# Adaptive IP scheduler design to support QoS guarantees over satellite systems

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***Abstract*—This paper presents an adaptive algorithm for managing the weight values of the Weighted Round Robin (WRR) scheduler to provide End-to-End (E2E) Quality of Service (QoS) guarantees for Broadband satellite systems. The weight calculation depends on the capacity variations present in the Digital Video Broadcasting-Second Generation (DVB-S2) satellite link. The algorithm is defined to optimize the bandwidth utilization while satisfying the QoS requirements for different traffic classes. The operation of the proposed algorithm is demonstrated using the NS-2 simulator tool. The results show that the proposed adaptive WRR algorithm optimizes the bandwidth utilization while enforces the priority level of each service class when an extreme reduction of bandwidth caused by rain events is experienced in the satellite system.**

***Index Terms*—QoS, DiffServ DVB-S2, ETSI-BSM QoS and GEO satellite**

## I. INTRODUCTION

TODAY, the support of new IP applications over Internet has experienced a fast and continuous growth. To guarantee the transport of applications such as Voice over IP (VoIP) and multimedia services through a satellite network, it requires considering different levels of individual packet treatment. This differentiation includes the Quality of Service (QoS) parameters to specify packet transmission priorities across the network nodes and the required amount of bandwidth assignment.

However, to provide QoS guarantees using satellite systems, it is important to consider the intrinsic characteristics present in GEO satellite systems that affect the QoS provisioning. Such characteristics are: delay, packet losses and link bandwidth variations. The presence of link bandwidth variations need to be seriously considered, as it is necessary to preserve the QoS levels when atmospheric events (such as rain) are experienced. Such events can also reduce the available capacity in the Digital Video Broadcasting-Second Generation (DVB-S2) [1] forward channel. To address this challenge, the DVB-S2 specification defines the use of the Adaptive Code and Modulation (ACM) techniques to achieve quasi-error free channel conditions for each individual user, by providing them with the most suitable modulation and code (*ModCod*) value according to the measured signal-to-noise-plus-interference ratio (*SNIR*).

In addition, the Broadband Satellite Multimedia (BSM) working group has defined a QoS functional architecture (ETSI-BSM-QoS) standardized in [2], which establishes the required QoS mechanisms to provide priorities among users and applications based on the Differentiated Services (DiffServ) framework [3].

Nevertheless, when the satellite system experiences a reduction of bandwidth capacity caused by a heavy rain event, it is important to consider a resource sharing model that takes into account the fact that the available capacity present in a satellite system is constantly changing. Therefore, a solution is to use a dynamic IP scheduler that manages the bandwidth distribution among service classes. This scheduler should enable sharing bandwidth resources in a suitable way, ensuring that the required QoS levels for each traffic class are maintained while the satellite link capacity is optimized.

In this paper, we propose a adaptive IP scheduler that manages the QoS requirements to optimize the utilization of the DVB-S2 satellite link capacity. The aim of this model is to share the available bandwidth among various service classes having a certain QoS level. The proposed adaptive IP scheduler uses an algorithm that considers two factors to determine the minimum required amount of resources. These factors are the QoS requirements of each traffic class, defined by the satellite operator, and the link bandwidth availability present on the satellite system.

The proposed design is developed inside the Hub. Here, we deal with the DiffServ architecture for implementing different packet treatments or traffic classes. For this purpose, we define a DiffServ model based on the ETSI-BSM-QoS Services and Architectures standard, which is adopted for working together with the adaptive IP scheduler.

The network topology for the design of the proposed adaptive IP scheduler is shown in 1. This topology represents the typical scenario in which users demand Internet applications by the intensive use of the DVB-S2 forward channel.

In this topology, three sources send data to a remote destination. Each source node supports different services, having a predefined QoS level. The first source bears a real-time Voice over IP (VoIP) application. The second source uses a Hypertext Transfer Protocol (HTTP) server, while the last source represents a bulk data transfer generated by a persistent File Transfer Protocol (FTP) transaction server.

Here, all the traffic entering the core router is directly sent to the Hub that supports the DiffServ architecture to guarantee the predefined QoS level for each traffic type. The DVB-S2 Hub, which is the main element in the proposed architecture, is responsible for applying the algorithm defined for the adaptive IP scheduler, sending the data to the destination host via the DVB-S2 forward channel. The return channel is based on the DVB-RCS specification [13].

The proposed IP scheduler is evaluated using the NS-2 sim-

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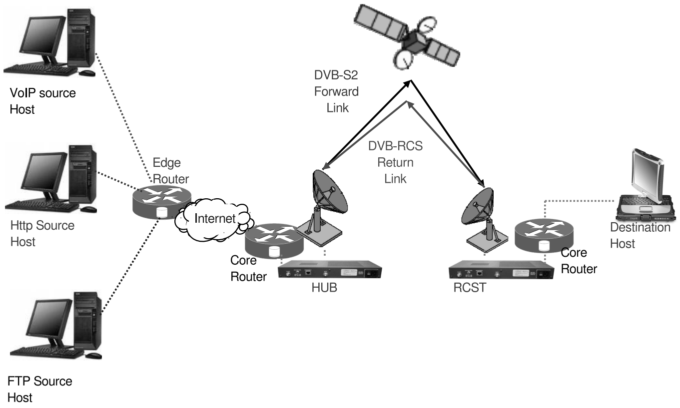

Fig. 1. DVB-S2/RCS satellite scenario

ulation tool. In the simulation environment we consider both the adoption of a DiffServ model to provide QoS guarantees and the most representative characteristics affecting the DVB-S2 forward channel (i.e. delay, losses and mainly the presence of link bandwidth variations). The presented simulation results demonstrate that when the adaptive IP scheduler is used, an enhanced satellite channel performance is achieved while maintaining the QoS levels even though a severe reduction of bandwidth is experienced.

This work is organized in 5 sections: in section 2 a description of the Hub and the adaptive IP scheduler is presented. In section 3, the proposed adaptive scheduler is evaluated using the NS-2 simulation tool and the performance evaluation results are shown. In section 4 the related studies are addressed and conclusions are formulated in section 5.

## II. ADAPTIVE IP SCHEDULER

In this section we present the design inside the Hub together with the proposed adaptive IP scheduler.

### A. Adaptive IP scheduler design

The proposed scheduler is designed inside the DVB-S2 Hub which fulfills the ETSI QoS Broadband Satellite Multimedia Services and Architectures standard [2]. We propose a model based on the DiffServ [3] framework, allowing IP traffic to be classified into a finite number of classes differentiated by priority, to support different QoS levels.

The architecture of the DVB-S2 Hub that supports the DiffServ architecture and exploits the proposed adaptive IP scheduler is shown in Fig.2.

The main components defined in the DiffServ model are: *the traffic classifiers*, which select packets and assign (if necessary) their Differentiated Services Code Point (DSCP) values; *the traffic conditioners* which mark and enforce the rate limitation policy; and *the Per Hop Behaviour (PHB)* that enforces the differentiated packet treatments. In this sense, there are three predefined PHBs: Expedited Forwarding (EF), Assured Forwarding (AF) and Best-Effort (BE). One of the main benefits of adopting the DiffServ framework is that the network complexity is translated to edge nodes, enabling to maintain the scalability and simplicity of the IP network.

The QoS policy implemented in the DiffServ model allows the EF traffic class to have the highest priority, while the AF traffic class has more priority than the BE traffic class. Nevertheless, the BE traffic class, which is based on a best effort scheme, uses the remaining link capacity, being able to use the bandwidth that any other class does not use.

The DiffServ model includes a traffic classifier that decides if a packet needs to be reassigned with a different QoS level by remarking its DSCP. Notice that the proposed scheme allows multiple flows to be aggregated and treated as a single flow per traffic class. The en-queuing system supported at the Hub has three traffic classes allowing each of them to have its own physical queue and implementing a drop tail mechanism.

Every traffic class implements a *token bucket (TB)* as a rate limiter to guarantee the transmission rate according to the bandwidth assignment established in the Service Level Agreement (SLA). Each TB-limiting rate is set to $\mu_{EF}$, $\mu_{AF}$ and $\mu_{BE}$ for the EF, AF and BE traffic classes respectively. Here, it is worth mentioning that our proposal considers the buffer length of each traffic class as a function of the Bandwidth Delay Product (BDP). This BDP value is set considering the minimum Round Trip Time ($RTT_{MIN}$) present in the satellite system and the associated TB-limiting rate.

All packets coming from each traffic class are sent directly to the adaptive IP scheduler. The scheduler design is based on the Weighted Round Robin (WRR) mechanism [5], which controls the order in which packets are extracted out from its queues. Along with the adaptive IP scheduler, there is a new module which is responsible for calculating the parameters to prioritize certain traffic classes. This component is referred as the *adaptive calculator* that takes into account a sinusoidal wave, to continuously update the bandwidth availability

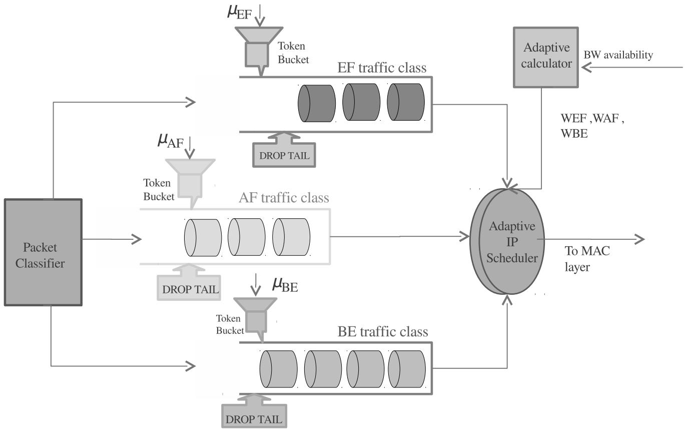

Fig. 2. Structure of the adaptive DVB-S2 Hub

($C_{OUT}$) present in the satellite system. Such parameter will be sent from the Physical layer to the Network layer by means of a cross-layer mechanism. The proposed adaptive IP scheduler will use these values as the input parameters to distribute the available bandwidth among service classes, providing QoS guarantees.

As it is observed, in Fig.2 the *adaptive calculator* module is decoupled from the adaptive IP scheduler. Therefore, the scheduler complexity is not increased and both modules can work independently based on their own settings.

For calculating the adaptive values to prioritize certain traffic classes according to $C_{OUT}$, we propose to use the current capacity of the DVB-S2 satellite link ($C_{OUT}$) as the main criteria for the allocation of network resources. This is done by using a particular algorithm implemented in the DVB-S2 Hub that works together with the adaptive IP scheduler.

Let's assume that the corresponding adaptive values defined to prioritize the resources for each traffic class are $W_{EF}$, $W_{AF}$ and $W_{BE}$ for the EF, AF and BE traffic classes respectively. The adaptive IP scheduler design proposed in this paper actively adjusts the adaptive values of each traffic class to enforce its QoS level. In this way, considering the three traffic classes defined in the DiffServ architecture (EF, AF and BE), the proposed algorithm will therefore prioritize the EF traffic class over the AF and BE traffic classes when the satellite system experiences a capacity reduction in the presence of a heavy rain event. This will be done by assigning high values to the EF traffic class while the AF and BE traffic classes will have the lowest values.

Similarly, when the intensity of the rain event has diminished and the link capacity has increased, the algorithm will keep the priority levels of the EF and AF traffic classes over the BE traffic by assigning high values to the EF and AF traffic classes while the BE traffic class will have the lowest value.

Finally when the rain event has ended and the bandwidth availability is enough to guarantee the high priority traffic (EF and AF), the assigned bandwidth for the BE traffic class will be reestablished and the values will be assigned according to the rate of the high priority classes.

In order to specify such functionality, we propose an algorithm that adaptively distributes the available capacity among each traffic class, using three capacity intervals delimited by two thresholds. The *Scarce Capacity interval* specifies when the system capacity ($C_{OUT}$) is scarce but it is still enough to guarantee the EF traffic class. It is delimited by $C_{OUT} \leq LowerCap_{THR}$ in which the $LowerCap_{THR}$ threshold is set to the EF TB-limiting rate.

$$LowerCap_{THR} = \mu_{EF} \tag{1}$$

Similarly, the *Constrained Capacity Interval* defines when the system capacity is enough to guarantee the rate for both priority classes (EF and AF). It is limited by $LowerCap_{THR}$ $< C_{OUT} < UpperCap_{THR}$. Here, the upper threshold called $UpperCap_{THR}$ is set to the sum of the EF and AF TB-limiting rates.

$$UpperCap_{THR} = \mu_{EF} + \mu_{AF} \tag{2}$$

Finally, the *Broad Capacity interval* considers that the available bandwidth in the system is broad enough to transport all the traffic classes. Therefore this interval will be considered if $C_{OUT} > UpperCap_{THR}$. The adaptive values at each interval as a function of the DVB-S2 system capacity ($C_{OUT}$) are shown in Fig.3.

Here, we assume that the sum of the adaptive values are set to K, where K is considered as a constant value that must be significantly high to avoid rounding errors:

$$W_{EF} + W_{AF} + W_{BE} = K \tag{3}$$

Given that the BE traffic class has the lowest priority level, our algorithm allocates the excess of resources to this class. Therefore, in all cases $W_{BE}$ is set to $W^R$ representing a residual and constant value.

$$W_{BE} = W^R \tag{4}$$

Particularly, when the system capacity is in the *Broad Capacity interval*, our algorithm assigns constant values to guarantee the high priority classes (EF and AF). To proportionally distribute the system resources [9], the ratio of $W^B_{EF}$ and $W^B_{AF}$ is set equal to the ratio of the associated TB-limiting rates, thus:

$$\frac{W^B_{EF}}{W^B_{AF}} = \frac{\mu_{EF}}{\mu_{AF}} \tag{5}$$

In a similar way, when the system capacity is in the *Scarce Capacity interval*, our adaptive model assigns constant values to guarantee the EF priority class over the AF and BE traffic classes. Therefore, $W_{EF}$, $W_{AF}$ and $W_{BE}$ are set as:

$$W_{AF} = W_{BE} = W^R \tag{6}$$

$$W_{EF} = K - 2W^R \tag{7}$$

Finally, to guarantee the EF traffic class over the AF traffic class, when the system capacity is in the *Constrained Capacity interval*, our algorithm allocates most of the resources to the EF traffic class. At this interval, we can apply either a linear or an exponential relationship between the values of the higher priority classes ($W_{EF}$ and $W_{AF}$) and the satellite link capacity ($C_{OUT}$). We have performed a practical analysis between the high priority classes and the available bandwidth at the constrained interval. Such analysis has enabled us to conclude that the values must change following an exponential function. However, we have also analyzed the case when a linear function is used, resulting in a faster variation where it is not possible to guarantee the EF priority traffic class when the available capacity is close to the $UpperCap_{THR}$. Therefore, in order to build a continuous function for each traffic class, we define $W_{AF}$ as follows:

$$W_{AF} = W^R \left[ \frac{W^B_{AF}}{W^R} \right]^{\frac{C_{OUT}-\mu_{EF}}{/\mu_{AF}}} \tag{8}$$

Similarly, the $W_{EF}$ is obtained as follows:

$$W_{EF} = K - W^R - W_{AF} \tag{9}$$

## III. PERFORMANCE EVALUATION

In this section the satellite network settings and the performance metrics are presented. In addition, the proposed adaptive IP scheduler is simulated and its performance is compared against the Round Robin (RR) and the conventional WRR scheduler.

TABLE I
TABLE 1. PARAMETERS OF EACH SERVICE CLASS

| **Traffic Class** | **Max Flows** | Rate [Kbps] | $C_{OUT}$ [Mbps] |
|---|---|---|---|
| EF | 10 | 400 | 0.6-3.4 |
| AF | 10 | 800 | 0.6-3.4 |
| BE | 10 | 3400 | 0.6-3.4 |

### A. Satellite network settings

The simulation is carried out employing the NS-2 simulator tool version 2.29. For QoS purposes the DiffServ module was developed using the library described in [10] in which the proposed adaptive IP scheduler has been added.

The simulated network topology used to test the adaptive IP scheduler is shown in Fig 1. The transport protocol used for the AF and BE traffic classes is the Sack [11] variant of the Transmission Control Protocol (TCP). We used the TCP Linux version [12], which includes this TCP variant. The EF traffic class is transported employing the User Data Protocol (UDP) to strictly guarantee bandwidth reservation. The details of each service class are presented on Table I. The DVB-S2 satellite network settings used throughout the simulation are configured as follows:

The satellite channel capacity, considered as the bottleneck link, is set considering the terminals in clear sky conditions. These will have 3.4 Mbps of bandwidth while terminals allocated under a rain event will have a reduced capacity set to 0.6 Mbps. Therefore, the sinusoidal link variation will fluctuate between 0.6 and 3.4 Mbps, as it is shown in Fig.3. The minimum Round Trip Time ($RTT_{MIN}$) experienced by the satellite system is set to 560 msec. The buffer length of each traffic class is set to the BDP value. Particularly, the buffer length of the BE traffic class is set to 90 packets. The Packet Error Rate (PER) is set to 1x10-7.

The transfer speed for each traffic class are: 400 Kbps for the EF traffic class and 800 Kbps for the AF traffic class, while the BE traffic class will use the remaining bandwidth. The $LowerCap_{THR}$ and the $UpperCap_{THR}$ values are set to 0.6 Mbps and 1.4 Mbps respectively.

### B. Performance metrics

The proposed analysis is carried out at the bottleneck-satellite link, therefore, the relevant TCP information such as: the transmitted/acknowledged packets, the congestion window and the RTT are collected at the senders side. Additionally, in order to assess the system performance with the proposed adaptive IP scheduler, two metrics are considered: the goodput and the buffer occupancy.

The *goodput* is defined as the average amount of correctly received data (excluding retransmissions) measured over a certain period of time. The goodput per-class is calculated by dividing the amount of transmitted data by the number of active data flows (10 flows) within a service class in a given interval. Particularly, as the satellite link will fluctuate between 0.6 and 3.4, the reachable goodput value for each traffic class must be in accordance with the QoS policy in which the EF traffic class has the highest priority. In this way, we expect to

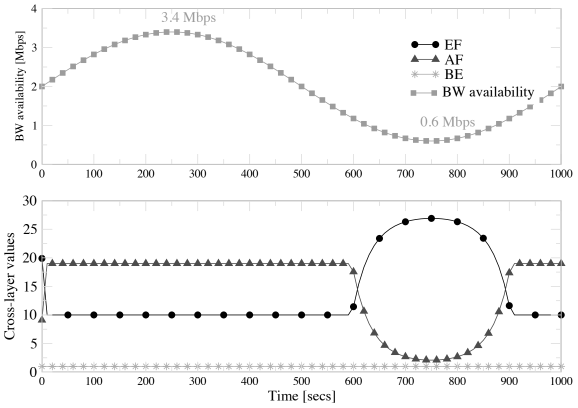

Fig. 3. Simulated values (lower graph) using the exponential algorithm as a function of the bandwidth availability (upper graph).

always guarantee 400 Kbps of goodput for the EF traffic class even though a severe reduction of bandwidth is affecting in the system. Similarly, as the AF traffic class has more priority than the BE traffic class, we expect to guarantee its 800 Kbps of goodput only if the capacity is enough to guarantee the EF traffic class. Finally, the BE traffic class will be able to use the remaining link bandwidth.

The *buffer occupancy* represents the fullness of the DiffServ queue during the simulation time. This value is closely related to delay, as it determines the system latency. One of the main goals in any satellite system is to reduce the system latency, because the lower the buffer occupancy levels, the lower the system latency. Therefore, we would rather an IP scheduler that improves low levels of queue occupancy. In our case, the simulation results consider the buffer occupancy for the IP queues allocated at the Hub (see Fig.2)

### C. Simulation results

In order to evaluate the performance of the adaptive IP scheduler, three simulation tests are considered: the first test is performed to assess the DVB-S2 system response when the Round Robin (RR) mechanism is employed. The second test considers the Weighted Round Robin mechanism with static weight values set to 6, 8 and 1 (K = 15) for $W_{EF}$, $W_{AF}$ and $W_{BE}$ respectively. These values are set considering the proportional distribution of resources [9]. Particularly, for the EF traffic class, we have assigned it with a higher weight value than its corresponding proportional value. This is done because its proportional value is not able to guarantee the priority level for the EF traffic class when the capacity is reduced. Finally, a third simulation test is performed considering our proposed adaptive IP scheduler that enforces the priority levels taking into account the link capacity variations. Here, we have calculated the adaptive values at the constrained interval considering two functions: a linear function (XL-linear) and an exponential function (XL-exponential).

The results of plotting the XL-exponential values are shown in Fig.3. Here, the sinusoidal wave represents a heavy rain event affecting the bandwidth availability ($C_{OUT}$), fluctuating between 0.6 and 3.4 Mbps. These results consider the exponential algorithm (using the analysis presented in section II.A) and the bandwidth rate previously set for each traffic class (see Table I). The K value is set to 30 and $W^R$ is set to 1.

The simulation results of goodput and queue occupancy for the EF, AF and BE traffic classes are shown in Fig.4, Fig.5 and Fig.6 respectively. Here the four mechanisms: RR, static WRR, XL-lineal and XL-exponential, working independently are compared.

As it is observed in Fig.4, using the RR algorithm (symbol $\bullet$) the EF traffic class is not guaranteed when a reduction of bandwidth, due to a rain event, is experienced. Particularly, during the 750-seconds time point (see the valley) only 200 Kbps of goodput level is reached. Similarly, when using the WRR mechanism with static weight values (symbol $\triangle$), the EF traffic class is able to reach 230 Kbps of goodput at the same time point. Although this goodput level is enhanced compared to the previous case, this is not enough to guarantee the high priority traffic class which is set to 400 Kbps. In both cases, the queue occupancy is overloaded, reaching its limit value (set to 90 packets), leading to an increase of the system latency.

In contrast to these results, when using the adaptive IP scheduler (either XL-lineal or XL-exponential), the EF goodput is able to reach its 400 Kbps during all the simulation time (see symbols $\blacksquare$ and symbol $*$).

In both cases, the EF buffer occupancy is reduced compared with the RR and static WRR. Particularly, when the linear function is employed (XL-lineal), a faster variation of the weighted values is generated and thus a peak value of 70-packets buffer occupancy is reached. However, when the exponential adaptive IP scheduler (XL-exponential) is used, the buffer occupancy for the EF traffic class is kept at lower levels, being able to reach 40 packets even though an extreme reduction of bandwidth is experienced. This result would be preferred when working with QoS satellite systems.

The results of goodput and queue occupancy for the AF traffic class are shown in Fig.5. As it is observed, in all the cases the more the capacity is reduced, the more the AF goodput level is affected. Similarly, the queue occupancy reaches in most of the cases its limit which is set to 90 packets.

Nevertheless, if we analyze the behaviour at the valley, when the bandwidth availability is reduced to 600 Kbps ($C_{OUT}$), during the 750-seconds time point, it is possible to see that the RR mechanism (symbol $\bullet$)) is able to reach 200 Kbps of goodput, which is the same value reached by the EF traffic class (see Fig.4). This situation is mainly because the RR mechanism extracts a packet every time it visits each queue. As a result, both the AF and EF queues receive the same treatment, having the same bandwidth assignment. Therefore, using the RR mechanism, it is not possible to guarantee the priority levels establish in the SLA, given that for all the traffic classes the same amount of bandwidth is assigned.

In contrast to this, when the static WRR mechanism is used (see symbol $\triangle$ in Fig.5), the AF goodput is enhanced, being able to reach 320 Kbps during the 750-seconds time point.

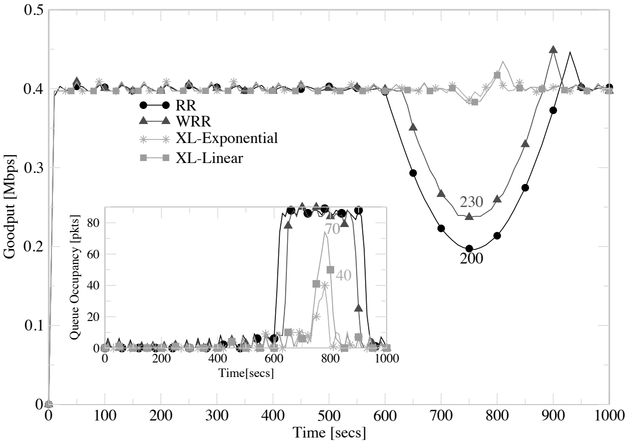

Fig. 4. EF Goodput performance results and queue occupancy when using RR, static WRR, XL-lineal and XL-exponential algorithms

However, at the same time-point, the EF traffic class is able to reach only 230 Kbps of goodput (see Fig.4). As it can be observed, the AF traffic class is assigned with more bandwidth level than the EF traffic class, although it has less priority than the EF traffic class. This is mainly because using the WRR algorithm with static weight values, the queues of the higher priority traffic classes become much more visited, depending of the static weight values. Therefore, using a proportional, static distribution of weights, it is not possible to guarantees the EF high priority traffic class in front of a heavy rain event.

Nevertheless, when using the adaptive IP scheduler, the AF traffic class is able to reach 200 Kbps of goodput during the 750-seconds time point (see Fig.5), which is an expected result given that the EF traffic class reaches its 400 Kbps of goodput, at the same time point. As a result, the bandwidth assignment for the EF and AF traffic classes are defined according to their priority level while considering the bandwidth availability present in the satellite system (which is reduced to 600 Kbps). Therefore, using the proposed adaptive IP scheduler, it is possible to totally guarantee high priority traffic class and assigning the remaining link bandwidth to the AF traffic class when a heavy rain event is experienced

This result is according to the specification defined in the predefined QoS policy in which the EF traffic class has the highest priority level, while the AF traffic class has more priority than the BE traffic class.

Finally, in Fig.6 the simulation results of goodput and queue occupancy for the BE traffic class are presented. Here, it is possible to observe that in all the cases the BE traffic class is able to use the remaining link bandwidth. This is mainly because the adoption of the DiffServ model, which allows the BE traffic class to use the bandwidth that any other class does not use. As a result, this class is able to follow the sinusoidal wave when an increase of bandwidth capacity ($C_{OUT}$) is experienced by the satellite system (see the interval between 200 and 300 seconds).

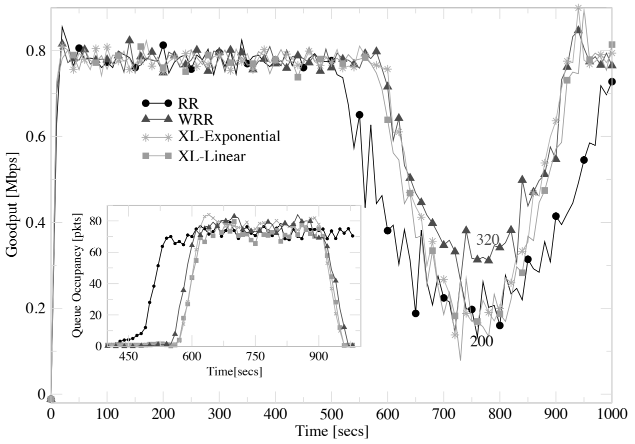

Fig. 5. Fig. 6. AF Goodput performance results and queue occupancy (average) when using RR, static WRR, XL-lineal and XL-exponential algorithms

On the contrary, when an extreme reduction of bandwidth is experienced (see the interval between 700 and 800 seconds), the bandwidth is assigned according to the algorithm used in each case (RR, WRR, XL-lineal and XL-exponential). In particular, for the cases when either RR and static WRR are used (see symbol $\bullet$ and $\triangle$ respectively), in most of the cases the priority levels of each traffic class are not kept, being unable to guarantee high priority traffic classes over the BE traffic class.

However, when considering our proposed exponential adaptive IP scheduler (symbol $*$) the goodput for the BE traffic class is kept at the lowest level while the queue occupancy is overloaded. Therefore, the priority levels of each traffic class are kept during all the simulation time, guaranteeing the higher priority traffic classes (EF and AF) over the BE traffic class when an extreme reduction of bandwidth is experienced.

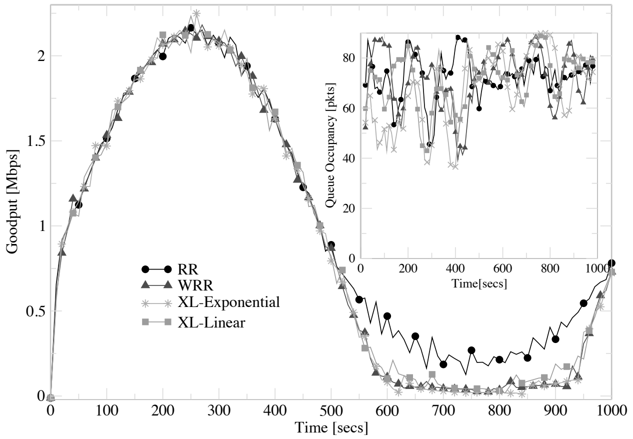

Fig. 6. BE Goodput performance results and queue occupancy (average) when using RR, static WRR, XL-lineal and XL-exponential algorithms

Summarizing, when the proposed IP scheduler is used, the bandwidth utilization is optimized because it is possible to know the available resources at each time by means of the proposed cross-layer optimization. In addition it is possible to maintain the QoS requirements for all the traffic classes while taking in tho account the bandwidth availability present in the satellite system. Finally, the proposed XL-exponential algorithm allows to enforce the QoS specifications when an extreme reduction of bandwidth because a heavy rain event is experienced.

## IV. RELATED WORKS

In order to calculate the optimal values to prioritize certain traffic classes, based on their QoS requirements, different criteria have been researched in the literature e.g. the mean packet size, queue sizes, revenue-based etc. In [6], a Variable WRR (VWRR) scheduler is proposed. This model uses the average packet length to adapt its weights. A weight value is calculated considering two parameters: the bandwidth requirements and the average length of packets. The problem of adjusting weights for the WRR scheduler guaranteeing the premium service has been analyzed in [7]. This work proposes a resource allocation model considering the average queue size, which is calculated using a low-pass filter. In [8], an adaptive scheduling scheme using the revenue-based WRR is presented. This proposal has been considered for guaranteeing the maximum service provider revenue. The proposed scheme, adjusts its weights using the revenue criteria to control the resource allocation. In [14], a modified Fair WRR (FWRR) scheduler has been proposed to protect the best effort traffic from the assured forwarding out-of- profile packets in the core routers based on the DiffServ architecture. This policy dynamically adjusts the weights and the buffer allocation using congestion hints to avoid unfair bandwidth sharing.

## V. CONCLUSIONS

We have presented an adaptive resource management algorithm based on a WRR scheduler. The proposed algorithm uses the link bandwidth variations present in the DVB-S2 forward link to determine the minimum amount of resources to prioritize different traffic classes.

The IP scheduler design is proposed inside the DVB-S2 Hub based on the DiffServ architecture. It includes a cross-layer optimization between the physical layer and the network layer to determine the bandwidth availability present in the satellite system.

To calculate the optimal weight values, we have applied two functions to associate the weights of the higher priority classes and the satellite link capacity: a linear and an exponential function. By employing the NS-2 simulator tool we have demonstrated that using our adaptive IP scheduler it is possible to ensure the QoS requirements for each traffic class and to optimize the bandwidth utilization when bandwidth fluctuations caused by rain events are faced.

The simulation results have shown that our exponential adaptive WRR model enforces the priority levels and guarantees the QoS parameters established in the SLA, while maintaining the queue occupancy at lower levels (compared to the RR and WRR mechanism), leading to a reduction of the system latency.

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## REFERENCES

[1] *ETSI ES 302 307*, ETSI Standard for 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). 2004.

[2] *ETSI TS 102 462*, ETSI Standard for Satellite Earth Stations and Systems (SES); Broadband Satellite Multimedia (BSM); QoS Functional Architecture. 2006.

[3] *IETF RFC 2475*, Standard for an Architecture for Differentiated Services, December 1998.

[4] S. Cioni, R.Gaudency, and R.Rinaldo.*Channel estimation a physical layer adaptation techniques for satellite networks exploiting adaptive coding and modulation*. International Journal of Satellite communication and networking, vol. 26 no. 2, 2008, pp. 157-188.

[5] H. Shimonishi and H. Suzuki, *Performance Analysis of Weighted Round Robin Cell Scheduling and Its Improvement in Atm Networks*, IEICE Transactions on Communications. vol. E81B, no. 5, 1998, pp. 910-918.

[6] Y. Ito, S. Tasaka and Y. Ishibashi, *Variably weighted round robin for core IP networks* Performance, computing and communication conference, 2002, pp. 159-166.

[7] H. Wang, C. Shen and S.K.G. *Adaptive-weighted packet scheduling for premium service* IEEE International Conference on Communications, vol. 6, 2001, pp. 1846-1850

[8] A. Sayenko, T. Hamalainen and P. Raatikainen *Adaptive scheduling using the revenue-based weighted round robin*. IEEE International Conference on Networks, 2004, pp.743-49.

[9] C. Dovrolis and P. Ramanathan, *A case for relative Differentiated Services and Proportional Differentiation Model*; IEEE Network Magazine, 1999, pp. 2634.

[10] P. Pieda, J. Ethridge, M. Bainess and F. Shallwani *A Network Simulator Differentiated Services Implementation*. Open IP Nortel Networks, 2000.

[11] *IETF RFC 3517*. IETF Standard for a Conservative Selective Acknowledgment (SACK)-based. Loss Recovery Algorithm for TCP, 2003.

[12] D.Wei and P. Cao, *A Linux TCP implementation for NS2*, available at the Internet, 2006.

[13] *ETSI EN 301 790* ETSI Standard for Digital Video Broadcasting (DVB); Interaction Channel for Satellite Distribution Systems; (DVB-RCS), 2005.

[14] S. Yi, X. Deng, G. Kesidis and C. R. Das *Providing fairness in DiffServ architecture*; IEEE Global Telecommunications Conference, vol. 2, 2002, pp. 1435-1439.

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