Improvements to Inter System Handover in the EPC Environment

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Abstract—**The Evolved Packet Core (EPC), defined by 3GPP, provides the possibility of integrating 3GPP as well as non-3GPP access network technologies. This opens up new options for mobility through the use of inter system handover over several access network technologies. This paper provides an overview of the introduced component Access Network Discovery and Selection Function (ANDSF) from the 3GPP as well as the Media Independent Handover (MIH) Service standard 802.21 from IEEE which aim to facilitate handovers, in particular the inter system handover. The paper provides an insight into how the two handover optimisation mechanisms can work together and complement one another. Furthermore a solution that combines MIH and ANDSF is proposed for improving the inter system handover behaviour.**

Keywords-component; Inter system handover; EPC; IEEE 802.21; MIH; ANDSF; WiMAX; LTE

I. INTRODUCTION

The ability to provide mobility independence to the subscriber is emerging as a key feature in the mobile networking area. One major difference between the 3G environment and the Evolved Packet Core (EPC), which is destined for 4G technology, is the possibility to integrate non-3GPP access technologies such as WLAN and WiMAX into the 3GPP defined EPC and thus provide access to Packet Data Networks (PDNs). The integration of non-3GPP access technologies into the EPC in combination of mobility provides a new set of opportunities and challenges relating to inter system handover. Since the network development goes towards 4G networks, the access networks are fast enough to serve real-time services but beside this, mobility should be supported as well. For a seamless handover, regardless whether an inter- or an intra-system handover is performed, certain requirements have to be fulfilled: the handover has to be processed within certain delay constraints of service interruption and the service quality should not noticeably degrade during handover. This means that the QoS can vary only within a limited range, so that changes are not noticeable to the user. To meet these conditions of seamless handover, 3GPP defined a new component called Access Network Discovery and Selection Function (ANDSF) in the 3GPP standard [1]. The ANDSF is not only limited to 3GPP technologies, it can also be used through non-3GPP access networks. On the other hand there is the IEEE solution defined within the IEEE 802.21 standard [2] which enables Media Independent Handovers (MIH). Both solutions aim to provide information for selecting the most suitable target network and further minimize the delay caused by the handover. Beside an overview of the two handover optimisation mechanisms and its combination this paper proposes a solution to eliminate packet loss and improve the resource release mechanism in the source access network. The paper is organized as follows: A discussion about related work is provided in section II. An overview of the two solutions focusing on inter system handover is given in section III and IV. Section V presents the possibilities to combine the two handover improvements. Section VI proposes a solution to eliminate packet loss and improve the resource release in the source Radio Access Network (RAN) when processing an inter system handover, without introducing an additional network element. Furthermore the ANDSF is used to improve the handover behaviour. Finally section VII concludes the paper.

II. RELATED WORK

In [3], the integration of mobile WiMAX with the EPC is addressed as an example of deploying heterogeneous next generation mobile networks. A novel inter system handover mechanism for single radio Mobile Nodes (MNs) is introduced containing a new functional element, the Forward Authentication Function (FAF), that authenticates the MN in the target access prior to the execution of the handover. As explained in an earlier paper [4], this solution makes a step towards seamless handover, but ignores two problems which are outlined in [4] when processing an inter system handover:

1) The MN does not inform the source network of moving to another access network. This will cause loss of buffered data.

2) The MN leaves the source network without proper disconnect procedure. As a result of this behaviour, the source network cannot release the resources once the MN has left, until it later becomes aware of the disconnection through timer expiration.

The proposed solution to these two problems in [4] is the introduction of an additional logical network element called the Data Forwarding Function (DFF) which eliminates the data loss during the inter system handover execution and resolves the problem of abrupt disconnection to the source network. In [3] and [4] the ANDSF is taken into account to provide information towards the MN, but the IEEE solution, the 802.21 standard for mobile independent handover [2], is not considered.

This paper provides an overview and a comparison of the 3GPP ANDSF and the IEEE MIH solution and investigates how the two solutions can complement one another. Furthermore, it introduces a solution to the two inter system handover problems through the deployment of the MIH [2]. The paper demonstrates that, if the MIH is deployed within the networks, there is no need for any additional components; because the first problem, the buffering of data, can be triggered by the MIH in combination with the IETF definition of PMIPv6 [5] and the 3GPP standard [6], both deployed for connecting non 3GPP access networks towards the EPC on the S2a/S2b interfaces. The second problem can be resolved through MIH signalling after the handover is completed and, as a result of it, the resources can be released.

III. Media Independent Handover

The IEEE 802.21 standard [2] aims to optimise handovers between heterogeneous networks that include both wireless and wired media. Therefore, link-layer intelligence and network environment information are provided to upper layers independent of the MN and access network specifications. To get as much information as possible about the surrounding networks, the MN and the network infrastructure are used as information sources. The minimal condition for processing an inter system handover is that the MN is a multi modal device (it has at least two interfaces). However, if both interfaces are wireless, severe interference problems can arise when they are simultaneously active. To avoid interference and also save battery, the interfaces are often used sequentially. This also aligns with the IEEE 802.21 standard framework media independent optimisation [2] by providing a generic interface to the upper layer mobility protocols. Within the IEEE 802.21 framework, no handover decisions are made. Even so, the framework provides a generic interface, the media specific technologies have to enhance Service Access Points (SAPs) and primitives to fulfil the generic abstraction. The Media Independent Handover Function (MIHF) is a logical entity and is the interface between the media specific technology and the MIH users, the layer 3 or higher mobility protocols. The MIHF provides the following services to higher layers:

Media Independent Event Service (MIES), Media Independent Command Service (MICS), and Media Independent Information Service (MIIS).

In order to benefit from the MIES, MIH users as well as MIHFs have to subscribe to events of interest to receive these specific event notifications. The events of interest may include specific state transitions or link layer changes, for example the state of a link layer changing to either up or down, notifications about handover completion, and reports of changes in link conditions that have exceeded a specific threshold. But events can also be predictive; for example, a decrease of the signal strength in a wireless access environment can be an indication that the link layer connection will be lost in the near future. These events facilitate handover decision for the upper layers and can optimise the whole handover process by improving the co-operation of the link layer and upper layer mobility processes.

MICS commands are sent from MIH users to the MIHF, while the interfaces receive commands from the MIHF. The receipt of commands at the MIHF can cause event indications to notify subscribed MIH users of a forthcoming event, such as a handover or a link layer change. The command service enables the MIH user to get dynamic information about the situation on the link layer like signal-to-noise ratio (SNR) and Bit Error Rate (BER). In addition, beside other possible applications, commands are used to subscribe or unsubscribe to/from events, configure thresholds for report events, activate actions on the link layer and even link layer resource reservation is possible with MICS. Even though all these possible applications with MICS are defined in the IEEE 802.21 standard this does not imply that all the possibilities with MICS can be exploited in every case, because it depends on the support of the access network technologies and the extension of the supported commands.

The MIIS includes a generic mechanism to allow providers and mobile users to exchange information on possible handover access network candidates. This information is mostly of a static nature contrary to the MICS. The MIIS provides the information through Information Elements (IE) which can be classified in three groups:

1) The general information and access specific information. It provides an overview of the available networks within an area associated with information such as the cost, QoS of the link layer, used frequency bands, the maximum data rate of the link layer, the operator of the network, or the roaming partners.

2) Point of Attachment (PoA) specific information. PoAs are network entities which terminate the layer 2, such as an access point (WLAN) or a base station (WiMAX). The IEs belonging to this group provide information about the PoAs of the available networks including but not limited to the channel range, the link layer address and the geographic location of the PoA.

3) Access network-, service- or vendor specific IEs. Such elements may provide network information about the supported higher layer services on the supported PDNs.

The main purpose of the mechanisms defined in the IEEE 802.21 standard is to speed up the handover and allow the decision making entity to select the most suitable and appropriate access network to handover to.

IV. ANDSF FUNCTIONALITY

Since the EPC allows non-3GPP (trusted and untrusted) access networks to access the EPC, the handover decision is more complex because the numbers of possible network candidates increased. To address this additional complexity, the ANDSF was introduced as an optional component in the 3GPP standard 23.402 [1] to exchange discovery information and policies with the User Equipment (UE) according to operator requirements. The ANDSF is accessible for UEs either through any 3GPP or non-3GPP access technologies that provide access towards the EPC. The ANDSF can provide the following types of information:

- Inter system mobility policy: This policy contains a set of operator-defined rules and preferences that have an impact on the handover decision. For example, which access network is optimal for EPC communication, but the mobility policies can also restrict inter system handovers in order to allow or deny certain inter system mobility.

- Access network discovery information: The ANDSF provides a list of access networks available for the UE, including the access type technology, a radio access network identifier (such as an SSID in the case of a WLAN), and other technology specific information like used carrier frequencies.

- Inter system routing policy: The ANDSF provides inter system routing policies to UEs that are capable of routing IP traffic simultaneously over multiple radio access interfaces. The inter system routing policies are used to route IP traffic differently, such as restricting specific IP traffic flow and/or specific Access Point Names (APNs) from specific access technology types, or to realise the appropriate selection, by the UE through application of IP filter rules, of the access technology, access network, and APN. The inter system routing policies consist of one or more IP filter rules that define the access technologies/access networks which shall or shall not be used by the UE to route IP traffic that matches these IP filters.

All three types of information provided by the ANDSF can have validity conditions, which indicate when provided policies or information are valid or not. These validity conditions can be associated for example with locations or time.

The information exchange between ANDSF and UE is based on the Open Mobile Alliance (OMA) Device Management (DM) [7] and uses the ANDSF Management Object (MO) specified in the 3GPP standard 24.312 [8] to manage the inter system mobility policy and access network discovery information provided by the ANDSF. The gained information in form of MOs is stored in the UE.

V. CO-OPERATION OF MIH AND ANDSF

Sections III and IV provided an overview of the two handover optimisation frameworks (IEEE and 3GPP). It was concluded that the main purpose of both the IEEE 802.21 standard and the 3GPP EPC solution with the ANDSF is to facilitate the inter system handover. But the way to achieve this common goal is different. Table I shows the similarities and contrasts between the introduced mechanisms of the IEEE and the 3GPP framework with ANDSF and EPC interaction. As can be seen from Table I, the only similarity is the distribution of the network information of the surrounding access networks to the MN through the MIH and the ANDSF. All the other mechanisms are different or have a related mechanism but not as comprehensive as the ones shown in bold in Table I. The two frameworks are for the most part different from each other and therefore could complement one another quite well if these frameworks were both deployed through the networks.

The event report triggers from the 3GPP framework include IP Connectivity Access Network (IP-CAN) bearer changes and location changes. However, these triggers are not as comprehensive as the event notifications from the MIES. The comparable solution from 3GPP to the MICS, the resource reservation mechanism from the EPC is performed during a handover towards 3GPP. Through the admission control and the bearer signalling the appropriate resources can be allocated. To enable the dynamic Policy and Charging Control (PCC) framework [9] for non-3GPP technologies the Gxa interface has to be deployed between the non-3GPP access network and the Policy and Charging Rules Function (PCRF). Such a scenario is shown in Fig. 1 on the basis of WiMAX as a trusted, non-3GPP access network. The use of the PCC

TABLE I. SIMILARITIES AND CONTRASTS OF THE IEEE AND 3GPP FRAMEWORK

<table>
<tr><th colspan="2">IEEE MIH</th><th colspan="2">3GPP ANDSF/EPC</th></tr>
<tr><td colspan="2">MIES
Events are sent between UE and network node.</td><td colspan="2">The Event Reporting Function of the EPC network is comparable to the MIES. It is located either in the Policy and Charging Enforcement Function (PCEF) or in the Bearer Binding and Event Reporting Function (BBERF) (depends on the deployed mobility protocol) and report events to the PCRF. Both, the PCEF and the PCRF are network nodes.</td></tr>
<tr><td colspan="2">MICS</td><td colspan="2">The EPC has also a mechanism to reserve resources but the MICS provide a wider range of commands than the EPC.</td></tr>
<tr><td>MIIS</td><td colspan="2">The information services are similar to each other.</td><td>Access network discovery information</td></tr>
<tr><td colspan="2">A mechanism similar to the inter system mobility policy is not supported within the IEEE MIH.</td><td colspan="2">Inter system mobility policy</td></tr>
<tr><td colspan="2">A mechanism similar to the inter system routing policy is not supported within the IEEE MIH.</td><td colspan="2">Inter system routing policy</td></tr>
</table>

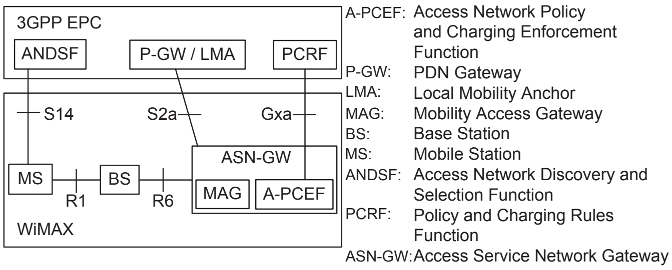

Figure 1. WiMAX EPC interworking

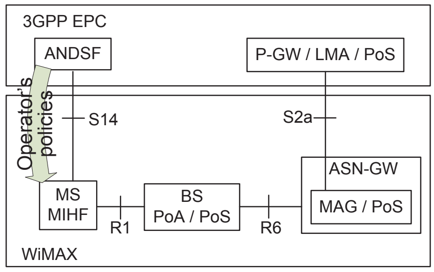

Figure 2. Mixed deployment of MIH and ANDSF

framework allows the distribution of charging and QoS related information of a subscriber. A big drawback of the IEEE MIH standard is the absence of any operators' policy. This is not considered in the IEEE MIH standard. But since inter system handovers, probably more than any other handover type, have to deal with different operators' networks, policies are very important to facilitate handover decisions. The 3GPP ANDSF provides, with the inter system mobility policy, a mechanism that allows to distribute operator defined policies to the MN. This will include rules and preferences that impact the selection of the access network. The following scenarios require policies to assist the decision making process.

- An area is covered with multiple different access networks. Through policies a preference can be defined such as: LTE is preferable to WiMAX.
- More than one access networks of the same type are reachable by the MN. The application of policies can assist on deciding which one to select. For example the WLAN with SSID X is preferable to the WLAN with SSID Y.
- Multiple access network types are reachable for the MN. Policies can define if a handover e.g. from LTE to WLAN is allowed or restricted.

These operator's policies can help in selecting the appropriate network for the MN. A wrong decision leads to a handover try and can result in a necessary fall back to the source network. Since the reason for a handover is mostly a decrease in signal strength, a fall back to the source network would lead to the same or even worse signal quality as it was before the handover. Wrong decisions can have a huge impact and can cause loss of sessions. The inter system mobility policy is therefore of such an importance to influence the behaviour of the handover that, at least this information should be distributed from the ANDSF to the MN. Fig. 2 shows a possible architecture with the components to deploy both, the MIH framework and the ANDSF. The deployment is as well shown with the WiMAX as the access network. The PoA terminates the layer 2 access network technology and is located in the WiMAX antenna, the Base Station (BS). The Point of Service (PoS) provides MIHF to the MN without having a layer 2 connection towards the MN itself. With the deployment shown in Fig. 2 the ANDSF can provide the important inter system mobility policy as well as the access network discovery information and if available the inter system routing information to the MN/MS. From the MIHF, the MN/MS is informed about the surrounding networks through the MIIS, can execute commands through the MICS, and can send events through the MIES.

VI. Resolve Delay and Resource Release Drawbacks with MIH and ANDSF

Two problems are identified in [4]. The first one is that the MN does not inform the source network of moving to the target network. As a result it causes loss of data. The second problem is that the environment lacks a proper disconnect procedure. As a result, the resources cannot be released until the source network is getting aware that the MN is not there anymore. Both problems contrast with the overall aim to realise a seamless handover. This section analyses the possibilities of the MIH [2] implementation and shows how the above problems can be eliminated through the deployment of the MIH and that the handover process can be improved through the use of the ANDSF. The scenario used to explain the behaviour is the inter system handover of a MN from a WiMAX access network towards a 3GPP LTE network, where the MN is a single radio MN. This means, that the MN uses the radio interfaces in a sequential manner. The handover process is shown in Fig. 3.

A. Improvement of the handover through the ANDSF

The information query consists of (1) the ANDSF information query, whereby the MN get the operator's policies and (2) the MIIS information query. As explained in Section V the operator's policies are only available from the ANDSF and not from the MIIS. In (3) the requirements about the candidate networks are provided by the MN to the WiMAX PoS within a list of preferred links and PoSs. The information about the operator's policies from the ANDSF improves the selection of the possible links and PoS, where a resource availability check (4) is processed.

B. Elimination of the data loss during handover

After the handover decision (5) the WiMAX PoS informs the decided target PoS, in this situation the LTE PoS, about the handover and request the preparation of resources. The LTE PoS forwards this information also to the MIH user, which is the MAG located in the Serving Gateway (SGW). The result of this request is sent back either to the WiMAX PoS where the Handover (HO) request is sent towards the MN, if it is a network (NW) initiated HO, or to the MN, if it is a MN initiated HO. The target MAG, located in the SGW, processes a pre-registration (7) towards the LMA. The necessary information about the MN is previously queried

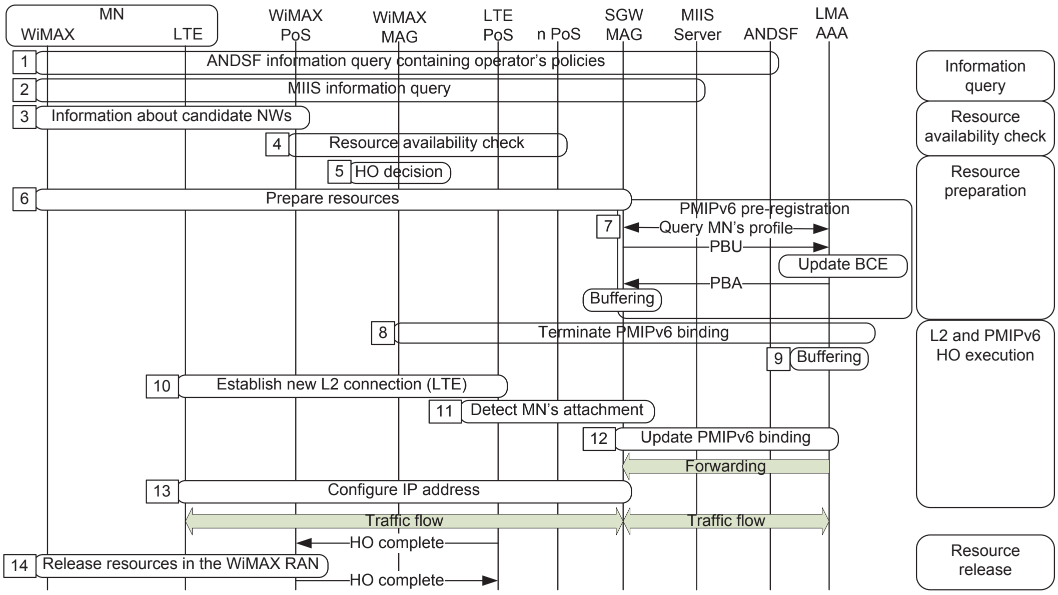

Figure 3. Handover process with MIH and ANDSF deployment

from an AAA server and afterwards this information are used to send a Proxy Binding Update (PBU) to update the Binding Cache Entry (BCE) and establish a new Generic Routing Encapsulation (GRE) tunnel between the LMA and the target MAG to enable the macro mobility towards the target MAG of the MN. After step (7) the data packets are forwarded from the LMA to the target MAG where the data packets are buffered. As a result of this pre-registration there is no loss of data during handover. Steps (8-13) have nothing to do with the elimination of the packet loss, but these steps are provided for a better understanding of the whole handover process. The old BCE is deleted by the WiMAX MAG (8) and the data packets were buffered at the LMA (9). The WiMAX interface is powered off and the LTE interface is turned on and establishes a layer 2 connection (10) that is recognized (11) by the network components (LTE PoA, LTE PoS, MAG/SGW). The target MAG processes the PBU (12) towards the LMA to update the BCE. After this PBU the data packets are forwarded from the LMA towards the MAG/SGW, where the data packets still are buffered, since the layer 3 connection is not yet available towards the MN. The layer 3 connection is available after the IP address is configured (13) and afterwards the traffic flows in a bi-directional manner between the MN (LTE interface), the MAG/SGW and the LMA.

C. *Improvement of the resource release*

After the handover process is completed the LTE PoS sends a *HO complete* message to the source WiMAX PoS, where the WiMAX resources are released (14). This notification from the target PoS to the source PoS about the end of the handover process enables the resource release right after the handover is completed and as a result a waste of resources can be avoided.

VII. CONCLUSION

This paper provides an overview of the two optimisation mechanisms to the inter system handover behaviour, the IEEE MIH and the 3GPP ANDSF. Both solutions aim to improve the handover behaviour, to get a step closer towards seamless handover. It has been shown, that a co-operation of these two optimisation mechanisms leads to an improvement of the handover process. Especially if the operator policies from the ANDSF can be taken into account and the MIH additionally is used. This positive influence with a deployment of both, the MIH and the ANDSF is also shown in the example of the handover from WiMAX to LTE. On the basis of the WiMAX to LTE handover, a solution is proposed to eliminate packet loss, triggering the resource release in the source network right after the handover is finished, and to improve the handover decision making process with additional operator's policies information from the ANDSF.

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