

An Access Selection Prototype Based on IEEE 802.21

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Abstract. The Mobilia project is facing the new challenges appearing in the forthcoming wireless communication scenarios in which one of the distinctive factors is their intrinsic and remarkable heterogeneity. The evolution of the technologies has brought about the possibility of having terminals equipped with different interfaces, and thus the end-user device should be able to select the most suitable from a broad range of access alternatives. This paper presents an illustrative use case, based on a businessperson who presents different communication needs while traveling through heterogeneous networking scenarios. Starting from this point, we derive a set of requirements which should be addressed by Mobilia, following the concept of always best connected. Finally, the paper presents a platform developed so as to evaluate the entities performing the mobility management, handover decision algorithms and architectural protocol extensions, as proposed in the project.

Keywords: Service platforms, Validation, Demonstration, Heterogeneous accesses, Media Independent Handover, Mobility.

1 Introduction

One distinctive characteristic of future network deployments in wireless communications is their intrinsic heterogeneity. This does not only affect the involved technologies, but it also spans to the operators behind the different networks. It is envisaged that current performance figures would not be enough to fulfill with the new expectations so it is required to study advanced techniques and new algorithms in order to improve the mechanisms which are employed to select the most appropriate access. Hence, it is quite sensible to assume that, in order to offer end-users a good service, different actors might need to cooperate between them.

After analyzing the requirements obtained from the proposed scenarios, Mobilia suggests a new architecture able to handle the identified challenges. Due to its growing relevance, it uses the framework provided by the IEEE 802.21 group, the Media Independent Handover as the transport mechanism for the signaling which will be required between the involved entities. The information carried over such messages will be used to foster an optimum access selection.

Another key element to be studied and evaluated in this work is the service platform. In order to offer the users the best Quality of Service (QoS), it is mandatory to adapt their performance to the characteristics of the subjacent wireless technologies, in terms of load, quality, etc. This implies that there must be some sort of interaction between the service platform and the access selection architecture.

The paper is structured as follows: Section II presents an illustrative use case where a businessperson presents different communication needs while traveling through heterogeneous networking scenarios. Based on these scenarios, section III introduces the requirements and concepts to be evaluated. Section IV describes the demonstrator process, based on a concrete use case derived from the first scenario. Finally, section V summarizes the main conclusions of this work.

2 Scenarios

This section describes a day-in-the-life of a business person. By looking at her necessities, we will be able to identify the communication requirements that Mobilia project needs to deal with. Before, we present the technical assumptions which must be taken into account.

2.1 Assumptions

The most important part of the scenario is the mobile terminal, since it is assumed to have the capacity to seamlessly interact with a number of new and legacy wireless technologies, including UMTS, HxSPA, LTE, WiMax and 802.11. As will be detailed later, this relevant heterogeneity needs to be emulated on a real platform, due to the limited availability of these technologies (especially if we are willing to integrate them with proprietary developments and procedures).

Regarding the services which will be involved, it is worth highlighting their broad set of different requirements, such as high speed, low delay, etc, (imagine e.g. video conference and high quality video streaming). We could even envisage some sort of business cases, considering several subscribers; whose are able to obtain a premium service by the reservation of the appropriate bandwidth required for their specific services/applications needs.

The scenario describes how these Premium services are launched. In the meantime, we would assume that the terminal is able to operate in a power saving mode, while being aware of new video calls or other services.

2.2 Story Line

The use case presented in Mobilia follows the story line of a businessman, John, travelling from Madrid to Bilbao for a meeting. The user owns a Personal Area Network (PAN) which consists of a laptop (WLAN, Bluetooth) and a Smartphone (that could be a; WLAN, UMTS, Bluetooth and WiMax).

John starts the journey connected to the Internet via the WiFi home network, so he establishes a conference with his colleagues in Bilbao and closes the agenda for the meeting in the afternoon. One hour later, just before leaving the house John shuts down the laptop, the PAN recognizes the action and transfers the conference to his

Smartphone. Until this moment the PAN is connected via the WiFi network and just before leaving the coverage area, the Smartphone starts to search new available networks (UMTS, WiMax) in order to continue the conference started earlier.

Once in the car, all the Smartphone functionalities are transferred over Bluetooth to the small remote control located on the steering wheel. John is able to continue with the conference using the hands-free mobile kit while the Smartphone connects to the company network, and starts to synchronize his corporate mailbox in the background.

The next step in the journey is a shopping centre. While John is having the breakfast in a coffee shop, the Smartphone detects a local Hot-Spot network which allows internet access with lower costs than UMTS technology and with a higher Quality of Service, so John finishes the conference using this access. During all this time he has been receiving offers to download multimedia contents over a podcasting service. On the other hand, the "hot-spot" detects John's laptop relaying capabilities so he is offered a discount on his connection if he makes the laptop work as a relay node extending the coverage of the station hot-spot to other end-users.

Finally, he arrives at the airport and starts a new connection to the internet using a WiFi hotspot. Since the WiFi hotspot is heavily loaded, and provided that Madrid airport offers a WiMax access network, John is able to access the news, update the Smartphone, and use all the Internet services he needs until boarding time using this alternative access.

3 Requirements and Concepts to Be Evaluated

The Mobilia Project, based, among others, on the previously identified challenges, is focusing on some of the technologies and general system requirements and features from what we refer to as IMT-Advanced [1]: below we enumerate some of the most relevant ones.

- Access and Handover Latencies to enable delay-sensitive applications.
- Support of Traffic classes with different latency and packet error rates performance, in order to meet the end-user QoS requirements for the various applications.
- Mobility environments (pedestrian, vehicular and high speed) Optimization for specific low speed scenarios.
- Global roaming capabilities.
- Mobile user interface. Ubiquitous access, support for unicast and multicast broadcast services.
- Peak and sustained data rates, capacity, latency, overall network complexity and QoS management.
- Based on open standards and protocols.
- Supporting state of the art and legacy applications as video, web browsing, e-mail, file uploading and downloading, streaming video and audio, Location based services, Voice Over IP (VoIP), instant messaging and on-line multi-player gaming.

The Mobilia solution supports the "always-on" paradigm based on two distinctive factors: the smart administration of the mobile energy and the support to a user

experience of moving seamlessly between heterogeneous mobile access technologies. In particular, Mobilia is focusing on the following technical goals.

- To achieve the capacity to seamlessly interact with a number of new and legacy heterogeneous wireless technologies.
- To avoid interferences and collisions at the physical layer (technologies with different frequency bands and power transmission).
- Lower delay, higher QoS, power saving strategies and improve energy efficiency.
- Use the standard IEEE 802.21 in order to facilitate the exchange of information process and help to improve it.

4 Demonstrator: Service Networking Components for Heterogeneous Accesses

Derived from the scenario which has been depicted above, this Section presents the architecture that has been designed in order to assess the feasibility of the previously identified concepts. It is important to remark that its main goal is to assess their feasibility over real platforms. Hence, the existing clear limitations regarding the technologies to be used need to be taken into consideration. We have to recall that, at the time of writing, the availability of cellular (and WiMax) communication infrastructures is difficult to be ensured, especially if we think about the possibility of modifying their legacy operation during the access selection (resource management) procedures, as will be further explained later.

We understand that a clear added value of this proof-of-concept platform is the role that the Media Independent Handover Function (MIHF) plays [2]; we have already seen that IEEE 802.21 will be of outer relevance in handling heterogeneity in forthcoming wireless communication scenarios. Although there are some recent works which have already provided some details about IEEE 802.21 implementation, we go beyond them, since we analyze its role on a particular use case and, furthermore, we extend its original purpose, by using it so as to handle message interchange between the entities which are within the same node.

4.1 Platform Implementation

The Mobilia Demonstrator comprises a number of off-the-shelf components, over which some of the concepts developed within the Mobilia Project, and which have been previously detailed, can be assessed and evaluated. As we have introduced before, this platform must take into account the limitations of the available technology, in order to establish some bounds on the degree of detail which is sensible approaching for the different aspects to be challenged.

The idea of using “real” heterogeneous networks (meaning completely different technologies) needs to be discarded, due to its inherent complexity and extremely high cost (UMTS licenses, etc). Moreover, the necessity of incorporating our own developments within the Access Points prevents the use of commercial products. For instance, currently available WiMAX equipments and their corresponding software are not open enough to allow modifying their legacy operation. On the other hand, the architecture, both at a conceptual and at an implementation level, is flexible enough

so as to enable the integration of additional technologies, if it was deemed necessary. The use of 802.21 ensures this degree of flexibility, although the limitation is more on the availability of the required products, Operating System support and possibility to tailor the legacy behavior of the network-side elements.

As a consequence, heterogeneous networks are emulated within the platform. We will use two different WiFi Networks (IEEE 802.11b and IEEE 802.11g) so as to guarantee a certain heterogeneity level (the two corresponding WLAN cells are configured in different and non-overlapping channels).

Traditional laptops are used for all the nodes which are part of the platform. All of them are running the Linux Operating System [3] (Ubuntu distribution) and use both their internal WiFi chipsets (Intel) as well as an external PCMCIA cards, based on the Atheros chipset. These wireless cards are essential, since they allow us the use of the *MadWiFi* [4] drivers and emulate the role of Action Point (AP) within traditional laptops.

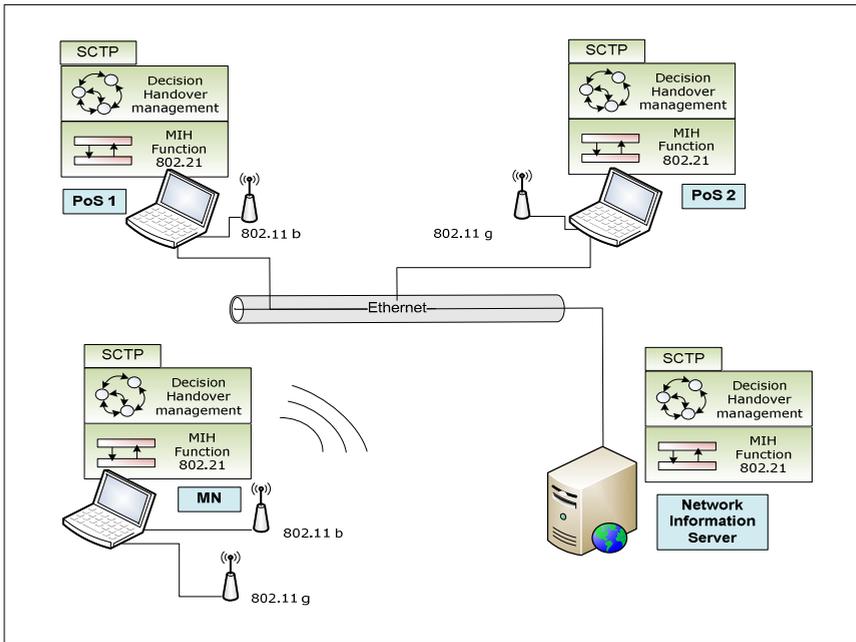


Fig. 1. This Figure depicts the demonstrator architecture used in Mobilia project

The figure 1 shows the architecture and equipment involved in the development of Mobilia demonstrator [5]. First, on the end-user side, we have the *Mobile Node (MN)*. It is represented by a laptop which incorporates two WiFi cards. On the network side, there are two laptops working as the two different *Points of Services (PoS)* and a *Network Information Server*, which exchanges information with the other entities. The two access elements are configured to emulate heterogeneous technologies, and thus they use non-overlapping channels, while the *Network Information Server* resembles the role of an Access Broker, able to assign resources based on the information it is aware of as well as its own rules and policies.

From a software perspective all the different nodes, incorporate a number of independent processes which interchange information between them. In particular, the following components, which emulate the Mobilia architecture to deal with heterogeneous accesses.

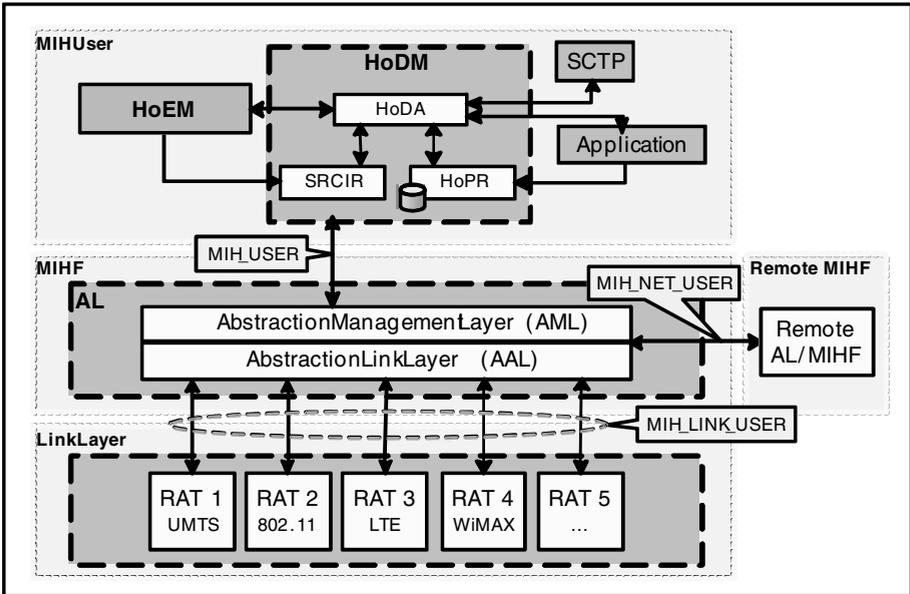


Fig. 2. The architecture proposed for Mobilia will inherit the framework defined by 802.21, creating on top of it a dedicated system to manage the information collection and management, the handover decision and its proper execution

We briefly describe the role of each element represented in figure 2, and afterwards, we provide some additional insights about them,

- **Link Layer:** Based on the MIH_LINK_USER SAP defined on the IEEE 802.21 specification, it facilitates to the different Radio Access Technologies (RATs) the data exchange with the Abstraction Layer.
- **Abstraction Layer (AL):** Its main function is to enable, either locally or remotely, the exchange of information and commands between the different devices involved in making handover decisions and executing handovers. It enables a fair and technology-agnostic comparison of the characteristics of the subjacent radio technologies.
- **Remote MIHF:** Provides to the framework the capabilities to share relevant information with remote elements through the MIH_NET_USER SAP.
- **Decision Handover Management (HoDM):** Based on the information provided by the Abstraction Layer through the MIH_USER SAP and a number of rules and policies, it takes a decision on which is the most appropriate access alternative.

- **Stream Control Transmission Protocol (SCTP):** It is a reliable, general-purpose transport layer protocol for use on IP networks that addresses mobility needs

IEEE 802.21 Signalling. One of the most important aspects of the demonstrator is the use of IEEE 802.21 as a transport medium for the exchange of information between different entities in the network [6]. The use of this standard will help to provide as much information as possible to the *Handover Decision Manager*, optimizing the decisions regarding the access point to be connected each time. The IEEE 802.21 signaling is based on a Type-Length-Value (TLV) codification, which offers different advantages from the point of view of implementation.

Abstraction Layer. The Abstraction Layer implements the 802.21 Media Independent Function, allowing the Handover Decision Manager to retrieve relevant information (and to instruct actions related to the handover process) from the different technologies its own device is equipped with, as well as with other network elements if needed.

More specifically, the Abstraction Layer (AL) designed within the Mobilia framework will be a custom implementation of the MIHF layer defined in IEEE 802.21 standard. It is structured into two different components, the Abstraction Management Layer (AML) and the Abstraction Link Layer (ALL)

The *Abstraction Management Layer* is in charge of managing the User MIH interface (MIH_SAP) and the remote interface (MIH_NET_SAP).

The *Abstraction Link Layer* manages the interfaces with the Link Layer (MIH_LINK_SAP).

For each Service Access Point (SAP) there are a group of primitives defined that are described in [6].

Handover Decision Management. The Handover decision management is performed by two elements: The *Handover Decision Manager (HoDM)* and the *Handover Execution Manager (HoEM)*.

Handover Decision Manager:

The HoDM is the core part of this entity, being the element with the final responsibility during the execution of the handover. All the data meaning and decision criteria are located at this level of the architecture. It is composed by the following elements:

- *Handover Decision Algorithm Module.* This HoDA element includes the necessary intelligence to decide when a handover shall be done.
- *Handover Policies Repository.* This HoPR repository is used by the HoDA to set the basis of the conditions to order a handover. This information is combined with the one provided dynamically by the Service Requirements Collector Information Repository (SRCIR).
- *Service Requirements Collector Information Repository.* The SRCIR implements the MIH_USER interface to the AL/MIHF and act as a dynamic repository for the information collected from the MN and the Network. This information is used by the HoDA.

Handover Execution Manager:

The HoEM interfaces directly with the MIHF through the SRCIR to manage the primitive exchange in order to execute the handover. This element owns the necessary intelligence to manage the event reporting and error handling that the handover procedure might create.

SCTP Protocol. As previously mentioned, SCTP is a transport layer protocol for IP networks. While the protocol was originally designed for telephony signaling (under the RFC 2960 [7]), SCTP provided some interesting additional functionalities. It solved some of the limitations of Transmission Control protocol (TCP) while borrowing beneficial features of User Datagram Protocol (UDP). SCTP [8] allows high availability, increased reliability, and improved security for socket initiation.

Mobilia will use SCTP as an alternative mobility mechanism to Mobile IP. The utilization of SCTP tries to explore alternative solutions to the wasteful use of bandwidth and the IP tunneling by Mobile IP that is forcing a lot of communications to go back and forth to the Home Agent location. In the case of high throughput communications like those proposed by IMT-Advanced this should be avoided if possible. The solution proposed should provide as well faster handover speeds as the ones provided by Mobile IP due to the intrinsically lower layer mechanisms involved.

Mobilia A SCTP proxy will be used at both sides of the channel. In the server side it takes an incoming UDP connection, establishing an outgoing SCTP connection. In the client side the process operates reciprocally; it takes an incoming SCTP connection and sends the data flow through an outgoing UDP connection. This solution has been selected in order to be able to use a standard video server and client such as the VideoLAN Client (VLC) media player. The SCTP proxy in the client has also a thread to test if one of its interfaces must be in the SCTP association and change it.

The distinctive capability of SCTP entailing it as a mobility solution is its multi-homing capacity. Multi-homing provides applications with higher availability than those that use TCP. A multi-homed host is one that has more than one network interface and therefore more than one IP address to which it can be addressed.

SCTP supports mobility because it does not require additional equipment such as the Home Agent of Mobile IP.

The last version of SCTP protocol is defined by RFC 4960 [9], and the optional extension for Dynamic Address Reconfiguration is defined by RFC 5061 [10]. This extension will allow an SCTP stack to:

- Dynamically add an IP address to an association.
- Dynamically delete an IP address from an association.
- Establishing the primary address the peer will use when sending to an endpoint.

These characteristics are also especially useful in handover scenarios, since they allow dynamic changes in the connection even if the terminal has only one interface. As a conclusion STCP provides features demanded by IMT-Advanced like lower latencies and seamless connectivity [1].

4.2 Use Cases

Looking back to the story line, we can extract three different use cases [11]:

- *Use case A* corresponds to the moment when the businessman in the middle of a conference shuts down the laptop and the conference is automatically transferred to the Smartphone. This time, the decision of execution of the handover comes from the user side.
This use case will be represented in the proof of concepts through a handover process from IEEE 802.11g to IEEE 802.11b (in place of UMTS) which will be initiated by a “Link going down” primitive.
- *Use case B* corresponds to the moment when the businessman arrives to the shopping centre and the Smartphone (connected by UMTS) detects a local Hot-Spot network which allows Internet access with lower costs than UMTS technology and without downgrading the current Quality of Service. As a consequence, the Smartphone will change to the Hot-spot network.
This use case will be represented in the proof of concepts through a handover process from IEEE 802.11b (in place of UMTS) to IEEE 802.11g which will be initiated by an application which requires more bandwidth and “prefers” lower costs.
- *Use Case C* matches the last handover process detailed in the scenario, when the businessman is in the airport using a WiFi connection which is suffering from a high load situation; in this case the handover process is initiated by the Serving Network. This time the handover is from WiFi to the WiMAX access network provided by the airport [12].
This use case will be represented in the proof of concept by means of a handover process from IEEE 802.11b to IEEE 802.11g (instead of WiMax) which will be initiated by the Network Information Server.

In the following, we provide a detailed description of the first use case, in which we depict all the primitives and components which take part on the whole process.

Use Case A: Flow Chart. The next figure shows a Handover process from IEEE 802.11g to IEEE 802.11b motivated by a *Link going down* event. This flow chart is emulating the handover process in the use case when John leaves his home and there is a handover process between WLAN and UMTS. The first step in the process is making a subscription to the events that the MN wants to receive in the future. A *MIH_Link_Parameters_Report* is generated when one of link parameters (e.g., the speed of link, QoS, and bit error rate) equals to a given threshold value set by *MIH_Link_Configure_Thresholds* command. This information goes up to the HoDM that will decide to have a handover. Right after that, the Mobile Node sends a *MIH_Get_Information* request frame to the Network Information Server. Then, it sends back a *MIH_Get_Information.response* frame which contains the available neighboring networks information [6].

This information is also forwarded to the HoDM, which decides to go on with a given list of potential candidate networks. To do so it sends a request to its serving PoS (located on 802.11 g Point of Service). This information is sent using the primitive *MIH_MN_HO_Candidate_Query.request*. Then, the serving PoS starts querying the available candidate networks (taking into account the information provided by the MN) asking for the list of resources available and including the QoS requirements of the user, this is performed by a successive exchange of *Query Resources* messages with one or several candidate PoSs (only with another PoS in our case). The result of

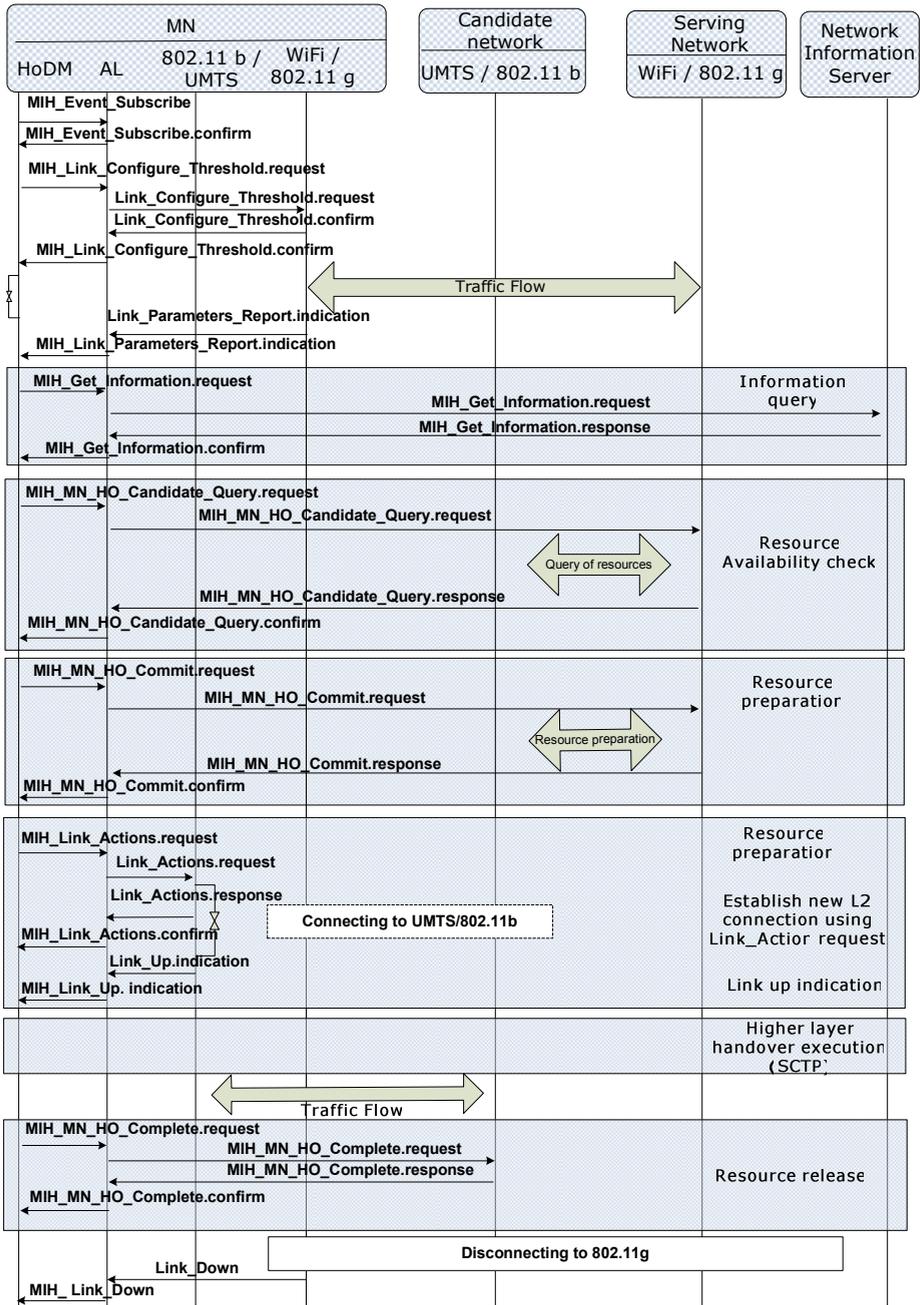


Fig. 3. This shows the flow chart concerning the Handover process from 802.11g to 802.11b motivated by a *Link going down* event [6]

the queries is sent to the MN through *MIH_MN_HO_Candidate_Query.response*. At this point, the MN owns enough information about the surrounding networks to take a handover decision.

Once the HoDM, Handover Decision Manager, has decided the target network to handover, the HoEM takes command of the situation and delivers this information to the Serving network using *MIH_MN_HO_Commit.request* which will exchange some information with the candidate network and will send a confirmation to the Mobile Node through *MIH_MN_HO_Commit.response*. The next step is establish new L2 connection using *Link_Action.request* and after issuing the commands to start UMTS/802.11 b connection establishment, the AL sends a message to the HoDM indicating the start of the connection. Then, there is a *Higher Layer Handover Execution (SCTP)* and the HoDM sends an *MIH_HO_Complete* message to the AL, which will inform the target PoS, which becomes the new serving PoS. Finally, there is a disconnecting process in the old serving network which finishes with a *Link_down* message.

5 Conclusion

The advent of heterogeneous wireless networks is already a reality. This has brought about the need for architectures able to deal with the upcoming challenges and requirements which will appear. Although there has been already some works proposing solutions towards this direction, most of them have not studied their feasibility over real platforms. We understand that this is a mandatory step, since we might obtain information elements so as to refine and fine-tune such architectures. In the Mobilia project we have faced this challenge and we have designed and implemented a demonstrator, using off-the-shelf technologies and components to assess the feasibility of the proposed architecture.

A number of use cases were established over a typical scenario (a day in the life of a business man), so as to identify the necessities and requirements which should be tackled by the Mobilia architecture. This scenario has been mapped onto a real platform, taking into consideration the limitations of existing technologies, and over such platform, different entities have been tested.

The demonstration encompasses various entities, both at the end-user and network side, and handles access selection based on different parameters, such as link quality and network load. In addition, different rules and policies can be established, based e.g. on the operator agreements and end user preferences.

One of the main contributions of the Mobilia architecture, in general, and in the demonstration, in particular is the role that it has been given to the Media Independent Handover Framework. It goes without saying that the work carried out by the IEEE 802.21 working group will play a key role in heterogeneous networking scenarios, and thus it is interesting assessing its feasibility over real platforms. In the presented demonstrator, the IEEE 802.21 specification has been used so as to handle the signaling interchange between the different Mobilia components.

Mobility is another feature which cannot be avoided in the considered scenarios; in order to handle IP addresses while shifting from one access to another, we have employed SCTP, although the architecture is flexible enough to use other solutions. The most remarkable aspect is that the mobility solution has been integrated the access selection engine, and reacts to its requests.

This platform will be extended, so as to be able to analyze different situations and algorithms. In addition, the conclusions which can be extracted from it will allow us to refine and fine-tune the proposed architecture, together with the simulation-based analysis which is being carried out in parallel.

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