Mobility architectures for DVB-S/RCS satellite networks

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ABSTRACT

In order to offer an appropriate support to the variety of current and future multimedia applications, broadband satellite systems need to support mobility. Mobility is currently an important issue, leading researchers to propose various kinds of solutions. Many proposals already appeared in terrestrial networks, but mobility in a DVB-RCS satellite access network implies new constraints. Due to the delay of one satellite hop for instance, the hand over time seems to be too long for current multimedia distributed applications.

Mobility scenarios depend on the type of mobility (user, terminal, session, network) or its “range” (micro-mobility/macro-mobility).
Using a realistic DVB-S/RCS satellite emulation test bed, experimental results based on multimedia applications traffic profiles have been obtained and analyzed. MIP6 has shown that it is able to maintain connections during the mobility phase, but induces too much latency due to specific satellite constraints. Using HMIP6, it is shown how hierarchical mobility allows reducing the hand over delay in micro mobility context thanks to a limited number (maybe none in some cases) of satellite/earth hops. In macro mobility, SIP-based solutions are able to significantly improve interactivity of real time applications.

The first part of this paper describes DVB-RCS satellite systems and mobility features. The second part deals with mobility in a DVB-RCS satellite system. The third part gives the results of our experimentation of MIP6 on our DVB-RCS emulation test bed and the evaluation results of HMIP6 and SIP scenarios. The last part concludes the paper with future works to be done in IST Satsix Project.

1. Introduction

1.1 DVB-RCS systems architectures

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. Data are 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 can 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 can be retained: UDLR (UniDirectional Link Routing) which emulates a cheap bidirectional solution through a terrestrial return link and DVB-RCS, which provides expensive but full bidirectional satellite architecture.

The return link access scheme in DVB-S/RCS systems is MF-TDMA. The return link is segmented into portions of time and frequency (“super-frames”). 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 super-frame 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).

Thanks to this introduction, Figure 1 gives a good overview of DVB-S/RCS satellite networks architecture, compliant with the architecture adopted within the ETSI BSM [3] group and the DVB-RCS standards. 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.
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.

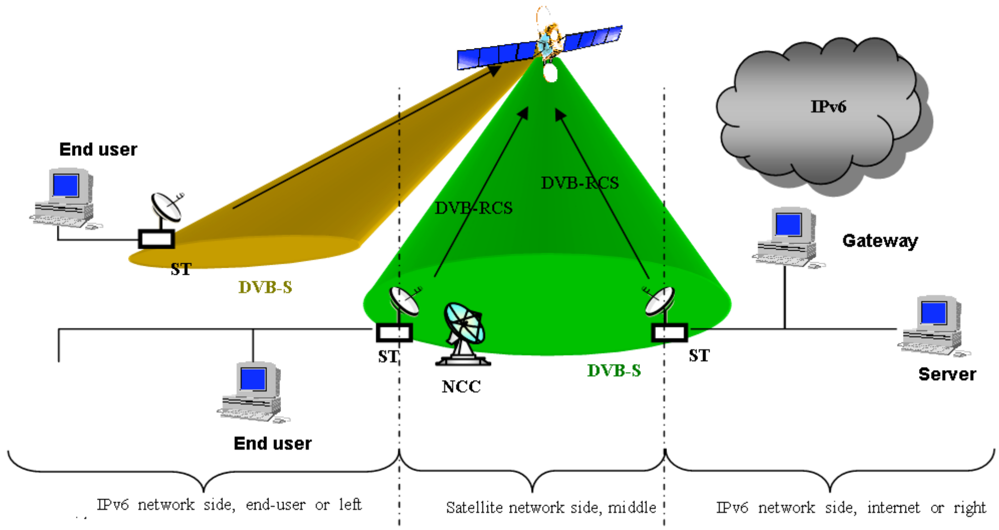

Figure 1 : DVB-S/RCS architecture

So, the 3 main components in the satellite network side (middle) are the Satellite, the Return Channel Satellite Terminals (RCST) and the Network Control Center (NCC)

1.2 Mobility in terrestrial networks

Most of current users of networks and Internet access are interested in mobility support. In terrestrial networks, the main difficulty comes from the IP addressing used in Internet. Designed to enable the connection of fixed terminals, addressing is related to the terminal location. Unfortunately, a mobile terminal is often changing from one network to another one. So, if the initial IP address is used in the new network, it will not work.

This problem may be solved differently according to the kind of mobility to be concerned. Let us consider the following taxonomy:

- User terminal move only:
  - Discrete mobility: the terminal only moves from the network to another one, it is shut down before leaving the first network and will be restarted after being connected to the new one.
  - Continuous mobility: The terminal moves from a network to another one, the terminal power is kept on and the current session are kept available and active during the terminal move.
- Network equipment move also: the network is able to move also and its connection point to Internet may change.

In this paper, only the continuous mobility is considered because it is focused on user terminal move only. Please note also that discrete mobility is simply done by auto-configuration of the moving terminal.

Two sub-cases of continuous mobility may also be defined:

- micro-mobility: the terminal stays in the same IP network, going from one Wi-Fi cell to another one);
- macro-mobility: the terminal moves from one IP network to another, staying in the same IP AS (Autonomous System).

In micro mobility scenarios, upper layer connections often are stopped during handovers even if the terminal is still connected to the same access network. Hierarchical mobility has then been proposed to avoid delays in connection due to layer 2 handoffs. In this scheme, a second level of mobility management is introduced and changes from one WiFi network to another one for instance is solved in a new level called regional level introducing an “local anchor point”.

In macro mobility scenarios, the handover introduced by network changes cannot be avoided. But different kind of anticipated changes can be introduced. The main idea consists of using an registrar in order to know where the mobile terminal is going to connect after moving. In that case, mobility is anticipated and the delay is reduced, setting up the connection changes before the old one is over.

It is then clear that the best solution to a mobility scenario is related to the kind of mobility to be used. It is also proven that the kind of mobility depends also upon the underlying technology used in the scenario. The solutions given above were designed and applied in terrestrial networks. Using satellite systems, transmission delays are very important for instance and terminal moves have high impacts as they need to communicate through the satellite segment to update the terminal connections. A dedicated study is needed to include efficiently satellite access networks in mobility scenarios as it will be shown in then next section.

2. Mobility Architectures and their emulation test beds

2.1 Mobility Implementation in DVB-S/RCS systems

2.1.1 MIPv6 description

Mobile IPv6 (MIP6) first provides the mobile user and his correspondents with a direct communication, avoiding communication resets during user moves, as described in RFC 3775 [2].

Many entities are involved in MIP6 :

- the mobile terminal (called MN : Mobile Node) mainly located in the home network, and moving into a visited network
- the Home Agent (HA), located in the home network of the mobile,
- the correspondent terminal (called CN : Correspondent Node) part of the correspondent network.

MN is an IPv6 terminal, able to move from one network to another one, CN is an IPv6 terminal communicating with MN. HA is a network device managing mobility.

The main idea in MIPv6 is that the mobile will be reachable anywhere at any time using the home address (HoA) it has received from its home network.

Routing is done as usually if the MN is located in its home network. But if the mobile node is in a visited network, thanks to IPv6 auto-configuration, the new MN address is called Care-of Address (CoA) compliant with the visited network addressing. At the beginning of the arrival in a new network, traffic sent to MN is first rerouted by its HA from its home network. The route optimization process will allow as fast as possible to use direct communication between MN and CN. All these steps are shown Figure 2.

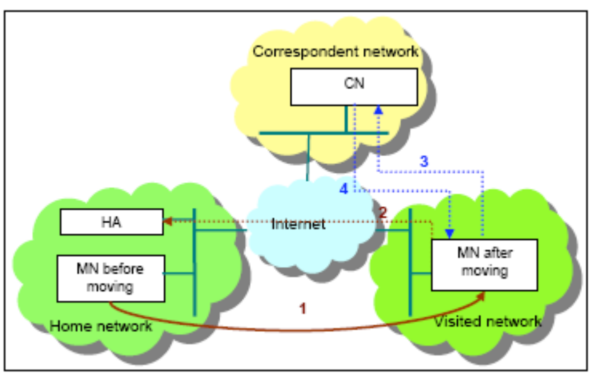

Figure 2 : Communication steps as MN moves (with route optimization)

2.1.2 *HMIPv6 (Hierarchical Mobile IPv6)*

MIPv6 is really inefficient if the terminal often changes its access point to Internet. Each time the terminal moves, each time messages have to be exchanged between MN and HA. If the distance between MN and HA is high compared to the moving distance of the terminal, then the update is implemented by several messages exchanged from MN and HA, introducing high delays due to the transmission delays between HA and MN.

This problem may be avoided using HMIPv6, introducing the concept of a local anchor point, it is able to manage well the short local moves of the terminal inside of an IP domain. HMIPv6 is described in RFC4140 [8]. HMIPv6 designed the MAP (Mobility Anchor Point), a router located in the visited network. It is used as a kind of “local home agent”.

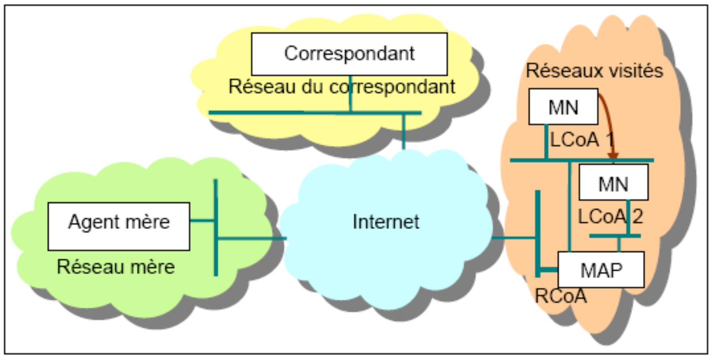

Figure 3 : HMIPv6 principle

When the mobile node is connected to a visited network, MN is given a temporary address given by a local router. This address is called LCoA (Link Care-of Address). Another temporary address is assigned by the MAP to the mobile; this address is called RCoA (Regional Care-of Address). MN is known by its HA using its unique RCoA. This address will change only if the MN moves to another region. If not, a move from a sub network to another one only needs to change the LCoA. This change done by the MAP is transparent to the HA and CN, thanks to the MAP functionality.

2.1.3 *SIP*

SIP (Session Initiation Protocol) protocol is now one of the most important protocols in the Next Generation Networks. SIP defines a URI (Uniform Resource Indicator) such as (sip:gayraud@laas.fr), Session Layer Address. This URI is not linked to the network address (IP address). It allows also the localization of the mobile user.

SIP architecture includes several logical functions such as:

- **Localization Server (LS)** to locate the user agent (UA) mapping one public URI to a set of local URI (sip:gayraud@helios.laas.fr) related to one terminal.
- **Registrar Server (RS)** to provide a database in which the location of the user is stored and modified each time it is needed if the user is moving.
- **Proxy Servers (PS)**, to relay requests from the UA, using he LS and RS in order to find the best URI in all the available URIs.

SIP is able to better manage the move of the user because it is designed to anticipate the move of the user. When it is detected that the MN is now in a new network, then the auto-configured MN sends a new message to its « partners » called **re-INVITE** giving its new SIP address. The receiver sends back an ACK, and then the communication is able to restart normally. Here, the application is able to see that the address has changed. Detailed explanations are available in

2.2 The Satellite System Emulation

This emulation testbed comes from the IST project Satip6. It was then enhanced in a second step by a joint work of LAAS and Alcatel Alenia Space. 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, SIPCommunicator* for Videoconferencing, *VideoLanClient* for Video streaming).

The main blocks in the testbed 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 synchronization and queues according to the authorizations 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).

2.3 Traffic Generation and Measurement

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. A set of traffic generation tools (FLOC+FLORE+FLAN) have been developed to analyze traffic characteristics from real applications, replay traffic traces and measure statistics.

FLOC (FLOw Capturer) is a piece of software used to capture all data transmitted by all connections from a multimedia communication. FLOC creates a tcpdump filter from the 4-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.

FLORE (FLOw REplayer) 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. 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.

FLAN (Flow Analyzer) analyzes statistics from FLORE output files and provides graphics such as 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 and also evaluation of loss rate for each connection distinguishing isolated loss and burst losses.

2.4 Mobility implementation in the satellite system test bed

The previous section has introduced the main components of different proposals to provide users with mobility support.

Concerning MIPv6, the protocol stack has to be available in MN and CN. The HA has to be located in the satellite access network. The usual location is close to the NCC, in the terrestrial segment belonging to the satellite service provider.

In HMIPv6 case, the new component MAP is deployed in the satellite access terminal (ST).

If SIP solution is used, then the specific servers (RS, LS) are located in the terrestrial segment belonging to the satellite service provider and the proxy servers (PS) are located in each ST.

3. Emulation and Evaluation Results

This section deals with the scenarios to be considered to evaluate mobility effects on applications streams.

If we consider all the mobility moves done by the MN, a mobility scenario is always a set of elementary moves given in Table1 below.

	Scenario Number	MN goes from…	To…
Macro-mobility	1a	Home Network	Visited Network
	1b	Visited Network	Home Network
	2a	Home Network	Correspondent Network
	2b	Correspondent Network	Home Network
	3	Visited Network 1	Visited Network 2
	4a	Visited Network	Correspondent Network
	4b	Correspondent Network	Visited Network
Micro-mobility	5	Subnetwork (behind ST1)	Subnetwork (behind ST1)

Table 1 – Elementary moves in mobility scenarios

So the evaluation of mobility has to be done from these elementary moves and then allows the reader to calculate the values related to the mobility case he wants to evaluate.

The results presented in this section were obtained first using theoretical evaluation and in a second step, these results were obtained from the evaluation platform and tools described previously in order to confirm these results.

3.1 Evaluation results

Handoff delays are evaluated using the following equation:

T (Handoff)= T (Layer 2) + T (Layer 3) + T (Messages restart), if :

- T (Layer 2) is due to synchronization, authentication and association delays. This duration is very short related to the over values and will be ignored later.
- T (Layer 3) is the time needed to obtain the new address, including the time to receive a Router Advertisement (RA) and to use DAD (Duplicate Address Detection). In a usual configuration, inter-RA delay is 50ms. As shown in [9], T (DAD) = 1500 ms. So, T (Layer 3)=1550 ms.
- T (Messages restart) is the duration from the stop of the old connection to the restart of the new connection, due to the move of the terminal, introducing the main timing differences between the different proposals (MIP6, HMIP6 and SIP).

If the satellite propagation time is not considered, then the propagation time of a SIP message is shown to be 50ms [10]. If the satellite propagation time is considered, then the propagation time of a SIP message from one network behind a satellite terminal to another network behind another satellite terminal is equal to 300 ms. A MIPv6 message is shorter than a SIP message and it was shown in [11] that this propagation time going through the satellite network is 275ms.

Considering the message sequence to be used in the different scenarios, the interruption times related to the different moves of the user terminal can be calculated.

	SIP		MIPv6 avec RO et RRT	HMIPv6
	no ACK	with ACK		
Scenario 1a	**2.15s**	2.75s	3.20s	**-**
Scenario 2b	0.65s	1.25s	0.65s	-
Scenario 4a	**1,65s**	1,75s	2.15s	-
Scenario 5	2.15s	2.75s	3.20s	**1.60s**

Table 2 – Interruption duration (RO=Route Optimisation, RRT=Return Routability Test)

Table 2 shows clearly that using SIP allows theoretically a better or equal interruption delay in the three first studied scenarios. In the micro mobility scenario, the better delay is obtained with HMIP. So, to optimize the delay, a hybrid solution has to be designed in future work.

3.2 Emulation results

The first measurements have been done using « pings » to evaluate the round trip time MN-CN. In this scenario, MN goes first from its home network to the network of CN and then comes back.

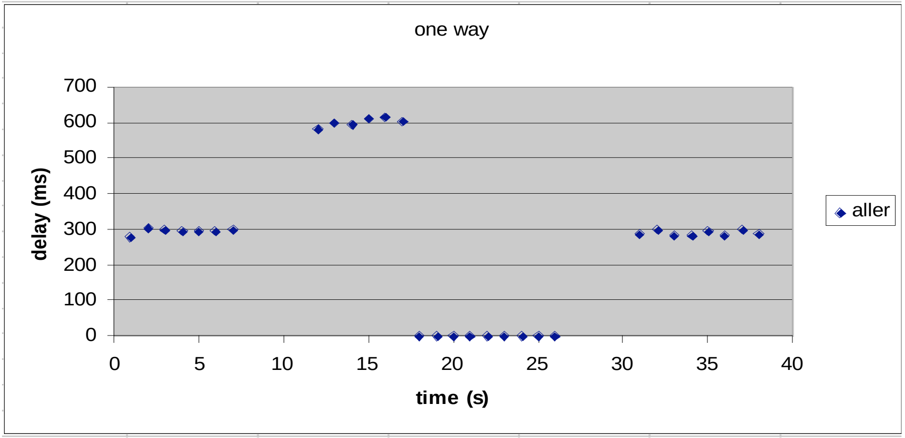

Figure 4 – Ping measurements between MN and CN (RTT)

Figure 4 shows 5 different steps:

1. T ≤ 11s: RTT is around 600 ms, due to 2 satellite hops to go from MN to CN.
2. 12s ≤ T ≤ 14s: packets are lost, the MN is moving.
3. 15s ≤ T ≤ 17s: 3 pings are shown with a RTT around 1200 ms, due to 4 satellite hops, before route optimization is activated (MN to HA + HA to CN + CN to HA + HA to MN).
4. 18s ≤ T ≤ 27s: MN and CN are communicating directly; the RTT is very short (around 0.200 ms).
5. 28s ≤ T ≤ 33s: MN is back in home network; RTT is around 600ms, with 2 satellite hops.

Next experiment is made using Gnomemeeting traffic so that the following figure is obtained.
The time measured here are only one way trip so they are around half from the previous one (RTTs).

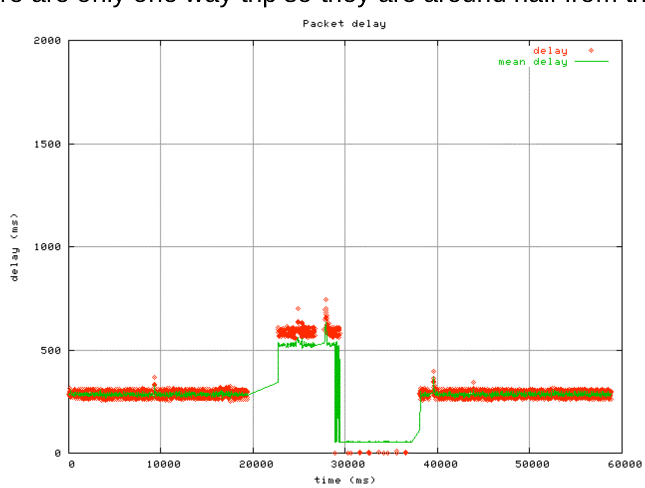

Figure 5 – End to End delay using Gnomemeeting videoconférence

The 5 steps identified previously using ping mechanism may be seen also here.

1. T ≤ 20 s, MN is in home network and CN is in a different network, behind 2 different satellite terminals and the delay is around 250 ms (1 satellite hop).
2. 20s ≤ T ≤ 23s: MN is moving; communication is suspended.
3. 23 s ≤ T ≤ 29s, delay is around 520 ms, route optimization is not already set (2 satellite hops: CN→ HA→ MN).
4. 29s ≤ T ≤ 37s, MN and CN are in the same network and the delay is close to 0 s.

5. 37s ≤ T ≤ 60s s, MN is back in its home network and as the communication restarts, the delay is around 250 ms.

Emulation results are shown to confirm the theoretical calculation, with additional delays and jitters, as expected. So the conclusion given by emulation testbed experiments is quite the same as the previous one, even if we consider MIP, HMIP or SIP.

4. Conclusion and Future Work

These results are really interesting and prove that mobility solutions even if they are designed mainly for terrestrial networks, are also working in a DVB-S/RCS satellite context. Unfortunately, the quantitative results are confirmed by our experiments and delays are long, due to the delays introduced by the satellite system itself. Interruption delays are especially too long, for time constrained streams as those used in multimedia applications. These delays may be reduced if specific extensions are done in the satellite segment.

According to the scenarios, the solution to support user mobility needs may be changed. A new way will consist of using among these different solutions the one which is the most adapted to the situation (HMIP in micro mobility and SIP in macro mobility).

Moving anticipation seems to be helpful in satellite context, minimizing interruption delays, especially with SIP, where it is possible to know where the user will reconnect after the move.

The last point deals with QoS features use in order to take benefits to priority treatment of some traffic class. All these features will be studied in the IST Satsix project.

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