A Media Independent Information Service Integration Architecture for Media Independent Handover

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***Abstract* — A present challenge in wireless networks is to provide mobility, regardless of the access technology in use, with guaranteed continuity of the service and transparency for the users. One approach to these seamless handovers is to prepare network access in advance, such as pre-authentication, before the mobile device actually physically connects to the desired network. This process requires that the mobile device can discover the parameters of the networks in their geographical area prior to connect to the candidate network. To address these issues, in this paper we propose an integration architecture for a Media Independent Information Service, where several networks elements collaborate in the discovery of information network, and mobile devices collect the desired neighboring network information with a query-response mechanism in two steps. A prototype has been implemented with of the shelf hardware, and several tests have been conducted. Results are better than the ones available in the literature, and network selection is performed in a short period of time.**

***Key words* – hetereogeneous handover; IEEE 802.21; MIH; mobility; network discovery.**

I. INTRODUCTION

The growth of new technologies for access networks over the years has increased the demand for mobility solutions across heterogeneous networks. There is a goal in this area: to incorporate the simultaneous use of multiple access networks to provide users with improved quality of service, regardless of the network in use, and to ensure continuity of session during the execution of handover, allowing the user to enjoy the best access, at any time, without incurring long delays (ABC; Always Best Connected concept [1]). To perform this interconnection between different networks, many challenges have to be solved, namely the network discovery and selection. The discovery of networks is meant as the ability of the mobile node to find appropriate access points and information of the network to which they belong, such as Dynamic Host Configuration Protocol (DHCP) address, bit rate or cost. This functionality helps to better support mobility, reducing the interruptions in the handover, through the possibility to perform tasks such as pre-authentication with the target network before the Mobile Node (MN) actually move to it. The network selection is intended as the decision to choose a new network with better attributes according to user's preferences, matched against the information collected about neighboring networks.

There are many related works in the area of network discovery [2][3][4][5][6][7]. However each of them defines its own schemes and mechanisms, and few actually developed a prototype.

In our research, instead of defining another schema for network discovery, the proposed architecture and developed prototype is based on statements and ideas of the Institute of Electrical and Electronics Engineers 802.21 (IEEE 802.21) Media Independent Handover (MIH), in particular the Media Independent Information Service (MIIS) [8]. Based on the schemes of this service, another challenge to solve is how to obtain efficiently all essential features of the current network. This issue comes from the fact that the MN alone is not able to obtain all the information defined in the MIIS scheme.

To handle these challenges, it was necessary to design an efficient architecture where issues of current network information discovery, network neighborhood discovery and network selection were resolved. This paper proposes an architecture that stands on a distributed model to discover information about networks, in order to build up the information server database.

On the other hand, a centralized storage approach is used, where the Point of Attachment (PoA) provides information about the current network and a centralized information server keeps the information about the neighboring networks to provide it to the mobiles when requested.

To improve performance, MNs will query network information with a query-response mechanism in two steps.

This paper also presents the implementation of a prototype, and test results have proved that of the shelf equipment, such as Access Points with limited processing capabilities, can participate in this approach. Processing times in our approach have improved the ones available in [6].

The remainder of this paper is organized as follows: Related works and researches in the area of mobility optimization, mainly about network discovery is described in Section 2. Section 3 describes the proposed architecture and respective schemes used in the prototype. An example of the information service implemented as well as the results obtained are shown in Section 4. Finally, in Section 5 some conclusions are presented and future work is proposed.

II. STATE OF THE ART

Recently, several standardization efforts have been made to introduce news protocols and architectures to optimize the support for mobility through access networks at different levels. Some task groups within IEEE 802 are currently working in this subject. IEEE 802.11k [9] introduces a measurement pilot frame facilitating handover decisions, which is transmitted periodically by an AP and provides information about it. Another effort is the IEEE 802.11i [10], which has the purpose of optimizing the authentication between the mobile node and a new access point. This is reach through the addition of a new entity in each AP that is responsible for the authentication. All exchanged messages of authentication are done between these news entities.

The 802.21 working group have been dedicated to the mobility across heterogeneous networks (MIH). This standard defines several services to help in the seamless handover, namely an information service MIIS. Through this service, the MN has the possibility to obtain network information. MIIS has already defined a set of information elements (IEs) as well as its representation and the type of mechanism for information transfer, which is query/response. The information provided by the IEs are mainly static link layer parameters, such as channel information, Media Access Control (MAC) address of PoAs, network type and many more. MIIS defines the representation of all this information elements through a common Resource Description Framework (RDF) scheme [11]. However, it is not in the goal of the standard to define how this information can be obtained. Our research reported in this paper takes into account this aspect, proposing a retrieval architecture, and considering constrains that limits on the information that should be retrieved, such as a geographical area.

There are also some researches made around the 802.21 standard to optimize the mobility management solution involving vertical handover. It is the case of a new technique called Media Independent Pre-Authentication (MPA) [4]. With this technique a MN can securely obtain an Internet Protocol (IP) address and other configuration parameters from a Candidate Target Network (CTN) before it physically attach to the CTN. The fact of communicating at the network layer before establishing link layer connectivity is a great benefit in terms of reducing handover delays. This process is possible through the Protocol for carrying Authentication and Network Access (PANA) [3] that establishes a bi-directional tunnel between the device and the PoA of the CTN.

However, it is not the purpose of 802.21 to design a new mobility protocol. This standard introduces a framework that provides helpful services to the nodes involved in the mobility procedure. So this framework must be used in conjunction with a mobility management protocol. The protocols that have been proposed to address this issue in heterogeneous networks are Mobile IP (MIP) [12], Stream Control Protocol (SCTP) [13] and Session Initiation Protocol (SIP) [14]. Reference [15] evaluates the performance of these three approaches in the handover process between Wireless Local Area Network (WLAN) and Ethernet. The times obtained in the mentioned paper with the times spent in the network discovery will condition the Handover (HO).

Addressing the particular issue of network discovery, the Internet Engineering Task Force (IETF) group published several Request for Comments (RFC) about this topic. In [5] some challenges were identified, such as the discovery of PoAs, the interaction with the Authentication, Authorization and Accounting (AAA) and networks capabilities discovery. From a more practical point of view, [6] describes some architectures and approaches for network discovery, addressing data-base built mechanisms for the gathered information. The implementation made was based on centralized information server. Although the used information scheme is not the same that the one in 802.21 standard, the information representation and the type of mechanism used there are the same, i.e. RDF and query/response respectively.

Similarly in cellular networks such as Global System for Mobile Communications (GSM) and Code Division Multiple Access (CDMA), some efforts have been done to support handover over different radio access technologies since these networks already support homogeneous HO through General packet radio service (GPRS) Tunneling Protocol. The next step in 3rd Generation Partnership Project (3GPP) networks is Long Term Evolution (LTE) that allows vertical handovers between LTE and non-LTE networks.

The developed prototype handle the issue of network discovery executing an architectural model designed to obtain the neighboring network information to be stored in a centralized server. Afterward all this data can be reached by queries. As the objective is to simulate real environments, there is a lot of information to be accessed and this can be an issue. The developed work tries to resolve this issue optimizing all schemes and mechanisms defined.

III. Proposed Integration

This section describes the proposed integration architecture for the MIIS (III-A), and details the implementation of the prototype, developed for this research (III-B).

A. *Architecture*

The architecture proposed for the prototype implementation uses a centralized model in the sense that an information server keeps the information about the network elements in several networks and will provide information about neighboring networks, after getting a request from the MN. However the harvesting of information about the networks to build up the information server database is distributed, in the sense that several network elements will participate in the process, e.g., MNs report the information about networks they are visiting currently.

The main principles of this proposed architecture are:

- The MN gathers the information about the visited network. In most of cases, the device cannot discover all the IEs without some help from the network side. The solution found has as assumption that the PoA knows the remaining network information to which it belongs to provide it to the MNs. This point will be detailed in the Section III-B.
- The obtained information is sent to the information server that keeps it in its Database (DB), as shown in Fig 1. The MN is responsible for the population and update of the DB.

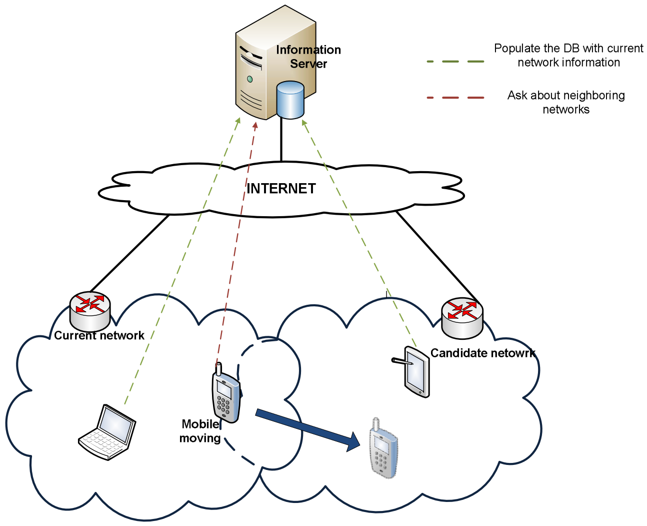

Figure 1. Network discovery in the architecture.

- When a subsequent MN decides to move into another network, it queries the server in order to obtain the IEs of neighboring networks as illustrated in Fig. 1.

With this kind of architecture, it is necessary to be aware if all MNs can be trusted to update the information server. Some control schemes are needed to certificate the authenticity of the information in the database.

The sequence diagram resuming the interactions between the network elements in our architecture is shown in Fig. 2. This interaction starts with information acquisition in the visited network and finishes with a network selection. Details of this process will follow bellow.

First the client searches for local information that it could find and afterward queries the PoA about current additional information of the network. After updating its own DB with the collected data, it queries the server to obtain IEs of the neighboring networks. This operation is made in two steps, i.e., two queries to the information server. The first is only to check if the server has new, additional or updated information. In this way, if there aren't any updates in server, it will not be necessary to make the second query. This avoids unnecessary exchange of data. As it will be possible to observe in Section III-B, the second query takes more time that the first one. This point is the advantage of this two queries scheme. As the information stored is mainly static, it means that few changes will occur in the server DB along the time and the queries to obtain data will acquire a repetitive and useless character. If in fact the server contains updated information, then the device will make the second query to get the IEs of neighboring networks and store this information in its local DB.

B. *Implementation*

According to the IEs scheme defined by MIIS and the architecture chosen above, this information service was developed based on real scenarios where the objective is to measure the prototype performance in terms of times. Many efforts have been done at the PoA side, since it is a component with limited capabilities. The components used in the prototype were the following:

- At the information server end, it was used an updated Joseki [16] version to interpret the requests (SPARQL - Simple Protocol and RDF Query Language) received from clients and send the information requested. Joseki is an Hypertext Transfer Protocol (HTTP) server and works as an interface to the Suitable Database (SDB) where the RDF data are stored as subject-property-object.
- At the PoA side, the Hardware (HW) used was an ASUS WL-500G Premium router with a DD-WRT [17] firmware installed. Some improvements were necessary such as the increase of Random-access memory (RAM) and the installation of a Java Virtual Machine to allow the functionality to retrieve the IEs from the current network to the devices. The process to get the IEs is similar to network discovery, where the MN sends a query to Joseki in PoA that is linked to a RDF file containing all data needed.
- The main component of this prototype is the client where an application was developed through Jena [18] with the following functions:
  - Visited network information acquisition;
  - Information server update;
  - Network neighborhood discovery;

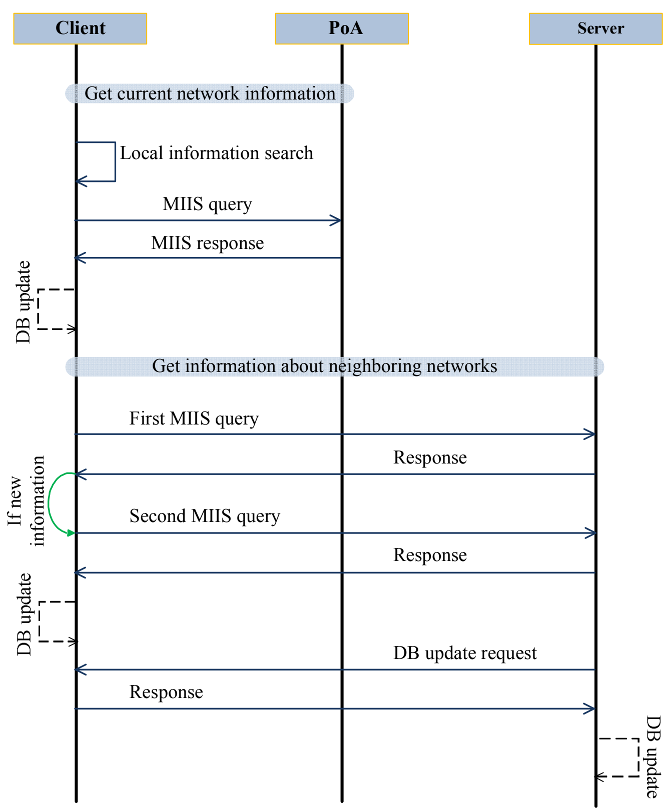

Figure 2. Sequence diagram of the information service.

- Local DB update;
- Network selection.

Fig. 3 represents an interconnection between all these software components in the centralized model.

IV. Simulations and Results

This section provides a demonstration of what the developed prototype can do and how it responds in some scenarios. To do that, two types of tests can be performed: functional and non-functional tests. The first one has the goal to demonstrate what the prototype can do and the other the analysis of the prototype performance.

One of the functional tests that can be studied is the reaction to changes in the neighboring environment. Some variables were defined, such as user's preferences.

For these tests we have considered in particular the data rate defined in the IEs.

In a first scenario a neighboring network increases it's available data rata. During one of the MN periodic queries, the MN will detect that there were changes in the server DB. Then, the MN makes the second query in order to obtain the new IEs. In this way, the MN will update its local knowledge about neighboring networks, and detects a network with a higher data rate than the one it is now connected to. Based on the user's preferences, the MN indicates a new candidate network, and triggers the handover execution.

In a second scenario, the response of the prototype was observed when mobility occurs, i.e., when the location of the device changes. When the MN moves, the neighboring networks obtained from the information server will change and may contain news networks with better data rates. When this is the case, the application on the client side will select a new candidate network to perform handover.

One way to analyze the prototype performance is to measure the processing times of the messages exchanged between the MN and the network elements, PoA and information server. The processing times refer to the time elapse from the transmission of query to the reception of the response on the client side. To analyze processing times, three tests were conducted. Table I indicates the conditions for those tests.

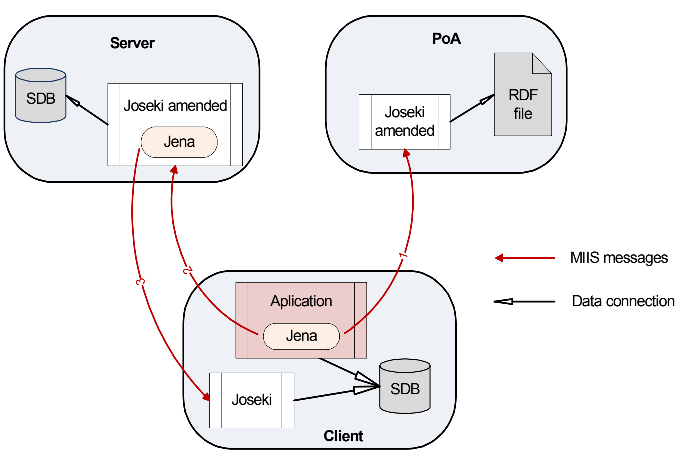

Figure 3. Software interconnection in the centralized model.

TABLE I. Performance tests

Test	Variable
1	Number of neighboring networks in server
2	Server query type
3	Number of PoA's clients

In the first test, the response of the prototype will be analyzed, regarding the interaction of the information server with the client, when the amount of neighboring data in the DB is increasing and consequently the exchanged data in the messages will also increase accordingly. The processing times for the first and the second query to the server were measured while increasing the number of neighboring networks.

As Fig. 4 illustrates, the response to the first query arrives with a constant delay. The processing times of the first query show independency of the number of neighboring networks in the server, with delays around the 100ms. This is due to the fact that the information gathered by this query is minimal, indicating only if there are or are not updates in the database. For the second query, which is sent to obtain all the IEs of neighboring networks, this behavior is not observed. The processing times have a tendency to increase with the number of networks. Until three networks in the server, the prototype retrieves the desired information in less than 2 seconds and reaches the 12 seconds when there exist 17 neighboring networks. This increase is mainly due to the time spent in the search done in the server database to retrieve the desired information. This is a consequence of the schemes used to store the RDF data and the mechanisms used by the SDB to make the match between the query and the data. The SPARQL query language is recent and still has some limitations, such as the definition of blank nodes to link information, without using well-known concepts like primary or secondary's keys.

In fact, blank nodes are how the properties with an

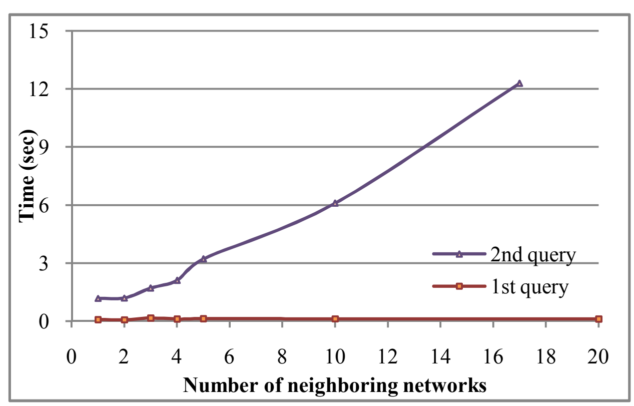

Figure 4. Processing time VS Number of neighboring networks in server.

abstract type are handled in SPARQL. Since most of the IEs are abstract, the information has many blank nodes pointing to the sub-properties generating an expanded tree representation with several levels.

The second test investigates the processing times of the information service during one hour of service, i.e., the evolution of the service along the time without any parameter change. The processing times of 3 queries were considered:

- First query;
- Second query with 1 neighboring network;
- Second query with 10 neighboring networks.

Fig. 5 portrays how these times have evolved. At the beginning of the service, it is possible to observe some high peaks, but afterwards the processing times have a tendency to alleviate. Table II compares the average values obtained for this prototype with another work done in the same area, which used similar schemes. In [6], a different approach with 2 queries to the server is also used, although with a different scheme than the one used in this implementation. The comparison done in the table is superficial, since there are not many details about their simulation conditions, such as the amount of data in the server, and effective number of neighboring networks. Nevertheless the scenario they have described has a maximum number of 3 neighboring networks.

With this prototype, the processing times up to 4 neighboring networks are better than the ones obtained in the compared paper, where only a maximum number of 3 neighboring networks could be used in their simulation scenario. For these reason our approach has a better performance. This could be justified by several reasons: the existent differences between the data schemas; a faster first query in our approach, where less data is exchanged; a more efficient implementation of our prototype.

The third test was the study of the PoA performance in a real multi-client scenario, i.e., with multiple clients sending queries to the PoA, in order to obtain network information.

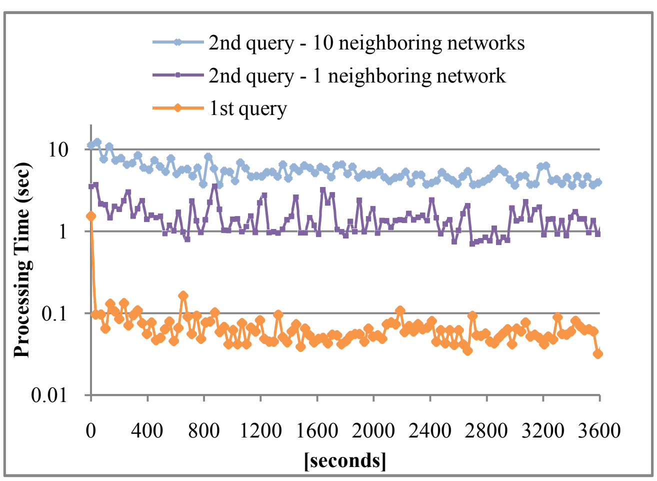

Figure 5. Server queries evolution along the time.

TABLE II. PERFORMANCE IN COMPARISON WITH RELATED WORKS

	First Query [ms]	Second Query [ms]	Total [ms]
[6]	2292	1473	3765
With this prototype:			
3 neighboring networks	765	1700	2465
4 neighboring networks	1094	2098	3192
5 neighboring networks	1235	3215	4450

To study the PoA behavior, an increasing number of MN queries the PoA. The period, at which the MN's send queries, is 30 seconds.

Table III shows that when just one client sends a query to the PoA, the Joseki, running within the PoA, takes only a few seconds to respond, being the total processing time of approximately 2 seconds. As the number of clients increases, the processing times also increase. This increase is more obvious when various requests arrive at the same time, causing a decrease of the performance. Still, the response times obtained in this simulation are quite good, if we take into consideration that the PoA has some limitations regarding available RAM and Central Processing Unit (CPU) performance.

CONCLUSIONS

The proposed and implemented architecture allows the gathering of neighboring information that can be subsequently used to prepare network activation, performing a pre-authentication, etc, with the selected candidate network, improving the handover process. The design of these efficient schemes and mechanisms for network discovery and selection reduce delays, when compared with available literature, which will improve a seamless user experience. This prototype shows that the PoA of the networks can help in this process by the adding some news functionalities to it, in order to help the MN in the harvesting of network information. This is possible even with networking elements with limited capacity such as

TABLE III. POA PROCESSING TIMES

Number of clients	Average of processing times [sec]
1	2.1635
2	7.4297
3	19.6885
5	26.8521

Access Points. The obtained results with this implementation demonstrate that the prototype allows reasonable processing times for a possible application of this information service in real handover scenarios. Depending on application requirements, these processing times can be sufficiently viable and practicable to meet the demands in the search and selection of a candidate network when a HO is approaching.

However there is space for some improvements in the near future. One possible improvement could be the iteration between the server and the client with three messages. The first message would have the same purpose as previously described. The second, depending on the user's preferences and their criteria of selection, would have the function to harvest only the necessary information that would really influence the choice of the candidate network. Then, the third message would give all IEs necessary for the HO. In this way, the HO process could initiate as soon the client would receive the answer to the second query, reducing overall delays.

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