Enhanced Dynamic Resource Allocation for DVB-RCS: a Cross-Layer Operational Framework

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***Abstract*— This work deals with an enhanced Dynamic Bandwidth Allocation (DBA) scheme designed for satellite communication networks deployed under DVB-RCS.**

Our contribution defines a DVB-RCS standard-compliant operational framework that, unlike other approaches, fixes some structure in the general and combinatorial DBA problem. This results in reduced signalling, increased robustness to PHY-layer changes and reduced complexity of the subsequent allocation. Thereafter, the DBA problem is cast in a mathematical optimization problem and a fast algorithm to solve it is proposed. Moreover, the problem formulation guarantees maximum fairness among users and establishes a link to deal with QoS requirements at higher layers. This cross-layer solution is specially interesting when merging the satellite subnetwork with the Internet TCP/IP-based core network.

Results show significant increases in both bandwidth utilization and overall transferred data rate by using the proposed method. Computational time is decreased by a factor of two when compared to existing solutions. And finally, the advantageous interaction with QoS requirements at higher layers is shown with practical examples.

I. Introduction

The social and increasing interest in mobile multimedia communications of the last decades has now a significant impact also in the space segment. Systems traditionally devoted to broadcast services (such as satellite TV) have been redesigned to include multimedia unicast services (IP services). This is the case of DVB-RCS (Digital Video Broadcasting- Return Channel Satellite) standard [1] as the counterpart of the DVB-S/S2 standard [2]. The former complements the latter by enabling a return channel that makes interactivity a reality. The mapping between Medium Access Control (MAC) and IP layer has attracted much attention. This fact encourages the effort in research to provide better solutions to the potential end user. In this work we concentrate in the multiple-access part, which is a Demand-Assignment Multiple Access (DAMA) and belongs to the Bandwidth on Demand (BoD) class of multiple access techniques [3], where users request resources based on their needs.

Our work has two goals. First, we aim to provide simple and efficient mechanisms to allocate the users (depending on their requests) in the transmitted stream, which in this case is based on Multi-Frequency Time Division Multiple Access (MF-TDMA). Roughly speaking, users are placed in a two-dimensional (time and frequency) space. We desire to take into account also propagation conditions. From the point of view of RCS Terminals (RCSTs), this implies choosing one coding scheme among the available pool (each scheme implies a different coding rate) to best fit the channel. Second, we want to give continuity to QoS requirements defined at upper layers with our allocation mechanism, which is part of the MAC. The motivation here is to find the best possible integration of the sub-satellite network in a general IP environment. Note that our proposal is cross-layer because we take into account both QoS defined at higher layers and information available at the physical (PHY) layer (channel state).

The rest of the paper is organized as follows. Section II contains an overview of the standard. Section III deals about the proposed framework and related issues. Finally, section IV is devoted to simulation results and section V concludes the paper.

II. DVB-RCS Standard Overview: Multiple-Access

Consider a transparent satellite network as depicted in Figure 1. Consider also a Network Control Center (NCC), which is the entity attached to the ground gateway station with the following mission: collect the

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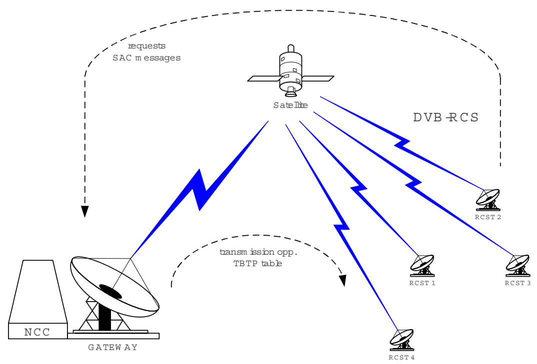

Fig. 1. System overview.

bandwidth demands of the RCSTs, run the Dynamic Bandwidth Allocation Algorithm (DBA) and send the resulting allocation back to the RCSTs. Terminals can emit their capacity requests in special time-slots or in data time-slots and the NCC collects the requests during each superframe (SF). However it is not mandatory to request bandwidth continuously. It is important to note here the challenging allocation problem: while the IP traffic is inherently connectionless, DAMA algorithms actually set up a connection over the DVB-RCS air interface, which is MF-TDMA. The MF-TDMA can be almost freely configured according to the standard. The highest level of division is constituted by the SF of duration T_{SF} seconds and each SF contains a number frames. The structure of the division of the frame in timeslots (TS) is signalled in the Frame Composition Table (FCT) and all the types of timeslots (i.e., different traffic TS, synchronization TS, etc.) are defined in the Timeslot Composition Table (TCT). Requests depend on the queued traffic at the MAC queues of each terminal and are sent basically using the standard-defined SAC (Satellite Access Control) messages.

The DVB-RCS standard defines three types of capacity request, from highest to lowest priority (we obviate the Free Capacity Assignment or FCA [4], which may be granted by the NCC, but not requested):

- Constant Rate Assignment (CRA): the RCST requires a constant rate all the time.
- Rate Based Dynamic Capacity (RBDC): a bandwidth request (in rate capacity) remains effective until it is updated or timed out. In contrast to CRA, RBDC strategy allows for statistical multiplexing among many RCSTs, resulting in a more efficient use of bandwidth.
- Volume Based Dynamic Capacity (VBDC): it requires for a certain amount of volume capacity to transmit information regardless the way it is done (no constant rate is needed).

The requests generated by all terminals in a beam during a SF constitute the inputs of the allocation problem. For each bandwidth allocation update, the NCC signals a Terminal Burst Time Plan (TBTP) to the RCSTs. It points out which timeslots in the MF-TDMA are assigned to each terminal. With that allocation, the terminal schedules the traffic stored in the MAC queues. It should be noted that the TBTP signals the shape and position of the timeslots in the MF-TDMA, which provides many degrees of freedom for the allocation.

III. Proposed Cross-Layer Framework

We decompose the multiple-access design into two parts, highly correlated, namely: i) structure imposed in the MF-TDMA and ii) the DBA procedure itself. Note that the performance in the latter depends on the decisions taken in the former. That is, a more structured DBA procedure (with less degrees of freedom) is expected to perform worst in terms of system occupancy. To illustrate the question, imagine that we impose no structure to the transmission and therefore each RCST is allowed to transmit with an arbitrary bandwidth and/or time duration timeslot. This would be in principle a good option. However, the organization of such a collection of TSs with different shape characteristics in the MF-TDMA may be difficult. Indeed, all the possible orderings should be checked and that search over a combinatorial number of possibilities turns the problem into NP-hard (not solvable in polynomial time). Instead, we consider a certain structure that we further optimize to maximize system performance. We achieve in this way a practical allocation process with reduced signalling and robustness to changing channel conditions.

In DVB-RCS, the allocation of resources is a reaction to the capacity requests of the RCSTs. As defined in the standard, the TBTP shall be updated and transmitted every SF, whereas bandwidth is allocated at a frame level. Let us assume the following SF configuration (although the standard allows other possibilities). Divide the SF into N_F frames sharing the whole bandwidth (BW_{TOT}). The time duration of the SF is T_{SF} (typically $265 ms$). Each frame contains several carrier types, that is, each one supports users transmitting through a carrier with a different bandwidth BW_i to accommodate different users accounting for different Service Level Agreements (SLAs), terminal equipment or location, so that an RCST uses only one type of carrier. Under these assumptions, the global allocation is decoupled into N_c independent sub-allocations (N_c standing for the number of carrier

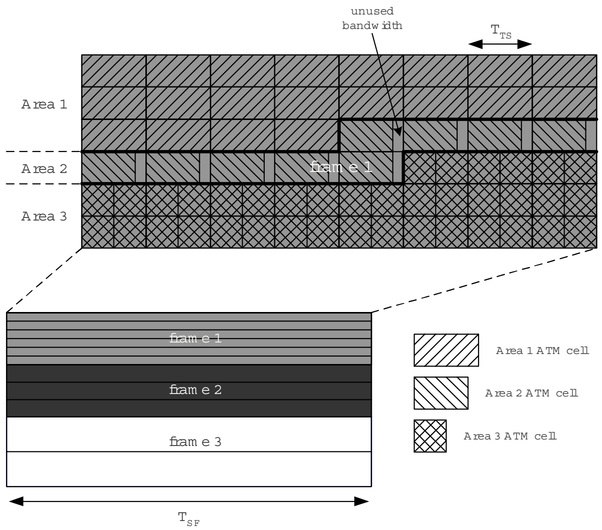

Fig. 2. Scheduling (bandwidth allocation) problem.

types or frames). See this in Figure 2 (bottom) where 3 different frames are depicted.

Thus the problem we consider consists in multiplexing N users into C carriers of BW_i bandwidth that transmit during T_{SF} seconds. See in Figure 2 (top) a possible allocation for frame 1. Without loss of performance and to facilitate upcoming issues, we group all RCSTs that transmit within the same carrier type (equivalently symbol rate) and the same coding rate (in the DVB-RCS, adaptive coding is envisaged to compensate the physical quality of the transmission, i.e. channel conditions). In the following, we refer to each of those groups as an area (interpreted as the earth surface zone where channel conditions are similar). We allocate MAC-layer units and in the rest of the paper we will consider ATM cells of 53 bytes. The method is valid for any MAC unit length.

Let us introduce now the key aspect of the proposed framework, which establishes the tradeoff choice between complexity and optimality: a common TS duration T_{TS} is fixed to all areas. In Figure 2 the idea is depicted with three areas. Due to the different coding rates, the transmission time of an ATM cell varies from area to area and so varies the percentage of the time during which the TS is used, i.e. the bandwidth efficiency per area. Note that it is possible to transmit more than one ATM cell per TS and more specifically, the standard allows 1, 2 or 4 ATM cells per TS. In this way, cross-layer information from the PHY layer is taken into account. To get cross-layer information from the upper layers, we propose to use the 4 bits available in the field *Channel_ID* available at SAC messages. Note that this field remains unused if the satellite is transparent. In this way, it is possible to distinguish different traffic types that request capacity using the same type of capacity request. For example, we can consider the QoS defined at IP-level in order to configure a satellite sub-network as transparent as possible at TCP level.

Further issues of the architecture are both a reduction in signalling and an increased robustness to RCSTs' PHY-layer changes. Regarding signalling, note that TSs with the same characteristics need to be defined only once (with repetitions) in FCT and TCT tables. Regarding robustness issues, note that in full-flexible solutions, the PHY-layer changes in the RCSTs require possibly a whole frame redesign in every superframe. This is not the case in our common TS approach.

IV. Cross-Layer Dynamic Bandwidth Allocation Algorithms

In this section we develop a practical algorithm [5] to compute the DBA in tens of milliseconds (which is small compared to the Round Trip Time or RTT). Furthermore, the solution is required to make the most efficient use of the available bandwidth and to maximize the system transported capacity at the same time that the fairness among users is maintained. Using known results in game-theory [6], an asymmetric fair distribution of P resources among N entities responds to the resolution of the following optimization problem, where the objective function is the product of the amount of resources allocated to each entity x_i. Entity is here a general concept, i.e. it can stand for user, RCST, connection or whatever.

$$\begin{aligned} \max_{x_1,\ldots,x_N} \quad & \prod_{i=1}^{N} x_i^{p_i} \\ s.t. \quad & \sum_{i=1}^{N} x_i \le P \\ & m_i \le x_i \le d_i \end{aligned} \qquad (1)$$

In the previous formulation, m_i is the amount of resources guaranteed to entity i and d_i stands for its demand. Finally, p_i is a weighting factor that represents the importance or priority of that entity (over the whole). It can be proved that the resolution of (1) with $p_1 = p_2 = \ldots = p_N$ achieves a proportional fair solution, which is a particular definition of fairness introduced by Kelly et al. [7]. It states that a feasible allocation $\boldsymbol{x}$ is proportionally fair if, for any other feasible allocation $\boldsymbol{x'}$, it holds that $\sum_{i=1}^{N} \frac{x'_i - x_i}{x_i} \le 0$. Otherwise (non-equal p_i's), it is asymmetric fair. We consider this formulation for DBA in the DVB-RCS, but other applicability examples include scheduling in the DVB-S2 or rate allocation in terrestrial links. Note that if $\sum_{i=1}^{N} x_i^{p_i}$ is considered as the objective function, the obtained solution can be interpreted under the perspective of opportunistic designs: the non-served entity with highest priority reaches its demand or gets all the remaining resources.

The problem in (1) can be easily converted to a convex optimization problem [8] introducing the logarithm in the objective function. The problem is then cast in the Network Utility Maximization (NUM) framework [9].

$$\begin{array}{cl} \max\limits_{x_1,\dots,x_N} & \sum_{i=1}^{N} p_i \cdot \log x_i \\ s.t. & \sum_{i=1}^{N} x_i \leq P \\ & m_i \leq x_i \leq d_i \end{array} \tag{2}$$

The utility function per user is, in this case, the logarithm of its allocation. In terms of "utility", the interpretation is that an extra resource is much more useful when the entity has a low number of resources. The resulting problem is analytically solvable using the Karush-Kuhn-Tucker (KKT) conditions [8], which imposes the solution

$$x_i = \left.\frac{p_i}{\lambda}\right]_{m_i}^{d_i} \triangleq \begin{cases} \frac{p_i}{\lambda}, & m_i \leq \frac{p_i}{\lambda} \leq d_i \\ m_i, & \frac{p_i}{\lambda} \leq m_i \\ d_i, & \frac{p_i}{\lambda} \geq d_i \end{cases} \tag{3}$$

where λ is a positive value such that $\sum_{i=1}^{N} x_i = P$. This value is usually obtained applying the bisection method [10]. However, as the number of entities grows, the method may require excessive computation time. The faster the allocation is computed, the higher is the number of users the system can manage.

A. Practical DBA Algorithm

A slight modification of the optimization problem in (1) allows us to model the DVB-RCS situation when the TS duration is fixed.

$$\begin{array}{cl} \max\limits_{\{x_{i,j}\}} & \prod_{i,j} (x_{i,j} \cdot K_i)^{p_{i,j}} \\ s.t. & \sum_{i,j} x_{i,j} \leq P \\ & \lceil \frac{m_{i,j}}{K_i} \rceil \leq x_{i,j} \leq \lceil \frac{d_{i,j}}{K_i} \rceil \end{array} \tag{4}$$

Now P is the total number of timeslots in the frame, $x_{i,j}$ stands for the amount of timeslots assigned to RCST i with request j and $p_{i,j}$ defines the priority of RCST i with request j. Similarly, $d_{i,j}$ and $m_{i,j}$ stand for demands and minimum guaranteed resources (in number of ATM cells). Finally, K_i establishes the number of ATM cells that RCST i transmits in a timeslot (this quantity depends on the time duration of ATM cells and thus on the RCSTs' coding rates) and $\lceil(\cdot)\rceil$ indicates the ceil function.

Note that we propose to solve a real-valued version of the true problem, i.e. without restricting $x_{i,j}$ to be integer. The final solution can then be obtained by simple down-rounding and redistribution of the remaining resources to users with highest $p_{i,j}$. Few degradation is expected as the number of ATM cells managed by a RCST is assumed to be high. However, other strategies can be adopted, such as variable threshold rounding [11].

We have developed a novel algorithm to efficiently solve problems such as the one in (4). For the sake of brevity, we omit here the details of the algorithm and we refer the interested reader to the authors' work in [12]. It is an efficient method that computes the allocation faster than the bisection method. In the next section, we support this with simulation results.

B. Cross-Layer Timeslot Optimization: Joint DBA and Frame Design

A common timeslot design of the frame provides both a simple frame structure and a simple application of efficient DBA algorithms. Still, a proper choice of T_{TS} is required to maximize system performance.

Let us include this new variable in the previous formulation by explicitly writing the dependencies on T_{TS}, which are $K(T_{TS}, t_{a(i)}) = \lfloor \frac{T_{TS}}{t_{a(i)}} \rfloor$ and $P(C, T_F, T_{TS}) = C \cdot \lfloor \frac{T_F}{T_{TS}} \rfloor$. Now, C is the number of carriers, T_F the frame duration and $t_{a(i)}$ is the time duration of an ATM cell transmitted by the i^{th} RCST, where $a(i)$ denotes the area (equivalently coding rate) of RCST i. The problem can be written in this way as

$$\begin{array}{cl} \max\limits_{T_{TS},\{x_{i,j}\}} & \prod_{i,j} \left(x_{i,j} \cdot \lfloor \frac{T_{TS}}{t_{a(i)}} \rfloor \right)^{p_{i,j}} \\ s.t. & \sum_{i,j} x_{i,j} \leq C \cdot \lfloor \frac{T_F}{T_{TS}} \rfloor \\ & \lceil \frac{m_{i,j}}{\lfloor \frac{T_{TS}}{t_{a(i)}} \rfloor} \rceil \leq x_{i,j} \leq \lceil \frac{d_{i,j}}{\lfloor \frac{T_{TS}}{t_{a(i)}} \rfloor} \rceil \\ & T_{min} \leq T_{TS} \leq T_{max} \end{array} \tag{5}$$

Clearly, the floor function ($\lfloor \cdot \rfloor$) converts this joint problem in T_{TS} and $\{x_{i,j}\}$ into non-convex. However, it is convex when solved for a fixed value of T_{TS}. The timeslot duration is a continuous variable in the range $[T_{min}, T_{max}]$, but not all the values are meaningful in our specific problem. Note this in the following lemma.

Lemma 1: Starting from a feasible value of T_{TS} and increasing it, it can only reduce the objective value unless a multiple of some of the $t_{a(i)}$'s is reached.

Proof: Start with $T_{TS} = T_{min}$ and increase T_{TS}. Stop when a multiple of any of the $t_{a(i)}$'s is reached. Call this value T^1_{mult}. Then, it is clear that K_i's do not change their value if $T_{TS} \in [T_{min}, T^1_{mult})$ but

TABLE I

RCSTs DEFINITION.

Area identifier	RCST	ATM cells per TS	Requests	Minimums	Priorities
1	1-2	1	$[15, 16]$	$[2, 0]$	$[1.75, 1.25]$
2	3-6	1	$[9, 19, 14, 5]$	$[0, 1, 2, 0]$	$[1.5, 2, 1.25, 1.75]$
3	7-13	2	$[17, 13, 4, 5, 13, 13, 8]$	$[1, 2, 2, 2, 0, 1, 1]$	$[1.75, 2, 1.5, 2, 1.25, 1.5, 1.25]$
4	14-20	2	$[12, 10, 2, 2, 7, 1, 8]$	$[1, 0, 2, 2, 2, 1, 2]$	$[1.5, 1.5, 1.75, 1.75, 2, 1.25, 1]$
5	21-24	2	$[14, 3, 2, 13]$	$[0, 1, 2, 3]$	$[1.5, 2, 1, 1.75]$

$P(T^1_{mult}) \leq P(T_{min})$. Therefore, the optimal solution of the global problem can not improve until (possibly) T^1_{mult} is reached. The same reasoning is also valid in $T_{TS} \in [T^1_{mult}, T^2_{mult})$ (where T^2_{mult} is the next multiple of any of the $t_{a(i)}$'s) and so on. And thus, it holds for the whole range, $T_{TS} \in [T_{min}, T_{max}]$. ■

In the DVB-RCS, we assume few areas and thus few different values of $t_{a(i)}$. Then the list of T^k_{mult} is small and (5) can be efficiently solved via exhaustive (small) search in T_{TS} and the usual procedure for obtaining $\{x_{i,j}\}$ (from Section IV-A). However, it is not necessary to get the optimal value of T_{TS} at each superframe, because: i) T_{TS} depends on slow time-varying area features (an area is an aggregation of many RCSTs and evolves as a mean process) and ii) the optimal T_{TS} is not very sensitive to slight variations in the requests.

V. Simulation Results

We divide this section into two subsections. In the first one, we describe an small scenario, we compute the allocation and we discuss about it. Then, another scenario is used to measure the overall system performance of the proposed framework.

A. Allocation Example

For the sake of clarity, assume a small system with 24 RCSTs sharing 100 TS. Results here exposed can be extrapolated to larger population and more resources. The scenario is summarized in Table I, defining each RCST with: i) assigned area; ii) the number of ATM cells per timeslot; iii) the RCSTs' demands; iv) the RCSTs' minimum guaranteed resources and v) the priority of each demand. Each RCST makes only one transmission request. Assume also the following mapping between priorities and services (different QoS levels): 2 for Voice over IP (VoIP), 1.75 for video streaming, 1.5 for telnet and gaming, 1.25 for web browsing and 1 for FTP or SMTP services. Note that services can be requested under the same request type but distinguished thanks to different priority values. We can also use these values to prioritize some RCSTs in front of others, which has not been considered here.

TABLE II

AREAS DEFINITION.

Area identifier	Coding rate	ATM cell duration
1	$r_1 = 1/2$	$t_1 = 1.06ms$
2	$r_2 = 2/3$	$t_2 = 0.795ms$
3	$r_3 = 3/4$	$t_3 = 0.707ms$
4	$r_4 = 5/6$	$t_4 = 0.636ms$
5	$r_5 = 7/8$	$t_5 = 0.606ms$

We plot the result in Figure 3. In black tone, the final allocation (in excess of the minimum); in pale gray tone, the minimum guaranteed resources (always assigned) and in dark grey tone, the demands. Note that RCSTs with higher priority are allocated a higher number of resources than RCSTs with lower priority, even when the request type is the same (for example: telnet, gaming, web browsing, FTP and SMTP are all requested using the same request type, VBDC). This issue is captured by the dotted horizontal lines in the figure. Compare RCSTs 12 and 11; the former receives a larger allocation thanks to its larger priority despite both request the same amount of resources. RCST 12 corresponds to streaming video whereas RCST 11 to web browsing.

B. Overall System Performance

Assume a SF duration of 26.5ms and consider the sub-allocation problem in 111 carriers of 540kHz spanning 60MHz in total. The PHY layer uses adaptive coding with five possible coding rates, as in the DVB-RCS standard using convolutional coding. See in Table II a description of the areas: coding rate and time duration

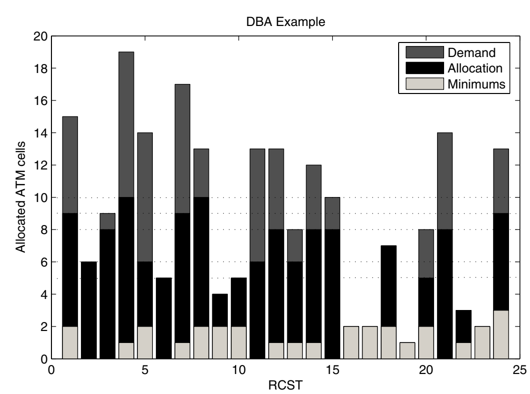

Fig. 3. Joint DBA example.

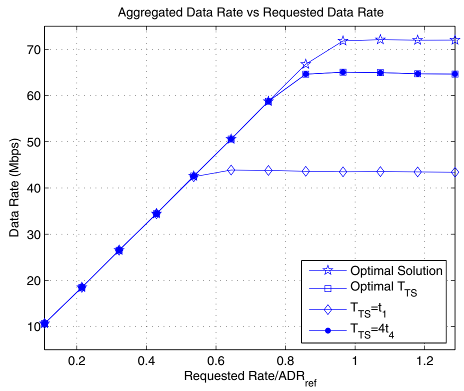

Fig. 4. Aggregated Data Rate (good conditions).

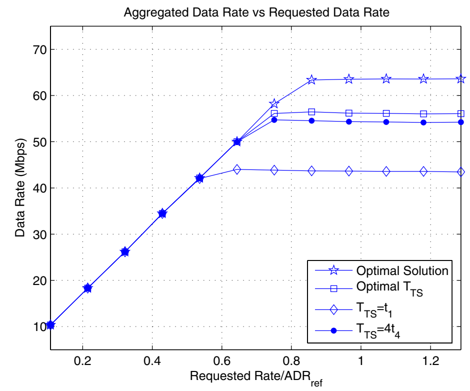

Fig. 5. Aggregated Data Rate (bad conditions).

of an ATM cell in the area. Quadrature Phase Shift Keying (QPSK) modulation using a raised cosine pulse with a roll-off factor of 0.35 is assumed. Furthermore, we limit the timeslot duration between $T_{min} = t_1$ and $T_{max} = 3t_1$.

Define $\boldsymbol{v}$ as the vector that contains, in its k^{th} component, the mean number of terminals in area k. An stochastic realization of that number is computed as $\mathcal{V}_k = \mathcal{U}[0, 2 \cdot v_k]$, where $\mathcal{U}[a, b]$ defines the integer uniform probability density function (pdf) ranging between a and b. For each realization of $\boldsymbol{\mathcal{V}}$, we compute the number of ATM cells requested by the i^{th} RCST, d_i, as $d_i \sim \mathcal{U}[0, 2\frac{D_{tot}}{\mathbf{1}^T \boldsymbol{v}}]$, where D_{tot} is the mean load offered to the system in number of ATM cells. In this way, all terminals request in mean the same, but their distribution among areas changes ($\mathbf{1}^T \boldsymbol{v}$ is the number of RCSTs). Note that the maximum achievable rate is obtained when the full SF is fulfilled with ATM cells of the highest rate (4662 in this case), which gives 74.59Mbps of data rate. Take this value as a reference for the Aggregated Date Rate (ADR) transmitted by the system or ADR_{ref}. We run Monte Carlo simulations with D_{tot} ranging from 500 to 6000 ATM cells (steps of 500 cells). We further assume equal priorities among RCSTs and that they have no minimum requirements.

In Figure 4 we plot the ADR in the system using either the proposed technique or the optimum allocation. Note that the latter requires an exhaustive search over a combinatorial number of possibilities to allocate the TSs (in this case equivalent to ATM cells). We compute it using a random subset of all ordering possibilities (we choose an adequate number of different random orderings), which should be very near to the optimum. More precisely, 50 random orderings are used and we always observe that few or no gains are reported by the last trials, which assures to fairly approximate the real optimum. The proposed technique is computed with three choices of TS duration: i) the optimal TS; ii) $T_{TS} = t_1$, the minimum feasible value, and iii) $T_{TS} = 4t_4$, which is a value that suits the current load and user distribution ($\boldsymbol{v} = [5, 10, 10, 30, 45]$). We assume that users are in rather good propagation conditions (which is realistic). Note that the TS optimization reports significant performance gains (compared to the initial design with $T_{TS} = t_1$). Note that performance is not very sensitive to the T_{TS} election, which is a desirable robustness feature in practical systems. In the figure, nearly the same results are obtained with the optimal T_{TS} value and a well-fitted one ($T_{TS} = 4t_4$). If a significant number of users is affected by a rain event and the user distribution changes to $\boldsymbol{v} = [20, 20, 20, 20, 20]$, we obtain the results in Figure 5. The robust behavior is confirmed with a slight decrease of system performance when T_{TS} is kept to $T_{TS} = 4t_4$, which is no longer the best value.

Figure 6 shows the signalling rate that must be sent to signal the scenario with good propagation conditions using both approaches, the optimal allocation and the proposed scheme. The figure reflects the amount of information required to signal the Frame Composition Table (FCT) [1], which basically indicates the position of each TS in the frame. In the optimal case, we need to signal the position of every TS and the FCT transmits $(174 + N_{TS} \cdot 72)$ bits in the frame duration (26.5ms), where N_{TS} is the number of allocated TSs. With our scheme, it is only necessary to signal the TS at the beginning of each carrier and indicate the number of repetitions in the carrier. The number of bits to be sent is $(174 + C_u \cdot 72)$ bits, where C_u is the number of carriers used in the frame. Results in Figure 6 show the advantage of an structured design, as signalling can be kept small. Otherwise, potential gains in data rate may be lost due to signalling. For example, at full system load an additional rate of 8Mbps can be sent using the optimal solution (see Figure 4) at the expenses of an increase of

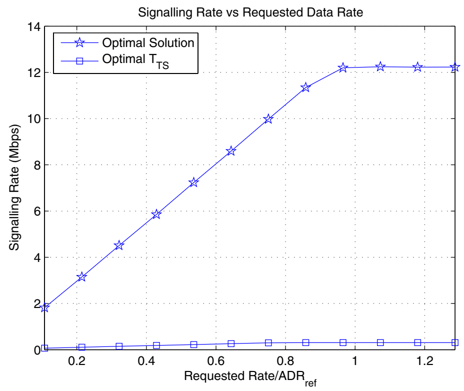

Fig. 6. Signalling Rate (good conditions).

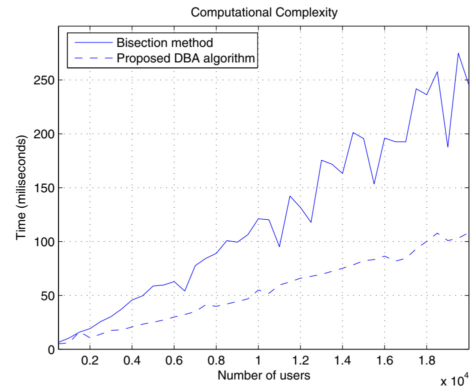

Fig. 7. Computational time (proposed DBA and bisection method).

around 12Mbps in signalling rate. Moreover, our design facilitates the computation of a fair and time-efficient solution. The latter is next discussed.

We compute both our DBA algorithm and the bisection method applied to (4) in a Pentium®-Mobile processor running at 1.73GHz. The inputs of the algorithm are discrete (integer) uniform random variables with different thresholds: i) $d_i \sim \mathcal{U}[1, 20]$; ii) $m_i \sim \mathcal{U}[0, 3]$ and iii) $K_i \sim \mathcal{U}[1, 2]$. Priorities are also discrete, $p_i \sim \mathcal{U}[1, 2]$, but with a step of 0.25 (i.e. $p_i \in \{1, 1.25, 1.5, 1.75, 2\}$). See in Figure 7 the computational time of both algorithms as the number of RCSTs grows. Note that the global DBA algorithm solves the allocation in approximately half the time the bisection method requires. In the DVB-RCS, within the 100ms available time, the bisection method can manage 8500 users while 18000 can be managed with our method.

VI. Conclusions

We have contributed in this paper with an optimized framework for DVB-RCS along with a fair and time-efficient DBA algorithm that takes into account cross-layer information both from the lower layer (PHY layer) and the upper layers (IP/APP-layers in our example).

Unlike other approaches, our contribution fixes some structure, the timeslot, common to all areas. This results in reduced signalling, increased robustness to PHY-layer changes, reduced complexity of the subsequent resource allocation and an easy integration of fairness issues. Then, depending on the spectral efficiency of the RCSTs within a given area, one or more ATM cells are transmitted. Results show that a good overall system performance is achieved with timeslot optimization and that the MAC cross-layer design enabled by an adaptive PHY layer reports significant gains.

Finally, the use of priorities at MAC-layer gives continuity to the QoS requirements defined at upper layers, such as IP-layer or APP-layer. Priorities can be explicitly signalled to the NCC or alternatively, the NCC can extract this information from the traffic.

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