Satcom Access in the Evolved Packet Core

Mirko Cano, Toon Norp, and Mariya Popova

TNO (Netherlands Organization for Applied Scientific Research),
Brassersplein 2 2612 CT Delft, The Netherlands
{Mirko.Cano,Toon.Norp,Mariya.Popova}@tno.nl

Abstract. Satellite communications (Satcom) networks are increasingly integrating with terrestrial communications networks, namely Next Generation Networks (NGN). In the area of NGN the Evolved Packet Core (EPC) is a new network architecture that can support multiple access technologies. When Satcom is considered as another access technology, EPC can provide the multiple access features and to integrate Satcom and NGN services. The current paper outlines the opportunities for NGN and Satcom integration, focusing on the mobility issues between EPC and DVB-RCS standards (representing the Satcom network) under a common Mobile IP based EPC core network.

Keywords: Next Generation Networks, Evolved Packet Core, Satellite communications, DVB-RCS, Mobile IP.

1 Introduction

Satellite communications (Satcom) are emerging in the broadband access market. The development of standards like DVB-RCS [1], that were initially intended for broadcast applications, have expanded the satellite communications market towards more interactive applications such as the Internet access in remote areas or the back up network for disaster scenarios.

There is a general trend in satellite communication to move away from Satcom specific stove-pipe architectures (e.g. Satcom access combined with Satcom specific core network and service architectures) to an integration of Satcom access with Next Generation Networks architectures. Within the concept of a Next Generation Network, the Satcom access will become one of the available access technologies; next to fixed, cellular and wireless access network technologies.

In the area of Next Generation Mobile Networks there is a new network architecture that can support multiple access technologies: the Evolved Packet Core (EPC) network [2]. The EPC is developed by 3GPP as the core network for the new LTE radio interface, but it also supports other access technologies like WiMAX, WLAN, and CDMA.

There are two versions of the EPC. One version is based on GPRS mobility management and is geared to mobility between LTE, UMTS and GSM. The other version is based on Mobile IP [3] technology and is more suited for mobility between LTE/UMTS and access network technologies like WLAN and WiMAX. Integration of Satcom with EPC is a logical extension of the two above trends.

N. Venkatasubramanian et al. (Eds.): Mobilware 2011, LNICST 93, pp. 107–118, 2012.

This paper focuses on how mobility would be supported across a DVB-RCS Satcom and a terrestrial access network, through a common Mobile IP based EPC core network.

2 Scenario

Alfred, who is travelling with his mobile phone in a cruise in the Mediterranean, would like to use his mobile phone for both voice and data services during his trip. Luckily his mobile network operator has an integrated satellite network or has an agreement with a satellite network provider that ensures the continuity of their services.

The mobile phone can connect to both the 4G network (LTE) and WLAN networks, depending on the coverage. When the cellular network coverage is lost, the mobile phone has the capability to switch to WLAN automatically if this network is available.

Alfred embarks the ship and when the ship leaves the port, there is a point when there is no more terrestrial network coverage. Inside the ship there is a WLAN that has access to land based telephony networks and Internet, thanks to the satellite connection. Alfred can make and receive phone calls when connected to the WLAN of the ship. He can also browse the Internet; his user experience is not affected by the change of access technology.

When the ship reaches the cellular coverage again, the mobile phone switches back to the terrestrial cellular network.

Although current technologies allow the mobile phone to switch from/to WLAN under 3G coverage, it is still to be studied how to combine the new EPC network with the satellite network in scenarios like this.

In the remainder of this paper, the feasibility of an implementation of the above scenario will be examined.

3 Technical Overview

3.1 DVB-RCS/C2P/Satellite Networks

Satellite Networks are widely used for commercial and governmental applications. The currently deployed satellites generally do not have any on-board digital processing, and the ground terminal basically uses the satellite to reflect its transmission to the coverage area (beam). Traditionally, the beam covers both the destination and also the transmitting terminal (single beam).

In other words, these satellites are classified as *transparent satellites*; they are either a bent-pipe satellite or a satellite that is able to perform physical layer switching without demodulation of the signal. *Regenerative satellite* is the term for satellites that include an on board processor, involving demodulation and capability of processing the data stream.

Within this paper, the role of the satellite is only to transmit the signal (i.e. a transparent satellite), since on board processors are not yet widely deployed and it is still unclear to what extend it will be deployed in the future.

As a representative of Satcom communications in this paper we chose DVB-RCS [1]. DVB-RCS is currently in the scope of the main activities of the European Space Agency (ESA) and standardization bodies such as ETSI with regards to the integration of Satcom and NGN, including the work towards the next DVB-RCS2 version of the standard. Also the DVB-RCS standard, together with the C2P protocol [4], provide the functionalities that are needed to bring further the topic of the satellite and terrestrial interworking.

DVB-RCS was recently updated with the DVB-RCS+M version, which provides support for a variety of types of terminals including mobile and nomadic terminals. In addition to this, it provides enhanced support for direct terminal-to-terminal communication (mesh connectivity).

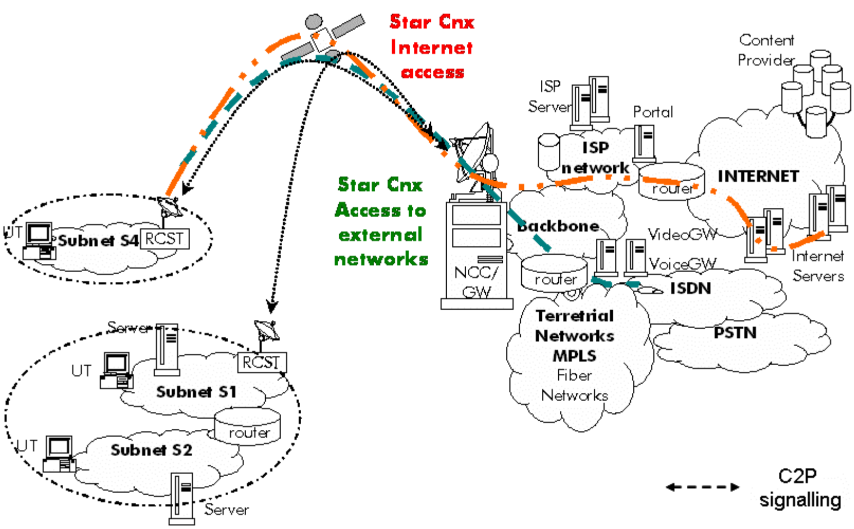

Fig. 1. Star Transparent Network Reference Scenario [4]

In DVB-RCS, any terminal can directly communicate with a specific hub (e.g. localised in the terrestrial network) and via the hub to the other terminals (e.g. with other ships, trains and so on). The management of the satellite connection is realized via (see Fig. 1):

- **The Network Control Center (NCC)** controls the satellite network, provides session control, routing and resource access to the subscriber RCSTs.
- **The Return Channel Satellite Terminal (RCST)** is the interface between the System and the external users. It can have different equipment attached to it, like a WLAN router.

– **The Regenerative Satellite Gateway (RSGW)** provides interconnection with terrestrial networks (e.g. Internet or in our case EPS). At the same time it manages all its subscribers, guaranteeing their Service Level Agreement. Since it is acting as the interface with the terrestrial sources, it supports Generic Routing Encapsulation[1].

In Fig. 1 we can see the generic view of an Interactive Network (formed by the RCSTs and the NCC), where a star configuration is represented. The NCC/GW can be located anywhere geographically as long as it is within the satellite beam. The RSGW would be located where the NCC is in the figure, acting as a bridge between the Satcom network and the terrestrial network.

The subscriber RCSTs work as routers in front of the final user terminals and provide IP connectivity, QoS, security and multicast facilities.

The connection control requires the usage of a signaling protocol between the satellite terminals and the Network Control Center (NCC). The Connection Control Protocol (C2P) provides this interaction between RCSTs/RSGWs and NCC to support set-up, modification and release of connections and channel bandwidth modification.

DVB-RCS defines an Interactive Network as a group of RCSTs and a NCC. There will be one unique NCC per Network. The NCC is in charge of executing control and management plane functions for the interactive network, while a co-located GW is in charge of executing user plane functions.

The DVB-RCS Terminals (RCSTs) provide the interface with the end users equipment. The RCSTs transmit bursts according to the DVB-RCS air interface standard and receive a forward link based on the DVB-S/S2 air interface standard.

In a star transparent network the communication between Return Channel Satellite Terminals (RCSTs) and Network Control Centre (NCC)/Gateway (GW) is based on a transparent satellite. In a mesh scenario, the RCSTs are capable of receiving DVB-RCS return signals transmitted by other RCSTs in addition to the DVB-RCS/S2 signals transmitted by the NCC/GW, allowing single-hop mesh communication between RCSTs.

The Regenerative Satellite Gateway, RSGW, provides the RCSTs internetworking capabilities to external networks such as Internet and PSTN (or EPS in the case we are studying). Furthermore, the RSGW provides QoS support such as service differentiation, QoS guarantees and traffic shaping.

3.2 The Evolved Packet System

EPS (Evolved Packet System) (see Fig. 2) is the evolution of the current mobile networks. It is formed by a new access radio network, LTE (Long Term Evolution)

---

[1] **Generic Routing Encapsulation** (GRE) is a protocol designed for performing tunneling of a network layer protocol over another network layer protocol (e.g. IP). It can encapsulate a wide variety of network layer protocol packet types inside IP tunnels, creating a virtual point-to-point link to various brands of routers at remote points over an Internet Protocol (IP) internetwork. It is used for example, in EPS mobility.

and a new core network, the EPC (Evolved Packet Core). A main characteristic of this system is that it is all based on IP protocols, removing the dependency on the previous circuit switched networks. The new all-IP network brings about a reduced number of nodes, better capacity and performance, and lower latency. Furthermore, it is backwards compatible, supporting previous mobile technologies (2G, 3G, HSPA).

Another important feature of the EPC is the capability to interwork with other access networks [5]: WiMax, WLAN, et cetera. EPC defines the mobility and connectivity with these systems (based on Mobile IP protocols).

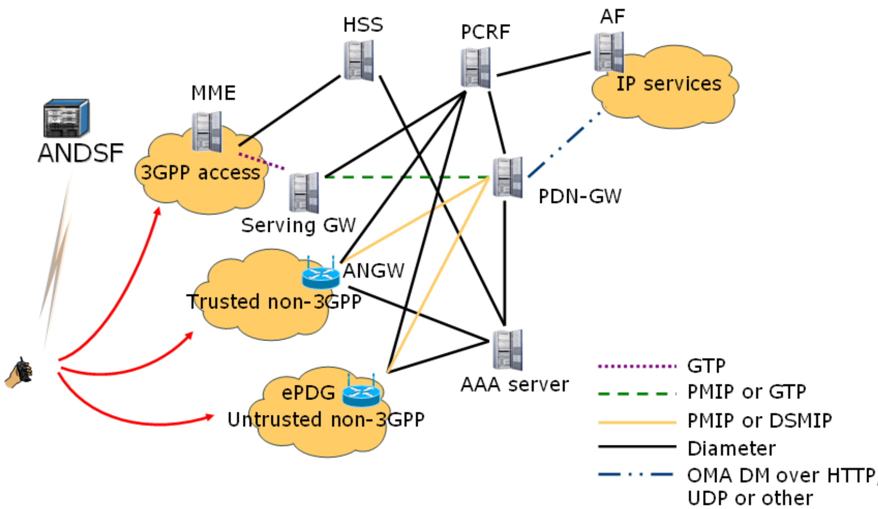

Fig. 2. Evolved Packet Core (EPC) general overview

The PDN-GW is the mobility anchor between 3GPP and non-3GPP accesses. It performs:

- User Equipment IP allocation
- Policy enforcement
- Per user packet filtering
- Charging support
- Lawful interception
- Packet screening.

The UE (User Equipment) can discover new access networks in the vicinity through the ANDSF (Access Network Discovery and Selection Function).

EPC is connected to various access networks through peripheral gateways, referred generically as Access Networks Gateways (ANGWs). They constitute the interface between the access networks and the Evolved Packet Core performing IP address allocation, mobility functions, QoS enforcement functions, et cetera.

4 IP Mobility and the Evolved Packet Core

The basic IP stack does not provide support for mobility. Problems arise when the UE moves and attaches to different networks acquiring different IP addresses, so packets destined to the UE's old IP address will not reach it and get discarded.

Mobile IP protocols [3] provide support for session mobility. With MIP the UE can change its point of attachment while maintaining its IP address for current transport sessions. The Home Agent (HA), in the Home Network, maintains the binding between both the local IP address and the IP address in a foreign network (called Care of Address or CoA). The role of the HA will be taken by the PDN GW of the EPC network in our scenario. When the UE attaches to a foreign network, it sends its new Care of Address to the Home Agent, which maintains the binding between the home address of the UE and the Care of Address. This way, the HA can route the packets to its destination when another UE (Correspondent Node) wishes to contact the mobile user (Fig. 3).

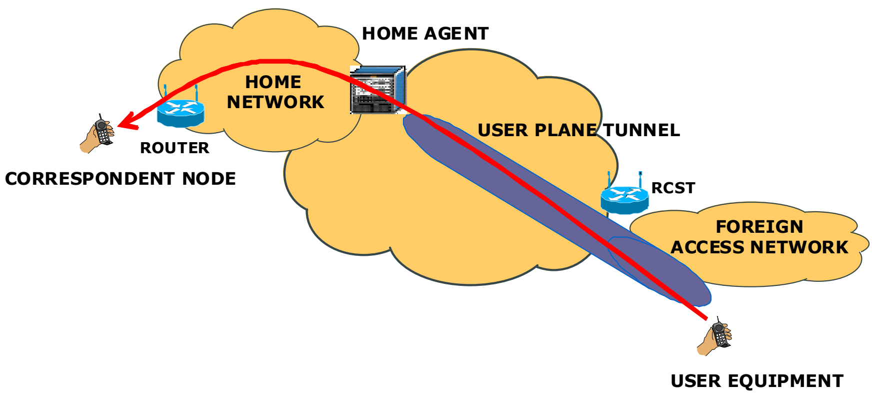

Fig. 3. Mobile IP concept

There are different variants of MIP, but we will focus on two of them: DSMIPv6 (Dual Stack MIP) [6] and PMIPv6 (Proxy MIP)[7], since both are supported by the EPC.

Dual Stack Mobile IP supports both IPv6 and IPv4. Although IPv6 will be introduced gradually, it is expected that IPv4 networks will still be present for some time. In EPC, the philosophy is that IPv6 is mandatory and IPv4 is optional, so it supports both IPv6 and IPv4. The foreign access network can be easily configured to support both IP versions as well. In case that the Satcom network between the home network and the foreign network supports only IPv4, the IPv6 packets from the UE are encapsulated in IPv4 packets. This does not mandate the RCST to support IPv4 since DSMIP can handle both versions of the IP protocol. The requirement that is imposed by DSMIP is that the UE must have an IPv6 Home Address in the EPC network. In case that IPv4 is used throughout all the access networks, EPC can support the use of MIPv4 as well [8]. In MIPv4, the Foreign Agent (FA) is the router that provides mobility services to the UE and where the UE is also registered (in the foreign access network).

Proxy MIPv6 (PMIP) shares a lot of things with MIPv6; the main difference is that it is a network-based mobility protocol, meaning that the UE is released from the mobility procedures and it doesn't need to have any mobility protocol implemented. Another entity, called the Mobility Access Gateway (MAG), acts on behalf of the UE as the Mobile IP client. In our scenario the RCST would perform this role. The Local Mobility Anchor (LMA) maintains the binding between the Home Address of the UE and its current point of attachment (the IP address of the MAG), see Fig. 4. The role of the LMA is very similar to the Home Agent in MIP, and it would also be performed by the PDN GW.

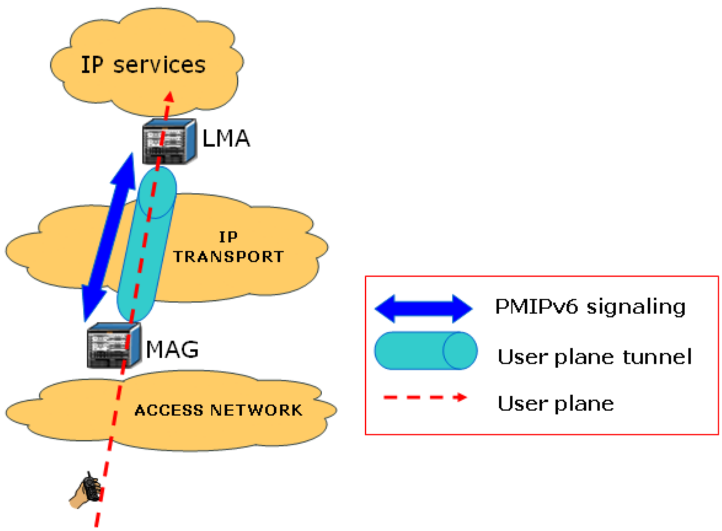

Fig. 4. Proxy Mobile IPv6 concept

The MAG makes sure that the UE gets the same IP address (Home Address) and other IP configuration so that the UE is not aware at IP level that it has changed the network. In order to do this, the LMA establishes a bidirectional user plane tunnel with the MAG. The MAG informs the LMA about its IP address (CoA) when the UE registers into the new network, and gets the information of the Home Address of the UE in response.

PMIPv6 supports dual-stack enhancements, so the foreign access network could be IPv4 only and IPv6 messages would be then encapsulated.

5 Mobility across DVB-RCS and EPC Networks

Fig. 5 depicts the architecture for mobility across the terrestrial network and the Satcom network. The architecture consists of three IP networks interworking with each other, detailed in the following sections.

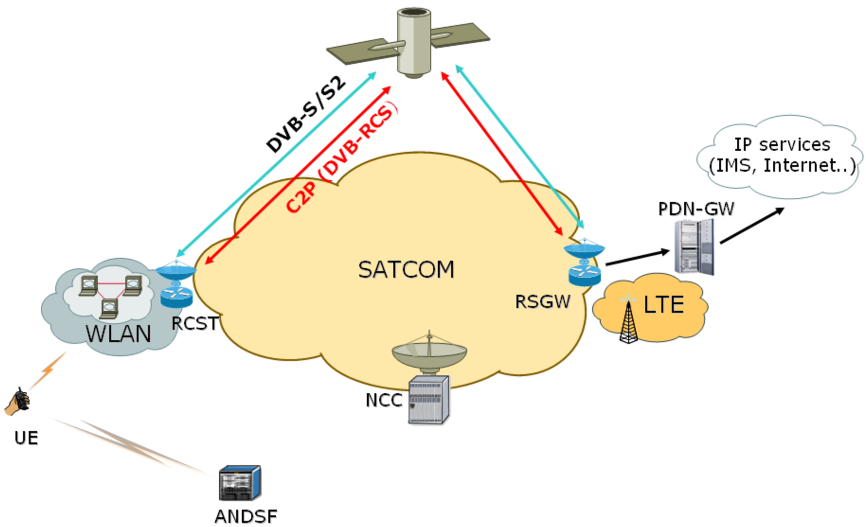

Fig. 5. System architecture EPC in combination with Satcom

In the proposed architecture we assume that the satellite has no on board processor. In other words, we are considering *transparent satellites* in this scenario.

The moving vehicle (ship, train, etc...) is not expected to move beyond the beam of the satellite (geographic extension that it is being covered). The beam of one satellite generally spans a very large geographic area. Switching between satellite beams would require a switch between two different satellites to ensure session continuity, which is not something we have considered in this paper.

The UE is makes use of the Evolved Packet Core as long as there is cellular coverage. When this coverage is too weak or lost the UE switches to the WLAN. In this network, the RCST assigns a local IP address to the UE. The UE continues sending and receiving IP packets, but these are now delivered through the RCST. The RCST encapsulates the packets and sends them through the satellite access network by making use of the DVB-RCS protocol. The DVB-RCS protocol has a return channel that can be used to receive the data destined to the UE.

There are two kinds of mobility to be considered here:

- The mobility of the RCST, which switches from the terrestrial network to the satellite network and back. This mobility is handled with the DSMIPv6 protocol. The PDN GW would keep track of the RCST mobility.
- The mobility of the UE, which switches between the LTE network and the WLAN. This mobility is handled with the PMIPv6 protocol. The RCST would act as a proxy on behalf of the UE, whereas the PDN GW would keep track of the mobility of the UE as well.

Once the packets reach the other end, the RSGW, they are de-capsulated and sent to the PDN-GW. In case that the UE in the WLAN is sending data to another UE in the terrestrial network (Correspondent Node), the PDN-GW makes sure that the packets reach their destination on both sides by keeping the binding between the home IP address and the WLAN IP address of the UE that is moving.

The RCST in the moving LAN acts both as a gateway and as a RCST (endpoint in the satellite network). The RCST receives broadcasts via DVB-S or DVB-S2, and it sends data by using the return channel and the C2P protocol specified in DVB-RCS.

The RSGW acts as the link between the satellite and the terrestrial network. It receives the IP packets from the moving network and forwards them after des-encapsulating, to the PDN GW via the standardized interface S2a (being either DSMIP or PMIP the protocol used). The RSGW works as the Access Gateway in 3GPP terms, serving as the link between both networks. The interface with the PDN GW has to support both DSMIP and PMIP, in order to serve the two kinds of mobility: the RCST mobility in DSMIP and the UE mobility in PMIP.

The interface between the RSGW and the PDN GW (S2a) is based on PMIP. There is also an interface between the UE and the PDN GW based on DSMIP (S2c). These messages have to be encapsulated and delivered through the Satcom network as well.

The PDN Gateway acts as a Home Agent (HA) as specified in MIP, or Local Mobility Agent (LMA) in terms of PMIP, storing the IP Home address of the RCST in the mobile network and its IP assigned by the satellite network (Care of Address). In this way it keeps track of the RCST wherever it is attached. It also stores the IP home address of the UE in order to forward the packets that are sent to the terminal when it is attached to the mobile network.

5.1 The Moving Network (LAN/WLAN)

The issue of a moving network has been widely studied [9], with some of the solutions leading already to the definition of the Mobile IP protocols. Nevertheless, in this case we need to make some new considerations since we have a moving element moving in and out of a moving network.

The means of transportation studied in this scenario, a ship, a train, a car, etc…has implemented a Local Area Network. The UE attaches to this network when the terrestrial network (LTE) is no longer available. This requires from the UE that it has a dual WLAN/LTE mode in order to switch between these networks. The UE switches according to the network conditions (e.g. coverage) or to the policies of the network operator (e.g. “switch from WLAN only when LTE is available” or “switch to WLAN only when no 2G/3G/LTE network is available”).

The gateway of the network is the RCST, which acts both as a router and as an end point for the Satcom network. It also implements PMIP for the mobility of the UE, and DSMIP for its own mobility when it attaches/detaches to the terrestrial network. It also performs the switching according to some predefined policies that can be static.

The scenario of this moving network does not differ too much from what is described in the NEMO (Network Mobility) [9]. Mobile IP protocols (DSMIP and PMIP) are used in order to support the mobility of both the UE and the RCST. The

RCST stores the IP addresses of the terminals attached and it activates a flag on the IP header along with the IP prefix of the network to the PDN GW in order to communicate that it is a mobile router or proxy instead of a UE (as specified in NEMO [9]). It also distributes the IP packets destined to each of the terminals attached to the WLAN.

5.2 RCST Mobility

The RCST acts both as a router and as an end-point in the satellite network (see Fig. 6). When the RCST is connected to the terrestrial network (e.g. when the ship is in the port or the train is in the station), it behaves as an UE registered in the EPC network. It also behaves as a member of the WLAN, so it has multiple interfaces, for both WLAN and the satellite network.

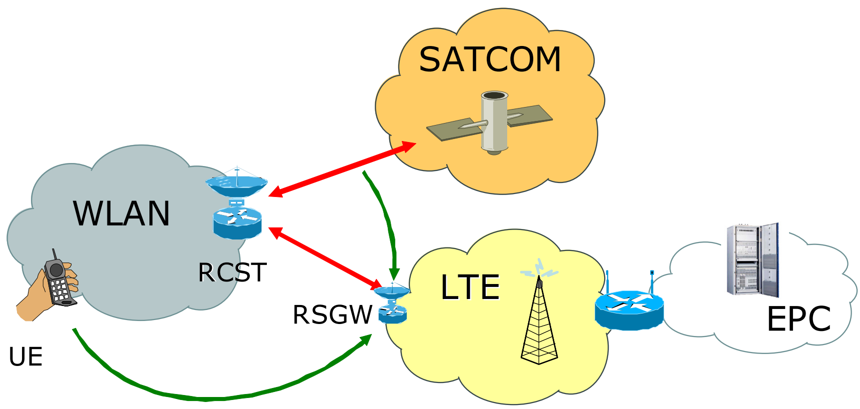

Fig. 6. RCST and UE mobility

When the RCST moves outside the coverage of the terrestrial network, it switches to the satellite network. The RCST in this case is connected to the RSGW that bridges the communication towards the PDN GW of the terrestrial network maintaining the IP connectivity. The mobility is handled by using DSMIP, a host-based protocol, so the RCST needs to have implemented the necessary software to support the protocol.

The RCST, as mobile equipment, sends its Care of Address (CoA) to the PDN GW, which keeps a table with the Care of Address and the original IP address of the RCST (Home Address). The PDN GW, or the Home Agent in MIP terms, sends the packets addressed to the RCST (via the RSGW) and/or the UE that is in the WLAN.

The PDN GW keeps track of the mobility of the moving WLAN, since every time the RCST attaches to a different network, it sends a BIND UPDATE message to the PDN-GW. Generic Routing Encapsulation encapsulates the packets that are sent through the Satcom network. They are later de-capsulated in the RSGW.

5.3 User Equipment Mobility

The UE is not aware of the mobility of the network. This means that it does not need to have implemented any mobility mechanisms. The procedures are simplified since a proxy, in this case the RCST, handles the work on behalf of the UE. The protocol that fits better here is PMIP.

The RCST acts as a proxy, it stores the original IP address of the UE and sends its own IP address to the PDN GW (LMA, or Local Mobility Agent in PMIP terms). The PDN GW knows about the RCST address and is aware of delivering the packets destined to the UE to that address.

The UE can switch back to a terrestrial network once it detects the coverage of a 3GPP network. It can also discover the available networks through the Access Network Discovery and Selection Function (ANDSF), as detailed in [5]. The Access Network Discovery and Selection Function can be used by the UE to understand the operator policies with regards to handover, for example whether to stay in the 3GPP network or switch to the WLAN in the ship or vice versa.

5.4 Quality of Service

With regards to the interworking between Satcom and EPS, the most important application is undoubtedly the Voice over IP (VoIP) service. DVB-RCS is mature enough and reliable to provide with VoIP transport. With the addition of QoS differentiation VoIP can have precedence to the available bandwidth when the up-link is congested. Dynamic resource allocation of bandwidth brings both satisfactory QoS for voice and maximizing bandwidth utilization.

However, there is still a lack of common design for the IP telephony features and applications over satellite, and for the Radio Resource Management and QoS that support VoIP. Standardisation activities should find optimized solutions for protocols, inter-working techniques and QoS mechanisms in this scenario.

Achieving end-to-end QoS is also a challenge, which would imply studying the mapping and interworking of the mobile terrestrial techniques (e.g. QCI in EPS) and satellite network techniques (dynamic bandwidth allocation). This is complicated by the fact that nowadays there is no standardized end-to-end QoS technique, since most satellite Bandwidth on Demand algorithms are proprietary.

It is also worth considering the inclusion of the Policy and Charging Control (PCC) framework [10], which is already an important part of the EPS and IMS systems, for a more dynamic QoS control of the sessions. For instance, one approach would be to implement the Bearer Binding and Event Reporting Function (BBREF) functionality in the RSGW, as specified in [5], to make the EPC system aware of session events (e.g. disconnection). Policies could be enforced in the RSGW, although this would need a standardized interface between the RSGW and the Policy and Charging Rules Function (PCRF). This possibility is being currently studied in ETSI SES (Satellite Earth Stations and Systems) BSM (Broadband Satellite Multimedia).

6 Conclusions

In this paper we have proposed a possible solution for the scenario of a Satcom network interworking with an EPS network in order to keep the IP connectivity when a mobile UE is switching between both.

Mobility between EPS and non-3GPP networks has been already specified in the standards, although the satellite network has not been considered yet as a possible access network to interact with the Evolved Packet System.

The solution comprehends using a double tunneling of PMIP and DSMIP protocols that cover the mobility of the wireless router/Satcom endpoint and the mobility of the UE. In both cases the PDN GW in the terrestrial network acts as an anchor that keeps the binding between the home address of the UE and the local IP address (CoA) in the WLAN. The IP packets are encapsulated and sent through the satellite network by using the DVB-RCS protocol.

Further work on the integration of DVB-RCS with the Evolved Packet Core is needed. Especially in the area of policy and QoS control there is further work to do. To get some more practical feedback on the challenges of integrating an EPC with a DVB-RCS access, we are planning to implement a test network that combines an Evolved Packet Core trial environment with a simulated DVB-RCS link.

References

1. ETSI EN 301 790 Digital Video Broadcasting (DVB): Interaction Channel for satellite distribution systems
2. 3GPP TS 23 401 General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Radio Access Network (E-UTRAN) access
3. IETF RFC3775 MIPv6
4. ETSI TS 102 602 Satellite Earth Stations and Systems (SES); Broadband Satellite Multimedia; Connection Control Protocol (C2P) for DVB-RCS
5. 3GPP TS 23 402 Architecture enhancements for non-3GPP accesses
6. IETF RFC 5555 DSMIPv6
7. IETF RFC 5213 PMIPv6
8. IETF RFC5844 PMIPv6 over IPv4
9. IETF RFC3963 Network Mobility (NEMO) basic support protocol
10. 3GPP TS 23 203 Policy and Charging Control architecture
11. Satcom Integration with IMS based Core Networks: Nokia Siemens Networks, SES Astra, `http://telecom.esa.int/telecom/www/object/index.cfm?fobjectid=28885`
12. Satcom Integra Multi-service IP next generation satellite networks: Thales Alenia Space, Ericsson, `http://telecom.esa.int/telecom/www/object/index.cfm?fobjectid=29662t`
13. Olsson, M., Sultana, S., Rommer, S., Frid, L., Mulligan, C.: SAE and the Evolved Packet Core: Driving the mobile broadband revolution. Academic Press
14. ETSI TR 101 895 Satellite Earth Stations and Systems: Broadband Satellite Multimedia. IP over satellite