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A NS-2 Simulation model of DVB-S2/RCS Satellite network

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Abstract

Satellite networks are enhanced permanently: new coding techniques, changes in the allocation algorithm or new technologies. These features are first implemented on a test bed in order to prove their efficiency, but an emulation platform is expensive and its implementation is time consuming. A simulation model can solve these issues, by giving a first try out and another way to obtain measurements. Of course, this model has to be as close as possible to the real system by its behavior but also by the layout of its components. The previous reasons lead us to realize a model of a DVB-S2/RCS satellite network on NS-2.

1 Introduction

In the last past years, the development of protocols Digital Video Broadcasting via Satellite (DVB-S2) and Digital Video Broadcast – Return Channel via Satellite (DVB/RCS), and the use of new satellite networks allowed to provide Internet access to wide area without using terrestrial networks. Nevertheless, the reliability of this connection will depend on the choice made by the developers: the algorithm used for the Bandwidth on Demand (BoD), the handling of different types of services, and the adaptive coding technique.

Coming from past IST projects, an emulation testbed (SATIP6/PLATINE) to evaluate satellite systems is available for experimentation. Even if emulation is really useful, there are some disadvantages: the size of the network is restricted by the number of computers, and setting up the testbed can be very expensive in term of time. Using the actual system to make experimental measures is risky because we don't know every users behavior. Involved in the OURSES project, measurements on a real current satellite system were made. But the evaluated scenarios were made with a limited number of terminals and it is not possible to enlarge the experimentation due to its induced cost. Running simulation model over Network Simulator 2 (NS-2) will allow us to obtain new measures, with an easily modifiable model and only one computer.

The first part of this paper summarizes the structure of DVB-S2/RCS satellite networks. The second part is focused on the design of our simulation model using NS-2 simulation tool. The third part is dedicated to the obtained results and their analysis, in order to prove that the behavior of our simulation model is close to the one we experiment in OURSES real system and in our emulation platform in LAAS-CNRS coming from IST Satsix project. The last part concludes on the model evaluation and future work.

2 Structure of DVB-S2/RCS satellite networks

2.1 Communication satellite systems

In a modern satellite network (see Fig. 1), we can consider three main components: the Network Control Center (NCC) allocating the bandwidth on demand, the Gateway (GW) allowing an access to Internet, and several satellite terminals (ST) connected to an access network. The geostationary satellite links up together these components and by being connected to one of the access networks, users will be able to use Internet services and to communicate one with another.

At first, satellite communication networks were only able to establish unidirectional communication from the server to the client, supporting mainly TV broadcasting. However, as Internet is currently the reference network, using satellite networks as an access network seems interesting and the need of a return channel became obvious in order to allow a bidirectional communication. The protocol Digital Video Broadcast / Return Channel via Satellite (DVB/RCS) described in [7] was developed in order to

complete the Digital Video Broadcasting via Satellite (DVB-S). On the forward link (from satellite to terminals), the bandwidth is really large (about 60Mbps) and all the communications can be transmitted without problem, but on the return link (from terminals to satellite) the bandwidth is ten times smaller, so the Method Access Control (MAC) and the method used to allocate it over the terminals will drastically affect the connections. The several possibilities will be discussed in the next sub section.

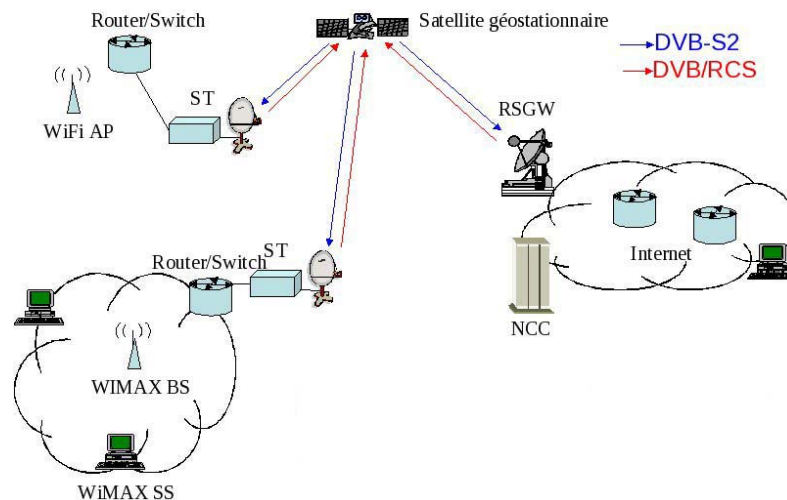


Fig 1: A DVB-S2/RCS satellite network

The increase of private connections bandwidth from 56kbps to more than 10Mbps in the last few years allowed the use of new applications such Voice on IP, Video on Demand, on-line games... These services need a short delay and a short presentation delay unlike FTP connections that just need some bandwidth. Therefore a differentiation between the various flows is needed; they are classified in Real Time (RT) services and non Real Time (n-RT) services. A Quality of Service (QoS) architecture is used in satellite networks in order to implement that classification and allows integrating them with the technology used in the core networks of Internet: Differentiated Services (DiffServ).

2.2 Encapsulation, Bandwidth Allocation and QoS Architecture

The frames passing around the network are ATM on the return channel and MPEG2-TS on the forward link. The access networks located beyond the ST and the Internet networks are using IP packets. In order to allow communication between these networks, encapsulation and fragmentation is necessary. This is done by means of ATM Adaptation Layer 5 (AAL5) and Multi Protocol Encapsulation (MPE). The sizes of ATM and MPEG2-TS frame are respectively 53 bytes and 188 bytes. Having a fixed size will make the calculation of the sending time for one frame easier, and this last parameter will only depend on the available bandwidth. But the overhead introduces by those two mechanisms is consequent (around 10%) and can alter the comportment of TCP by changing the reactions of the congestion window. This mechanism is rather important and need to be represented.

As explained earlier, the bandwidth of the return channel cannot be wasted. The geostationary satellite networks have a consequent delay (about 120 ms) and if collision occurs this will result in a delay bigger than 300ms. In DVB-S/RCS satellite systems, a Time Division Multiple Access (TDMA) method is employed, the temporal slots are assigned to terminals and they can emit the frames without any risk of collision. To obtain a bigger bandwidth, Frequency Division Multiple Access (FDMA) is also used.

The easiest way to allocate these slots is to statically split them over all the terminals and according more slots to the one used as GW. This approach is efficient for a small number of terminals, but the

bandwidth is not allocated according to the needs of the users. The Demand Assignment Multiple Access algorithm offers the possibility to allocate slots in two ways:

- Statically : Constant Rate Assignment (CRA)
- Dynamically : Rate or Volume Based Dynamic Capacity (RDBC or/and VBDC)

Each terminal owns one CRA slot and send request to the NCC if it needs more. Depending on all the requests, the NCC responds to each terminal with the new allocation. The requests are sent periodically so the unused bandwidth can be split over the remaining ST needing it. They are compute by checking the level of the buffer located between the Link and MAC levels. With the response, the MAC can send the frames at the determined time, so they fit in the slots.

By providing an Internet access via the satellite network, traffic types are mixed even if they have various characteristics and requirements. In order to have a differentiation between services and to guarantee a Quality of Service, communication networks implement a specific architecture. With the DiffServ model, the routers won't act any more on the packets, but they blend them and compute the flows, allowing the network to easily guarantee QoS for some of them while the others are processed in a Best Effort way. With a similar architecture, flows can be differentiated at the IP layer in the ST with three different buffers Assured Forwarding (AF), Expedited Forwarding (EF) and Best Effort (BE). The frames are also classified between MAC and Link layer by using two distinct queues: Real Time (RT) and non Real Time (n-RT). This architecture introduces a Quality of Service and allows a differentiation between the packets.

3 Design of the Model

The model has been designed in order to stick with the components and the behavior of a real satellite system. Therefore, the main components of a DVB-2S/RCS satellite networks described in the first part and implemented in the model are:

- the NCC handling connections to the satellite system,
- the GW giving access to the Internet network,
- the STs with an access network.

They are connected up together by the geostationary satellite and the satellite links. The physical channels are linked with the nodes through a satellite interface containing a protocol stack similar to the real one.

Satellite networks are handled by Network Simulator 2 (NS-2), but only some features are implemented. There is no dynamic bandwidth allocation neither Quality of Service architecture, so the bandwidth and the delay of the connections are not satisfactory. In order to improve the efficiency of the model, a DAMA algorithm and a flow differentiation need to be added. This part will first describe the DAMA model and the improvement that need to be done, and then we will study how this changes can be implemented.

3.1 Model principles

The starting point of our implementation is the model of F. Zampognaro and R. Secchi described in [1]. It already contains the DAMA algorithm and the essential associated mechanisms:

- Static and Dynamic allocation of the bandwidth,
- Request management in the NCC.

As in the real system, the requests are computed at MAC layer depending on the level of the queues and sent to the NCC. The response contains the number of slots available for each ST, and they will be able to calculate the bandwidth they got. The slot assignment will be made statically in CRA and dynamically in RBDC. Since the fragmentation of IP packets is not possible with Network Simulator 2, the MAC layer adjust the sending time to the available bandwidth based on the assigned slots.

The simulation made on this model shows a really efficient behavior with a dynamic allocation and a fast establishment of the connections. However, in order to be closer from the real system and to improve the performance, some features need to be added:

- Dynamic encapsulation of the IP packets,

- Substitution of the single queue at MAC layer by two distinct queues,
- Addition of queues at IP layer (DiffServ architecture).

The next sub sections describe these mechanisms and their implementation in NS-2.

3.2 The encapsulation

The frames on the satellite network are MPEG2-TS on the forward link and ATM on the return link while in the access networks IP packets are traveling. On the real system, an encapsulation and a fragmentation are made in the STs, but modeling the entire fragmentation is not possible due to the limits of the simulator. To overcome this issue, when a packet arrived in a terminal, we change its size by adding the overhead corresponding to the successive encapsulations from IP to ATM. In the satellite, the packet size is changed to fit to the encapsulation from IP to MPEG2-TS, and when it goes out from the arrival terminal, the original size of the IP packet is put back on.

The size of ATM and MPEG-TS frames are respectively fixed to 53 bytes and 188 bytes. The protocol used to pass from IP to ATM is ATM Adaptation Layer 5; it adds a padding in order to build full sized frames, so this will be process first and then the overhead is computed:

$$\text{Padding} = (\text{Size} + 8) \% 48$$

$$\text{Overhead} = 8 + ((\text{Size} + \text{Padding} + 8)/48)*5$$

The process is quite the same for the change from IP to MPEG-TS but there is no padding:

$$\text{Overhead} = 16 + (\text{Size}/184.0)*4 + 1$$

To implement these feature in NS-2, the following components need to be added : new packet headers corresponding to ATM and MPEG2-TS, two agents defined in C++ structures inherited from encapsulator and decapsulator, and a Otcl procedure in order to put the agents in the right place and link them with the others components. The routing of the packets from the node entry to the agents was a problem at first, but we solved it by changing the address demultiplexer and so it sends non-ATM packets to the agents.

3.3 The RT and n-RT queues

The queue located between the Link and MAC layers stores packets until they can be sent to the medium. In order to add a Quality of Service architecture, a second file has been added as done on wireless networks with the implementation of Enhanced Distributed Channel Access (EDCA) in [2].

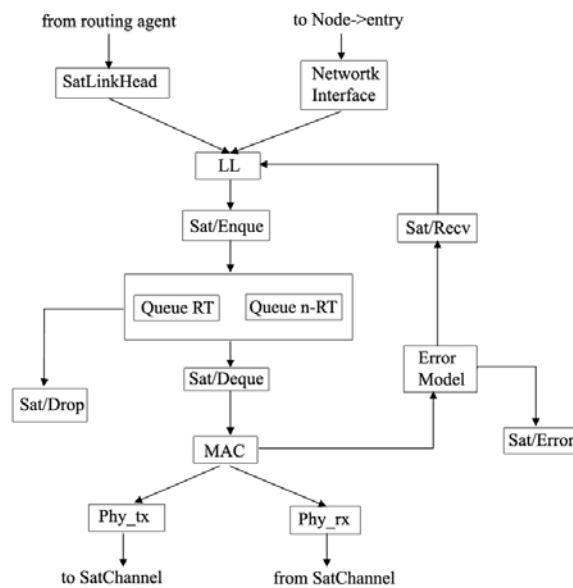


Fig 2: Satellite network stack of NS-2

When arriving at Link layer, packets are sorted according to their flow id and store in the Real Time or in the non Real Time queue. By giving higher priority to one queue, the system will be able to guarantee less waiting time to some flows. The others flows will be treated when enough priority packets have been sent.

In order to implement this “double” queue, two structures are added in NS-2: DTail inherited from the class Queue, and PriQ inherited from the class Dtail. The PriQ class is in interaction with the Link and MAC layers, has the same interface as a classic queue and contains the two queues DTail. The single adjustment for the MAC layer is the scheduling of a new method that checks the levels of the RT and n-RT queues and selects the packets to be dequeued. This method is schedule every time a packet is queued and at the end of a transmission.

3.4 Addition of the IP queues

Applied on most of the edge and core routers of the Internet network, the DiffServ architecture allows merging packets together in flows and simplifying the process done in the core nodes. The packets are stored in three different queues depending on their flow ID. This classification is done at IP layer, so by choosing the file in which the packets are unqueued, the system will also make a scheduling above the two MAC queues introduced previously.

Unlike the wired links in NS-2, the satellite links do not contain buffers, and we cannot use the DiffServ function available in the basic version of the simulator. To overcome this issue, this feature has been implemented between the Encapsulation agent and the entry of the node.

Several types of traffic will be stored in these queues; they are sorted in three types of services:

- Expedited Forwarding (EF) needing low delay,
- Assured Forwarding (AF) needing a minimal bandwidth,
- Best Effort (BE): others flows non sort.

In our model, the packets arriving in a node are sorted and stored in the queues, where they stay until the MAC buffer level is not beyond a given level. This way, we will able to prevent the RT and n-RT queues to overflow and to avoid unnecessary loss. The check is performed by a method called every time a packet is queued or when a packet is unqueued from the MAC queues.

The implementation has been done like the programming of the MAC buffers. This modification is transparent for the components of the model, only the SatLinkHead contains a timekeeper to the buffers.

4 Results and Analysis

4.1 Scenario configuration

The scenario to be studied was selected because of its conformance to the real system we experiment in OURSES project.

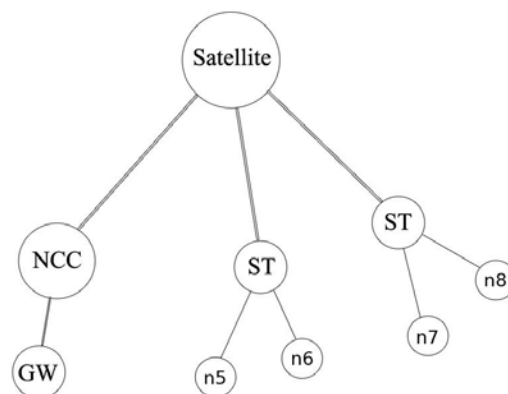


Fig 3: Model topology

The network topology (Fig 3) can be seen as a star network with the satellite and the terminals or as a tree network by adding a third level, the access network. This topology has been chosen in order to be as close as possible to the real network. The Gateway is located beyond the Network Control Center because the DAMA algorithm used runs at the MAC layer in the terminals, and the server must be in a ST. The terminal number can be increased up to the number of slots.

In order to observe the efficiency of QoS architecture, two different types of traffic have been generated: TCP/FTP and UDP/CBR connections. IT was done so to guarantee a low delay with a few losses to the CBR traffic and to allow the FTP connection to being established and to have the bandwidth as large as possible. The following connections will start at the same time (worst case):

- one CBR from the GW to all the nodes,
- one FTP from the GW to the node n5,
- one CBR and one FTP from the node n7 to the node n5.

Since the NCC got more CRA slots and can get more RBDC slots than the others terminals, the connections between the GW and the nodes allow observing the dynamic allocation in the NCC. The connection between two nodes is more useful to analyse the competition between two types of traffic with a low bandwidth on the return channel (one slot in CRA, and maximum one slot in RBDC).

The sizing of the simulation is done in the Otcl script and has been adapt to the OURSES project. The main point of this project is to provide medical services via satellite to a wide area not connected to high speed terrestrial networks. The several parameters like the slot size and the packets size are the same, and the bandwidth fits with the bandwidth of the real system without FDMA. The slot size has been set to 128 kbps, with one slot allocated in CRA and one more slot available in RBDC for the standard STs.

4.2 Evaluation of the model without QoS architecture

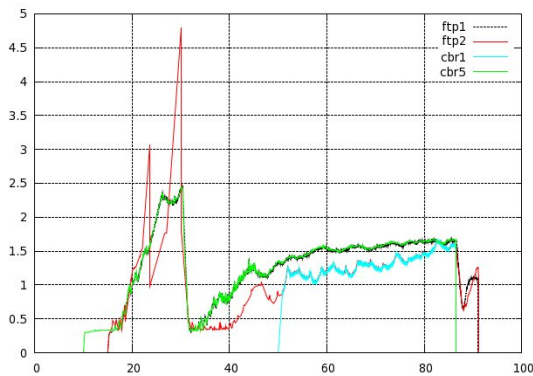


Fig 4: Connections delays for several flows

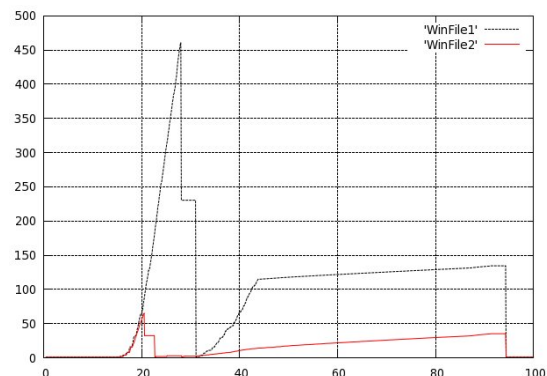


Fig 5: FTP connections congestion windows

The figures 4 and 5 above show the behavior of the DamaMac model. The delays of the RT and n-RT flows are the same when there is no QoS architecture. The effect of the congestion window is rather important: if the threshold has not been set, the delays at the beginning of the simulation are above 3 seconds for the FTP connection between two users' nodes.

As explained in the design part, the behavior is correct so our work aimed at adding a QoS architecture without radical changes on the allocation algorithm.

4.3 QoS architecture evaluation

The main point is the differentiation of the RT and n-RT flows. The graphics below show the effects of our contribution.

The figure 6 shows the connections delays over a 100 seconds simulation. The delays of the RT services are stable and below 400 ms while the n-RT flow delays are changing from 500 ms up to 2s for the FTP connection between the GW and one node, and up to 3s for the FTP connection between two nodes.

The disruption introduced at 50s on the link between two nodes by adding a RT connection affects the FTP connection and makes it unstable for 10s. Three different phases can be considered during that time: first the FTP connection fills up the buffers since it has less bandwidth than previously, then the sending agent is aware that packets are lost and the congestion window is reduced, and finally the queues are emptying and the connection restarts slowly.

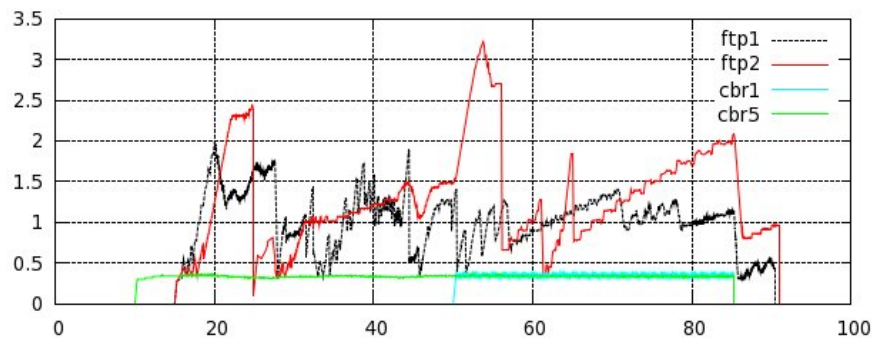


Fig 6: connections delays with the QoS architecture

Like the delay, the throughput of the FTP connections is seriously affected by the RT connections, even if it reaches a maximum value after a given time, it is really unstable at start (figure 7). In the FTP connection between two nodes, the encapsulation results in a useful bandwidth about 240kbps which is about 93% with two slots allocated. When the RT connection starts between the same nodes the throughput is divided by more than a half. Indeed, the rate of this connection is 128kbps (16kBps) and with the encapsulations, the FTP connection can just use the remaining bandwidth (about 12kBps).

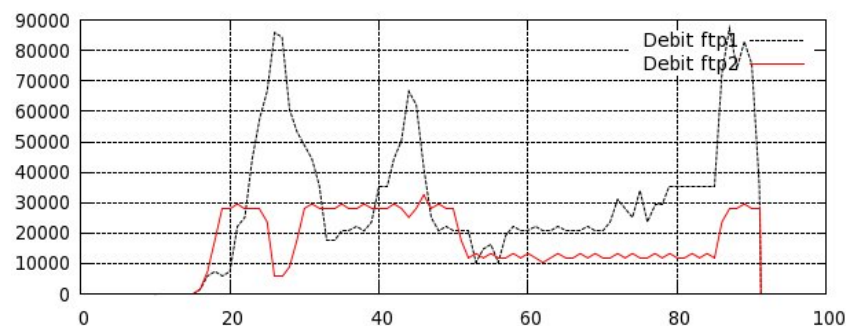


Fig 7: Throughput of the FTP connections with the QoS architecture

The obtained results are interesting and as we can predict, having a high priority on the RT flows results in neglecting the n-RT ones. But this is acceptable since an FTP like connection doesn't need low delay and jitter, the throughput is big enough to allow Web navigation or small size files transfer. Nevertheless the throughput of the FTP connections is as high as it can be with a RT communication.

5 Conclusion

The main point has been achieved with the modeling of a QoS structure on the simulator NS-2. By adding this architecture, the model can differentiate several flows and is able to provide Quality of Service guarantee to the claiming services. We were able to realize a model close to the real system, with the same topology, the same parameters and a similar behavior.

Having a model of a satellite network with a QoS architecture is useful since the results can be compared with the actual real system and the emulation platform. We haven't done that work yet because the experiments on the OURSES project didn't took the same scenarios at the time we ran the simulations. Anyway the model behavior fits with the obtained results on the FTP connections and we can expect to have the same behaviors by adding the RT flows.

The QoS introduced in the satellite network model of NS-2 needs to be used as a complement to the DamaMac model and can be used as a test bed for coding techniques or a new allocation algorithm. Some improvements should be made by changing the selection method when unqueueing a packet from the queues; if the actual method is quite simple, an algorithm like EDF can be implemented in order to have better differentiation based on priority levels.

Another future work to be done is the study of the model behavior at a large scale and the model ability to handle wireless access networks to support the simulation of larger networks and the merge of several technologies in the access network on the client side before the ST.

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