Proactive Vertical Handover Optimizations in the 3GPP Evolved Packet Core

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Abstract. Mobility in a wireless heterogeneous scenario in which the mobile devices are able to connect to more than one access technology available in their vicinity requires a re-consideration of the access network reselection mechanisms as to ensure seamless handovers for real deployments. This paper describes and evaluates a new proactive vertical handover optimization which enables a fast reselection, independent and in addition to the classic proactive procedures. It uses as central concept the separation between the proactive context establishment and the actual handover triggered operations which may be at their turn active or proactive. This concept is exemplified on the 3GPP Evolved Packet Core and evaluated on a minimal prototype implementation.

Keywords: Access Network Discovery and Selection, Heterogeneous Networks, Fast Handovers, Evolved Packet Core.

1 Introduction

A multitude of wireless access networks are already available (e.g. WiFi, WiMAX, LTE, UMTS etc.) having different delays for attachment and offering various levels of resources to the mobile users. A growing number of deployments are already using more than one access technology in specific locations for an enhanced throughput of the wireless environment as to be able to offer extended services to the mobile users.

Due to the large number of wireless access networks available, the mobile devices are not able any more to select by themselves the most appropriate target access network. Because of this, multiple handover network architectures (e.g. 3GPP Evolved Packet Core, IEEE 802.21 Media Independent Handover etc.) introduce a network function which offers to the mobile device information on the momentary preference of the operator for the target access network and its parameters in order to be able to execute a fast handover which supports the service continuity.

These functions offer the discovery and selection information to the mobile devices either based on a request from the mobile device or based on some other internal network triggers. The information does not imply any connection to the actual execution of the handover which includes the operations of authentication and authorization, the link layer attachment and the network layer reachability establishment (i.e. IP address

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allocation and mobility association – Mobile IP procedures). Although, the information is already available in the network prior to the handover which is triggered by the mobile device due to loss or prediction of loss of connectivity to the source access network, it does not influence directly the handover procedures. One reason for this is that all the proactive procedures considered in the literature presume that a complete context is established in the target access network when they are executed which implies a high consumption of the resources of the target access network.

This paper considers a new type of context to be established on the target access network immediately when the network located selection functionality takes the decision to which access network the mobile device would handover to in case this is necessary in the near future. The context does not presume the reservation of the actual resources on the target access network, but a proactive preparation for the case the mobile device triggers a handover. Using this shallow context, the mobile device is able to connect faster to the target access network and by this reducing the delay of the handover procedures, which is especially benefic for handovers from source accesses in which the connectivity is lost fast (e.g. WiFi) to target accesses in which the context establishment has a large duration (e.g. UMTS, LTE etc.). The procedures of establishment, activation and release of the shallow context are further exemplified using the 3GPP Evolved Packet Core (EPC) and they can be applied for any other convergent network architecture. The Evolved Packet Core is standardized by 3GPP as an IP based multi-access core network which integrates both 3GPP e.g. GSM, UMTS, LTE etc. and non-3GPP e.g. CDMA, WiFi, WiMAX access technologies. A main concept of the EPC architecture is the mobility of the users based on coordination between link, network and application layer. The concept here presented integrates in the EPC as an extension of the access network selection and discovery functionality.

The remainder of this paper is organized as follows: Section 2 provides the background of the proposed method. Section 3 describes the general concept which is then exemplified on the 3GPP Evolved Packet Core architecture. Section 4 describes the testbed followed by the evaluation of the experimental results and in Section 5 conclusions are provided.

2 Background

The current state of the art considers separately the procedures of network based access network discovery and selection and the handover optimizations e.g. the 3GPP Evolved Packet Core ([1], [2]), IEEE Media Independent Handover ([6]) and IETF NetLMM ([8]) etc. Related to handover, for the network discovery and selection the following two mechanisms are defined, as depicted in Fig. 1:

1. Network discovery and selection decision independent of the triggering or of the handover operation – in the 3GPP EPC architecture
2. Network discovery and selection decision triggered by the trigger of the handover operation – in the IEEE MIH architecture.

In the first case, the network makes the network discovery and selection decision and transmits the information to the mobile device depending on other external parameters. When a handover is triggered by the mobile device, due to parameters which can be measured only at the mobile device i.e. signal strength or internal policies, the handover operation is executed. This implies that no proactive procedure is executed on the target access network before the handover is triggered, either actively or proactively. Considering the active handover case in which the connection over the source access network is suddenly lost and that the procedures over the target access network have a large delay, the handover procedures have a large delay which impedes the seamless quality of the communication.

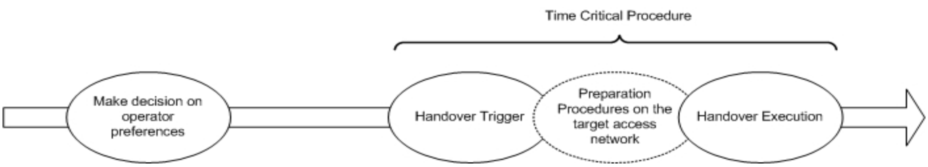

Fig. 1. State of the art in handover procedures

In certain scenarios, the network entity which makes the network selection decision is aware with a high probability of the access network to which the handover will be executed, but not of the moment of the handover trigger (active or proactive) which is mobile device dependent. In these cases, the network selection can be followed by an indication to the target access network in order to prepare for a future handover. Using this preparation, the time critical execution of the handover can be minimized.

In the second case, the network makes the network discovery and selection decision and transmits it to the mobile device only after the handover is triggered by the mobile device. In this case, all the procedures related to the handover are executed after the handover trigger, namely after the network receives the network discovery and selection request from the mobile device. Even though the handover trigger may be proactive (e.g. based on a rapid decrease of the signal strength), all the procedures related to the handover are executed after the event happens, which from the perspective of this article is similar to the previous case.

Thus, for both cases, only after the event of an imminent handover is available at the mobile device, the procedures of handover are executed which may contain a proactive or a preparation phase and an actual handover execution phase. The procedures for the handover have to be faster than the loss of connectivity to the source access network otherwise there is an interruption in the service due to the handover. Even though information is already available in the network, it is not used before the handover trigger due especially to the resources consumed by such a procedure in case the handover is not executed.

For example, in the IEEE 802.21 Media Independent Handover (MIH) architecture [7], [12] two types of operations are defined depending on the location of the Media Independent Handover Function (MIHF) which receives the handover event. For the first type, the handover is controlled by the MIHF of the mobile device while in the second it is controlled by the network MIHF. In the mobile device controlled scenario, its MIHF detects the event of handover and then requests to the network MIHF network discovery and selection information. All the handover related procedures are executed after the handover trigger which can include proactive procedures over the target access network.

In the network controlled handover, the network MIHF executes some proactive procedures and only afterwards transmits a handover command to the mobile device. In this case, the handover decision is not made by the mobile device and the handover trigger is received from the network. By this, the execution of the proactive procedures and the execution of the handover are tightly coupled. The handover has to be and is executed immediately after receiving the information from the network and it is not based on events which may be received only by the mobile device e.g. Link_Going_Down or Link_Down.

This second approach was extensively developed by the research community together and apart from the development of the 802.21 Media Independent Handover standard. For example, several approaches ([15], [17], [18]) consider that the required resources can be completely reserved over the target access network during the proactive phase of the handovers and prior to the actual handover execution. Other approaches ([16], [19]) consider also the integration in the proactive context of pre-authentication and pre-service signaling in the proactive context establishment.

However, due to the complete context which is created over the target access network, for the mobile device the resources are reserved twice: once in the source network and once in the target access network which are not strictly needed for the operation and have to be cleared in case the handover does not occur. For this reason, the proactive context establishment was bound to the proactive handover trigger as to have a higher degree of certainty of the handover. Also, because the context is established after the proactive handover trigger, due to the time constraint of the handover procedure, it may not be completely established for handovers between specific access technologies such as from technologies in which the signal strength is rapidly decreasing (e.g. WiFi) to access technologies in which the context establishment has a long duration (e.g. 3GPP access technologies). For this reason, the establishment of a shallower context prior to the handover triggers which may or may not be completed through a proactive procedure as the previous ones presented from the standards and literature is enabling a reduced delay of the overall procedure.

As an example architecture to validate the concepts here presented the 3GPP Evolved Packet Core (EPC) ([1], [2], [13]) was chosen due to its goal of providing network convergence between different types of accesses and because it may be considered the next-generation transport level for signaled services, by offering to the mobile terminals transparent support for mobility between different heterogeneous access networks.

As depicted in Fig. 2, EPC architecture includes a number of gateways which are transparently unifying the parameters of the different access technologies like LTE, UMTS, WiMAX, CDMA2000, WiFi etc. The Serving Gateway (S-GW) and the evolved Packet Data Gateway (ePDG) are responsible for the 3GPP and respectively the untrusted non-3GPP accesses while other technology specific gateways are used for trusted non-3GPP accesses e.g. for WiMAX or CDMA2000. The Packet Data Network Gateway (PDN GW) is the central anchor for all the data traffic. The gateways ensure the reservation of resources required by the mobile device, named User Endpoint (UE), through both the wireless environment and the EPC. Also they support the mobility protocol at network layer i.e. Mobile IP and variants.

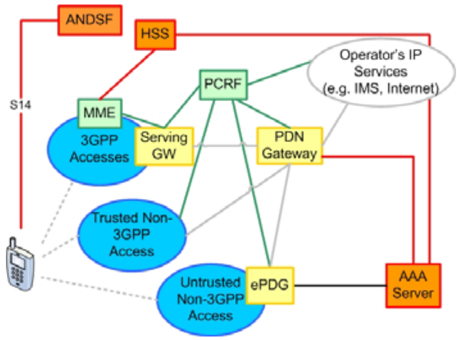

Fig. 2. 3GPP Evolved Packet Core

The Policy and Charging Rules Function (PCRF) ([2], [4], [5]) maintains the control over the resource reservations according to the user profile and to the communication with the service providers. It makes policy based decisions on the QoS levels that can be momentarily reserved for the UEs and enforces them on the gateways.

For the authentication and authorization of the UE the EPC uses a Home Subscriber Service (HSS) for the core network and an AAA Server for the Trusted and Un-trusted Non-3GPP accesses. For inter-3GPP technologies access control and mobility a Mobility Management Entity (MME) is used. It maintains the user context and offers services like reachability, resource management and handover signaling between the prior considered access networks.

The Access Network Discovery and Selection Function (ANDSF) ([3], [14]) transmits information available in the network to the UE related to the access networks to which it may connect to. In the current 3GPP standards only the interface to the mobile device (S14) is defined, thus being independent of the rest of the procedures of the EPC, therefore making the information transmitted to the UE independent of any handover execution procedures. On specific conditions, the mobile device alone initiates the handover procedures, without giving to the ANDSF the possibility of transmitting indications on immediate reselection.

Even though the ANDSF is aware that one or more of the access networks are highly probable to be selected by the mobile device in the near future and that a handover procedure is to be executed, no indication is transmitted to any other network entity in order to prepare for this future handover. When the handover event happens at the mobile device, it executes the handover procedures without having any proactive procedure executed in the network. Also in this case, all the re-selection procedures are executed after the handover trigger is received. If the attachment to the target access network takes a long period of time (e.g. in 3GPP accesses – GPRS, UMTS, LTE) and the connectivity to the source access network is fast lost (e.g. WiFi accesses), then a reduction of the duration of the procedures executed after the handover trigger has to be considered.

Therefore neither the 3GPP nor the MIH consider that any procedures are executed on the target access network prior to the active or proactive handover trigger, leaving that all the handover procedures are executed after it.

3 Concept

This article proposes a novel method for the execution of a proactive phase prior to the handover trigger, by executing a reduced context establishment on the target access network. The context is denominated from now as shallow context. It also considers that a new interface between the entity in the access network which makes the decision from the network side to which access network the mobile device may attach to in case a handover event occurs and a correspondent entity in the target access network which establishes the shallow context.

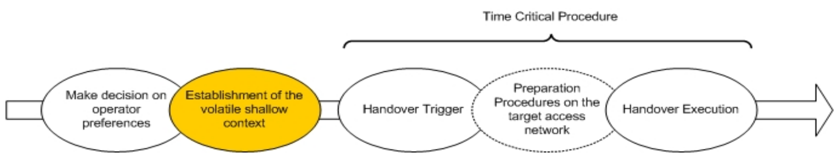

Fig. 3. Concept

The indication for the establishment of the shallow context in the target access network is transmitted when the information on which access network may be reselected is transmitted to the mobile device. The solution considers that the context is created due to the new information transmitted to the mobile device; independent of the moment when the handover event is received by the mobile device as depicted in Fig. 3.

The operations selected for the establishment of the shallow context are part of the steps which are executed during the handover procedure to the target access network. They don't have to be executed anymore after the handover event is received by the mobile device. The conceptual architecture is made of the following functional elements:

Network Access Selection Decision Function (N-ASDF) – it makes the decisions on the access network reselection from the network side. This function maps to the ANDSF in EPC.
Mobile Node Access Selection Decision Function (MN-ASDF) - it makes the decisions on the access network selection due to the triggers that are available only at the mobile device.
Network Access Selection Enforcement Function (N-ASEF) – it is attached to the target access network and executes the establishment if the context of the mobile device. It is a generic representation of the target access network entities.
Mobile Node Access Selection Enforcement Function (MN-ASEF) – it executes the selection procedures according to the decision taken by the MN-ASDF and it is equivalent to the attachment functionality of the UE in EPC.

Using this generic architecture, this article proposes the following access network reselection method:

Step 1: N-ASDF makes the decision on network selection policies that the MN-ASDF has to execute in case a handover event happens

Step 2: N-ASDF sends an indication with the decision to the MN-ASDF.
Step 3: N-ASDF makes the decision on which is the most probable access network that the N-ASDF would select in case a handover event happens
Step 4: N-ASDF sends an indication to the N-ASEF to establish a shallow context on the access network decided in Step 3.
Step 5: N-ASEF establishes the shallow context which will be further detailed for the EPC in the following sections.
Step 6: Independent of the previous steps, the MN-ASDF receives a handover event and makes the decision which access network to be selected.
Step 7: The decision is enforced to the MN-ASEF which selects the access network on which the N-ASEF has established the shallow context. The context is activated by this enforcement.

The shallow context should include information on the identity of the mobile node as to be able to identify during handover for which node the shallow context was created. The information is available in the N-ASDF because it is also the identification for the communication with the MN-ASDF.

It should also contain information necessary for the authentication of the mobile device in the target access network as to reduce the authentication procedures during handover – e.g. authentication vectors for the specific mobile node.

The context may include information on the active data flows of the mobile device which enables a faster resource reservation for the mobile device after the handover event. This information may be received from the MN-ASDF and/or may be augmented by information available already in the network.

It also should include information on the link layer, network layer and mobility protocol which otherwise would be available only after the handover event. For example, in the case Proxy Mobile IPv6 is deployed, it contains the home prefixes of the mobile device in the Mobility Access Gateway (MAG) and a secondary tunnel between the MAG and the Local Mobility Anchor (LMA).

In the EPC, the role of the N-ASDF is taken by the ANDSF as being the function which offers information to the mobile device on the accesses; while the role of the N-ASEF is taken by the gateways for the non-3GPP accesses i.e. ePDG and by the management entities for the 3GPP accesses i.e. S-GW or MME.

In order to establish the volatile context, the N-NREF can initiate: pre-authentication procedures based on the identity of the MN received from the N-ASDF (in the EPC the communication with the HSS), discovery of a path through the target access network (in EPC the discovery of the PDN GW) and its preparation (e.g. for Proxy Mobile IPv6 the creation of the tunnel between the gateway of the specific access and the PDN-GW anchor). It also may initiate policy and charging rules which bring the information on the QoS that has to be enforced in case the handover will occur (e.g. Gateway Control Session and PCEF Initiated IP-CAN Session Modification procedures in case of the EPC).

The context should not be initialized during the establishment procedure, but the information should be maintained on the network entities (e.g. for the EPC, the PCC and QoS rules and event triggers are available in the network entities in case a handover event happens, but they are not enforced).

The shallow context establishment does not presume the reservation of the actual resources on the data path. The resources which may be required in case of a handover can be further considered as available resources in the specific access network. This may lead to a failure of resource reservation in case of a handover, due to the allocation of these resources to other mobile devices. For this reason, the shallow context here introduced should be integrated with the proactive handover procedures as extensively researched in the literature.

During the context establishment, the network part of the wireless context may be retrieved by the gateway of the specific access networks e.g. for UTRAN the PDP context information.

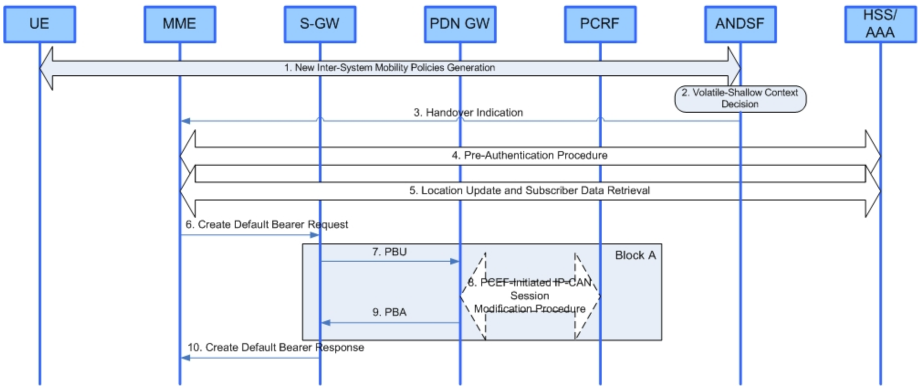

Fig. 4. E-UTRAN Shallow Context Establishment

Having the shallow context established when a handover occurs it is activated by a reduced number of procedures in case the resources required are still available. Otherwise, the handover procedures are similar to the state of the art procedures in which the resources required by the mobile device are not available in the target access network, scenario which was extensively presented in the literature. For the authentication, the communication is reduced to the one between the mobile node and the first network entity (e.g. the gateway or the manager of the access network). No inside network communication is necessary anymore. Also no communication for the resource reservation is necessary anymore, as the resources should be reserved by the activation of the shallow context which should be executed by each entity when the first upload packet is received or by the minimal authentication procedure considered in this paragraph.

For each type of access networks of EPC a different procedure is to be executed for the establishment and the activation of the shallow context. In the example of this article, E-UTRAN access network is chosen as the target access network and Proxy Mobile IPv6 as the mobility protocol as depicted in Fig 4.

Step 1: New inter-system mobility policies are generated for the UE by the ANDSF. The new policies are transmitted to the UE containing the accesses to which the UE may select for ensuring service continuity.

Step 2: ANDSF makes a decision for which access network from the information transmitted to the UE, a shallow context may be beneficial, based on the access network to which the UE is already connected to, the target access network type and

the probability of a handover. For the E-UTRAN, ANDSF selects the MME which would serve the UE in case of a handover.
Step 3: The ANDSF transmits a handover indication to the MME. It is considered that by knowing the access network to which the UE may handover to, the ANDSF is aware also of the MME which will serve the UE in that access network.
Step 4: The MME contacts the HSS and authenticates the UE. The authentication procedure is based on executed only on the network side and includes the retrieval of the authentication vectors from the HSS based on the identifier received from the ANDSF in the previous step as presented in 3GPP TS 33.401 section 6.2.1.
Step 5: The MME retrieves the subscriber data from the HSS, including the PDN GW identity and the information on the PDNs the UE is connected to over the source access network.
Step 6: The MME selects a Serving GW for the case no APN was provided by the UE as described in [1]. The MME sends a Create Default Bearer Request to the selected S-GW which includes the information received from the ANDSF.
Step 7: The S-GW sends a modified Proxy Binding Update (PBU) to the PDN GW which contains for the Handover Indication (HI) a new value which indicates that the tunnel has only to be created and that the data traffic should not be routed through it unless uplink data traffic is received or the source tunnel is not available anymore.
Step 8: Since the PDN GW is aware that a shallow context is created, it executes the mobility and resource reservation procedures as follows. When the PBU with the Handover Indication is received, a new tunnel is created, without routing the data traffic to it. An indication to the PCRF is transmitted which contains the flag that a shallow context is established similar to the resource modification of the standard procedures. The PCRF correlates the request with the identity of the UE and maintains in the subscriber structure that a shallow context is established. The PCRF makes the authorization and the policy decision considering that a handover may occur in the near future. A response is sent to the PDN GW indicating which resources have to be reserved and which event triggers are to be activated case the connectivity over the source access network is terminated or that the connectivity over the target access network is established. The resource reservation rules and event triggers received from the PCRF are maintained by the PDN GW until the shallow context is activated. No operations are executed.
Step 9: The PDN GW responds with a Proxy Binding Acknowledgement to the S-GW which contains the IP address or prefixes to be assigned to the UE in case of a handover.
Step 10: The S-GW responds with a Create Default Bearer Response to the MME. This message allows the MME to determine that the shallow context was established.

When the UE attaches to the E-UTRAN, the following operations are executed:

Step 1-2: UE selects E-UTRAN as a result of a handover event and of the policies received from the ANDSF.
Step 3: The authentication procedure is executed. As the MME is aware of the identity of the UE, the procedure is executed only between the UE and the MME and may be entirely skipped.
Step 4-9: The wireless link is configured. The UE may receive its IP address at this step or through the router solicitation/router advertisement mechanism.

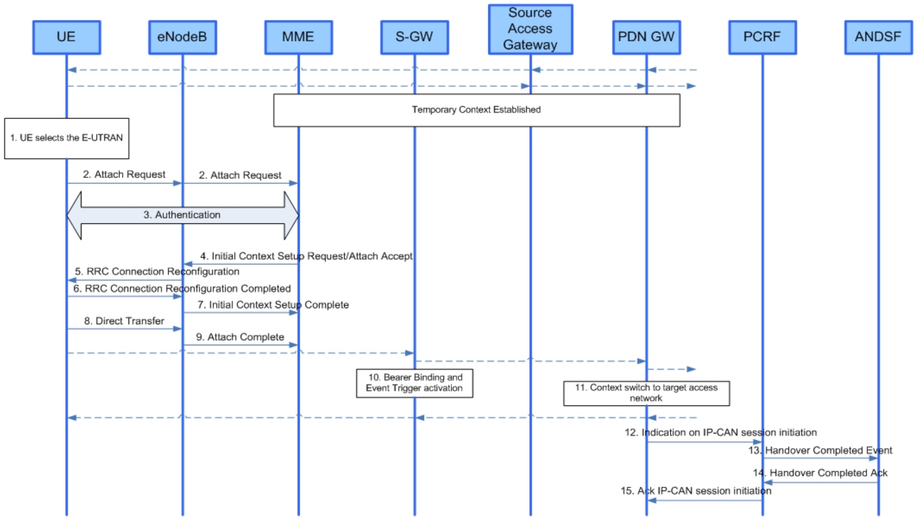

Fig. 5. E-UTRAN Shallow Context Activation

Step 10: The first upload packet triggers the activation of the shallow context in the S-GW. The activation includes the enforcement of the QoS rules and the bearer activation. It also includes the activation of the PMIPv6 tunnel from the S-GW side. No procedure for PMIPv6 or for required resources is executed as in the state of the art.
Step 11: The first upload packet triggers the activation also in the PDN GW for the resources, the PMIPv6 tunnel and the event triggers. No procedure is to be executed between the network entities as the information is already available from the shallow context establishment. The data traffic is exchanged bi-directionally on the target access network
Step 12-15: An indication is sent by the PDN GW to the PCRF and from the PCRF to the ANDSF in order to acknowledge the activation of the context.

The attachment procedure and the shallow context establishment may happen synchronously. As the control of the E-UTRAN is given to the MME, it may act as a synchronization point. For example, in the authentication procedures, if the pre-authentication procedure was already initiated when the request is received from the UE, the MME waits for the response from the HSS and responds to the UE. The delay is smaller than the case in which the MME issues a new request. Similar inferences are valid also for the other operations of the handover.

4 Testbed, Results and Evaluation

To test the applicability of the proposed procedures in a real environment an IPv6 based testbed was built as depicted in Fig. 6. A UE able to connect to a WiFi access network and to a public operator UMTS network was chosen. As the public operator offers services only using IPv4, all packets being sent by the UE to that network are encapsulated in IPv4 packets and are sent through the network architecture of the public operator which is out of control of our testing system.

Two gateways were deployed: a S-GW for the UMTS which acts as the MME and S-GW together from the previously presented procedure and an ePDG for the WiFi. The gateways have PMIPv6 Mobility Access Gateway (MAG) functionality and are connected to DHCPv6 serves which offer the IPv6 address to the mobile device.

A PDN+PCRF server takes the role of the PMIPv6 Local Mobility Anchor (LMA).

An ANDSF was also deployed able to make handover decisions which are then transmitted to the mobile device using a minimal OMA DM PUSH mode mechanism and to the S-GW in the form of requests for establishing a shallow context.

The public 3G network presents a variability of the delay which affects the measurements in the mobile device, in the same way the need to tunnel IPv6 packets also adds a small delay in both the UE and the S-GW, but in such a realistic scenario the delay of the handover procedures is made more visible as this procedure typically does not only involve the internal network procedures.

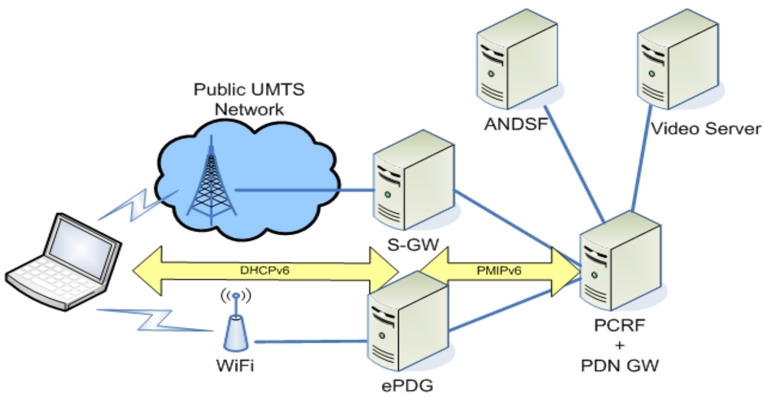

Fig. 6. Testbed Architecture

The implementation of the communication between the network entities is based on the FOKUS Diameter Stack for Linux while the minimal PMIPv6 implementation is based on Ubuntu Linux-based Operating System primitives. For the signaling part user-space raw sockets were used in both the PMIPv6 LMA and MAG. For the data tunneling, the standard IPv6 over IPv6 tunnels offered by the Linux kernel were considered.

The scenario measured and evaluated by this article considers that the UE is already connected to the WiFi network. An indication is transmitted by the ANDSF to the UE that in case an application is started to use the 3G network instead. At the same time a similar indication is transmitted to the S-GW to establish a shallow context.

The testbed considers that a shallow context contains the information on the IP address of the mobile node and the establishment of an inactive PMIPv6 tunnel between the S-GW and the PDN GW; limiting the efficiency of the shallow context to the network layer procedures (no resource reservation or authentication was considered).

When the user initiates the application, the UE executes a handover to the 3G network and only afterwards executes the service establishment.

This scenario based on an application initiation trigger is similar to the loss of signal in WiFi scenario, but it enables the operator of the testbed to easily run multiple consecutive tests.

Based on this minimal scenario, at the following entities, different delays have been measured:

UE attachment delay – The duration of the attachment with and without a shallow context including the DHCPv6 and the PMIPv6 procedures.

S-GW delay – The duration of the attachment with or without shallow context measured at the S-GW which translates into the duration between the moment the attachment request is received from the UE and the moment the attachment completion response is transmitted, in the case of the testbed, the duration between the DHCPv6 solicit and response.

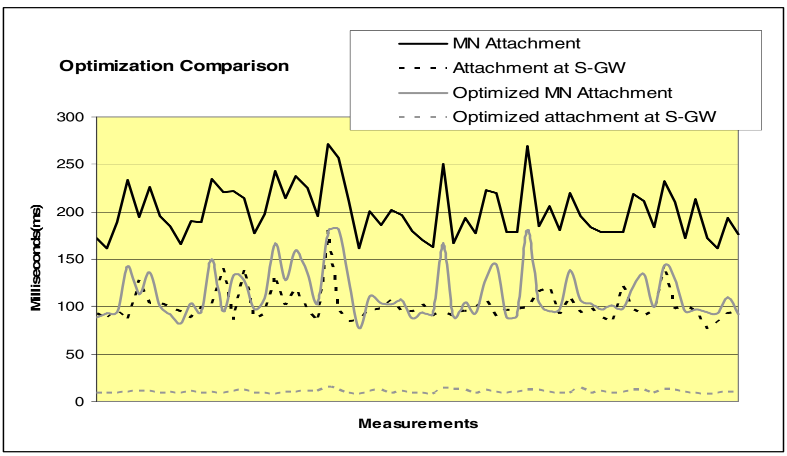

Fig. 7. Measured Values

As depicted in Fig. 7, the values obtained translated in percents bring an optimization of a median of 90.22% of the procedures executed in the S-GW for the connection of the MN and 47.62% for the overall connection procedures of the MN which also include the delivery over the wireless access system, with instable delay and not controlled by the testbed.

Although the number of measurements was limited and the procedures were executed for one MN and only for the network layer operations necessary for an access network reselection, the measured values prove the optimizations proposed by this article. A complete use of the shallow context would include also the pre-authentication operations and the subscriber data and the required resources retrieval in the gateway of the specific accesses or in the MME. It is expected that the same optimization is obtainable for these operations too, around 50% of the overall procedure time, which makes the shallow context usage beneficial for the handover between access networks in which the signal is suddenly lost and the ones in which the attachment procedures have a long duration.

Thus, the opportunity of using a shallow context in the real deployments depends first on the physical characteristics of the access networks and on the determined level of probability that a handover to the specific access network will be executed.

5 Conclusions

This article presents a new concept of optimization for vertical handover procedures in which a set of proactive procedures are executed immediately after the network located access network selection makes the decision which access network has a high probability to be selected by the mobile device in the near future.

These procedures enable the creation of a shallow context on the possible target access networks. Due to the high degree of uncertainty that a handover will occur to the target access network, the shallow context does not presume any resource reservation on the data path as considered by previous proactive handover solutions. Instead, only the information on the resources which may be required in case of a handover is transmitted to the target access network entities. For this reason, the here presented procedures are introduced as an addition to the existing proactive procedures.

From another perspective, this concept enables the access networks to prepare for a future possible handover which means that the network is dynamically reactive not only to the attachment of the mobile device to the different access networks, but also to the logical decisions on which access network to select. Thus, the solution considers a two stage type of preparation: one in which the information on the requirements of the mobile devices is transmitted to the entities on the target access network and a reservation one when the handover trigger (active or proactive) is received.

The concept was exemplified in the 3GPP Evolved Packet Core and evaluated and validated on a minimal prototype implementation. From the delay values obtained we can conclude that the solution is feasible to be directly implemented in the real-life deployments as the delay decrease is beneficial compared to the functionality introduced in the network. However, the solution has to be further evaluated as impact on the network of the establishment of the shallow context in case the handover to the specific accesses does not occur and also how it integrates as an addition to the current proactive handover procedures.

References

1. 3GPP TS 23.401, General Packet Radio Service (GPRS) enhancements for Evolved Universal Terrestrial Access Network (E-UTRAN), http://www.3gpp.org (access)
2. 3GPP TS 23.402, Architecture enhancements for non-3GPP accesses, version 8.4.1 (January 2009)
3. 3GPP TS 23.203, Policy and Charging Control Architecture, version 8.4.0, (December 2008)

4. 3GPP TS 24.302, Access to the Evolved Packet Core (EPC) via non-3GPP access networks, version 8.0.0 (December 2008)
5. 3GPP TS 29.212, Policy and Charging Control over the Gx reference point, version 8.2.0, (December 2008)
6. 3GPP TS 29.214, Policy and Charging Control over the Rx reference point, version 8.3.0 (December 2008)
7. IEEE P802.21/D05.00, Draft IEEE Standard for Local and Metropolitan Area Networks: Media Independent Handover Services (April 2007)
8. IETF Network-based Localized Mobility Management Workgroup (NETLMM), http://tools.ietf.org/wg/netlmm/
9. IETF RFC 5213, Proxy Mobile IPv6 (August 2008), http://www.ietf.org
10. Linux Advanced Routing & Traffic Control (March 2004), http://lartc.org
11. Open Mobile Alliance, Device Management Group, http://www.openmobilealliance.org
12. Piri, E., Pentikousis, K.: IEEE 802.21: Media Independent Handover Services. The Internet Protocol Journal 12(2) (June 2009)
13. Corici, M., Magedanz, T., Vingarzan, D.: The 3GPP Evolved Packet Core – the Mass Wireless Broadband All-IP Architecture. In: World Telecommunication Congress 2010, Vienna, Austria (September 2010)
14. Corici, M., Diez, A., Vingarzan, D., Magedanz, T., Pampu, C., Zhou, Q.: Enhanced Access Network Discovery and Selection in 3GPP Evolved Packet Core. In: IEEE LCN 3rd Workshop on User Mobility and Vehicular Networks (ON-MOVE), Zurich, Switzerland (October 2009)
15. Prior, R., Sargento, S., Gomes, D., Aguiar, L.R.: Heterogeneous Signaling Framework for End-to-End QoS Support in Next Generation Networks. In: 38th Annual Hawaii International Conference on System Sciences, Hawaii, USA (2005)
16. Dutta, A., Das, S., Famolari, D., Ohba, Y., Taniuchi, K., Fajardo, V., Lopez, R.M., Kodama, T., Schulzrinne, H.: Seamless proactive handover across heterogeneous access Networks. Wireless Personal Communication (2007)
17. Papadopoulou, E., McBurney, S., Taylor, N., Williams, M.H.: A Dynamic Approach to Dealing with User Preferences in a Pervasive System. In: International Symposium on Parallel and Distributed Processing with Applications, ISPA 2008, Sidney, Australia (2008)
18. Kim, I., Jung, Y.-C., Kim, Y.-T.: Low Latency Proactive Handover Scheme for Proxy MIPv6 with MIH. In: Ma, Y., Choi, D., Ata, S. (eds.) APNOMS 2008. LNCS, vol. 5297, pp. 344–353. Springer, Heidelberg (2008)
19. Boysen, E.S., Kjuus, H.E., Maseng, T.: Proactive Handover in Heterogeneous Networks Using SIPs. In: Seventh International Conference on Networking (icn 2008), pp. 719–724 (2008)