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Satellite diversity system emulator

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Current satellite telecommunication systems are facing growing demand, in particular for broadband markets. In order to reach higher data rate and minimize the cost per Mbps, upcoming VHTS systems are targeting Terabit capacity.

One of the most promising solution is to dedicate the whole Ka band to the user links to maximize the user link capacity whereas the feeder links operate in Q/V bands. However, the use of these higher frequencies (in the Q/V bands) raises new challenges, because of the increased sensitivity of these bands to meteorological events that may affect gateways link budget, making them unable to handle any traffic during a rain event. A simple solution to this shortcoming for ensuring constant service to users is to add additional gateways to the system and perform a handover to a redundancy gateway when a nominal gateway faces too strong fading^{3,4}. For example, a pan-european system with a dozen of operational gateways and a few redundancy gateways would be economically viable: the benefits brought by increased system availability compensate for the additional cost of the redundancy gateway. Different design choices to realize diversity are possible:⁵ this work studies in particular geographical diversity, so-called (n+p) diversity. This (n+p) diversity scheme provides the required availability with very few redundant gateways. However, the impacts on service continuity during gateway switching has still to be evaluated.

This paper presents a diversity emulation test-bed developed to experiment different types of gateway handover scenarios to measure their impact on user's experience. This emulator has been developed by IRT Saint Exupéry in the framework of the ALBS project (Advanced Link for Broadband Satellite). This project is investigating different research topics in order to design more robust and capacitive waveforms, to develop signal processing techniques to compensate distortion and interferences, to study future optical links and also to operate site diversity in the Q/V bands.

The emulator is able to simulate both ground network and satellite links, up to the user's terminals. It is designed to be representative of the network transit and switching losses and delays, as well as the satellite onboard switch behavior. It will be used to investigate the influence of the effects that switching mechanisms can have on the ongoing communications. It will also allow to investigate design optimization and provide recommendations to handle these ongoing communication during the gateway handover.

I. Introduction

A. Project goals

The reference system is based on a high capacity geostationary satellite and a ground segment composed of several satellite gateways and a large number of satellite terminals. To achieve high availability, few redundant gateways are considered, implementing an $(n + p)$ diversity scheme. Only one active and one redundancy gateway are needed to validate the hand-over mechanism and evaluate its impact on the service.

B. Switching model

The management system will decide to switch from a gateway facing high fading to a redundancy gateway. The decision itself is outside the scope of the paper and can be based either on channel estimation or weather forecast.

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All relevant modifications on the system elements will occur in reference with this triggering event (synchronous, fixed or user settable delay) and consist in:

- i) on-board of the satellite, to modify the links from old to new feeder for forward and return path,
- ii) on the terrestrial network, to redirect all traffic to the new gateway by activating the required ground link,
- iii) the backup gateway, initiate a transitory mode for the switching duration,
- iv) on the active impaired gateway, to stop transmission, when switching has been completed.

This model is representative of the onboard satellite switching, where configuration of the real switches is changed on both forward and return links. The duration of the forward and return link switching are configurable and can be triggered also at any delay. The ground station modular design allows flexible adjustments of the model parameters, especially for a backup gateway (buffer size, buffering strategy, queues priorities, packet filtering...).

For the network part, it has been assumed that the active impaired gateway and the redundancy gateway are physically connected but are virtually separated by distinct VLAN. The operation of switching will consist in changing the active VLAN. As a result of a switching scheme, the end-to-end link between the user and the ground network will be disrupted. This disruption can be modelled accurately. The switching scheme has to be transparent from an end-user point of view and should have no impact on the satellite terminal.

C. Purpose of the platform

The purpose of the emulator is to represent the full communication system. This study will focus on the elements affected by the switching schemes.

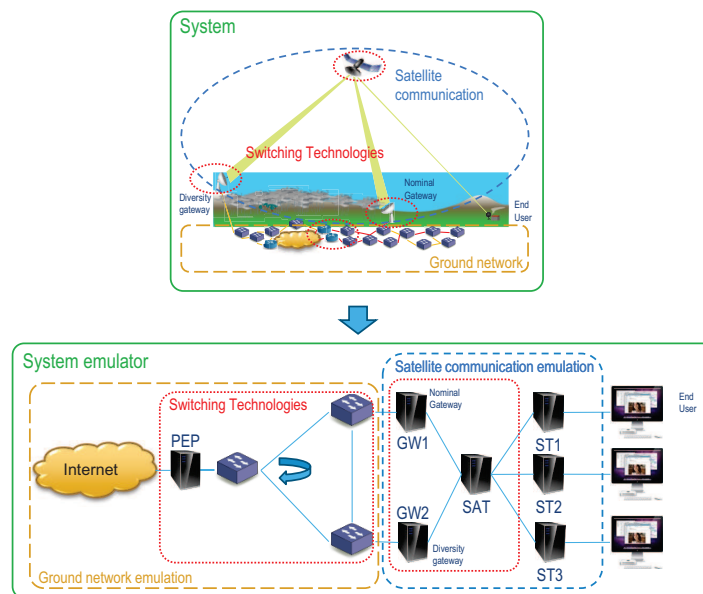


Figure 1: Mapping between the real system and the system emulator (Fig 1a depicts a real satellite system with diversity, Fig 1b depicts the system emulator)

Figure 1a represents a satellite broadband communication system providing Internet access to end-user. The traffic of many end-users is concentrated by the satellite toward an access gateway. This gateway is responsible for ensuring a ground connectivity to give Internet access to the end-user. The elements implied in the switching are depicted: the satellite, both satellite gateways, the ground-network. Figure 1b shows how the different real system elements have been mapped into our emulator. The satellite system has been modelled by the satellite emulator. The ground network is emulated by network connections with switchable links. The mapping between the real elements and its corresponding elements in the emulator is straightforward.

II. Emulator architecture

The emulator is installed on 8 servers and uses two Layer3 SDN-switches (Software Defined Networking). These servers are connected to a management network and emulation networks having the purpose to represent the different networks encountered, from the Internet to the end-user, including satellite link and dedicated WAN links. The bench provides 5 main services: i) a scenario orchestrator, ii) a satellite link emulator, iii) a satellite switch, iv) a programmable ground network switch, v) a PEP (Performance Enhancing Proxy). The hardware platform is depicted on Figure 2.

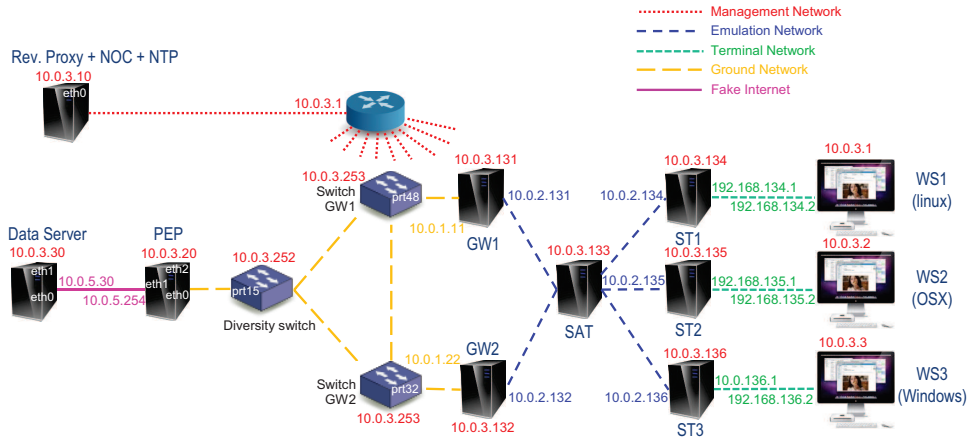


Figure 2: Hardware architecture of the emulator

A. Services and bench control

In order to play any scenario, all servers are managed remotely and host a controller agent in order to offer scheduled operations, which are managed by an orchestrator. This orchestration service enables to send remote commands to all entities. The service is responsible for the whole timing of the switching emulation and is hence designed to have a precision in the order of a few milliseconds. The orchestration service is implemented by a centralized master (where the scenario are defined) and by an agent running on every host. To provide testing material for real applications, a data server (on the ground side) is used. It offers different multimedia services (video streaming, videoconference, file transfer, p2p). The bench is instrumented with evaluation tools to measure the quality of application either on empirical basis (user experience) or through measurable outputs. The bench also implements a set of base protocol performance evaluation tools.

B. OpenSAND

OpenSAND is an open-source satellite emulation test-bed initially developed during the SATIP6 project.¹ Secondly, the development has been continued in the frame of the SATSIX project.² SATIP6 and SATSIX are both European projects. Finally, several CNES research studies have contributed to the enhancement of the test-bed together with internal Thales Alenia Space R&D effort. This framework is currently maintained and enhanced under the control of the French Space Agency, CNES, together with Thales Alenia Space. Current OpenSAND version is providing support for multi-gateway (N gateways are serving a set of terminals with a static and exclusive allocation). Our emulator uses OpenSAND with this functionality and two gateways. OpenSAND emulates a real satellite system, with the different protocols for the access layer (physical, MPEG-TS/ULE/GSE, DVB-S2/DVB-RCS). The scheme for radio resource control are also implemented.

C. Satellite switching implementation

OpenSAND has been modified to include new functionalities related to switching: dynamic allocation of terminals to the gateways, uncorrelated satellite switching of the forward and return link, gateway framework integration to tune the switching scheme design. To enable hot redundancy needed by the diversity scheme, the current emulator management system based on a set of configuration files has been modified. Each

gateway is now storing dynamic information on a distributed NoSQL database, which was interfaced with the original OpenSAND code. A selective replication mechanism of the databases is also used to spread useful information on the different gateways. The gateway behavior was modified to migrate to a more flexible utilization of the configuration parameters. For example, the Login scheme was slightly modified to allow an end-user's session to continue on a gateway if this session was created on another gateway, thanks to real-time parameters exchanges. As a consequence, the backup gateway is able to handle the STs from their original gateway dynamically. The dynamic storage seems a promising contribution to the OpenSAND emulator and it is planned to be made available at the end of the project. The satellite and gateway entities have been modified to be able to process external commands called telecommands corresponding to the switching mechanism. The satellite can now handle four START/END commands to control the switching operations. Two "START" commands initiate the switching process by resp. disabling the forward and the return link with the nominal gateway; Two "END" commands terminate the switching process by resp. activating the forward and return links with the redundancy gateway. The 4 telecommands are applied to the satellite in a logical sequence derived from the satellite switching model. The gateway has been modified similarly as the satellite to handle a set of command related to buffering operations. The principle is to start to buffer all traffic when the switching is started on a dedicated space during the whole duration of the switching and to dequeue when the end-user are receiving the information. As soon as possible, this additional storage will be "unplugged", and the gateway will resume normal operation.

D. Network switching

In addition to the satellite switching, the ground network needs also to be switched from the original gateway to the backup gateway. A SDN-programmable switch has been used. An OpenFlow controller can, on demand, modify the flow towards the Gateway. As explained in the ground switching model, when the switching event is triggered, the flow towards the gateway are tagged with the VLAN of the modified gateway, and the traffic is routed to the redundancy gateway. The switching mechanism is performed at Layer2 level, making it representative of the real switching scheme in a real provider environment.

E. TCP PEP

In order to solve the issue of GEO satellite delay for TCP protocol, PEP mechanisms are usually used. An external PEP software has been integrated to the overall testbed for TCP acceleration. To overcome the PEP synchronization issue raised by the hand-over, a centralized approach is considered. The implementation of the PEP is based on PEPsal,⁶ an open-source PEP implementation.

III. Preliminary results

Figure 3 shows an example of gateway switching, where the following events were triggered manually:

- i) a ping to the Satellite Terminal (ST) from the nominal gateway(GW1), received by the ST
- ii) a ping to the ST from the redundancy gateway(GW2), that should not reach the ST before switching
- iii) a ping from the dataserver, received by the ST through GW1, then through GW2 after the network and satellite switching.

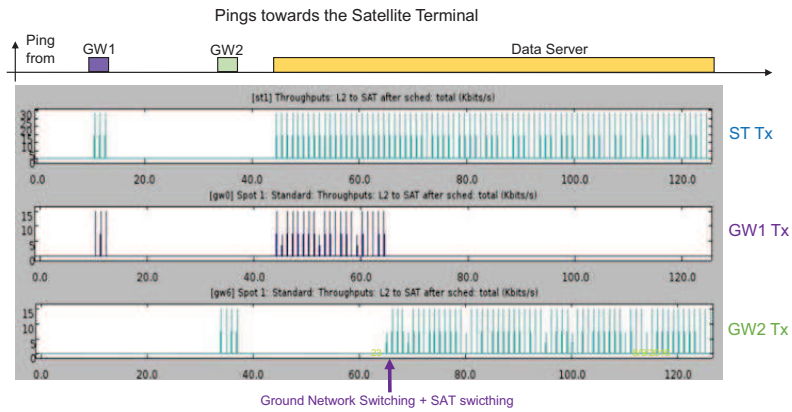


Figure 3: Example of satellite with two gateways during switching event

The initial scenario presented previously can be replayed with our scheduler in order to have a precise synchronization (up to millisecond). The high level steps of a scenario with gateway switching are depicted on Figure 4. These steps enable to control the scenario.

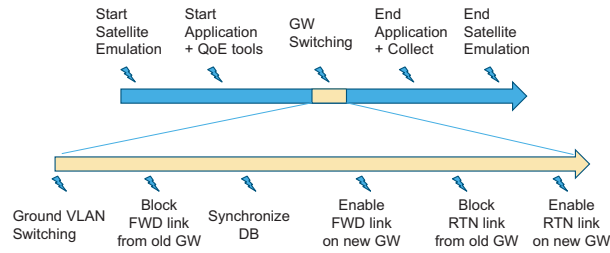
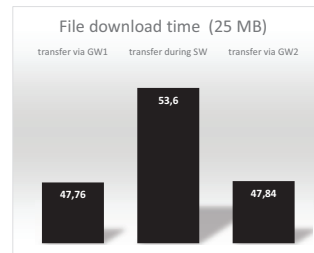
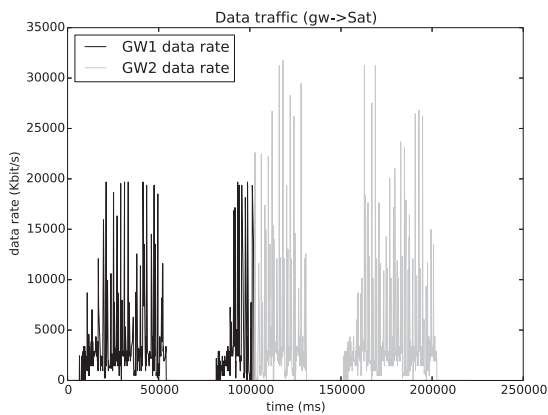


Figure 4: Typical scenario used to investigate the influence of GW switching on end-users applications

The second part of this picture depicts the events associated to the switching mechanisms. The first event is the ground switching event. The DB synchronization step aligns the configuration of the diversity gateway with the nominal gateway. All other events describe the hardware switching on the satellite.



(a) Gateways datarate before and after switching

(b) File download time before, during and after switching

Figure 5: First tests

In order to evaluate the consequences of the switching mechanism on applications, experiments were conducted on our bench, trying to evaluate the download time of typical file small and large file transfers, during a gateway switching, and using various transfer protocols.

The figure 5a shows three identical 25MB file transfers performed through GW1, then during switching event, and finally via GW2. The transfers are performed using the FTP protocol.

The figure 5b shows the obtained results. The gateway switching has increased the duration of the file transfer. The un-optimised switching (without buffering) will encounter data loss and packets will be retransmitted on the application layer initiative. The use of buffer will introduce a delay but will avoid retransmissions that would be very ineffective because of the global satellite link latency.

IV. Conclusion

The diversity emulator bench enables to assess the impact of the gateway switching mechanisms on end-user applications. It offers time accurate and reproducible means to evaluate different switching scenarios with various usage conditions (load, traffic profiles, transmission protocols). These features allow fine tuning of the system configuration, in order to achieve best performance with the objective to provide switching transparency for the end-user. The impact on users experience for different applications will be further analyzed with the same bench and many applications should not suffer from the gateway switching. However, very time sensitive applications like video conference will exhibit noticeable discrepancies on a short period following the switching event. Future works will focus on the optimization of the diversity mechanisms taking into account the interactions between the buffer management and TCP congestion control and the access loop (ACM and radio resource management).

This tools is flexible enough to cover additional system scenarios for example load balancing or mobility uses cases.

Acknowledgments

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