Network-Based Mobility with DVB-RCS2 Using the Evolved Packet Core

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Abstract. The network of the future consists of a combination of different access networks, each providing a level of network availability and mobility suited for a wide range of applications. Mobile network developments culminated in work on the E-UTRAN and Evolved Packet Core (EPC) network and can provide mobile broadband access to many citizens. However; the reach of these or other networks leaves remote and rural areas without network coverage, even in Europe. Satellite communication networks traditionally have a strong position in serving remote and rural areas and can potentially fill the gap. On the other hand, satellite communications can benefit from technology reuse by aligning with mobile standardization initiatives. The work presented in this paper describes how DVB-RCS2 satellite networks can be connected to the network-agnostic EPC to achieve network-based mobility with terrestrial mobile networks. We identify challenges and propose optimizations to improve the integration.

Keywords: LTE, DVB-RCS, EPC, mobility.

1 Introduction

The network of the future consists of a combination of different access networks, connected to an IP based core network, and each providing a level of network availability and mobility suited for a wide range of applications. The initiative of the 3rd Generation Partnership Project (3GPP) to define a competitive mobile network for the long term resulted in LTE or "Long Term Evolution". This standardisation effort includes both a new radio access network (evolved UMTS terrestrial radio access network, or E-UTRAN) [1] and a packet core network ("Evolved Packet Core", or EPC) [2] which supports mobile services over multiple access technologies, and has found broad industry acceptance.

EPC is a multi-access, multi-service architecture that includes policy and QoS control, charging, and service continuity functions under control of a core network operator. Supported access networks include both 3GPP access networks such as E-UTRAN and non-3GPP networks like WiMAX, WiFi and wired networks.

The EPC builds on established Internet standards from the IETF, applied in an operator environment. It supports both client-based and network-based mobility

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between 3GPP and non-3GPP access networks. Charging, policy and QoS control are supported through the Policy and Charging Control (PCC) architecture [3], which provides an access-independent framework to control and monitor access network resources.

In satellite communications, DVB-RCS [4] is the only multi-vendor VSAT standard for interactive service access. DVB-RCS2 [5] is the successor of DVB-RCS of which the lower and higher layer specifications were recently approved by the DVB Project, and formal standardization is planned through ETSI early 2012.

DVB-RCS2 provides improvements on all layers compared to the first DVB-RCS set of standards. It has native support for IPv6, improved performance, enhanced security and QoS control. The forward channel is based on the DVB-S2 specification [6] for efficient transport of IP traffic, and higher layer protocols draw heavily from IETF standards. These improvements and a standards-based approach, combined with wide coverage make DVB-RCS2 a viable access option in the future IP networks. For example, it can connect underserved remote and rural areas as a complement of terrestrial mobile networks. Sharing a common packet core network offering mobility management, secure communication and QoS control would aid integration and promote technology reuse.

The work presented in this paper describes how DVB-RCS2 satellite networks can be integrated with the EPC to achieve network-based mobility with terrestrial mobile networks. We identify challenges and propose optimizations to improve the integration, for which an illustrative scenario is considered (adapted from [7]): a dual-radio terminal serves as a network gateway towards a mobile backhaul (e.g., a backhaul for a WLAN in a train). When the terminal has cellular network coverage, it is connected to E-UTRAN; otherwise it performs a handover to a DVB-RCS2 network.

First we describe network-based mobility features of the EPC in section 2, followed by the policy and control features in DVB-RCS2 in section 3. Section 4 then describes the integration of the two networks, and we conclude in section 5.

2 EPC and Network-Based Mobility

A high-level overview of the EPC is depicted in **Fig. 1**, including both 3GPP and non-3GPP access networks. Non-3GPP accesses can be “trusted” or “untrusted”, where untrusted access networks require the operator to deploy an evolved packet data gateway (ePDG) that ensures authentication of the user equipment (UE) and secure access to the EPC. For trusted accesses the EPC relies on the access network for providing appropriate security mechanisms. A packet data network gateway (PDN GW) is responsible for IP address assignment, and connects to a serving gateway (SGW) and access gateway (AGW) in the 3GPP and non-3GPP access networks, respectively. The policy and charging rule function (PCRF) is part of the PCC architecture and is a policy decision point for QoS enforcement and gating by both the policy and charging enforcement function (PCEF) in the PDN GW and the bearer binding and event reporting function (BBERF) in the access network gateways. For profile access and authentication, authorization and accounting (AAA) the home subscriber (HSS) and 3GPP AAA servers are used.

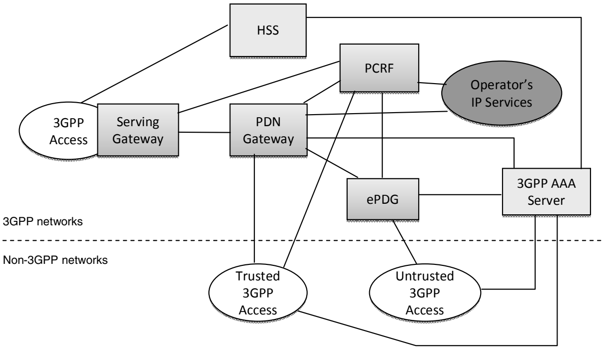

Fig. 1. The EPC architecture [8]

The EPC includes two mobility protocols for handovers between 3GPP and non-3GPP access networks: DSMIPv6 [9] for client-based mobility and PMIPv6 [10] network-based mobility. In this paper we focus on network-based mobility management.

The PDN GW implements a local mobility anchor (LMA). In the access network there is a functionality called the mobile access gateway (MAG). The MAG sends binding updates to the LMA on behalf of the UE. When the UE attaches to another access network the MAG makes sure the UE keeps the same IP address and that the LMA knows where the UE is now attached. To be able to uniquely identify a UE across multiple access networks (each could implement its own identification mechanism), 3GPP has introduced a network-access identifier (NAI) based on the international mobile subscriber identity (IMSI) for all PMIPv6 interfaces.

The 3GPP standards describe how a handover is performed from a 3GPP to a trusted non-3GPP access network using PMIPv6. First the UE is attached to a 3GPP access network (e.g., E-UTRAN). When a supported trusted non-3GPP access network is discovered the UE can initiate a handover based on mobility policy rules. The handover starts with non-3GPP attachment procedures, after which the authentication procedure starts based on the improved extensible authentication protocol method for 3rd generation authentication and key agreement (EAP-AKA') [11]. When the UE is authenticated, the UE can trigger an attachment on the network layer (IP), for instance a DHCP request. This triggers the policy control system in the trusted non-3GPP access network to contact the PCRF in the EPC. After this step the PMIPv6 proxy binding update is sent by the MAG in the trusted non-3GPP access towards the LMA in the PDN GW, and the policy control function in the PDN GW contacts the PCRF. The address of the associated PDN GW is registered in the HSS, and the LMA sends a proxy binding acknowledgement towards the MAG. At this moment the PMIPv6 tunnel is created. Optionally, extra policy rules can be provisioned in the trusted non-3GPP access network. This concludes the network layer attachment of the UE which now has an IP address assigned, and the connection to the 3GPP access network is released.

Note that for the support of network mobility (i.e. mobility of not just one host but an entire network segment for which the UE is the network gateway) work is ongoing in the IETF on NEMO [12], which is an extension of the DSMIPv6 (client mobility) standard that not only delivers address mobility for one host, but does this for a complete IP network. More recently an Internet Draft was published [13] describing the use of NEMO-like capabilities in combination with PMIPv6.

Now that we have described the high-level procedures for handovers using network-based mobility in the EPC, the following section elaborates the DVB-RCS2 network focusing on network attachment to be able to perform a handover using the EPC.

3 DVB-RCS2

DVB-RCS2 can be used in different network topologies of which the transparent star topology is most common. A satellite network operator can divide its network into one or more virtual networks which are assigned to one or more virtual network operators. An active RCS terminal (RCST) can be a member of only one virtual network. For simplicity we consider a DVB-RCS2 network relative to such virtual network (i.e. we do not consider the existence of multiple (virtual) operators in the same physical network). The RCST connects to a network control center (NCC) to get access to and request resources from the satellite network. The NCC manages the network resources and distributes the real-time network configuration using the DVB-S2 forward link. The transparent gateway (TS-GW) is the function forwarding user traffic to and from the satellite network (often collocated with the NCC), and the network management center (NMC) provides overall management of the network elements (including service level agreements assigned to a RCST). The DVB-RCS2 specification is split in a lower layers (MAC and below) and higher layers part. Below we discuss network attachment and QoS procedures in a DVB-RCS2 network relevant for the handover procedure.

When a RCST wants to attach and logon to the network it first initializes the physical layer such that it can receive network information and configuration from the NCC through DVB-S2. When the information is received and processed by the RCST it can send a logon request to the NCC. It then enters a negotiation phase which on success will complete initialization of the lower layers and puts the RCST in an operational state (called the TDMA Sync state). Typically 2 to 4 protocol exchanges are needed to get to this state which completes MAC layer attachment, each exchange incurring latency of around 500ms due to propagation delays. When the logon is accepted the RCST receives several descriptors in the terminal information message (TIM) sent by the NCC: for example a descriptor with unsolicited timeslot allocations, or a list of request classes that describe lower layer services and their restrictions.

The RCST can request additional resources using solicited allocation which are mapped to request classes. It can use these network resources for higher layer initialization (e.g., request for an IP address using DHCP).

The RCST uses an IP classification table and higher layer service (HLS) mapping table to map IP traffic to request classes. These tables are provisioned by the NMC using management commands (not part of the logon procedure). A higher layers initialization descriptor is used to be able to boot the higher layers by the NCC at logon. For user traffic interfaces a DHCP option descriptor can be included in a TIM which for each MAC interface can provide configuration information. The supported DHCP options can be advertised by the NCC in a TIM broadcast (TIM-B) message received by all terminals (as opposed to a TIM unicast or TIM-U message which is designated to a specific terminal). The RCST requests for specific DHCP options in the logon request. A subsequent higher layer DHCP exchange is needed to obtain an IP address for the interface.

In an operational state (after a successful logon) the NCC can force the RCST to disable transmission, after which the RCST enters a standby state. The forward link is kept in an operational state during standby, while the RCST ceases transmission and associated network resources are released. In order for the RCST to return to an operational state a new logon procedure is required (e.g., after an enable transmission instruction from the NCC). These procedures can be used by the NCC to control the RCST before and during a handover.

4 Handover to a DVB-RCS2 Access Network

In geostationary satellite communication networks resources are relatively expensive and latencies high compared to terrestrial mobile networks (mostly due to propagation delays). We consider two prerequisites for integration: the RCST should only attach to the network when DVB-RCS2 becomes the active access network (according to the mobility policy), and the number of control protocol messages exchanged over the DVB-RCS2 network to perform the handover should be minimized. A trade-off following from these prerequisites is the state in which the RCST is kept when it is inactive: keeping a terminal attached makes IP address preservation across handovers difficult, and can result in unused network resources (especially when a large share of resources is unsolicited), however it would allow for a faster handover procedure (because less protocol exchanges result in less handover delay). In our proposed solution (shown in **Fig. 2**) we try to strike a balance between these two modes, considering both mobility and QoS management.

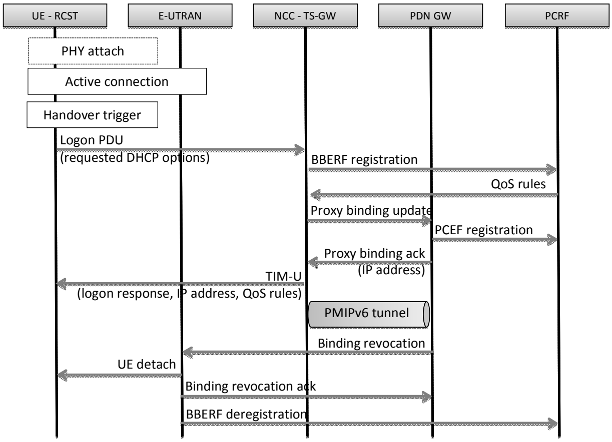

Fig. 2. Optimized handover to the DVB-RCS2 access network using the EPC

4.1 Attachment and Mobility Management

Network selection in the EPC can either be manual or through mobility policies. In our illustrative scenario a handover takes place automatically based on changing network conditions (e.g., when a terminal moves out of E-UTRAN coverage). We assume that policies are pre-provisioned for the UE to avoid extra control protocol exchanges. The pre-provisioned policy contains rules that trigger a handover to the DVB-RCS2 network based on E-UTRAN network availability. The triggers for a handover can be access-network specific and are out of scope of the EPC standards; in any case when a drop in network signal occurs the satellite network should establish connectivity before network connectivity to the E-UTRAN is lost and disruptions become noticeable. This could for example be achieved with signal strength measurements and thresholds, or a provisioned coverage map combined with real-time location information.

In a dual radio setup the delay introduced by attachment to the DVB-RCS2 network could be compensated by maintaining connectivity to the 3GPP access network until attachment is complete (i.e. "*make before break*"); however this is of limited use when a fast moving terminal (e.g., on the train from our illustrative example) moves out of network coverage and the radio signal drops quickly; in any case we believe there is a need for a procedure considering both handover delay and network resource efficiency for satellite networks.

Before a network handover is initiated based on mobility policy rules, the RCST is in a stand-by state such that (unsolicited) network resources are not committed to the terminal and IP address preservation is possible.

To reduce the number of control protocol exchanges during attachment we propose the use of a new DHCP option which indicates that a handover takes place and allows the RCST to retrieve its IP address in a TIM-U response (the IP address is assigned to the RCST by the PDN GW based on PMIPv6 procedures). Consequently the address is configured before IP-level connectivity is available for stateless [14] or stateful [15] address autoconfiguration. The NCC can announce the support of such DHCP option in the TIM-B message, and if supported by the RCST it can request for it in the logon request to the NCC. This would allow for attachment to layer 3 without additional higher layer control protocol exchanges (each exchange would cost at least 500ms), but requires the NAI to be present in the logon request.

Another consideration affecting handover attachment is network security. When the DVB-RCS2 network is assumed to be a trusted network to the EPC (note that this is not a characteristic of the access network but an operator agreement), the EPC relies on the access network security in the non-3GPP access network (i.e. DVB-RCS2 data link layer security). For the security between the non-3GPP access network and the EPC network domain security from 3GPP should be applied, as specified in [16]. This authentication would require additional control protocol exchanges before the handover is completed. Optimizations could be made by exchanging (part of) the authentication vector over E-UTRAN, or combine EAP exchanges with the DBV-RCS2 logon procedure.

4.2 QoS Management

Part of the handover is informing the EPC QoS functions of the access network change, which is separate from the PMIPv6 signaling. Although support of PCC is optional for trusted non-3GPP accesses, we do believe support is meaningful as it allows consistent QoS management across access networks. During a handover PCC integration involves registering the BBERF (located in the DVB-RCS2 TS-GW) with the PCRF, and the PCEF (located in the PDN GW) modifying the access network session by updating the PCRF. In response the BBERF receives the QoS rules and event triggers that it should enforce. The QoS rules contain maximum and guaranteed bitrates for defined service data flows (i.e. an aggregate set of packet flows).

In DVB-RCS2 QoS rules are not only provisioned in the TS-GW but also in the RCST, and we suggest to translate the PCC QoS rules into the request classes configuration in the lower layer service descriptor in the TIM-U in order to provide QoS rule enforcement in both the RCST and TS-GW: the RCST uses its IP classification table (now associated to the PCC service data flow templates in the QoS rules) and HLS mapping table to map IP traffic to the request classes. When the service data flow templates provided by the PCRF are changed this requires updating of the IP classification table and HLS mapping table using management commands by the NMC, therefore keeping these templates stable would improve performance of the handover with integrated QoS management.

5 Conclusion and Future Work

The integration of DVB-RCS2 with the EPC can strengthen the network of the future where multiple access networks provide connectivity, especially for remote and rural areas. Effort is needed on mobility management and QoS management to ensure an efficient integration given unique properties of geostationary satellite communication networks (e.g., large coverage, propagation delays). We have translated this observation in two prerequisites in our study of network-based mobility: the RCST should only attach to the network when DVB-RCS2 becomes the active access network, and the number of control protocol messages exchanged over the DVB-RCS2 network to perform the handover should be minimized. Based on these prerequisites we have proposed solutions to reduce the number of messages needed during a handover by adding a new DHCP option carrying an assigned PMIPv6 address in response to a successful DVB-RCS2 logon procedure. The same TIM-U response message is used for carrying QoS configuration to the terminal such that integration with PCC is established without requiring additional control protocol exchanges provided that some pre-provisioning is performed. Without optimization the handover would require around 8 to 10 protocol exchanges for authentication and attachment (both MAC and IP), which can be reduced to 4 or less. Considering propagation delay of 250ms this shows that the integration of DVB-RCS2 with the EPC is feasible; however there is room and need for improvements to optimize network-based handovers.

Based on the proposed solution we are working on an implementation and validation of the proposed solution in our EPC testbed and plan to propose enhancements that further improve the integration of satellite communication networks with terrestrial mobile networks.

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