IEEE 802.21 MIH-enabled Evolved Packet System Architecture

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Abstract. The main motivation of IMT-Advanced is to enable the mobile users with capacity to handle high data rates and low delay services such as high quality video and online gaming. Two technologies are competing in this field: LTE-Advanced and Mobile WiMAX. Following the Always Best Connected (ABC) paradigm, the integration of these two technologies with legacy ones is imminent. The Evolved Packet Core (EPC) is the 3GPP new core network which aims to integrate 3GPP and non-3GPP access networks through an All-IP core network. The IEEE 802.21 standard is another important contribution, optimizing vertical handovers, by providing a common framework between the data link and network layers. Although the 3GPP has already defined optimized vertical mobility procedures, these are dependent on the technology, and much effort is needed in order to achieve the so desired seamless mobility. In our work, we propose a new mobility architecture and several enhancements on handover signaling to provide seamless mobility between IMT-Advanced candidates and legacy wireless technologies. We further compare our proposed mobility framework with current approaches, showing the advantages of the integrated approach.

Keywords: Evolved Packet Core, Quality of Service, Mobility, Seamless Handovers, Heterogeneous Networks, Media Independent Handover.

1 Introduction

Recently, the Long Term Evolution (LTE) of the Universal Mobile Terrestrial Service (UMTS) [5], and its All-IP core network (Evolved Packet Core - EPC) [4], is a serious candidate to the core support of next generation networks (NGNs). Simultaneously, the IEEE 802.16m [2], also known as Mobile WiMAX, is also running fast in order to achieve the IMT-Advanced requirements [9]: 1Gb/s for low and 100Mb/s for high speed mobility. Therefore, mobility and the integration of these technologies with legacy ones plays an important role in such evolved scenario, and the EPC can be the key to support this scenario. To achieve the integration of heterogeneous technologies such as LTE, WiMAX, WiFi with legacy 3GPP (GSM/EDGE, UMTS/HSPA), it is required to supply common features

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like the Authentication, Authorization and Accounting (AAA), policy and charging, handover (HO) with minimal delays, and QoS levels support while the user equipment (UE) moves between multiple technologies. The IEEE group has also contributed to this integration, defining a technology independent framework between the data link and network layers to optimize handovers. To perform an optimized handover, the UE also needs to discover potential Radio Access Networks (RANs) when moving. Full scanning procedures are very battery and time consuming and shall be avoided. Moreover, the gathered information through scanning is not sufficient considering the high heterogeneity and dynamicity of future networks. This issue requires an access network discovery service.

The 3GPP specified optimized architectures and handover procedures between 3GPP and WiMAX [3]. We have dived into such approaches and identified four gaps in these architectures that, in worse cases, can lead to handover failures: a) The absence of an abstraction layer for HO signaling; b) The absence of a network discovery service in optimized handovers; c) Target network selection does not take into account the resource availability; d) Resources on non-optimized handover are not reserved prior to handover execution. Therefore, we propose an enhancement to EPC's architecture by introducing IEEE 802.21 Media Independent Handover (MIH) features, discussing their design options and advantages in an EPC architecture. We also address the cooperation between the different servers in the EPC and IEEE 802.21 architectures, the Access Network Discovery and Selection Function (ANDSF) and the Media Independent Information Server (MIIS). The main reason behind our approach is that the services provided by the IEEE 802.21 enable the support of seamless handovers without packet loss [12].

This paper is organized as follows. Sections 2 and 3 introduce related work and background information on Evolved Packet System (EPS) and IEEE 802.21. Section 4 presents our detailed study of 3GPP inter-technology mobility and its problems. Section 5 proposes the IEEE 802.21 MIH-enabled EPS architecture and a novel handover signaling scheme. The conclusions and future work are presented in Section 6.

2 Related Work

The seamless integration of Mobile WiMAX and legacy 3GPP is addressed in [15]. The authors introduce a novel handover mechanism enabling seamless mobility without supporting simultaneous transmission on both accesses. Their solution is built around the Forward Attachment Function (FAF) element [3], working as a target Base Station(BS) entity in order to optimize the handover.

In [14], it was identified that the above solution accounts for packet loss and abnormal disconnection from the source. So, [14] introduces the Data Forwarding Function (DFF), which works as a source BS entity, buffering the incoming packets and forwarding them to the target network, mitigating such issues. This approach is similar to the intra-LTE handover solution, regarding the forwarding of already arrived packets. Simulation results show that their proposal is effective in minimizing data loss during vertical handover (VHO) execution.

In [10], the enhancement and placement of IEEE 802.21 features in EPC nodes is discussed, referring that tight coupling between the source and the target network is needed to achieve seamless mobility. However, this kind of solution is strongly technology dependent and is, therefore, not scalable. The 3GPP approaches work in this way. The main advantage of the IEEE 802.21 standard is the technology specificities abstraction, providing a common mobility framework for all technologies. However, this approach contains several assumptions that are not compatible with current philosophy of both 3GPP and IEEE, e.g. interface between the WiMAX ASN and the Packet Data Network Gateway (PDN-GW) through Serving Gateway (S-GW), which is not the fact, because the S-GW is the user plane traffic anchor point for 3GPP technologies only.

In [13], the authors addresses the VHO support among NGNs and features an optimized handover framework based on the IEEE 802.21. In addition, they make a relevant study on how the IEEE 1900.4 standard can help handover procedures, by collecting context information, decision making, operator policies and regulatory constraints. The mapping of IEEE 802.21 MIH entities to the 3GPP EPC nodes was just briefly discussed, requiring more investigation.

The work in [6] presents the placement of IEEE 802.21 MIH features in EPC nodes and uses the ANDSF as a solution for the issues of [14]. However, important details and potentials of this integration are superficially addressed.

3 Background

The overall architecture of the EPS is presented in Figure 1. The EPC [4] is an All-IP network architecture supporting many access network technologies, managing QoS, Mobility, Policy, Charging, and has connections with other networks and services (e.g. Internet and IP Multimedia Subsystem (IMS)).

The 3GPP accesses are connected to the EPC through the S-GW for user-plane data and through the Mobility Management Entity (MME) for control-plane data. Trusted non-3GPP accesses are connected directly to the PDN-GW,

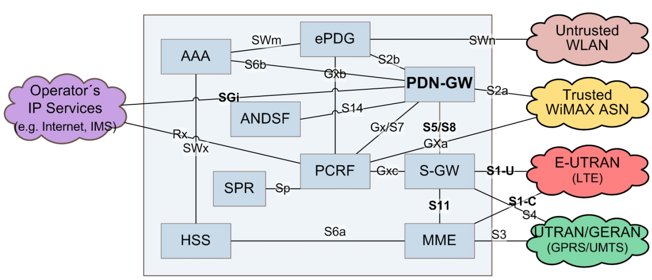


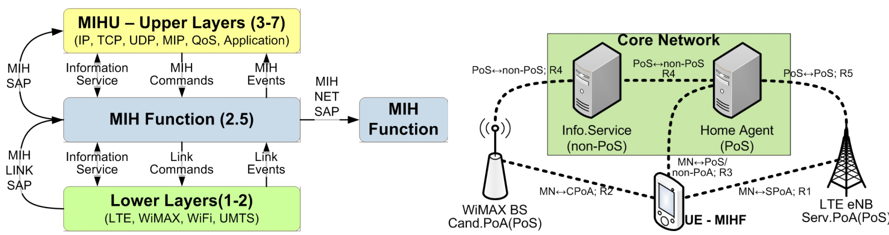
Fig. 1. 3GPP EPS Architecture

while Non-Trusted goes through the Enhanced Packet Data Gateway (ePDG). The common architectural point for these components is the PDN-GW which has interfaces for other packet data networks.

Moreover, the Policy and Charging Rules Function (PCRF) maintains the service flows, QoS levels and charging methods allowed for a user. The Home Subscriber Service (HSS) and AAA registers the UE to the EPC. The EPC also contains the Access Network Discovery and Selection Function (ANDSF)[4]: an entity capable of storing flexibly data for network discovery and mobility policy.

As far as the IEEE 802.21 MIH [1] is concerned, its main goal is to allow a seamless handover and enhance the user experience while the UE is moving across heterogeneous access networks. The IEEE 802.21 framework can be seen as a glue, allowing higher layers to interact with lower layers providing technology independent abstraction by using a common language.

To deal with technology specificities, the IEEE 802.21 standard provides a MIH_LINK_SAP Service Access Point (SAP) interface between the MIH Function (MIHF) and each one of the communication technologies, while the MIH_SAP interfaces the MIHF and MIH Users (MIHU) (Figure 2a).



(a) MIH Function (b) MIH Architecture

Fig. 2. IEEE 802.21 Media Independent Handover

The IEEE 802.21 standard provides all its functionalities through 3 services:

– Event Service (MIES): events that are propagated from lower to upper layers;
– Command Service (MICS): commands sent from upper to lower layers in order to check the status/control/configuration of a link;
– Information Service (MIIS): allows the UE to gather information about access networks in its vicinity to help the network selection algorithm.

The IEEE 802.21 also defines other network entities, as seen in Figure 2b:

– MIH Point of Service (PoS): a MIH entity which exchange messages with the UE. An UE may exchange messages with more than one PoS;
– MIH Point of Attachment (PoA): we may have two types of PoAs: Serving-PoA is the current L2 UE's connection, and Candidate-PoAs are other PoAs in which it would be possible to establish a L2 connection;
– MIH non-PoS: does not exchange messages with the UE directly (e.g. MIIS).

4 Vertical Handover Procedures and Architecture Analysis

In this section we present mobility architectures for HO between non-3GPP and 3GPP networks. The optimized approaches described below are tight coupled with [3]. In this study, we identify also some problems of these approaches.

1. FAF: it works as a Target BS (e.g. WiMAX BS or 3GPP LTE eNB) authorizing the UE access and preparing resources on UE's behalf, while still on source side (Figure 3). The reason for the creation of this element is twofold: First, the UE may not be able to transmit on the target network while the serving network is in use; Second, it is needed to avoid the creation of specific interfaces between the serving and the target network [15].

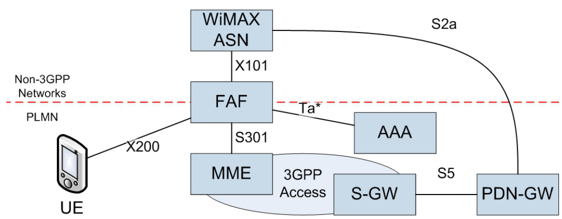


Fig. 3. WiMAX from/to LTE Optimized HO Architecture using FAF

2. L2/L3 tunneling: technology specific messages are carried out through L2 or L3 tunneling in the S101 reference point between the WiMAX ASN and the MME (Figure 4). According to [3], in case of L2 tunneling, messages are sent between UE and eNB as Radio Resource Control (RRC) messages. The source eNB forwards these messages to the MME and thus to the WiMAX ASN as IP payload. In L3 tunneling, all messages are sent as IP payload.

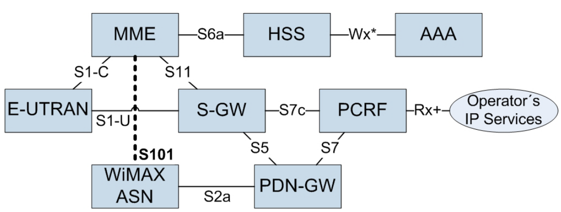


Fig. 4. WiMAX from/to LTE Optimized HO Architecture using L2/L3 tunneling

The main advantage of the FAF model is that no hard links and interfaces between the source and the target networks are necessary, avoiding tight coupling between different technologies [15]. However, one drawback of this approach is that a new network element has to be introduced on the operator's core network.

4.1 Optimized Handover Procedure from LTE to WiMAX

According to [3] this HO procedure is divided into two main phases: Pre-Registration and Handover. For better understanding, we divide the latter (Handover) into Preparation, Execution and Completion phases, as follows:

1. Pre-Registration: lets the UE to pre-register/attach to the target network (WiMAX) in advance of a handover, reducing HO time. If allowed, the UE shall pre-register/attach/authenticate/authorize itself and transfer necessary context to the WiMAX ASN through one of the above mentioned methods (FAF or L2/L3 tunnelling) while attached to the 3GPP access (LTE).
2. Preparation: based on E-UTRAN measurements, the network instructs the UE to make WiMAX measurements. Then, based on received measurements and network selection criteria (the specification does not refer how these criteria are acquired) the network decides to handover to WiMAX. Thereafter, the UE tunnels a WiMAX HANDOVER REQ through the LTE access in order to prepare the resources on the target network.
3. Execution: the UE switches to the WiMAX interface and synchronizes with the BS. Hereafter, the Proxy Binding Update messages are exchanged between the target network and the PDN-GW.
4. Completion: resources on the LTE source network are freed.

4.2 Optimized Handover Procedure from WiMAX to LTE

1. Pre-Registration: lets the UE to pre-register to the network. The decision to pre-register can be done either by the UE or the network. Then, the UE requests its attachment through FAF or tunnels (L2/L3), which triggers the creation of the default EPS bearer for a single selected PDN Connection.
2. Preparation: can be performed by the network or the UE:
   - Network Initiated: in this design choice, the UE measures LTE candidate networks, sends measurement reports to the WiMAX ASN through the FAF or L2/L3 tunnelling, and selects the target network. The admission control and resource reservation is performed in the eNB. Absence of enough resources to support the dedicated EPS bearers fails the handover preparation. The MME is notified if not all bearers could be established. Finally, an indication of preparation ending is sent to the UE.
   - Mobile Initiated: the UE also performs measurements, but makes the target network selection by itself. However, the specification does not clarify if handover policies are used or not, and hence, how policies are acquired. Afterwards, the MME forwards a HANDOVER REQUEST including the Qos profiles to the target eNB. Similarly, the admission control and resource preparation is also performed.
3. Execution: after the preparation phase, the UE switches the radio to LTE and executes the handover (e.g. PMIPv6).
4. Completion: the resources on the source network are released.

4.3 Non-optimized Handovers between non-3GPP Access and LTE

1. Initiation: the handover starts when the RSSI/SINR levels start to degrade.
2. Preparation: the UE queries the ANDSF for HO policies and networks in its vicinity, check their presence through scanning, and selects a target network. As there is no FAF or L2/L3 tunneling in this approach, the UE needs to turn on the target network interface in order to start its attachment, being it very time consuming. In case of single-radio UEs, it accounts for packet loss. The UE attachment triggers the authentication, location update and the creation of the default EPS bearer for a single selected PDN connection (APN). 3GPP documents do not specify how the APN is selected.
3. Execution: in this phase, the path is switched from the source to the target network. Remaining PDN Connections and dedicated EPS bearers, if any, are created only after the execution of handover.
4. Completion: resources on the source network are released.

4.4 Issues and Discussion

In the three cases above, we point out four main issues we have identified.

1. These handover procedures use technology specific messages and cannot be simply applicable to handovers among different technologies such as WiFi.
2. In optimized handovers, neither the UE nor the network uses the already specified 3GPP network element ANDSF to acquire information about the networks surrounding the UE. Therefore, when measurements are performed, the UE needs to make a full scan, which is considerably time consuming.
3. There is no resource checking before the network selection is performed. Accordingly, the handover may be blocked or fail if there are no enough resources on the target network to handle the ongoing communication sessions.
4. There is no resource reservation phase in non-optimized handovers (e.g. WiFi to LTE) and QoS pipes are created only after the execution of the handover.

5 Handover Enhancements on 3GPP Platform

This section describes the enhancements proposed to the 3GPP platform and handover signaling procedures in order to support optimized/make-before-break handovers by using the IEEE 802.21 MIH.

The first issue above identified can be solved by introducing the IEEE 802.21 MIH functionalities into the EPC. By using the IEEE 802.21 MIH, the operator can have identical handover signaling for all wired/wireless technologies. The adaptation of the technology specificities is performed in the MIH_LINK_SAP, and thus, it is not needed to create new handover signaling mechanisms when a new technology is introduced. This is one of the greatest benefits of the IEEE 802.21 MIH. However, challenging implications need to be addressed in order to achieve this integration, which will be studied in the following sections.

5.1 MIH-Enabled EPC

With regard to the requirements of LTE integration in NGNs, although the 3GPP has already defined the core network architecture and mobility procedures, we identified that those can be further enhanced using the IEEE 802.21 MIH framework. In order to do this integration, we studied the main network elements with regard to the EPS and the IEEE 802.21, as well as mobility and QoS signaling from both standards. As a result, we developed an architecture based on EPC, with IEEE 802.21 elements, which can be seen in Figure 5 (denoted as MIH), and further discussed below. The decision to reuse the EPC elements is that the EPC is the result of the effort to fulfill main operator's requirements, and then, it is able to comply with most of them.

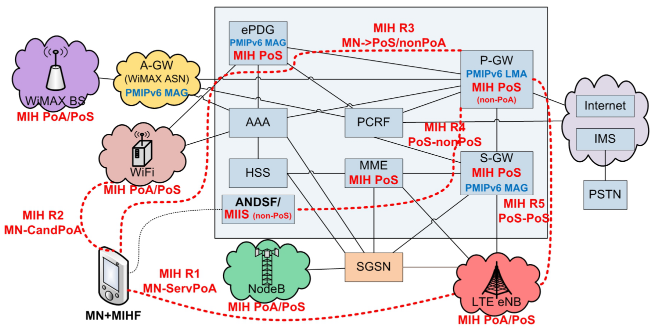


Fig. 5. Evolved Packet Core enabled with the IEEE 802.21 Architecture

Since the EPC entities are already well defined by 3GPP, we will concentrate in the IEEE 802.21 entities and reference points and its integration in the EPC. The following items will detail the reasons for the placement of some MIH functions in the 3GPP core network platform.

- MIH PoA: the PoA shall be placed where an L2 connection may be setup with the UE, e.g. in each radio access point. In Figure 5, we can see a PoA in each supported technology, namely: WiMAX BSs, WiFi Access Points (APs), UTRAN/GERAN Node Bases (NBs), LTE Enhanced Node Bases (eNBs);
- MIH PoS: being an entity which exchanges messages with the UE, it can be collocated with PoAs or in other nodes that need to exchange MIH messages with the UE. In case the PoS has the function of Radio Resource Management (RRM) or resource reservation for the creation of QoS pipes, it is collocated with the PoA. In the case of WiFi for example, if QoS for this technology is not supported, the PoS can be placed only in the ePDG. Other network entities may have the PoS, such as the PMIPv6 LMA/MAG [7]. Moreover, a PoS shall be present in the MME, because many handover signaling and decisions with regard to 3GPP technologies are handled by this network element. A non-placement of PoS in PCRF is explained by the

fact that the PCRF contains specific information about policy and charging for the EPC, which are not in the scope of the IEEE 802.21 MIH;
- MIH non-PoS: in our case, there is only one entity that is the MIIS, which does not exchange MIH messages directly with the UE, but through other PoS. The reference point R4 is shown only once, but we may have several R4 interfaces, e.g. between the PoS located in the access networks and the MIIS.

5.2 Introducing the ANDSF on 3GPP TR 36.938 Approach

The second issue early mentioned above is that the ANSDF is not used in the handover procedures specified in [3]. As already mentioned, full scanning procedures are very battery and time consuming.

The WLAN technology has two scanning methods. In Passive Scanning mode, the UE listens to the PHY medium for Beacon Frames during at least the Beacon Interval (BI) for each channel (around 100ms). So, being N_{Chan} the total number of channels, the time for Full Passive Scanning (FPS) mode can be expressed by $T_{FPS} \geq N_{Chan} \times BI$. In Full Active Scanning (FAS) mode, the UE broadcasts Probe Requests and waits at least MinChannelTime (MinCT) for each PHY channel. If the UE receives a Probe Response during MinCT, it waits until MaxChannelTime (MaxCT) for more Probe Responses. After scanning, we can approximate this value using $T_{FAS} = N_{EmptyChan} * MinCT + N_{BusyChan} * MaxCT$. However, the associated delay to get information from the ANDSF/MIIS needs to be taken into account in this analysis.

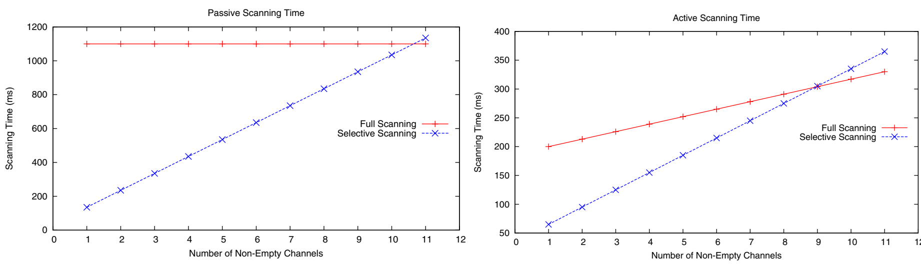
In order to evaluate empirically, we used the same handover scenario as in [12]. Considering the WiFi→WiMAX case, the discovery time is approximately 35ms ($T_{NetDiscovery}$). Assuming 11 WiFi Channels, a FPS would take at least 1100ms. Being $N_{SelChan}$ the number of channels to scan (retrieved from ANDSF/MIIS), the Selective Passive Scanning (SPS) time can be expressed by $T_{SPS} = N_{SelChan} \times BI + T_{NetDiscovery}$, while the Selective Active Scanning (SAS) time is expressed by $T_{SAS} = N_{SelChan} \times N_{MaxCT} + T_{NetDiscovery}$. In the numerical/graphical evaluation presented in Figures 6a and 6b, we assume 100ms for the BI, 17ms for MinCT and 30ms for MaxCT. In [11], the authors use smaller values, i.e. MinCT=6.5ms and MaxCT=11ms. However, considering high load on the WiFi APs, the UE may not receive probe responses during short times. Since most implementations use 30ms for MaxCT, we just apply this ratio (6.5/11) to the 30ms MaxCT time, obtaining 17ms for MinCT.

In Figure 6a, we can see that the only case when the Selective Passive Scanning is slower than Full Passive Scanning is when the retrieved networks uses all 11 channels and this is due to the ANDSF/MIIS discovery time. In 6b, the Selective Active Scanning is faster than Full Active Scanning when no more than 8 channels are used. However, if an operator considers only non-overlapping channels (3) in order to avoid frequency interference, the gain is significant.

Therefore, we introduced the “Access Network Information Request” just before the UE measurements, as described respectively in Section 4.1 and Section 4.2. With the insertion of this message, a selective scan may be performed, reducing the number of channels to scan, and consequently, reducing handover latencies. In Figure 8, Step 3, the insertion of such message is illustrated, by using the IEEE 802.21 "MIH_Get_Information.Request/Reponse" message.

5.3 Cooperation between ANDSF and MIIS

Since the functionalities of both 3GPP and IEEE will be integrated in our proposed solution, it also considers the integration of the mechanisms for network-assisted discovery service. It is then required the cooperative interworking between the IEEE 802.21 MIIS and the 3GPP ANDSF.



(a) Passive Scanning (b) Active Scanning

Fig. 6. WiFi Full Scanning Times x Selective Scanning Times

Figure 7 presents 2 types of mobile nodes: one standard model (on the left) which supports only 3GPP/OMA-DM protocol, and another with support for both 3GPP/OMA-DM and IEEE 802.21. The standard UE may acquire access network information and mobility policies from the Cooperative ANDSF/MIIS server by using an OMA-DM "Access Network Information Request/Response" message. On the other side, the IEEE 802.21 MIH-enabled UE may use also the "MIH_Get_Information.Request/Response" message.

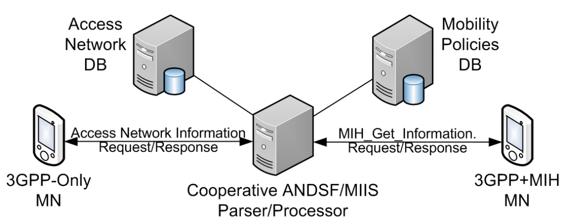


Fig. 7. Cooperative ANDSF/MIIS Server

The IEEE 802.21 MIH does not cover specific network selection algorithms. To cope with this requirement, it is necessary for the operator to support the transmission of network selection policies for the UE through the IEEE 802.21 MIH protocol. However, this may be considered as a drawback, because the user also wants to have control of the network selection procedures. In this sense, the IEEE 802.21 MIH can be flexible allowing both user preferences and operator policies in order to select the best network following the ABC principle [8].

In a standard IEEE 802.21 MIH based architecture, operator's mobility policies are not supported. In our architecture, the UE is allowed to use IEEE 802.21 MIH messages to acquire such mobility policies. With our approach, the mobile user may want to define its own preferences, but simultaneously obeying the operator's rules. Moreover, network mobility policies can help the UE network selection algorithm to find the best possible target network among candidates.

To avoid duplicate records in different ANDSF/MIIS databases, we propose the design depicted in Figure 7. In this architecture we have two databases, one for network discovery and the other for mobility policies. The Cooperative ANDSF/MIIS server works as a parser/processor, interpreting the content of both OMA-DM and IEEE 802.21 incoming messages, gathering data from the databases, joining and formatting this data with regard to the kind of request. Moreover, it is required that the Cooperative ANDSF/MIIS supports both the 3GPP S14 interface, as well as the IEEE 802.21 MIH R4 reference point. Figure 8, Step 3, depicts the utilization of the IEEE 802.21 MIH for acquiring discovery and policies information. In gradual IEEE 802.21/3GPP EPC integration/deployment or 3GPP-only UEs, the 3GPP/OMA-DM may still be used.

Finally, the result of the integration of these discovery and policies services, concerning the exchange of both 3GPP and MIH messages for information discovery in a common platform, can be seen as a MIH Policies (MIHP), where the information available in the already specified ANDSF Management Object (MO) can be delivered to both standard UEs (using the OMA-DM format) or MIH-capable UEs (using the RDF/XML or TLV format).

5.4 Resource Checking before Handover Decision

The third issue to address is the absence of a resource checking procedure on the target network before handover. If we decide to handover to a resourceless network, we may have a bad user experience while moving from one access network to another; in worst cases, our connection will be dropped. In standardized 3GPP handover procedures, this important step during handover preparation phase does not happen in advance, and thus, a bad handover decision/target network selection may be performed. In 3GPP approach, the resource checking is usually done during admission control/resource reservation, which may lead to handover failure when no sufficient resources were found. The 3GPP already realized this problem and an interface between ANDSF and PCRF is under discussion but not yet fully standardized.

The proposed handover mechanism will use as much as possible the IEEE 802.21 signaling from non-3GPP to LTE access. First of all, there is no equivalent procedure for resource check prior to handover decision in 3GPP approaches, as we can see in Step 5. In our approach, after gathering network discovery and mobility policies information (Figure 8, Step 3), the UE performs a selective scan to check which of the retrieved networks are present (Step 4), by using the MIH_Link_Actions . Request/Response(LINK_SCAN) message, which is equivalent to the LTE measurement process. The Resource Check (Figure 8, Step 5) is performed by sending a MIH_MN_HO_Candidate_Query.Request message to the Serving PoA, which queries the resources on every candidate network found in Step 4. After that, the Serving PoA sends the query response back to the UE. In [12], the authors propose the concept of a dynamic information server without the need to send resource query messages over the air.

In addition to this, in several cases, the vertical inter-technology handovers within the 3GPP context are not optimized, when compared to the IEEE 802.21 handover procedures. In other words, it means that the new target network interface needs to be turned on to prepare and execute the handovers.

5.5 Resource Reservation in Non-optimized HO from untrusted non-3GPP Access to LTE

The last issue is the absence of a resource reservation phase on the target network prior to handover execution when handovers are non optimized, e.g. from untrusted non-3GPP access (i.e. WiFi) to LTE. According to the 3GPP specifications, and as described in Section 4.3, dedicated EPS bearers and additional PDN connections are created only after handover execution, in a procedure called UE-requested PDN connectivity. In order to cope with this issue, we developed three ways of optimizing such handovers.

1. Use IEEE 802.21 MIH network elements, reference points, and optimized/ make-before-break handover procedures;
2. Make use of the 3GPP FAF component (Figure 3), introducing a new interface X400 between the ePDG and the FAF;
3. Using the L2/L3 tunneling architecture (Figure 4), introducing a new interface X500 between the ePDG and the MME;

Our choice falls on the first, i.e. the utilization of the IEEE 802.21, because once deployed, no additional technology specific interfaces and protocols need to be introduced. By using the IEEE 802.21, resources can be provisioned before the handover execution phase. As seen in [12], our choice also rests in the IEEE 802.21 MIH because it can provide seamless handovers with no packet loss.

After the Network Selection (Figure 8, Step 6), the UE performs the resource reservation procedure by sending a Commit.Request to Target PoA through Serving PoA (Step 7). Arriving in the target PoA/PoS, the MIH_LINK_SAP maps this media independent message into a technology specific procedure. Being LTE the target network in our example case, the Commit.Request is mapped to a Handover Request message, which in turn triggers the Create Session Request message. This message is sent to the PDN-GW, checking if the EPS Bearer is allowed to be created. Then, the creation of the EPS Bearer starts, considering the

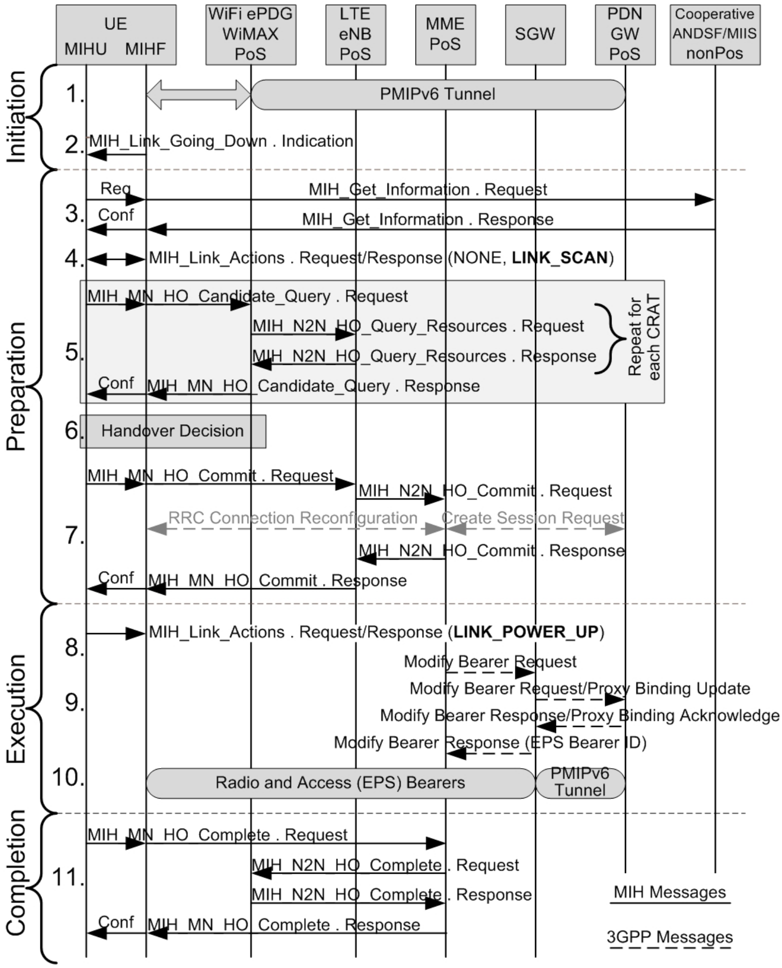


Fig. 8. Proposed IEEE 802.21 handover signaling from non-3GPP to LTE access

EPS Bearer QoS Profile (QCI, ARP and GBR), and triggers the sending of a RRC Connection Reconfiguration message in order to continue the QoS pipe establishment until its other end, i.e. the Target PoA.

Finally, the UE switches to the target network interface (Figure 8, Step 8) and performs the handover execution through a Modify Bearer Request message. The reception of this message triggers the PMIPv6 Proxy Binding Update process (Step 9). After the execution, the EPS Bearers establishment is completed and the UE may start to receive data through the new network interface (Step 10). Then, the resources on the source network are released by sending a Complete.Request message to the previous network through the new network, in order to release the previously allocated resources (Step 11).

6 Conclusion and Future Work

In this paper, we focused on 3GPP handover architectures and procedures, identifying their weaknesses and requirements to achieve inter-technology seamless mobility. We have described the main elements of 3GPP EPC and IEEE 802.21 MIH as a basis for having a common mobility and QoS platform. The standardized technology dependent handover procedures were fully studied and the gaps for inter-technology mobility were identified. As a solution, we proposed the integration of the IEEE 802.21 MIH standard within the 3GPP evolved core network, and we presented the mechanisms and enhancements to address each identified issue. Finally, as the possible integration between these standard shall happen gradually in phases, we consider that hybrid handover approaches may appear, using the IEEE 802.21 MIH features as much as possible, which leads to more flexibility for end users, or using IEEE 802.21 MIH only to fill 3GPP's gaps. As a future work, we consider the development of a multi-operator protocol for a common ANDSF/MIIS interworking platform and the study of network selection algorithms considering both operator and user preferences.

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