Performance Evaluation of Handover Policies in Mobile Heterogenous Networks

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***Abstract*— The increasingly ubiquitous deployment of wireless networks together with efforts to complete the standardization of Media Independent Handover (MIH) will support the 4G (Fourth Generation) vision in offering seamless access and an integrated network-of-networks (i.e. all IP network). In the same time, the handover process complexity will increase in next generations of wireless networks, creating the need for augmented knowledge about context, as well as more flexibility in managing the resources. The last two objectives cannot be addressed using the current static (hardcoded) mechanisms for handover initialization, decision and execution; therefore, a new policy-based architecture is proposed to assure the required level of adaptability and flexibility and to respond to user and network dynamics.**

Keywords-mobile heterogenous networks, vertical handover, MIH, context aware, policy-based management.

I. INTRODUCTION

Next generation of mobile wireless technologies, defined in cellular terminology as *fourth generation* (*4G)*, must support targets peak data rates of about 100 Mb/s for highly mobile access (at speeds of up to 250 km/h), and 1 Gb/s for low mobility (pedestrian speeds or fixed) access.

Besides meeting the above date rates, the 4G networks will consist of heterogeneous access networks providing a broad range of services to subscribers. In such an environment, vertical handover between various access technologies will be a common operation; therefore finding ways to handle optimally the network dynamics and complexity will be a challenging task requiring a great level of flexibility, scalability and adaptability.

Currently, there are many efforts devoted to interworking, seamless mobility techniques on integrated all-IP network and on self-managing virtual resource overlay that can span across heterogeneous networks, support service mobility, quality of service and reliability. In Europe, as part of ICT FP7 (Information & Communication Technologies Seventh Framework Programme), the relevant studies have been carried out in several projects such as WINNER (Wireless World Initiative New Radio) [12], HURRICANE (Handovers for ubiquitous and optimal broadband connectivity among Cooperative networking environments) [11] and AUTOI (Autonomic Internet) [10].

Moreover, System Architecture Evolution (SAE) in 3rd Generation Partnership Project (3GPP) [1] dedicates itself to cope with interworking and handover signalling, which aim at solving seamless mobility between different packet switched domains belonging to existing and evolving 3GPP access networks and non-3GPP access networks.

One-step in offering seamless handover is made by the standardization of Media Independent Handover Services (MIH) [13]. This standard tries to provide link layer intelligence and other related information to upper layers to optimize the handovers between heterogeneous media. The standard focuses primarily on the decision (or pre-execution) phase of handovers, but only reducing the handover latency is aiming to have little or no perceptible disruption of the users' applications, is not enough. However, there still exist several limitations in MIH architecture as follows:

- In MIH, the handover process typically based on measurements and triggers supplied from link layers, which disregards the influence of the application and user context information on mobility management.
- The network information provided by MIH lacks of flexibility since only less dynamic and static information derived.

To cope with network complexity and to be able to offer service continuity (e.g., context transfer, resource reservation), only using the facilities offer by MIH is not enough, therefore an aggregated view of user, network, mobility and service context should be taking in account during handover process. This augmented knowledge about context, as well as flexibility in managing the resources cannot be achieved without a certain level of automation and abstraction. To achieve above-mentioned requirements the solution proposed in this paper combines the use of policy-based management framework and context aware information to manage the handover process.

The reminder of this paper is organized as follows. Section II gives an overview of policy-based handover systems and shows possible network architectures. Section III gives a brief description of the proposed policy-based management architecture. Section IV describe the primary scenarios, validate the policies and evaluate the solution through simulation. Finally, in Section V we conclude our work and discuss possible directions of future work.

II. BACKGROUND AND RELATED WORK

The idea of handover control, which is not based only on the received signal strength (RSS), has been heavily studied in the past years. Most of the papers propose either a framework or taxonomy, but they are lack on implementing the framework in a simulation or testbed environment.

Paper written by Kassar et al. [16] make a summary of the policy-based handover solutions as follows:

• Decision function-based strategies (DF) [7, 8];
• User-centric strategies (UC) [2, 20];
• Multiple attributes decision strategies (MAD) [6]
•Fuzzy logic and neural networks based strategies (FL/NN) [21]
• Context-aware strategies (CA) [17, 22].

The solutions using DF strategies seem to be more flexible for the use of vertical handover policies but less efficient on this aspect for real-time applications. The use of FL and MAD algorithms gives the best and accurate solution with regrouping all the decision factors, but they are weak in flexibility. CA strategies try to ensure a high flexibility as important as a high efficiency facing a heterogeneous environment, but this comes with a drawback related to reactivity in case of real time applications.

To overcome the limitations of the above-mentioned solutions and to be able to validate the results in a simulation environment, we define a new policy-based architecture to assure the required level of adaptability and flexibility and to respond to user and network dynamics. Our solution combines the context-aware (CA) and multiple attribute decision strategies (MAD) using the MIH protocol to convey the policies and context information.

III. CONTEX-AWARE HANDOVER MANAGEMENT

In this section, we describe the proposed high-level architecture to manage handover process using policy-based management framework and context aware information.

Policy-based management defines high-level objectives of network, and system management based on a set of policies that can be enforced in the network. The policies are a set of pre-defined rules (when a set of conditions are fulfilled then some defined actions will be triggered) that determine allocation and control of network resources. These conditions and actions can be established by the network administration with parameters that determine when the policies are to be implemented in the network.

Policy-based management provides a high-abstraction view of a network to its operator, as it does not need to consider details concerning the size or complexity of the network [18].

The architecture combines the design principles of MIH and PBM (Policy-Based Management) frameworks. On one hand, it uses the services of MIH to exchange the policy information and to facilitate a distributed way of taking the handover decision and on other hand makes use of PCIM framework [3] to offer a high level of flexibility and adaptability of the system.

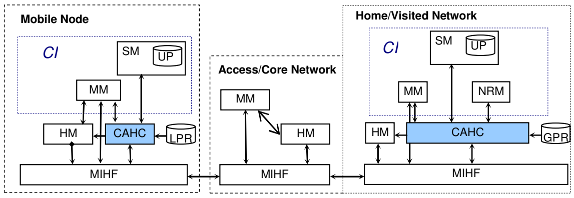

Figure 1. System architecture

As seen in fig. 1 the main functional entities of handover management architecture are Context Aware Handover Controller (CAHC) and Handover Manager (HM). These two functional entities are either assisted or makes use of the services offered by mobility management protocols (L3MP – e.g. MIP or SIP), context information (CI) triggers and policies stored in policy repository (PR) which are either local (MN side) or global (network side).

A. *Context Aware Handover Controller*

Context Aware Handover Controller (CAHC) plays the role of Policy Decision Point (PDP) in policy-based management framework and MIH User (MIHU) in MIH framework. It uses the rules stored in Policy Repository (PR) to take decisions and to enforce the required actions further to HM. Policy Repository can be located at MN level using local rules stored in Local Policy Repository (LPR) or at network level and in that case the repository store the global rules, therefore is called Global Policy Repository (GPR).

CAHC it is able to extract relevant information from received triggers and if need, to query for additional information from external entities, aggregate the information and then take decision. In order to receive triggers the CAHC must first register to external entities specifying the type and number of events that should be received. The context information (CI) can convey user, service, and network or mobility information.

In this paper, we will not develop further the protocol used to convey the context information or the message exchange between CAHC and external functional entities. We will try to summarize the requirements for such kind of protocol. First, the protocol must support a registering mechanism, which will allow specifying types and numbers of the events that CAHC it is willing to receive later. Secondly, the protocol must support on-demand query for context information without prior registration. This will facilitate a better usage of the network resources and will increase the scalability of the solution. Last but not least the protocol should convey context information to/from remote entities (e.g. terminal to network) in order to allow distributed decision (e.g. network controlled and terminal assisted).

For an integrated approach and to achieve the above-mentioned requirements the MIH protocol can be re-used, extending the Media Independent Event Service (MIES) and Media Independent Information Service (MIIS).

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B. *Handover Manager*

Handover Manager (HM) identifies the Policy Enforcement Point (PEP) in policy-based management framework and MIHU in MIH framework. HM implements decisions coming for CAHC execute the proper handover procedure and release the right resources.

C. *Policy information exchange*

In general, the policy information exchange is decoupled from the handover management process. As presented in the fig. 2, depending on capabilities of the CAHC, policy information can be pulled by the MN or can be pushed by the CAHC from the network side. In the second case prior to any interrogation, the MN must first register to CAHC.

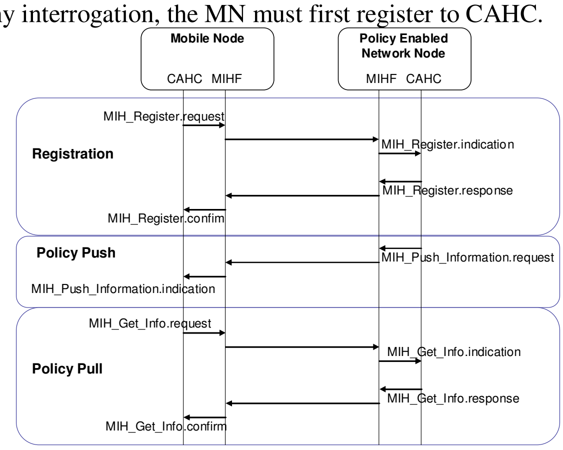

Figure 2. Registration process

From the architecture point of view, it is possible to coordinate the decision-making on network side or on the terminal side, but the later one can lead to scalability issues [9].

In this section we will present the main steps encountered during handover process from initialization to execution in case of network controlled handover.

The handover process may be conditioned by the measurements and triggers offered by different sources, such as the link layer or application layer, or network context from network side. There are two methods to obtain the required trigger events and the related information for MIH users (CAHC or upper layers).

The first method is registration mechanism. The registration mechanism enables an endpoint to register its interest in particular event type. After registration, the MIH users may specify a list of events for which they wish to receive notifications from the MIH Function. MIH users may specify additional parameters during the registration process in order to control the behaviour of the Event Service.

The second method is query/response mechanism. The query/response mechanism is to retrieve the available information. CAHC may send a request to Mobility Manager (MM), Service Manager (SM), Network Resource Manager (NRM) or User Profile (UP) server with additional parameters. In this case, the prior registration is unnecessary. The corresponding response includes either application/user information in client side or the static or dynamic information in network side.

There are four categories of context information (CI) that can be received or queried:

- User Context (UC) – user context information identify, either static user information (billing preferences, energy, security level) or dynamic user information (location). User Context (UC) information can be triggered or queried from User Profile server (UP) placed on network side or can be stored at MN level.
- Service Context (SC) – service context information can be triggered or queried from Service Manager (SM), see the Fig. 1. The SM controls and authorizes the requests coming from local applications in case of SM placed on Mobile Node (MN) or globally for application requests managed at the network level. When a new service request is received by the SM, or there is a change of an already establish service, the SM can generate a trigger to notify the CAHC with regard service characteristics (QoS parameters, service type). The SM performs service level management: planning, provisioning, offering and fulfilment of the services required for end-to-end QoS-enabled content deliver.
- Network Context (NC) – network context information is provided by Network Resource Manager (NRM) and can specify static (cost, throughput, network type, power consumption, topology information) or dynamic (network load, latency, packet loss, jitter, and congestion level) network related information. The NRM it is a functional entity placed on the network side, which is responsible for managing the resources at network level (see the Fig. 1).
- Mobility Context (MC) – mobility context information is provided by Mobility Manager (MM), see the Fig. 1. Mobility Manager stores the current status provided by MIH protocol and higher-level mobility protocols (L3MP), such as MIP (Mobile IP) [4, 5] or SIP (Session Initiation Protocol) [15, 16].

The vertical handover can be divided in three steps: handover *initiation*, *decision* and *execution*. During the handover initiation step, the mobile nodes equipped with multiple interfaces have to determine which networks can be used and the services available in each network. In the handover decision step, the mobile node determines which network it should connect. The decision may depend on various parameters, which define the aggregated user context. Finally, during the handover execution step, the connections need to be re-routed from the existing network to the new network in a seamless manner. This step also includes the authentication and authorization, and the transfer of user's context information.

D. *Handover Initialisation*

In this phase, the CAHC is starting to gather more information about the current context:

- query MM for available networks and mobility protocols supported;
- query user profile server (UP) for user preferences (cost, network type) and user location;
- query the NRM about network load, type, throughput and other useful information;

When all the information, which defines the user context, is present, the aggregate information is used to match policies stored in policy repository (PR).

The process can be further optimized with a caching mechanism at CAHC level, which can be combined with registering mechanism or with query/response interrogation. Each context information will have associated a specific lifetime depending on category of information cached (e.g. topology vs. network load).

E. *Handover Decision*

In this phase, the aggregated information will match a policy from the PR list and based on the user context. The aim is to find an appropriate network. The reference network and other candidate access networks will be ranked according to certain policy. Finally, the one before the reference network is selected as the target network. Therefore, both user experiences and resource efficiency could be guaranteed in this mechanism.

Then current network sends handover preparation request to target network, with the information of MN capability and context. The target network will reserve the resources for MN in order to reduce interruption time and to preserve service continuity.

F. *Handover Execution*

After link layer handover is finished, higher layer mobility protocol (MIP or SIP) signalling is exchanged over the radio network. When the handover execution is complete, the resources from previous network are released.

IV. EVALUATION OF POLICY HANDOVER STRATEGIES

Architecture validation is done implementing the complete framework of the ns-2 [19] simulation environment for both vertical handover (Wi-Fi to Wimax) and horizontal handover (Wimax to Wimax). The energy model is part of core functionalities of ns-2 and the 802.21 functionality is incorporated in ns-2 as add-on modules developed by the National Institute of Standards and Technology (NIST) based on 802.21 (draft 3)[23]. Starting from the basic handover types, we define a set of six primary scenarios used to handle mobility (MIP or MIP+MIH). Finally, the primary scenarios are validated for different simulation parameters (speed, signal strength, advertising interval).

A. *Scenarios*

In defining the scenarios we took into account the *mobility type* – horizontal (between different cells of the same technology - HHO) and vertical (between different types of technologies - VHO), *protocol(s)* used for mobility management – MIP or MIP with MIH support and the usage of the *multiple interfaces* in case of vertical handover.

We evaluate the scenarios using user velocity, RSS threshold and routing advertising interval:

1) HHO-MIP

In this scenario, the user is performing a horizontal handover and the decision is based on signal strength and mechanism offered by the MIP for move detection.

2) HHO-MIP-MIH

In this scenario, the user is performing a horizontal handover and the decision based on triggers offered by MIH (link down or link going down) and mechanism offered by the MIP for move detection.

3) VHO-MIP-single interface

In this scenario, the user is performing a vertical handover, the decision based on signal strength and mechanisms offered by the MIP for move detection and use one interface at a certain time.

4) VHO-MIP-multiple interfaces

In this scenario, the user is performing a vertical handover, the decision is based on signal strength and mechanism offered by the MIP for move detection, but during handover preparation and execution uses both interfaces (e.g. Wi-Fi and Wimax).

5) VHO-MIP-MIH-single interface

In this scenario the user is performing an vertical handover and the decision is based on triggers offered by MIH (link down or link going down) and mechanism offered by the MIP for move detection and use one interface at a certain time (either Wi-Fi or Wimax).

6) VHO-MIP-MIH-multiple interfeces

In this scenario the user is performing an vertical handover and the decision is based on triggers offered by MIH (link down or link going down) and mechanism offered by the MIP for move detection, but during handover preparation and execution use both interfaces (e.g. Wi-Fi and Wimax).

B. *Simulation results*

In this section, we present the results obtained by simulating the primary scenarios. For each scenario, we measure (i) system packet loss, (ii) handover time (latency), (iii) bandwidth efficiency and (iv) energy consumption.

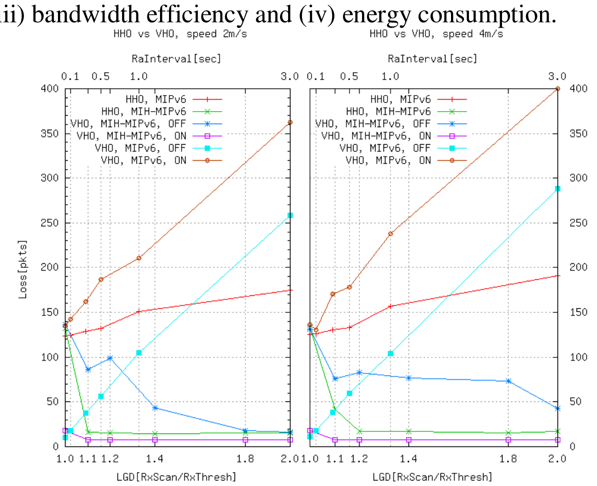

Figure 3. Packet loss

Fig. 3 shows the packet loss in the system. The packet loss in the system is the difference between the total number of packets sent by the CN and the number of the packets received by MN (including both Wimax and Wi-Fi interfaces).

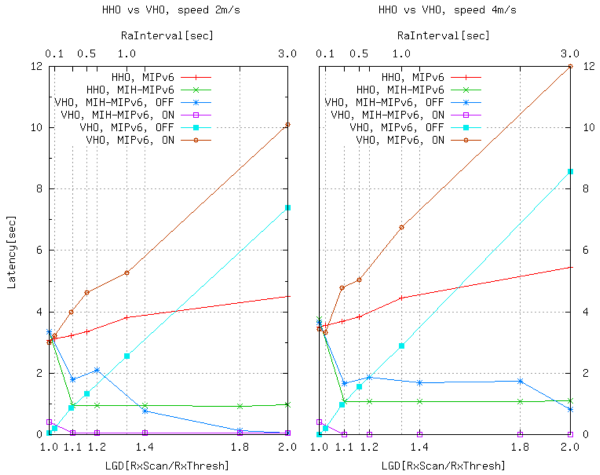

Figure 4. Handover time (latency)

Fig. 4 shows the evolution of HO time from old to new access network. The HO time is the amount of time that elapses between an interface is becoming *DOWN*, it is sending a MIPv6 *Redirect Request* to the CN and is receiving the correspondent *Redirect Ack* from the CN.

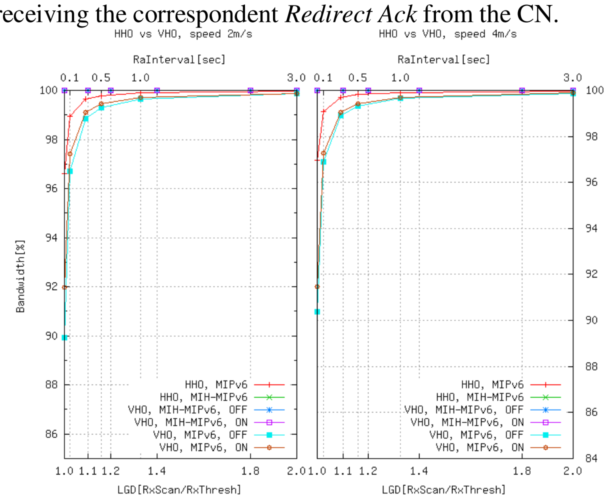

Figure 5. Bandwidth efficiency

Fig. 5 presents the efficiency in utilizing the bandwidth available in the system. The bandwidth efficiency measure the ratio of bandwidth used for application traffic and total bandwidth (application and signalling). The application traffic represented by video stream of UDP packets sent at a constant bit rate (CBR) of 409.6 kbps. The data is used o exchange control information in between functional elements (MIH message and/or ND messages).

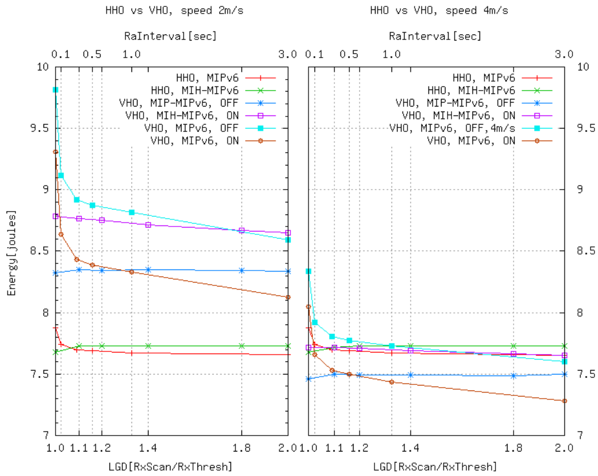

Figure 6. Energy consumption

Fig. 6 shows the energy consumption variation. The energy consumption it is another way of expressing the battery lifetime of the mobile node and it measure the amount of energy consumed during simulation time.

C. *Policy enforcement*

In order, validate the architecture we define two simple policies. First policy (Policy 1) specifies that during the handover the number of packet loss is lower or equal to 20 packets. Second policy (Policy 2) is defined based on energy consumption and it requires that energy consumed during 100 sec (simulation time) to be lower or equal with 8 joules.

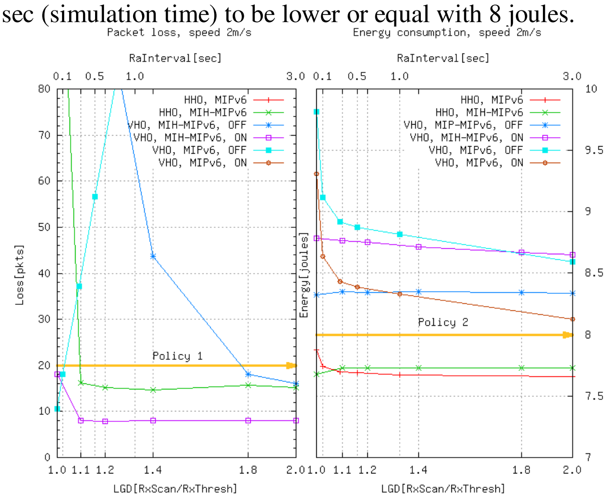

Figure 7. Policies enforcement for the same user context

When we apply the two policies for the same user context (e.g. same user velocity), the solution space will be different in terms of possible handover types, mobility protocols, usage of multiple interfaces or signal strengths (see Fig. 7).

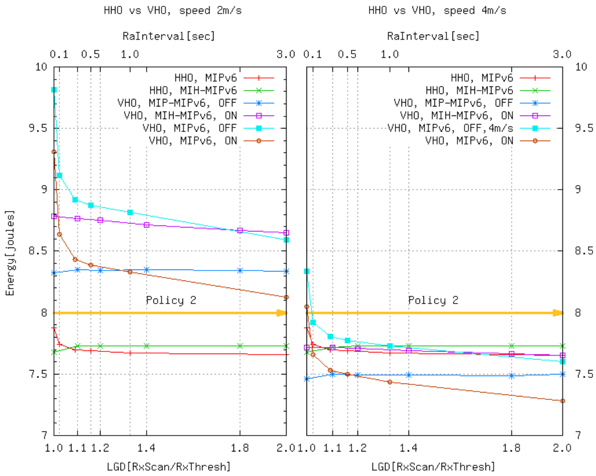

Figure 8. The same policy in two user's contexts

Similarly, if we apply the same policy in different user contexts (see Fig. 8) the solution space will depend on the same parameters, but with other results.

Combining more than one metrics in one policy (e.g. Policy 3 = (Policy 1 && Policy 2)) will narrow the solution space for a specific user context.

The use MAD strategies gives the best and accurate solution by regrouping all the decision factors (e.g. solution space), but they are weak in flexibility. Combining the decision factors with CA strategies will ensure a high flexibility and a high efficiency facing a heterogeneous environment.

V. CONCLUSON AND FUTURED WORK

In this paper, we provided an integrated architecture for handling the handover process in next generation of wireless networks using policy-based management and aggregated context information.

Handover process complexity will require an augmented knowledge about context, as well as more flexibility in managing the resources. Previous objectives cannot addressed using the current static (hardcoded) mechanisms for handover initialization, decision and execution, therefore a policy-based architecture is proposed to assure the required level of adaptability and flexibility and to respond to user and network dynamics.

Integrating the proposed architecture in a policy based management framework together with MIH services can further add flexibility to the network management and allow operators to make abstraction of the concrete wireless technology existent in the access network.

The details of the protocol messages used convey policy information and its behaviour are under investigation. In addition, the design considerations related to coordinated decision on network and terminal side, caching mechanism and context information lifetime are open to further research, pending for a formal validation based on a prototypical implementation and performance evaluation.

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