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PLATINE: DVB-S/RCS Testbed for Next Generation Satellite Networks

O. Alphand, P. Berthou, T. Gayraud and F. Nivor from *LAAS-CNRS, Toulouse, France*
S. Combes, C. Baudoin from *Alcatel Space, Toulouse, France*

Abstract

Evaluating performances over real data links or network is often costly, even impossible for systems in development phase. In such situation, emulation is the key to provide a low cost and demonstrative platform. The main problem is to overcome the emulation weakness which is the accuracy of the model reproducing the systems to be evaluated. Owing to its modular design and implementation, the PLATINE satellite emulation platform, presented in this paper, is able to emulate a complete DVB-RCS (Digital Video Broadcasting – Return Channel via Satellite) system in a realistic and flexible way. It is possible to configure the platform to simulate a transparent DVB-RCS system dimensioned around a single Hub, or to simulate a system using a regenerative satellite with an on-board switching matrix only by changing some configuration files. A DVB-RCS protocol stack is implemented, and the modulation/coding part is simulated in real time thanks to pre-calculated BER files. A DiffServ-like QoS Architecture that couples MAC and IP-Layer QoS mechanisms has also been implemented. In this paper, we mainly focus on the emulation platform and the tools developed to help the performance analysis of the simulated system.

I. Introduction

Evaluating performances over real data links or network is often costly, even impossible for systems in development phase. Simulation and emulation both provide the opportunity to evaluate performances, at low cost, on more or less realistic systems. When simulation needs a complete modelisation of the systems from applications to physical network and operates in virtual time, emulation is more demonstrative since real applications can be deployed over the model describing transfer characteristics, delay and error behavior for instance.

For these reasons, the choice was made for the IST SATIP6 [1] project to set up a satellite emulation platform (PLATINE) to demonstrate the network and application services integration on next generation satellite systems and the possibility to interoperate with terrestrial networks. As current simulation tools do not implement DVB-RCS architecture or current DVB-RCS satellite systems do not provide quality of service neither on board switching satellite, our platform is a good opportunity to test new schemes, protocols and services for next generation satellite networks.

This paper first briefly sums up the main functionalities of DVB-RCS satellite systems. The second section depicts the design and the implementation of our full DVB-S/RCS emulated satellite platform. It mainly focuses on the satellite Physical and Data Link layers emulation techniques and the final QoS Architecture that was retained to provide differentiated QoS on a satellite network. The final section presents the tools developed to capture system statistics and help performance analysis.

II. Introduction to DVB-RCS systems

A. PLATINE objectives

The Satellite network emulation testbed (PLATINE) developed in SATIP6 is compliant with the architecture adopted within the ETSI BSM [3] group and the DVB-RCS standards. The scenario, shown in Figure 1, gives a good overview of next generation satellite networks architecture. It consists in a geostationary satellite network with onboard switching capabilities, Ka MF-TDMA (Multiple Frequency Time Division Multiple Access) uplinks and Ku TDM (Time Division Multiplexed) downlinks. The satellite is regenerative meaning that only a single hop is needed to interconnect two end users. Satellite Terminals (RCST) provide single PC or LANs with the access to the network, while Gateways (GWs) allow the connection with Internet core networks. The uplink access from each RCST is managed through DVB-RCS interfaces. STs and GWs are boundary devices between the satellite and terrestrial links and play an important role in access to satellite resources and hence in QoS provisioning. Both devices implement IP routing and have an IP interface on the satellite segment, as IP serves as a common denominator between the satellite and terrestrial

networks. That is to say that Satellite Network is considered as a special link from a classical network point of view.

Figure 1 depicts the satellite network architecture emulated by the PLATINE platform. On the left is represented the end-user side of the platform. On the right is shown the provider/enterprise/Internet side of the platform. We distinguish also between the satellite network side (in the middle) and the IP network sides (on left and right ends), interconnected by RCSTs.

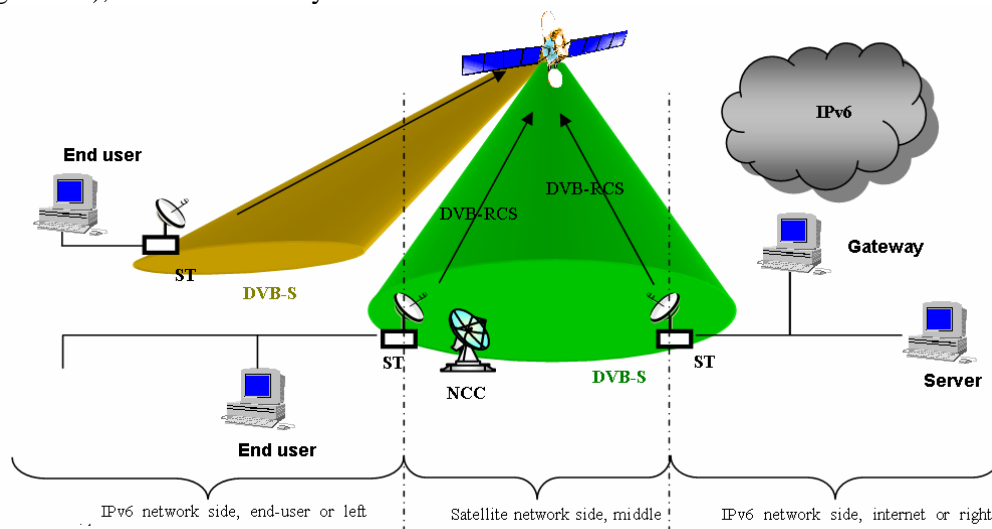


Figure 1 : DVB-S/RCS architecture

Three main components have to be distinguished in the satellite network side (middle): the Satellite, the Return Channel Satellite Terminals (RCST) and the Network Control Center (NCC)

The role of the different network elements (NCC, RCST) is explained in a brief introduction to the main ETSI recommendations related to QoS in satellite.

B. Introduction to DVB-RCS Architecture

Initiated in 1993, the international European DVB Project published, in the end-nineties, a family of digital transmission specifications, based upon MPEG-2 (Motion Picture Expert Group) video compression and transmission techniques. In each specification, data are thus transported within MPEG-2 transport streams (MPEG2-TS) which are identified through DVB Service Information Tables. Adapted for satellite systems, DVB-S defines one of the most widespread formats used for Digital TV over the last years and still nowadays. However, DVB-S Satellite Terminals (RCST) can then only receive frames from the satellite. The need for a return link rapidly becomes essential so as to support emerging Internet services via satellite. Two main alternatives, based on DVB-S, can be retained: The UDLR (UniDirectional Link Routing) standard which emulates a cheap bidirectionnal solution through a terrestrial return link and DVB-RCS, published in March 2000, which provides expensive but full bidirectionnal satellite architecture. Concerning IP encapsulation, various schemes already exist and are still being specified for the forward and return link.

The return link access scheme in DVB-S/RCS systems is MF-TDMA. The return link is segmented into portions of time and frequency ("superframes"), each of which is divided into timeslots ("bursts") of either fixed or variable durations and bandwidths during which STs are able to transmit MPEG2-TS packets or ATM cells. The entire satellite system control, especially STs synchronization and resource allocation, is performed by the NCC. It periodically broadcasts a signaling frame, the TBTP (Terminal Burst Time Plan), which updates the timeslot allocation within a superframe between every competing ST. This allocation can be dynamically modified on STs demand thanks to a bandwidth on demand protocol called Demand Assignment Multiple Access (DAMA). It supplements the STs with the ability to frequently request capacities that fit their current respective traffic load to the NCC. However the DAMA request/assignment cycle exhibits a non negligible latency and additional delays that cannot always match interactivity requirements of multimedia services. In order to both maximize satellite resource use and meet multimedia requirements, the DVB-RCS norm discriminates RCST capacity requests into 4 categories:

- *Continuous Rate Assignment (CRA)*: Fixed slots are assigned in each MF-TDMA frame for the whole duration of a RCST connection

- *Rate-Based Dynamic Capacity* (RBDC): a dynamic rate capacity (in slots/frame) granted in response to explicit RCST requests
- *Volume-Based Dynamic Capacity* (VBDC): a dynamic cumulative volume capacity (in slots), granted in response to explicit RCST requests
- *Free Capacity Allocation* (FCA), which is assigned to STs on an “as available” basis from unused capacity

The standard, after defining separate MAC traffic priority queues (Real-Time, Variable Rate and Jitter-Tolerant priorities), suggests a requesting strategy for each of them, that is to say a relevant mapping between traffic and request categories. Any given RCST can be assigned one or a mix of the four capacity types. In general, higher priority classes of service (e.g. IP DiffServ EF and AF classes) are associated with guaranteed capacity (CRA, RBDC), while lower priority classes (e.g. Best Effort) are predominantly given best effort capacity (VBDC, FCA).

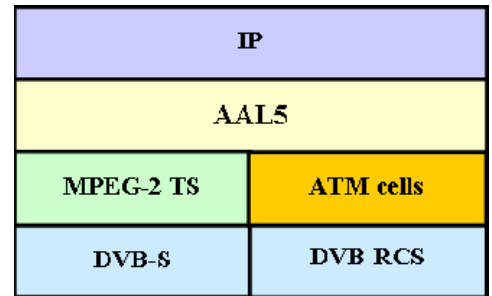


Figure 2 : PLATINE protocol stack

Thanks to this introduction, we are able to present the satellite protocol stack that was finally adopted in our emulation platform (**Erreur ! Source du renvoi introuvable.**).

C. Experimental platform

The testbed we have built is able to emulate a complex scenario for next generation satellite network as presented in figure 1. Each network element involved in the satellite network is emulated in our platform on a dedicated node. In fact, 3 users LAN of two nodes (standard Linux systems) are connected to the emulated satellite network with 3 RCTS that implement an almost complete DVB-S/RCS stack. The satellite core network is emulated thanks to the Satellite Emulator (SE) as link emulator and the Network Control Center (NCC) for bandwidth management (DAMA). 11 computers are used as described in Figure 3.

We first describe the protocol stacks implementation, the satellite carrier emulation, the MAC layer implementation and then the QoS architecture.

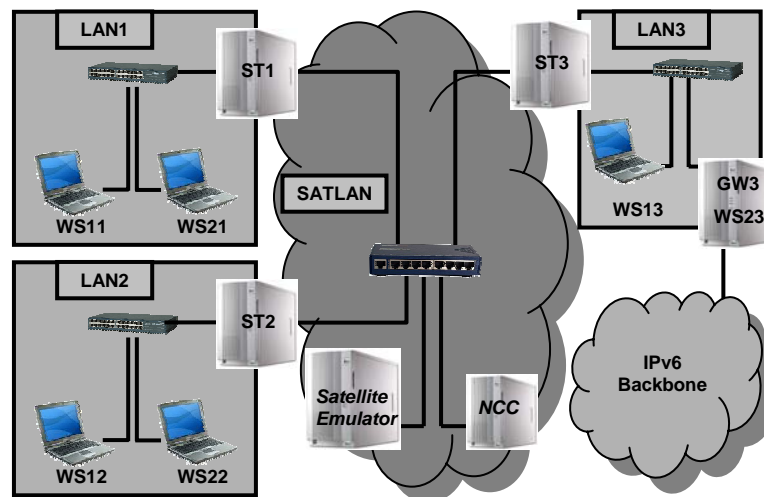


Figure 3 : Full PLATINE testbed

III. The PLATINE architecture implementation

A. The Satellite System Emulation

In order to have the most modular platform and so preserves room for future evolution (DVB-S2, ULE), stringent requirements were fixed before the development phase.

At first, the aim was to take advantage of a linux system (Fedora Core 2) which natively supports Ipv6 and a wide panel of IPv6 applications (*Apache* as HTTP Server, *Mozilla* as HTTP Client, *Vsftpd* as FTP Server, *Gnomemeeting* for Videoconferencing, *VideoLanClient* for Videostreaming).

Then the next step was to decide how to implement the Satellite Protocol stack and the main satellite systems functionalities. We choose to directly reuse a derived GPL product for the runtime. It is called Margouilla [2], a C++ runtime that provides platform independent messaging, a set of common blocs ready to use (IP/ATM/Ethernet layers...), a graphical editor with SDL design style and utilities package offers basic tools, such as Configuration file and logging mechanisms for error and debug messages. For the purpose of PLATINE, Margouilla at first enables the running of automatically generated piece of codes compiled from an SDL description. Secondly, its runtime provides us with a multi-platform synchronisation toolkit and finally stands for a formal platform for collaborative development.

The final PLATINE protocol stack is the following one that is detailed in Figure 4.

The blocs that were developed within the Margouilla runtime are:

- The *satellite carrier* package is responsible for the different satellite carriers emulation on top of Ethernet (DVB-RCS, DVB-S and Signaling Channels) and the simulation of typical satellite bit errors and delay
- The *DVB-S/RCS* package implements a framing structure compliant with the DVB-S/RCS standards. and fills DVB-RCS frames with ATM-like cells coming from the AAL5 layer. In order to achieve proper QoS, this layer manages synchronisation and queues according to the authorisations a DAMA algorithm delivers.
- The *DAMA* package implements the DAMA algorithms used to manage the satellite resources allocation at layer 2
- The *IP Dedicated* package implements an AAL5 like layer which is responsible for segmentation and reassembly functionalities and for a specific tagging mechanism targeted towards IP. It also implements a dynamic address resolution protocol in order to use that mechanism.
- The *IP QoS Package* implements common mechanisms to enable differentiation at this level. It treats packets incoming from IP network and forwarded on the DVB-DCS uplink according to a committed QoS behavior and is in charge of discriminating, regulating and scheduling this traffic in to 3 classes of Service (Real-Time, non Real-Time and Best Effort).

A detailed description of the way the different layers are emulated is done through the following paragraphs.

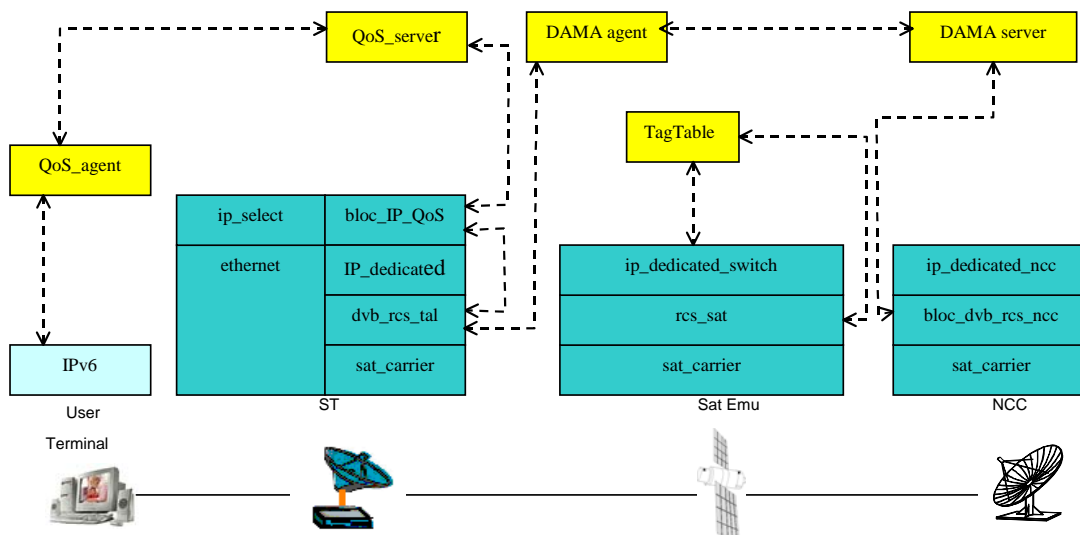


Figure 4 : PLATINE emulation platform architecture

1. The satellite carrier emulation

The satellite carrier emulation is designed to operate on top of Ethernet frames and for each satellite channel corresponds an Ethernet multicast address. Ethernet was chosen for its native broadcast abilities (like a spot) and also for its high bandwidth capacities.

For each spot, we distinguish at least 4 channels:

- A dedicated channel for each data DVB-S flow spot descending from the satellite (one channel per DVB-S flow per spot)
- A dedicated channel for each data DVB-RCS flow on each spot ascending to the satellite
- Two dedicated channels for control frames (connection request, connection confirm, TBTP, ...) one for the ascending flow and one for the descending flow

2. *The Satellite Link Emulation*

The satellite emulator can both act as a transparent or a regenerative satellite and it is able to simulate spot changes and signal format conversion. Indeed, the regenerative satellite with an onboard switching matrix processes DVB-RCS frames, switches ATM cells received from these frames and rebuilds them into DVB-S frames. This switching table could be updated by appropriated control message. Currently, it is allocated statically.

However the main functionality of the SE is its satellite link emulation module which simulates in real time the modulating/coding part thanks to precalculated BER files. The error model is based on precalculated data files from IST BRAHMS project. In addition to inject bit errors, the satellite emulator introduces delay and jitter that can be also tuned. The default values were put to 250ms with no jitter.

3. *Medium Access Control*

This section deals with the MAC allocation procedure that is adopted in the PLATINE demonstrator. The DVB-RCS frame synchronization scheme and the DAMA algorithm are presented in the following paragraphs.

The **frame synchronisation** is carried out by emitting Ethernet frame at fixed instant on all RCST (super frame tick) and then internally by awaking processes each frame ticks (50ms) to send already queued packet. The default reference values on which the allocation procedure is based are:

- The superframe composed of 10 internal frames
- Frame duration of 50ms
- Periodicity of ATM cells allocation on a super frame basis: *i.e.* each 500ms.

The reproduction of an exact DVB-RCS allocation scheme based on ATM bursts cannot be exploited using classical ethernet hardware interface since there is no possibility for a given station to fill an ethernet frame emitted by another station. Thus ATM cells allocated to a RCST for a superframe are shared among DVB-RCS frames encapsulated in Ethernet frames that are efficiently distributed over the superframe duration.

The *allocation procedure (DAMA algorithm)* implementation in the demonstrator is described below:

- At log-on RCSTs request a fixed bandwidth (CRA) for MAC “real-time (RT)” traffic. There is no further allocation demand for that kind of traffic.
- Then RCSTs mainly do their request according to the number of ATM cells that feeds the ‘non real-time (NRT)” MAC queue during the previous superframe and the NRT MAC buffer queue length at the beginning of the current superframe. Formulas and algorithms are detailed in [4]. In particular there is an *overprovision* factor that takes into account sizes of queues during the 2 last super frames. Its goal is to enhance capacity requests according to the traffic recently experienced, it helps voiding the queues if congestion occurred. It is governed by a factor $(1-\alpha)$. If α is equal to 0 there is maximal overprovision. If it is equal to 1 there is no overprovision.
- Each Capacity Request (CR) is launched at the beginning of a super frame. Each CR is then delayed by the satellite emulator and reach NCC $250\text{ms}\pm 10\text{ms}$ after. CRs are processed by NCC upon arrival.
- NCC computes allocations at the beginning of each super frame according to an internal SACT table based on CR received. Authorisations are sent back to RCSTs using a TBTP table (if $FCA > 0$, even not requesting logged on station will receive extra-bandwidth if available).
- Upon reception of a TBTP, allocation are stored by RCST and used in the next super frame

B. **The QoS Architecture**

As presented in the firsts section, our platform implements a QoS architecture compliant with the ETSI Broadband Satellite Multimedia (BSM) group. This architecture links the MAC layer with the IP Layer to ensure the QoS continuity in the satellite protocol stack. The link between applications and IP layers is described in [5].

1. MAC Layer

Two MAC queues are available in the PLATINE system, one to satisfy a “real-time (RT)” service based on CRA assignment, and one to provide a “best effort” service. The RT queue is associated to a Continuous Rate Assignment (CRA) in the satellite network and thus benefits from a constant bandwidth, without needing any Capacity Request (instantaneous send). This traffic class experiences a low access delay. The non real-time (NRT) queue provides a best effort service and is linked to a mix between VDBC and FCA capacity assignments. Then, as capacity requests are needed a longer delay can be experienced

IP Layer

The IP Layer component defines QoS classes and implements buffer and bandwidth management mechanisms to assure fair allocation of bandwidth among contending users/applications and to control queuing delays.

Differentiated Services are performed through 3 Classes of Services (RT, NRT and BE):

- Real Time (VoIP, Videoconference) : delay and jitter sensitive traffic with hard constraints that must take benefit from the guarantees provided by the static capacity assignment defined in III.A.3
- Non Real Time (Multiplayer gaming, Videostreaming): tolerant to delay, jitter and loss threshold. A minimum bandwidth is needed and therefore can resort to use dynamic capacity assignment.
- Best Effort (Web, E-Mail ...): All the traffic that can recover from medium losses and support high delay

RT and NRT traffics are policed and shaped (dual token bucket) while BE is not policed.

2. Cross Layer mechanism

The BSM group recommends cross layer mechanisms to enhance the adaptation between the IP and the MAC layers. All the ATM cells resulting from the segmentation of RT IP Packets are positioned into the RT MAC queue, when IP BE and NRT packets are placed into the NRT MAC Queue. Finally, in order to prevent MAC-layer buffer overflows, the scheduler no more forwards IP Packets to the MAC Layer as long as the NRT MAC queue length exceeds a predefined threshold.

IV. PLATINE statistics

Emulation certainly belongs to the best tools to evaluate a system in particular thanks to two main characteristics. At first, the possibility to test real implementation of protocols and applications is an undeniable asset. Secondly, it provides a certain number of measurement points which would not be so easily accessible in real systems. Regarding our satellite emulator, statistics are computed at each superframe at the NCC/GW side, and at each frame at the RCST side (for both MAC layer and IP QoS layers).

It includes delay measurements, load measurements, queue statistics, DAMA and congestion control statistics.

Figure 6 shows several measurement points at different levels on the RCST return link channel. Measurement points are located at ingress points, at egress points as well as inside of IP_QoS and MAC layers of the satellite network emulator. As a result, the DAMA algorithm effects can be observed at different levels of the system.

So, when higher layers transmit traffic, we are able to measure the throughput per traffic category at IP layer ingress points and egress points. The throughput crossing the IP_QoS layer can be therefore characterized.

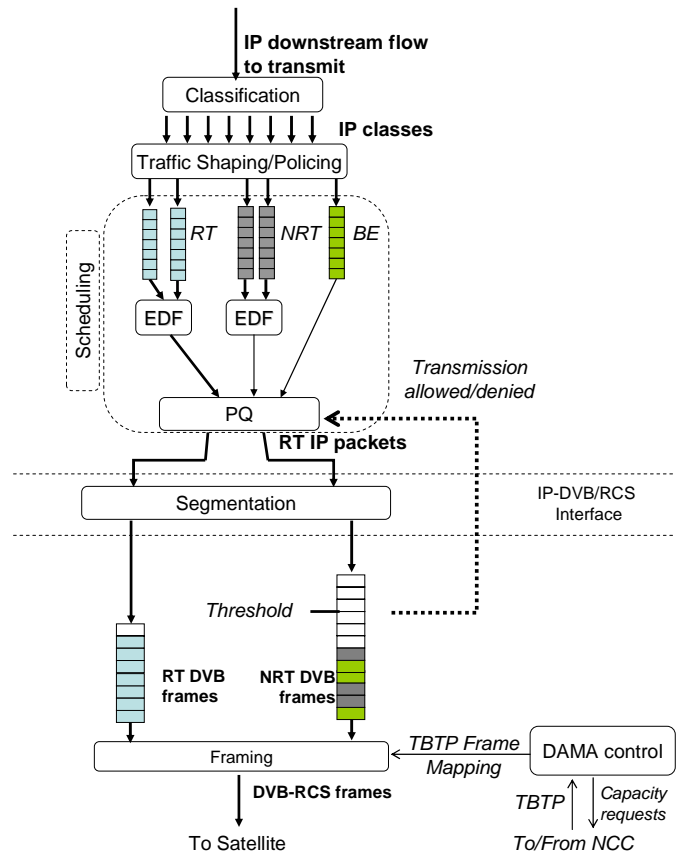


Figure 5 : PLATINE QoS Architecture

Other statistics measured inside the IP_QoS layer gives relevant information about congestion occurrences through, in particular, queues measurements: the FIFO queue size, the number of incoming, outgoing and dropped packets in the queue, and their associated sojourn time. This enables us to analyze the classifier (shaping, policing) behavior in interaction with the traffic to reduce congestion occurrence. Moreover, an egress measurement point allows to evaluate the traffic sent by the IP priority scheduler (PQ) Figure 5 to the underlying MAC layer.

The MAC layer behavior can also be analyzed through the study of the throughput at ingress and egress measurement points. Inside the MAC layer, the DAMA algorithm behavior can be evaluated. The evolution of capacity requests can be obtained for the NRT MAC service class in term of kbits/s and time-slot number. The DAMA efficiency can be directly obtained through the ratio between used time-slots and allocated slots.

We also benefit from statistics on the downlink channel, like the downlink traffic throughput received on the AIR interface by the RCST and the uplink traffic throughput sent on the AIR interface by the RCST.

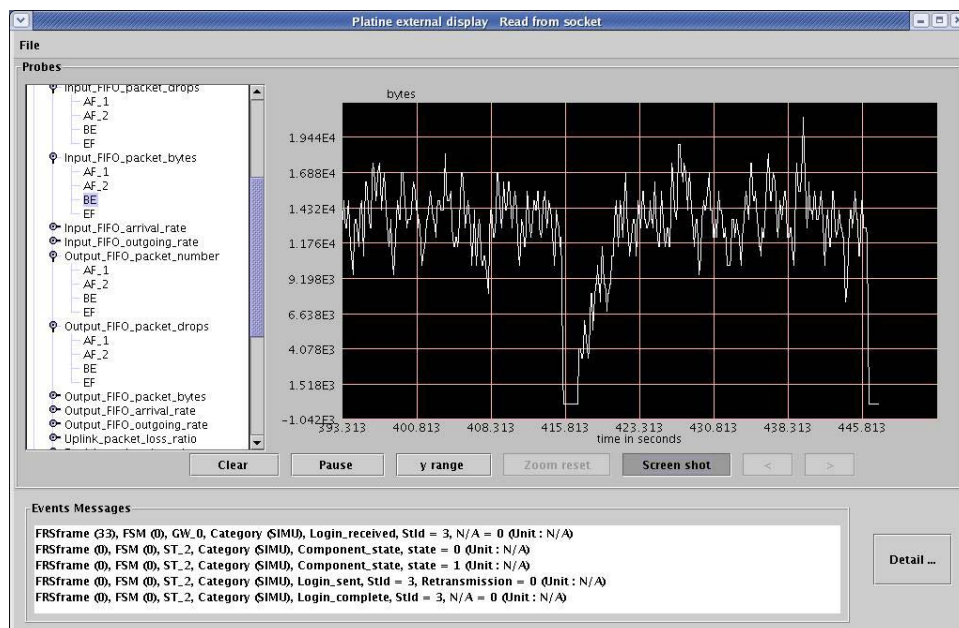


Figure 6 : PLATINE statistics tool

V. Traffic Generation & Measurement

A. Background traffic

What's more, in order to study more thoroughly the DAMA algorithm efficiency in a configuration comprising numerous RCSTs, the NCC is supplemented with the ability to emulate virtual RCSTs. To do so, the MAC scheduler is able to replay virtual CRs and takes them into account in addition to CRs sent by individual emulated RCSTs. These virtual CRs may be obtained through past recorded logs or created from scratch. More over, this tools allows to generate background traffic to study congestion for instance.

B. Special traffic

The main goal of this traffic generation tools is to reproduce multimedia traffic and to study the Satellite network impact on the data transmission. The use of real applications is mostly interesting to evaluate the quality the user perceives but is not sufficient to obtain metrics to adjust some algorithms or mechanisms used in Satellite network. Then, in PLATINE, a set of traffic generation tools have been developed to analyze traffic characteristics from real applications, replay traffic traces and measure statistics.

These statistics are those specified by ITU-T recommendation Y.1541 which are the bandwidth (especially different between the before and after bandwidth crossing over the Satellite network), the end to end delay

(IPDT: IP Packet Delay), the jitter (IPDV: IP Packet Delay Variation), the packet loss rate and profile lost (IPLR: Loss Ratio & IPER: Error Ratio).

Flow Capturer: FLOC

The first tool, FLOC is a software that allows to capture all data transmitted by all connections from a multimedia communication. Data retained to characterize the behavior of multimedia applications are the number of opened connections, the transport protocol associated to each connection (TCP or UDP), the absolute timestamp of captured packet (from which we mainly deduce the packet inter delay) and load size at transport level associated to this packet.

To capture the profile of a multimedia application, we start this later at the same time with FLOC tool. FLOC automatically makes the link between the application name and its associated connections. FLOC creates a tcpdump filter from the quad-tuple (source IP, destination IP, source port and destination port) from which the capture of traffic will be done. FLOC stores captured traces in a file.

FLOW REplayer: (FLORE)

The next step is to replay traffic from the captured traces. For this, the FLORE tool is composed of a server that transmits traffic from information of the trace file, and a client that receives multimedia replayed data. Both are NTP synchronized at millisecond near. For each multimedia packet to transmit, the server identifies at which connection the packet belongs, knows when to send the packet (timestamp), inserts a sequence number and pads it to its real size.

During multimedia data arrival, the client creates an output trace file per connection, containing statistics like the arrival time (with the departure time), the sequence number, the size, the delay and the inter packet delay. 6 pre-defined profiles are also available with this tool: GSM, G711, Xvid, H263, MPEG and DivX.

Flow Analyzer: FLAN

Finally, three scripts analyze statistics from output traces file: they provide graphics that show the throughput for each initial and replayed captured multimedia connection, the end to end replayed transmission delay, the sequence number evolution, the packet delay following its size, the inter packet delay. They also provide evaluation of loss rate for each connection distinguishing isolated loss and burst loss.

The remained statistics are lead from numerical analyze software (Scilab) on obtained traces.

VI. Conclusion & Further works

This testbed is an interesting feature in order to evaluate DVB-S/RCS system performance. Providing the user with several kinds of measurement, traffic flows and results analysis tools, it is an interesting way to investigate how to configure and use such systems.

This testbed is efficient enough to support various kinds of experimentation, dealing with multimedia user applications for instance. It may be enhanced in order to implement mechanisms such protocols ULE and DVB-S2. Thanks to the software design of the testbed, enhancements may be done easily.

The main inconvenience is still that the setup of the testbed is hard using the current release. It will be easier to deploy the next one. Using the testbed is not easy, but not less than any other simulation or emulation tool. Any interested user is welcome.

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