CONNECTION ADMISSION CONTROL ISSUES IN DVB-RCS SYSTEMS

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INTRODUCTION

In the last few years the research in telecommunications has been oriented towards the development of a global system capable of offering to the users access to a wide range of broadband services. In such a scenario, satellites will play a main role \cite{1} mainly thanks to their wide geographical coverage and broadband capability.

The way to conceive the use of satellite systems has recently made many steps forward. The first low-interactivity satellite systems for the simple broadcast of information are being substituted by more interactive satellites, which enable the single user to directly use satellite links to communicate. Specifically, the digital transmission standard of DVB-RCS (Digital Video Broadcasting – Return Channel via Satellite) \cite{2-4} has realized the dream of a bi-directional communication over satellite links, by designing a return channel via satellite. Obviously, in order to obtain an efficient usage of the satellite return channel, to design appropriate channel management policies is a must, thus reducing the resources waste and maximizing the number of users who can contemporary access the channel.

Referring to the SkyplexNet/HotBird6 (HB6) satellite system \cite{5-6}, the main objective of our work is to implement an efficient Connection Admission Control (CAC) policy that draws advantages from the dynamic allocation of the satellite bandwidth, trying to avoid any resource waste during the periods of inactivity or rate reduction of some traffic sources.

The remaining part of the paper is organized as follows. At first, we briefly summarize the features of the DVB-RCS standard and describe the reference satellite system of SkyplexNet, highlighting the traffic characterization and the Medium Access Control (MAC) policy. Then we introduce our proposed CAC algorithm, and finally we show some simulation assessment results demonstrating the effectiveness of our proposal.

THE DVB-RCS STANDARD AND THE SKYPELEXNET SYSTEM

Demand for interactivity can be found in all telecommunication systems. The user wishes to be an actor in the communications scenario and he/she is not satisfied to receive passively data on his/her terminal. This justifies the recent birth and diffusion of applications such as pay-per-view, home shopping, and e-commerce. In such cases, the user is asked to use a low-data-rate return channel to interact with the system. On the other hand, the increasing request of bi-directional multimedia communications ask the networks for supporting high and variable data rate applications. Therefore, the use of satellite systems to deploy broadband infrastructures that offer wide coverage and user interactivity is as more convenient as larger is the number of users to be served.

The need to design the characteristics of a return channel via satellite made the DVB-Technical Module to form a research team, called DVB-RCS, with the main aim to formulate the system detailed requirements and submit them to the attention of normative administration. These detailed lists, completed on March 2000, have been formally adopted by the European Telecommunications Standards Institute (ETSI), which has added the DVB-RCS standard to the other DVB ones. The new standard introduces an interactive network within a DVB system, in order to enable the information broadcasting-multicasting and to achieve broadband bi-directional communications.

The DVB-RCS system design has faced some issues of an interactive network architecture (MAC technique, resource allocation strategies, channel modulation), leaving to the network administrators the freedom concerning other design aspects, such as the traffic management.

Two are the main entities of a DVB-RCS architecture:

- RCST (Return Channel via Satellite Terminal), that is the bi-directional terminal capable both to receive and transmit via satellite;
- NCC (Network Control Centre) that represents the control centre of the whole satellite network, which includes some RCST terminals, one or more satellites, some content providers and the gateways for the interfacing with different networks.

In order to allow the management of a high number of RCST terminals, the DVB-RCS standard foresees the usage of the Multi-Frequency Time Division Multiple Access (MF-TDMA) as multiple access scheme on the return channel. MF-TDMA permits the RCSTs to communicate one another and with the gateways using a set of carriers divided into
time slots. NCC reserves to terminals a certain amount of resources in terms of frequency, bandwidth, start transmission
time and duration time.

Our reference satellite system is the SkyplexNet platform [5-6] of Alenia Spazio. Although SkyplexNet has been
designed for the television broadcasting, the capability of the MPEG2 protocol to efficiently convey IP packets allows
the system to face the growing requests of multimedia interactive services provided both in Ka and Ku bands.

The SkyplexNet architecture includes some fundamental elements:

- Network Operation Centre (NOC),
- Gateway,
- End User Terminal SaT-A,
- End User Terminal SaT-B,
- Provider Terminal PrT-A,
- Provider Terminal PrT-B.

Fig. 1 shows the reference scenario. NOC has the same functions of NCC in the DVB-RCS architecture. It must be
noted the presence of two different user terminal classes: SaT-A terminals have a data rate up to 2.112 Mbps, while
SaT-B terminals have a data rate of 6.336 Mbps. Both can be mono- or bi-directional. In the same way, the provider
terminals (PrT-A and PrT-B) have capacities equal to a multiple of the SaT terminals (that is N*2.212 or N*6.336
Mbps). For the TDMA multiple access channel, SkyplexNet allows to choose between two different lengths for the uplink
frame: 48 or 256 MPEG2 Transport Streams (TS) packets. Hereinafter we will refer to the frame formed by 256
MPEG2 TS packets with a duration time of 0.06 seconds.

Fig. 1. The SkyplexNet Reference Scenario

The traffic that is expected to be delivered over the SkyplexNet system can be classified in three main categories:
Constant Bandwidth Allocation (CBA), Dynamic Bandwidth Allocation (DBA), and Best Effort Allocation (BEA).
CBA traffic (consisting of MPEG2 real time traffic) is generated by applications with very tight constraints in terms of
delay and packet loss ratio (PLR). DBA traffic has relatively stringent delay and PLR constraints. The CBA class
includes applications that generate constant bit rate or variable bit rate traffic, and have a constant amount of bandwidth
assigned for the entire connection duration. On the contrary, the DBA class is assigned resources based on dynamic
bandwidth allocation through Capacity Request messages sent by the terminal to NOC frame-by-frame. Finally, the
BEA traffic is satisfied with “volume-based” allocation when the bandwidth resources are available. This type of traffic
has no requirements in terms of delay or loss.

Table 1 shows the traffic profile classes [6] in terms of Quality of Service (QoS) parameters. In particular, Maximum
Packet transfer delay (MPTD), jitter (JtPDV) and packet loss ratio (PLR) are considered. Table 2 [6] shows the
mapping between traffic classes and profiles.

In [7] we proposed and analysed a MAC protocol that foresees a differentiated treatment for the three service
categories. To the CBA connections, resources are allocated in a permanent way for the duration of the calls. Instead, to
both DBA and BEA connections, the resources are dynamically allocated after sending a request message to NOC.
Obviously, the DBA connections have higher priority than the BEA ones have. In fact, the BEA connections do have
neither delay nor packet loss bounds guaranteed. Moreover, in order to better satisfy QoS requirements, each CBA connection is allocated a capacity equal to its peak data rate, even in the case in which it has a variable bit rate nature and generates bursty traffic. To reduce the bandwidth waste and improve the MAC efficiency, our MAC algorithm aims at “reusing” the amount of bandwidth that is temporary unused by CBA sources to advantage the DBA and BEA traffic categories. Further details can be found in [7]. This solution is without any doubt beneficial, but it is partial. In fact, to allow full exploitation of the unused bandwidth, the MAC algorithm should be harmonized with an appropriate CAC. Therefore, in this paper we propose a two-step CAC policy, which extends a CAC algorithm proposed for ATM networks [8] to the satellite system, in order to introduce at the satellite terminal a sort of statistical multiplexing of the CBA sources with variable bit rate (VBR) nature. As for the CBA sources with constant bit rate (CBR) nature, their admission is decided based on the required peak data rate.

<table>
<thead>
<tr>
<th>Profile Class</th>
<th>MPTD (One Way)</th>
<th>PiPDV</th>
<th>PLR</th>
<th>Application example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>highly sensitive (some hundreds ms)</td>
<td>highly sensitive (some tens ms)</td>
<td>Loosely sensitive ($\leq 10^{-3}$)</td>
<td>Voice-based</td>
</tr>
<tr>
<td>2</td>
<td>sensitive (less than 1 s)</td>
<td>highly sensitive (some tens ms)</td>
<td>Sensitive ($\leq 10^{-4}$)</td>
<td>Real time TV-cast, Interactive TV</td>
</tr>
<tr>
<td>3</td>
<td>highly sensitive (some hundreds ms)</td>
<td>not sensitive (no upper bound)</td>
<td>highly sensitive ($\leq 10^{-6}$)</td>
<td>SkyplexNet/HBB Connection Control Signalling</td>
</tr>
<tr>
<td>4</td>
<td>loosely sensitive (1 s)</td>
<td>not sensitive (no upper bound)</td>
<td>sensitive ($\leq 10^{-4}$)</td>
<td>Web Browsing, Interactive Games</td>
</tr>
<tr>
<td>5</td>
<td>loosely sensitive (some sec)</td>
<td>not sensitive (no upper bound)</td>
<td>highly sensitive ($\leq 10^{-6}$)</td>
<td>File transfer</td>
</tr>
<tr>
<td>6</td>
<td>not sensitive (no upper bound)</td>
<td>not sensitive (no upper bound)</td>
<td>not sensitive (no upper bound)</td>
<td>e-mail, Fax</td>
</tr>
</tbody>
</table>

Table 2. Class Mappings

<table>
<thead>
<tr>
<th>Transfer Capability Class</th>
<th>Profile Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>CBA</td>
<td>X</td>
</tr>
<tr>
<td>DBA</td>
<td>X</td>
</tr>
<tr>
<td>BEA</td>
<td></td>
</tr>
</tbody>
</table>

CONNECTION ADMISSION CONTROL ISSUES

As we argued above, an efficient admission and management policy of satellite connections is important in order to guarantee appropriate QoS levels to all users. This is even more true when admitting high-priority connections, such as CBA ones. Concerning this, we have to consider that, allocating the peak data rate (PDR) for CBA connections means wasting a large amount of bandwidth even adopting the MAC policy we mentioned above. So, we propose a CAC algorithm which exploits the concept of “effective bandwidth”, allowing both increasing admission probability of VBR-CBA connections and guaranteeing low packet losses to DBA connections.

Due to the peculiarity of the DVB-RCS system architecture, the CAC control will be “distributed” on two main entities: the user terminal and the NOC.

The first CAC phase consists in the admission decision performed at the user terminal, which is labelled as CAC_T in Fig. 2. In fact, a RCST terminal allows several users to share the same uplink station in order to access the satellite transponder. Each terminal has an uplink data rate of 2.112 Mbps (SaT-A) or 6.336 Mbps (SaT-B), which is shared among several applications of different users. As mentioned above, we suggest the use of a statistical CAC in the terminal, based on the concept of effective bandwidth.

Once a terminal accepts a new connection, the admission control has to be performed at NOC, which is labelled as CAC_N in Fig. 2. This needs messages to be sent out-of-band from SaT to NOC. NOC has the knowledge of the bandwidth requested by all terminals as a result of the CAC_T phase, and is able to definitely decide the admission according to the available bandwidth up to the satellite.
The BEA traffic does not pass any CAC phase; it is allowed to exploit the available bandwidth when it is possible on a demand basis. As for the DBA sources, their admission is decided according to the sustainable data rate (SDR) requirements. CBA connections are managed according to their traffic nature; if the traffic is CBR the source is managed according to the peak data rate, if it is VBR the effective bandwidth is computed and the admission is decided according to the algorithm detailed in the following.

**CAC for VBR-CBA Connections**

We analyse the admission procedure for the *real-time* CBA connections with VBR nature (hereinafter CBA*VBR_RT*). Let N be the number of currently active CBA*VBR_RT* connections, we define \( \text{Tot\_Eb} \) as the sum of the effective bandwidth (EB) of all the N connections plus the EB of the new CBA*VBR_RT* connection asking to be admitted:

\[
\text{Tot\_Eb} = \sum_{i=1}^{N+1} \text{EB}_i
\]

We also define \( \text{Tot\_PR} \) as the sum of the Peak Data Rate (PDR) of these N+1 CBA*VBR_RT* connections:

\[
\text{Tot\_PR} = \sum_{i=1}^{N+1} \text{PDR}_i
\]

Given a new CBA connection asking to be admitted, we define two different amounts of bandwidth required by all CBA connections:

\[
\text{Min\_Req} = \text{CBR\_Bw} + \text{Tot\_Eb}
\]

\[
\text{Max\_Req} = \text{CBR\_Bw} + \text{Tot\_PR}
\]

where \( \text{CBR\_Bw} \) is the amount of bandwidth already allocated to active constant bit rate CBA connections. Equation (3) represents the minimum bandwidth occupation of the CBA class if all CBA*VBR_RT* connections are allocated the effective bandwidth. Equation (4) represents the maximum bandwidth occupation of the CBA class if all CBA*VBR_RT* connections are allocated the peak bandwidth.

This means that if it is possible the terminal tries to assign the PDR to the CBA sources, otherwise if the available resources are less than the Max\_Req it reduces the assigned bandwidth down to the EB.

Let C be the available bandwidth to a terminal. If:

\[
C < \text{Min\_Req}
\]

then the satellite terminal cannot accept the new connection because it is able to guarantee neither the equivalent bandwidth. On the contrary, if:

\[
C > \text{Max\_Req}
\]

then the bandwidth allocated to all CBA*VBR_RT* connections will be:

\[
\text{VBR\_Bw} = \text{Tot\_PR}
\]

On the other hand, if C is larger than Min\_Req but smaller than Max\_Req, the bandwidth reserved for all the CBA*VBR_RT* connections will be:

\[
\text{VBR\_Bw} = C
\]
When a CBA connection is terminated, the system status must be updated. If the terminated connection is CBA_CBR and had a bandwidth assigned equal to \( PDR \), then the update is very simple:

\[
CRB\_Bw = CBR\_Bw - PDR
\]  
(9)

If the terminated connection is CBA_VBR_RT, then the update is similar to that executed during the admission phase. The number of active connections is decremented by one (\( N = N - 1 \)), and the available bandwidth \( C \) at the terminal is compared to \( \text{Max\_Req\_Bw} \) (the remaining peak data rate connections sum), if:

\[
C > \text{Max\_Req\_Bw}
\]  
(10)

then the amount of bandwidth allocated to the CBA_VBR_RT traffic is:

\[
VBR\_Bw = \text{Tot\_Pr}
\]  
(11)

where \( \text{Tot\_Pr} \) is the updated value not including the peak data rate of the terminated connection. Otherwise if (10) is not satisfied, then:

\[
VBR\_Bw = C
\]  
(12)

The Effective Bandwidth (EB)

The EB calculation used by the CAC algorithm comes from [9]. Referring to MPEG sources, we can affirm that, given \( N \) sources and a fixed GOP (Group of Pictures) pattern (e.g., IBBBPBBPBBPBB), it is statistically unlikely that they contemporary transmit at their highest data rate. In [9] it has been demonstrated that, given \( N \) sources, each one having a lag of a finite and integer number of MPEG frames (referring to the GOP pattern) respect to the other ones, the equivalent bandwidth of the \( N \) sources is equal to:

\[
\sum_{i=1}^{N} EB_i = \sum_{S_I} I_{\text{max}} (j) + \sum_{S_P} P_{\text{max}} (j) + \sum_{S_B} B_{\text{max}} (j)
\]  
(13)

In this formula \( I_{\text{max}}, B_{\text{max}} \) and \( P_{\text{max}} \) represent, respectively, the maximum production bit rate of I, B, and P MPEG frames. The sets \( S_I, S_P, S_B \) appearing in the summations represent a subset of sources that transmit contemporary a given type of frame (I, P or B, respectively). The sets \( S_i \) are pairwise mutually disjoint sets such as their union give all the sources.

Giving that:

\[
I_{\text{max}}(i) > P_{\text{max}}(i) > B_{\text{max}}(i)
\]  
(14)

for every \( i \), it is easy to see that [9]:

\[
\sum_{i=1}^{N} EB_i < \sum I_{\text{max}} (i)
\]  
(15)

for every lag values. There is a simple case when all the sources start to transmit simultaneously, that is the lag is zero for each source, in such conditions we have:

\[
\sum_{i=1}^{N} EB_i = \sum I_{\text{max}} (i)
\]  
(16)

it coincides with the PDR allocation being the I frame larger than the other ones.

SIMULATION ASSESSMENT

In order to assess performances of the suggested CAC algorithm, a comprehensive simulation campaign has been conducted. The main simulation parameters are listed in Table 3.

<table>
<thead>
<tr>
<th>Table 3. Simulation parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Return Link Capacity</td>
</tr>
<tr>
<td>Terminal Capacity</td>
</tr>
<tr>
<td>Frame Duration</td>
</tr>
<tr>
<td>Time Slot per Frame</td>
</tr>
<tr>
<td>Time Slot Capacity</td>
</tr>
<tr>
<td>Round Trip Time</td>
</tr>
<tr>
<td>Access Scheme</td>
</tr>
</tbody>
</table>
The return channel is shared among six RCSTs, each with a capacity of 6,336 Mbps. We have chosen such a number in order to load the system and test it in high load conditions. The typologies of connections managed by RCSTs are reported in Table 4.

### Table 4. Traffic Source Typologies

<table>
<thead>
<tr>
<th>Connection Type</th>
<th>Service Class</th>
<th>Return Channel occupancy</th>
<th>Mean Connection Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phone</td>
<td>CBA</td>
<td>64 kb/sec</td>
<td>300 sec</td>
</tr>
<tr>
<td>Video Phone</td>
<td>CBA</td>
<td>384 kb/sec</td>
<td>300 sec</td>
</tr>
<tr>
<td>Video Broadcasting CBA_VBR_RT</td>
<td>Max 2048 kb/sec</td>
<td>3000 sec</td>
<td></td>
</tr>
<tr>
<td>File Transfer</td>
<td>DBA</td>
<td>Max 1024 kb/sec</td>
<td>900 sec</td>
</tr>
<tr>
<td>Web Browsing</td>
<td>BEA</td>
<td>256 kb/sec</td>
<td>500 sec</td>
</tr>
</tbody>
</table>

The CBA_VBR_RT traffic features, obtained through MPEG-2 VBR type compression techniques on some video sequences taken out from several movies, are referred in [10] and not reported here for length constrains. The achieved results refer to two simulative scenarios in which the traffic percentage typologies change (see Table 5).

### Table 5. Simulation scenarios

<table>
<thead>
<tr>
<th>Scenario</th>
<th>CBA</th>
<th>CBA_VBR_RT</th>
<th>DBA</th>
<th>BEA</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20%</td>
<td>25%</td>
<td>25%</td>
<td>30%</td>
</tr>
<tr>
<td>2</td>
<td>20%</td>
<td>40%</td>
<td>40%</td>
<td>0%</td>
</tr>
</tbody>
</table>

Performance is measured in terms of (i) blocking probability, that represents the probability to reject a new connection asking to be admitted into the system; (ii) bandwidth utilization, computed as the fraction of used bandwidth over the reserved one; (iii) packet loss ratio, representing the fraction of lost packet.

All the curves are for CBA_VBR_RT connections and are reported as a function of the generation rate of new connections in the system. Curves labelled as “Peak” refer to the case of PDR allocation to all CBA sources, curves labelled as “Eb” refer to the effective bandwidth allocation for CBA_VBR_RT connections.

Figures 3 and 4 show the blocking probability of CBA_VBR_RT connections in scenario 1 and 2, respectively. It must be noted that adopting the proposed CAC algorithm leads to a sensible decrease in the percentage of blocked connections in both scenarios. Scenario 2 presents higher values of blocking probability than scenario 1. This is because the percentage of real time sources in scenario 2 is higher.

![VBR-RT Blocking Probability Scenario 1](image)
The introduction of the statistical multiplexing implies a more efficient usage of the CBA_VBR_RT allocated bandwidth. Figures 5 and 6 show the bandwidth utilization in the considered scenarios. When the PDR allocation is used, the utilization factor remains below 30%; while the introduction of the EB allocation dramatically improves the performance. In Scenario 2, the gain is less evident due to the higher percentage of CBA_VBR_RT connections.

Finally it is important to note, in Figures 7 and 8, that the packets loss, unavoidably introduced by the adopted CAC policy, lies well below the bound fixed by the SkyPlexNet profile classes reported in Table 1.
CONCLUSIONS

In this paper a CAC framework for DVB-RCS systems was presented. The CAC is performed both at the satellite terminal and at the network control centre. CAC is applied to the different traffic classes (CBA, DBA, BEA) in a different way. In order to obtain efficient exploitation of the allocated resources an “effective bandwidth” approach was considered for CBA traffic with VBR nature. Through a simulation campaign the robustness of the proposed algorithm was tested and the obtained results are very encouraging.

REFERENCES

[2] ETSI EN 301 790: Digital Video Broadcasting (DVB); Interaction channel for satellite distribution systems.