POLICY CONTROLLED HANDOVER IN MOBILE HETEROGENOUS NETWOKS

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Implementarea pe scară largă a rețelelor fără fir împreună cu eforturile de standardizare a protocolului MIH (Media Independent Handover) vor facilita realizarea cerințelor de termen lung a rețelelor din generația a patra (4th Generation), ce își propun să ofere accesul continuu şi utilizarea unei rețele unice de transport (all IP). În aceste rețele complexitatea procesului de transfer va creşte, fiind necesară atât o cunoaştere detalită a contextului în care se află stația mobilă şi rețeaua care o deserveşte, cât şi o flexibilitate sporită în gestionarea resurselor rețelei. Aceste obiective nu pot fi atinse utilizându-se mecanismele actuale (statice) pentru inițierea, luarea deciziei şi executarea transferului. Articolul propune o nouă arhitectură bazată pe politici, ce oferă un nivel ridicat de flexibilitate şi adaptabilitate, putând răspunde dinamicii de la nivelul utilizatorului şi al rețelei.

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. These 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 heterogeneous networks, vertical handover, MIH, context aware, policy-based management

1. 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.

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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 environment vertical handover between various access technologies will be a common operation, therefore finding ways to optimally handle network dynamics and complexity will be a challenging task requiring a great level of flexibility, scalability and adaptability.

Currently there are a lot of 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) [1], HURRICANE (Handovers for ubiquitous and optimal broadband connectivity among Cooperative networking environments) [2] and AUTOI (Autonomic Internet) [3].

Moreover, System Architecture Evolution(SAE) in 3rd Generation Partnership Project (3GPP) [4] dedicates itself to cope with interworking and handover signalling, which aims to solve 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 current efforts to complete the standardization of Media Independent Handover (MIH) [5]. This emerging 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 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 is 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 is 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 into 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 2 gives a brief description of the proposed policy-based management architecture. In section 3 we exemplify with a possible usage scenario, where the handover process is controlled from network side, together with short description of the four types of context information that can be used during handover process. In section 4 we describe the network configuration used to run ns2 simulations. Section 5 presents the simulation results and highlights the main benefits of proposed architecture. Finally, in section 6 we conclude our work and discuss possible directions of future work.

2. Context-aware handover management

In this section we describe a generic architecture to manage handover process using policy-based management framework and context aware information.

Policy-Based Management (PBM) 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.

PBM 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. The proposed architecture combines the design principles of MIH and PBM frameworks. On the one side, it uses the services of MIH to exchange the policy information and to facilitate a distributed way of taking the handover decision and on the other side it makes use of policy framework [6] to offer a high level of flexibility and adaptability of the system.

As seen in the picture below 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).

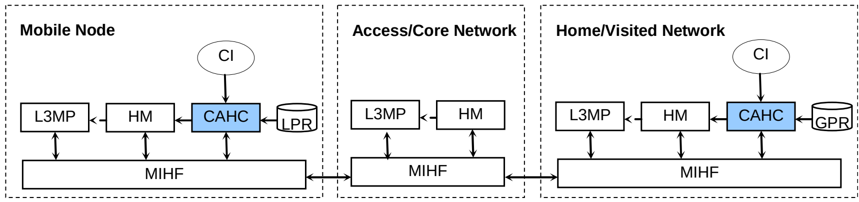

Fig. 1. Generic MIH and PBM based architecture

2.1. 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 use the rules stored in PR to take decisions and to enforce the required actions further to HM. PR 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 is able to extract relevant information from received triggers and if it is necessary, to query for additional information from external entities, aggregates the information and then takes decision. In order to receive triggers the CAHC should register itself firstly to external entities specifying the type and number of events that should be received. The context information (CI) can convey user, service, network or mobility information.

In this paper we will not develop explicitly the protocol used to convey the context information or the message exchange between CAHC and external functional entities, but we will try to summarize the requirements for such kind of protocol. Firstly the protocol should support a registering mechanism, which will allow to specify the types and the number of the events that CAHC is willing to receive later. Secondly the protocol must support on-demand query for context information without prior registration. Last but not the least the protocol should convey context information to/from remote entities (e.g. terminal to network).

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).

2.2. 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.

2.3. Policy information exchange

Generally the policy information exchange is decupled from the handover management process. Depending on CAHC capabilities, 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 should firstly register itself to CAHC.

3. Network controlled handover

From the architectural point of view it's possible to coordinate the decision making on the network side or on the terminal side, but the later one can lead to scalability issues. Fig. 2 presents a generic network controlled HO scenario.

In Fig. 2 we introduced higher layer entities grouped in a module called *Context Information* (CI) as:

- Mobility Manager (MM).
- Generic Service Manager (SM), including an User Profile (UP) .
- Network Resource Manager (NRM), server with additional parameters.

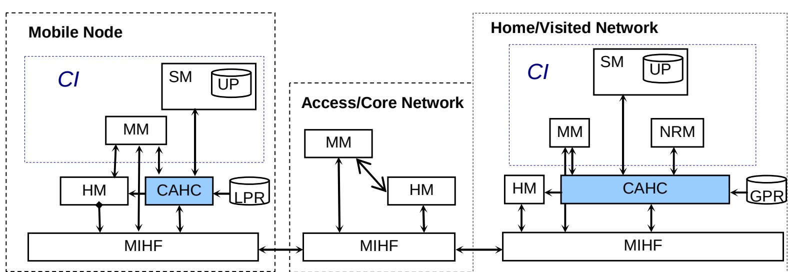

Fig. 2. Network controlled handover scenario.

The SM is supposed to manage the high level services (VoIP, Video on Demand, Data-oriented services etc.). It contains inside an User Profile server and a data base.

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

- *User Context (UC)* – identifying information, either static user information (billing preferences, energy, security level) or dynamic user information (location). UC information can be triggered or queried from UP placed on network side inside SM block or can be stored at MN level.
- *Service Context (SC)* – information can be triggered or queried from SM. 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 established service, the SM can generate a trigger to notify the CAHC with regard to service characteristics (QoS parameters, service type). The SM performs service level management: planning, provisioning, offering and fulfillment 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 related information (network load, delay, jitter, latency, packet loss, congestion level). The NRM is a functional entity placed on the network side and is responsible for managing the resources at network level.
- *Mobility Context (MC)* – mobility context information is provided by MM which stores the current status provided by MIH protocol and higher level mobility protocols (L3MP), such as MIP (Mobile IP) [7, 8] or SIP (Session Initiation Protocol) [9, 10].

In this section we will present the main steps encountered during handover process from initialization to execution in case of the 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, Service Manager, Network Resource Manager or User Profile 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/dynamic information in network side.

The handover can be divided in three steps: *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 to. 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.

To illustrate the applicability of the proposed architecture we assume that at a certain moment a mobile node must fulfil four constraints: ***use the best access network*** (e.g. WIFI is preferred access technology), ***extend the battery life***, ***minimise the packet loss*** and ***latency*** during handover. User context is defined by all four constraints and should be taken into consideration together when we will search for appropriate policies.

3.1. Handover Initialisation

Suppose a mobile node arrives in an area with two available access technologies – WIMAX (802.16e) and WIFI (802.11b). Based on user preferences and MM information, CAHC decides that the mobile must change the access network, therefore the handover process is initiated.

At this stage 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 aggregated 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).

3.2. Handover Decision

In this stage the aggregated information will match a policy from the PR list. The aim is to find the appropriate network. The reference network and other candidate access networks will be ranked according to certain policy. And finally the one before the reference network will be selected as the target network. Therefore, both user experiences and resource efficiency could be guaranteed using 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.

3.3. 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.

4. Evaluation scenarios

In order to validate the proposed architecture a network topology consisting of one WIMAX base station, one WIFI access point, one mobile node and two routers is used. Fig. 3 presents the network topology and Table 1 presents values for the most relevant variables.

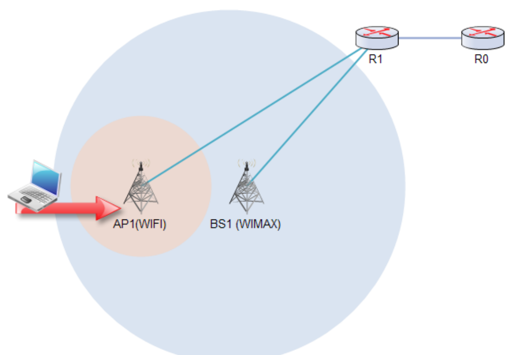

Fig. 3. Vertical handover (WIFI-WIMAX)

Table 1

Simulation parameters.

Number of mobile nodes	1
Mobile node movement	Rectilinear movement at 1m/s
Propagation channel model	Two Ray Ground
Wired links	100Mbps
Traffic parameters	UDP, CBR, video, 396,8kbps
WIMAX parameters	Technology: 802.16e, 16QAM (10Mbps) BS TxPower: 25mW(14dBm), 3.5GHz RxThresh: 1.26562e-13 (~-96dBm)
WIFI parameters	Technology: 802.11b (11Mbps) AP TxPower: 25mW(14dBm), 2.4GHz RxThresh: 2.72123e-09 (~-70dBm)

Energy Model	Initial energy [Joules]: 100 RxPower [W]: 0.660 TxPower [W]: 0.395 Sleep power [W]: 0.010 Transition from sleep to idle (active)[W]: 0.020 Transition time [sec]: 0.005 Idle power [W]: 0.035

Traffic is generated by the core network router R0 and the receiver is the mobile node. During the validation we study two main scenarios: *(i) keep both interfaces up*, *(ii) keep only the active interface up*.

5. Tests results

In this section we present the results obtained after simulation studies modelled in the ns2 event-based simulator[11]. In the performed simulation studies, multiple metrics were evaluated to characterize the handover performance: *(i) packet loss, (ii) handover latency, (iii) throughput* and *(iv) energy consumption*.

5.1. Keep interface ON after the HO

In this scenario both interfaces, WIFI and WIMAX, are running during entire simulation, but only one is active to handle the user traffic. Initially the mobile node is attached to WIMAX access network and receives video traffic till it's enters in the WIFI hotspot coverage. Based on user preferences the mobile node will be switched to WIFI access and it will stay there till it's losing the WIFI signal and then will switch back to WIMAX.

The policy to trigger the first handover (WIMAX to WIFI) is defined by the following user context: *(i) user preferences:* use WIFI whenever is possible, (ii) *service constrains:* minimise packet loss and handover latency, *(iii) network context:* WIMAX coverage.

The second handover (WIFI to WIMAX) is triggered by another policy which match the new user context: *(i) network context:* WIFI coverage, *(ii) service context:* minimise packet loss and handover latency, *(iii) mobility management context:* handover imminent.

Average packet lost: **18**
Average HO latency: **0.397522 sec**
Average energy consumption: **13.5642 Joules**

5.2 Stop interface after the HO

In this scenario only one interface, either WIFI or WIMAX, is running and handle the user traffic. Initially the mobile node is attached to WIMAX access network and receives video traffic till it enters in the WIFI hotspot coverage. Based on the user preferences the mobile node will be switched to WIFI access.

The policy to trigger the first handover (WIMAX to WIFI) is defined by the following user context: *(i) user preferences:* use WIFI whenever is possible, (ii) *service constraints:* minimise packet loss and handover latency, *(iii) network context:* WIMAX coverage.

The second handover (WIFI to WIMAX) is triggered by another policy which match the new context: *(i) network context:* WIFI coverage, *(ii) service context:* minimise packet loss and handover latency, *(iii) mobility management context:* handover imminent, *(iv) user context:* minimise the battery consumption.

To meet the battery constraint, the mobile node will use only one wireless interface at a time, after each handover the interface used for the old access network is turned off. To implement this behaviour the mobile node will stay on WIFI till it will reach a *dynamic* threshold for the signal to noise ratio (SNR). In this moment it will start to scan for available access networks and before losing the WIFI signal the mobile will switch back to WIMAX.

Average packet lost : **16.1**
Average HO latency: **0.0489353 sec**
Average energy consumption: **10.0032 Joules**

5.3. Results summary

In this section we present the summary of the measurements performed during ns2 simulations. The Fig. 4 it showing comparatively the throughput obtained in the two scenarios together with the transitions from one technology to another and Fig. 5 presents the energy consumption.

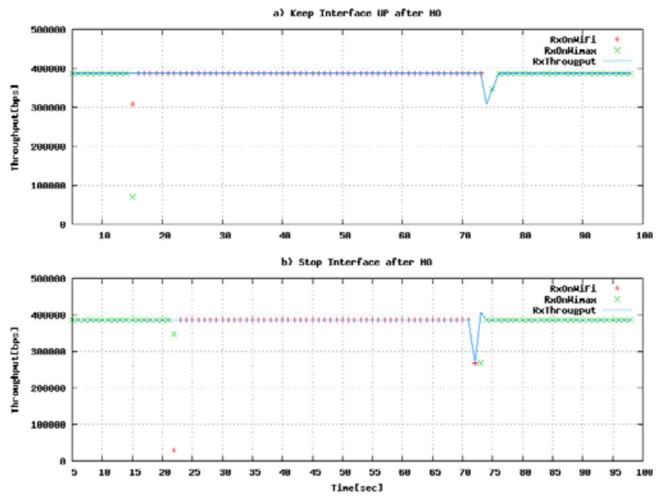

Fig. 4. Throughput and transition between access technologies

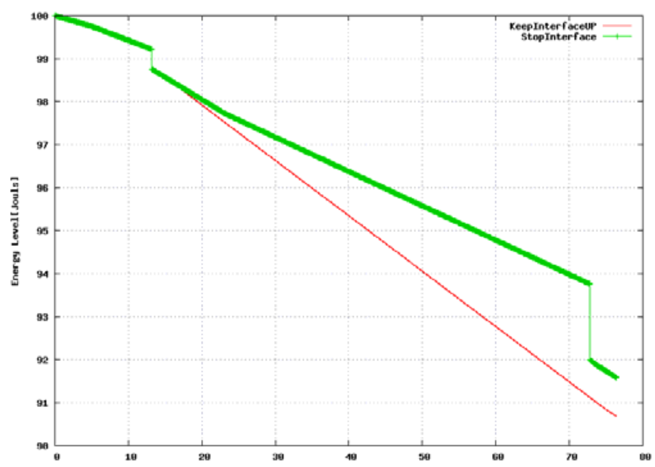

Fig. 5. Battery consumption

In the second case, based on the algorithm used for network selection and dynamic threshold allocation for network scanning, the battery lifetime is prolonged with ***35.6%*** while conserving the packet loss and handover latency.

Table 2

Handover performance.

	Packet Loss [No]	**HO Latency [sec]**	**Energy [Joules]**
Keep interface ON after the HO	18	0.397522	13.5642
Stop interface after the HO	16.1	0.0489353	10.0032

6. Conclusion and further 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 be 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 formats and its behaviour are under investigation. In addition the design considerations related to a network and terminal based coordinated decision, caching mechanism and context information lifetime are open to further research, pending for a formal validation based on a prototype implementation and performance evaluation.

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