# An Evaluation of an UMTS/WLAN Interworking Architecture using IEEE 802.21

Alexandru Vulpe [1] and Octavian Fratu [2]

*Abstract* – **This paper proposes an interworking architecture for mobility between UMTS/HSDPA and WLAN access networks based on the IEEE 802.21 (Media Independent Handover - MIH) standard. This architecture uses MIH signalling and blocks to provide information flows for a Resource Manager which controls the handover. The architecture is flexible and can be used for other types of access networks, but the focus is on UMTS and WLAN interworking because of the common presence of these two technologies in today's wireless networks. The architecture is evaluated using the EXata Network Emulator, and results are presented as handover time between UMTS and WLAN networks.**

*Keywords* – **access network selection, vertical handover, heterogeneous wireless networks, IEEE 802.21.**

## I. INTRODUCTION

The 3rd Generation of mobile communication systems is not focused on a ‘‘golden service”, responsible with the most revenues. It considers a diversity of services, with different requirements and, consequently, with different solutions for an optimal access technology. For this reason, a heterogeneous access network was a continuous dream both for operators and for the network equipment providers and only the technical difficulties and the estimations of higher costs for such access networks made that the interest for such solutions to be moderate. Fortunately, the technical progress in this matter is now important (the approval of the IEEE 802.21 standard [1] focused on Media Independent Handover – MIH is only an example) so the doubts on the technical difficulties related to the implementation of such heterogeneous access networks for 3G mobile communications systems, as well on the corresponding CAPEX and OPEX must be now reconsidered.

There are different candidates for the access network technologies in order to be considered as suitable in a heterogeneous environment for the 3G mobile communications systems:

- The regular 3G access network (the two well-known FDD (WCDMA) and TDD (TC-CDMA) access networks promoted by 3GPP for UMTS-like systems or the one proposed by 3GPP2 for CDMA2000 systems). These access networks represent an optimal answer for covering the regular functionalities of the access networks in a high mobility environment, especially for interactive or conversational services, but not at very low operational costs;
- The WLAN/WiFi-type of access networks, including here the latest versions of this family of wireless access network standards, very simple for deployment and suitable in the case of stationary or nomadic wireless access, with low costs both for investments and for operation;
- The WiMAX type of access networks, very convenient for deployment in rural areas or in emerging regions, brings the benefit of reasonable quality in NLOS propagation conditions in a low mobility environment, but the quality of service (QoS) in high mobility conditions is questionable;
- The digital broadcasting technologies (DVB-H, but also DVB-T or DVB-T2) can bring a benefit for services or applications including a large broadcast or multicast downlink distribution of the required information;
- The WPAN technologies can represent a very attractive access solution for low or very low range, with a potential good management of the battery and of the radio spectrum.

It is clear that the diversity of the available access network technologies represents both a technical challenge and a potentiality in optimizing the access network performances.

Due to the popularity of the UMTS 3G networks and of the WLAN technologies, we consider that both represent a must as starting point in any discussion related to the performances and the optimization of the implied heterogeneous network and, for this reason, these technologies will be discussed in the present paper.

The rest of the paper is organized as follows: Section II presents some related work in this field, Section III presents the proposed algorithm and Section IV presents its implementation in the EXata Network Emulator. Simulation approach and results are presented in Section V while conclusions are drawn and further work is outlined in Section VI.

## II. RELATED WORK

Many papers have studied and are still studying ways to achieve interworking between heterogeneous wireless networks.

[1] Alexandru Vulpe is with the Faculty of Electronics, Telecommunications and IT at POLITEHNICA University of Bucharest, 1-3 Iuliu Maniu Blvd, Bucharest 061071, Romania, E-mail: alex.vulpe@radio.pub.ro.

[2] Octavian Fratu is with the Faculty of Electronics, Telecommunications and IT at POLITEHNICA University of Bucharest, 1-3 Iuliu Maniu Blvd, Bucharest 061071, Romania.

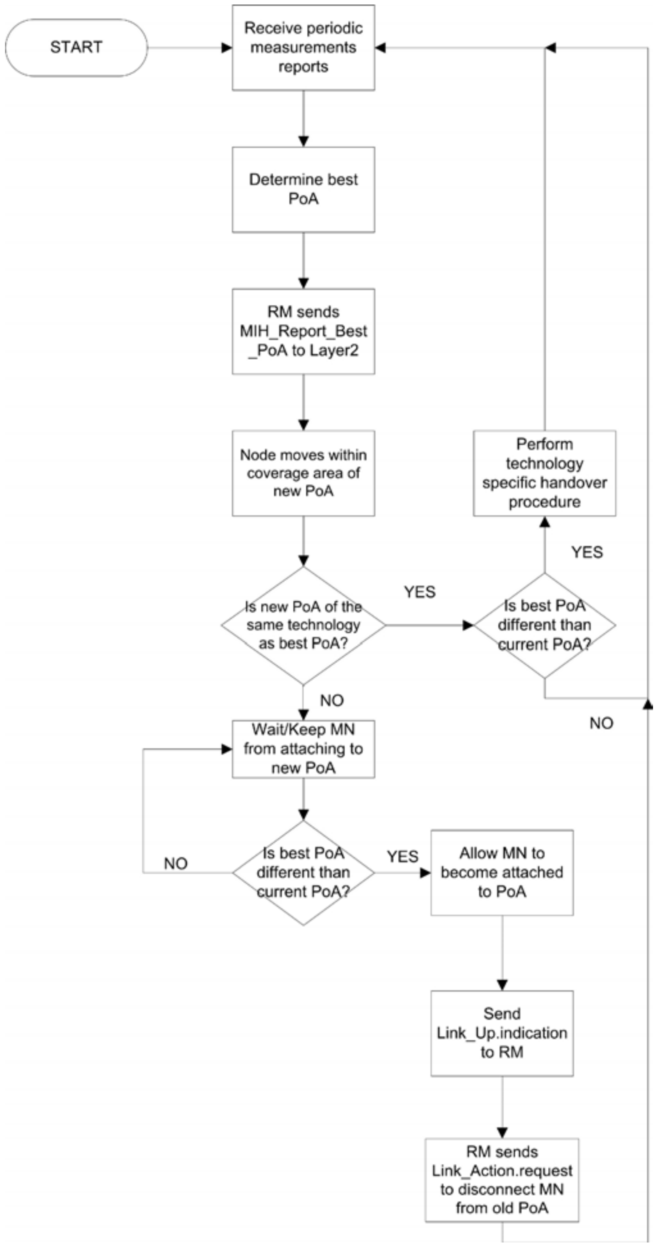


Fig. 1. Proposed framework flow

The current solutions considered in standardization bodies are discussed in [2]. These include I-WLAN (Interworked-WLAN), GAN (Generic Access Network) and IEEE802.21. Of these, I-WLAN is currently adopted by 3GPP, the GAN model, while not being restricted to WLAN networks is more commonly implemented as unlicensed mobile access (UMA)-enabled terminals, and IEEE802.21, although offering a flexible framework to facilitate different handover scenarios, has not seen adoption in 3GPP, but only in IEEE 802 standards.

In [3], the authors propose a WLAN/HSDPA Interworking Architecture for Linux-based mobile terminals. It is implemented on a Linux laptop with commercially available HSDPA modems and WLAN cards. However, the testing is done through a movement simulator, which could provide inaccurate results.

WLAN discovery schemes based on MIH Services are presented in [4]. They are either channel information based, location information based, or channel *and* location information based. The obtained results are good, but the one thing assumed and lacking at the moment is an implementation of a Media Independent Information Server (MIIS).

The authors in [5] propose an interoperability mechanism for WLAN and UMTS-HSDPA based on the output of a cost function as handover metric. However the study is carried out for HIPERLAN/2, which hasn't been widely implemented in commercial networks.

Another paper [6] proposes a load balancing scheme using Admission Control and Vertical Handoff in a cellular/WLAN integrated network. It measures its performance by means of data call throughput per voice call arrival rate, which is a questionable evaluation metric.

## III. Framework Description

The flow of the proposed framework is described in Fig. 1. A Resource Manager (RM) that is running on the mobile node collects the Received Signal Strength (RSS) (or Received Signal Code Power (RSCP) for UMTS) and Carrier-to-Interference-plus-Noise-Ratio (CINR) (or Ec/No for UMTS) values from periodic measurement reports done by the multi-radio mobile node (MN). These are fed into a decision-making engine, where it is possible to implement any handover decision-making algorithm. It should be noted that the RM could collect any other handover metrics (such as available bandwidth, user preference or cost), and that these are not currently reported by measurements done by technology-specific link layers. In the end, the RM should output the best point of attachment (PoA) to which the mobile node should be connected. The PoA is termed "the best" in respect to it fulfilling the handover decision criteria as defined by an access network selection algorithm.

The RM then issues a primitive called "Report_Best_PoA" which carries the PoA identifier and the radio access technology that is enabled on that specific node. This is broadcast to the lower layers of each radio access technology protocol stack of the Mobile Node where it is stored. When the mobile node roams inside the coverage area of a new PoA, two situations may occur, depending whether it is of the same technology or not. If it is of the same technology, then, if it becomes the best PoA (determined by the RM), then normal technology-specific (horizontal) handover procedures (cell selection/reselection - in UTMS or association and authentication - in WLAN) are carried out. Otherwise, nothing is done, and the RM keeps receiving measurement reports. If the newly discovered PoA is of another technology, then, naturally, the radio interface of the corresponding technology belonging to the mobile node will want to carry out an attachment procedure to the PoA (the terms used are *PS attach* for UMTS and *association* for IEEE 802.11). However, this is not wanted if there is no need for a handover (the current PoA has better SNR, or greater bandwidth etc., i.e. it is still the best one), so the attachment procedures will not be executed until that PoA becomes the best PoA.

TABLE I
802.21 PRIMITIVES IMPLEMENTED IN EXATA

| MIH Service | Primitive | Description |
|---|---|---|
| Event | Link_Up | Layer 2 connectivity established |
| Event | Link_Down | Layer 2 connectivity loss |
| Event | Link_Parameters_ Report | Link parameters periodic reporting |
| Event | Link_Going_Down | Layer 2 connectivity loss imminent |
| Command | Link_Get_Parameters | Request parameters from link layer |
| Command | Link_Action | Request an action on a link layer connection |

When the MN becomes attached to a PoA, it sends a Link_Up.indication as per IEEE 802.21 specifications [1]. When the RM receives it, it will send a Link_Action.request message to the Link Layer of the radio access technology corresponding to the old PoA. It contains the command to disconnect from the old PoA. Therefore, the control of the handover procedure is partially taken over by the Resource Manager.

## IV. IMPLEMENTATION

The framework described in Section III has been implemented in the EXata Network Simulator/Emulator. It uses a layered architecture which is similar to the one used in the TCP/IP protocol stack. In order to implement new protocols, or modify existing protocols, the source code (written in C/C++) of EXata has to be modified [7]. The main components of the IEEE 802.21 standard that have been implemented are:

- **The MIH Function (MIHF)**: It receives MIH messages from the local link layers or a peer MIH node and forwards them to the MIH User. It is implemented as a protocol included in the Network/IP layer of the EXata protocol stack.
- **The MIH Protocol**: It provides a way for conveying MIH primitives between remote MIH nodes and includes an acknowledgement service in the case that the transport protocol used is unreliable
- **The Link SAP**: It is a collection of primitives used for interfacing between the media dependent link-layer and the MIH Function. Only a selected set of primitives has been implemented, and they are represented in Table I. The SAP is implemented as a separate library and included in the EXata source code.
- **Link layer extensions**: The media dependent link layers have been modified in order to support the above-described algorithm. These are done by modifying the source code of the MAC Layer of the EXata protocol stack associated with a specific link-layer technology (in this case, UMTS and WLAN).
- **MIH User**: The MIH User, which is termed here “Resource Manager”, has been implemented as a simple RSS-based handover decision, in order to prove the concept. The IEEE 802.21 standard does not restrict the implementation of the MIH User to be above the MIHF, so, for ease of coding, it is implemented at the same layer as the MIH Function.

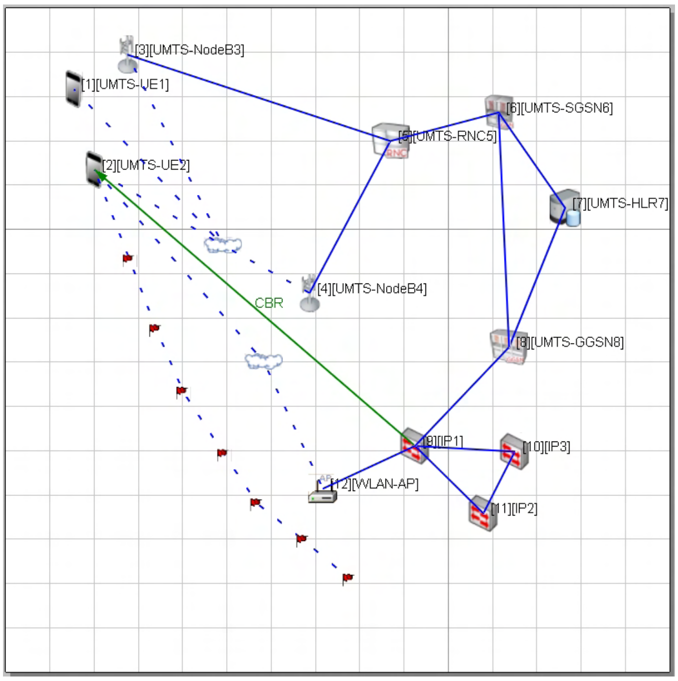


Fig. 2. Scenario Topology

Simulations regarding the accuracy and performance of the implementation of the protocol have been published in previous papers [8-10]. However, there we had not implemented a UMTS link extension, but only dealt with WLAN and WiMAX.

## V. SIMULATIONS AND RESULTS

The simulated network topology consists of a UMTS Radio Access Network (RAN) and a WLAN network connected to each other via an IP network. The topology is depicted in Fig. 2. Node 2 is a mobile node with both UMTS and WLAN radio interfaces and is connected to the UMTS RAN (Nodes 3-8) and the WLAN Access Point (Node 12). Nodes 9, 10 and 11 form an IP network backbone which connects the UMTS RAN to the WLAN network. The MN moves through the UMTS network, following the path outlined by the read waypoints in Fig. 2, and comes into the coverage area of the WLAN Access Point. At this point, the MN would have the tendency to become associated with the AP, but, instead, the procedure described in Section III takes place: only when the RSS of the WLAN access point becomes better than the one from the UMTS network, by a margin of 2 dB, the Resource Manager, by processing measurement reports, determines that the best PoA is the WLAN Access Point, and, therefore, the normal procedure of association and authentication takes place. A Link_Up.indication primitive, originating from the WLAN link layer of the multi-radio mobile node is sent to the RM via the MIH Function. The RM then sends a Link_Action.request message to the Mobile Node’s UMTS

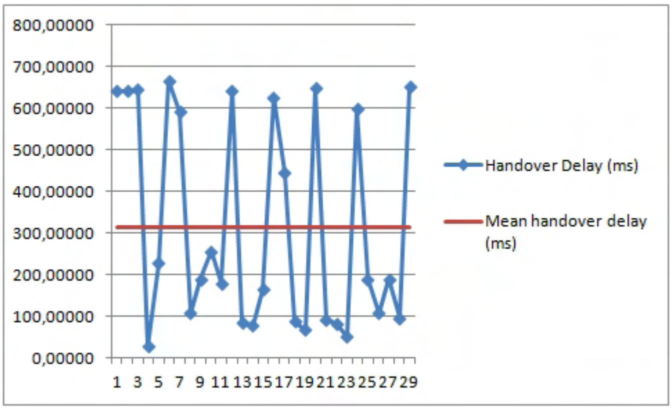


Fig. 3. UMTS to WLAN handover delay

interface, requesting it to disconnect from the network. In this way, a make-before-break handover takes place.

Fig. 3 shows the handover delay measured for 30 simulations, done with different seed values. We can conclude that the handover delay from UMTS to WLAN varies around a mean value of 313 ms, with the lowest value reaching about 27 ms, and the highest value situated at 667 ms.

## VI. Conclusion and Further Work

This paper proposed an interworking architecture for mobility between heterogeneous networks based on the IEEE 802.21 (MIH) standard and applied to handover from UMTS to WLAN networks. It defines a framework for providing handover-related information flows to a Resource Manager in charge of taking the handover decision.

Results have shown that the handover delay has relatively small but different values as they depend also on network conditions. Further studies have to be carried out. In particular, the handover delay between WLAN and UMTS networks needs to be measured and evaluated in different network conditions (also the corresponding scenarios implementation in EXata can be improved) in order to evaluate it in a general manner. Also, different handover metrics can be introduced. The framework also needs to be enhanced to support more technologies, especially LTE, as it is the leading emerging cellular technology.

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