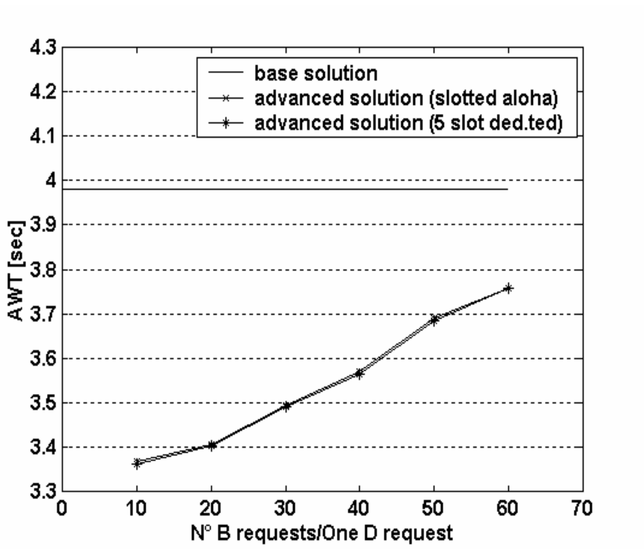

Fig. 7 Class D Requests AWT

In the following, MAC scheme based on the priority queuing discipline and on the slotted Aloha access protocol will be referred to as “Base solution”. On the other way, the proposed innovative MAC scheme will be called “Advanced solution”.

In Fig. 6 a comparison between two schemas considered, in terms of class B capacity requests AWT, is reported. The AWT impacts on the QoS provisioning to the active connections on terminal: reducing class B requests processing time results in a higher probability to satisfy CTD (Cell Transfer Delay) and CDV (Cell Delay Variation) parameters.

The *advanced* solution ensures an AWT substantially lower than that got by *base* solution (Fig. 6). In particular, the *advanced* solution is effectively favourable if the $Q_{C/D}$ queue is accessed after a number of Q_B requests, at least 60, have been processed. Fig.7 shows that both the configurations (5 slots dedicated or 0 slot dedicated) of the *advanced* solution ensure the same performances which are definitely better than those related to the *base* solution. An interesting result comes out by comparing Fig.6 and Fig.7: fixing the Slotted Aloha as U/L channel access protocol, a MAC schema adopting an advanced scheduling policy provides AWT values, for both class D and class B capacity requests, which are better than those got by using of a priority queuing discipline. Moreover, a hybrid U/L channel access schema combined with the advanced scheduling policy ensures noticeable advantages to the class B requests while the class D requests AWT improves if a right number of class B requests to be served before satisfying a class D request is chosen.

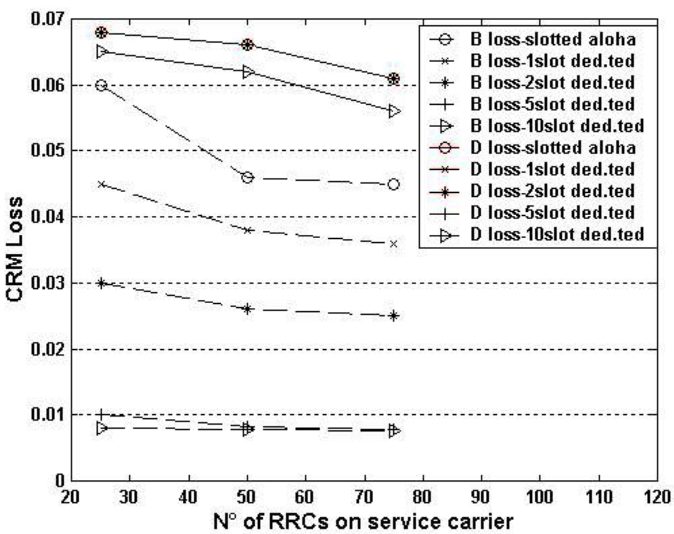

Fig. 8 Capacity requests loss depending on channel access schema

Fig.8 shows the effects of the U/L channel access protocol on the number of capacity requests lost; in particular, each configuration has been tested for different values of RRC slots belonging to the service carrier reserved to the considered terminal. A hybrid channel access schema involves a noticeable performance improvement, in particular with regard to the class B capacity requests. The performance gap between the Slotted Aloha and the hybrid access scheme increases as the number of RRC slots, reserved to each one of the connections, increases too. In addition, the simulation results have revealed that adopting an access schema characterized by more than five slots dedicated per connection does not involve a significant performance improvement: the dedicated slots exceed the effective class B capacity requests (MPEG-2 traffic) so they are used by other leaning requests related to class D connections.

An analogous kind of analysis has been carried out for capacity requests related to class D connections, Fig. 8 shows what simulations revealed. Moreover, it is noteworthy that the choice of the U/L access protocol does not significantly impact on the performances, in terms of discarded capacity requests, except in specific conditions. In particular, the hybrid channel access schema using ten dedicated RRC slots per connection is able to improve significantly the performance.

VI. Conclusions and Future Work

In this paper MAC Layer QoS mechanisms have been defined so as to identify the most suitable to a geostationary satellite network supporting various service classes. The performed simulations have revealed the effectiveness of the solving schemes proposed about resource requests scheduling and uplink channel access protocol.

Future research activities are going to test exhaustively the proposed scheme by considering a multi-service environment supporting FTP and e-mail traffic, in addition to MPEG2 and HTTP. Moreover, the typical problems of a satellite channel are going to be considered so as to evaluate their impacts on MAC performances.

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