A Vertical Handoff Implementation in a Real Testbed

Blaise Angoma, Mohammed Erradi, Yahya Benkaouz, Amine Berqia, Mohammed Charaf Akalay[1]

Networking and Distributed Systems Research Group

ENSIAS, Université Mohammed V-Souissi, Rabat, Maroc

1. MEDI TELECOM S.A, Maroc

angomablaise@yahoo.fr; erradi@ensias.ma; y.benkaouz@um5s.net.ma;

berqia@ensias.ma; charaf.akalay@meditel.ma

Abstract

The demand for the ubiquitous service is increasing due to the rapidly growing demand for increased data rates, mobile Internet and the diversity of wireless communication technologies. Also due to the challenges to interconnect heterogeneous network technologies and to offer ubiquitous services, telecommunications operators look after the best way to provide continuity of service during handover and how to give the mobile client the possibility to get the best connection anywhere and anytime. Our contribution guarantees the continuity of service during a communication while moving between heterogeneous access network technologies. The suggested solution ensures a Vertical handover between WLAN, WiMAX and 3G. A performance evaluation of our testbed implementation is shown using a streaming application.

Keywords

Vertical Handover; Seamless Handover; Heterogeneous Networks, Mobile IPv4; WiMAX; 3G

Introduction

Nowadays, telecommunication operators offered the diversity of mobile networks and services, users are increasingly demanding in terms of services without worrying about the technological constraints associated with this diversity. User application like streaming applications needs more bandwidth, few drop packets, and little latency. These characteristics impose new challenges for operators and service developers to design and implement services that can function independently of the underlying network technology.

One of the challenges is to offer users the ability to migrate from one area of a network type to another by changing completely the network technology. The telecommunication operators must develop a strategy for collaboration between different types of existing networks to ensure the connection "Anywhere" and "Anytime" taking into account the quality of service contract that the user subscribed too.

As shown in Figure 1, Mobile users have a Horizontal Handover when they change a Point of Attachment (PoA) without changing the access technology but they have a Vertical Handover when the connection session was transferred from one network access to another. Mobile Node (MN) uses vertical transfer related to an automatic transition from one technology to another in order to maintain its communication session. The Horizontal Handover is triggered between different network cells of the same Network but a Vertical Handover holds between different network cells that haven't the same data link layer used to access the network.

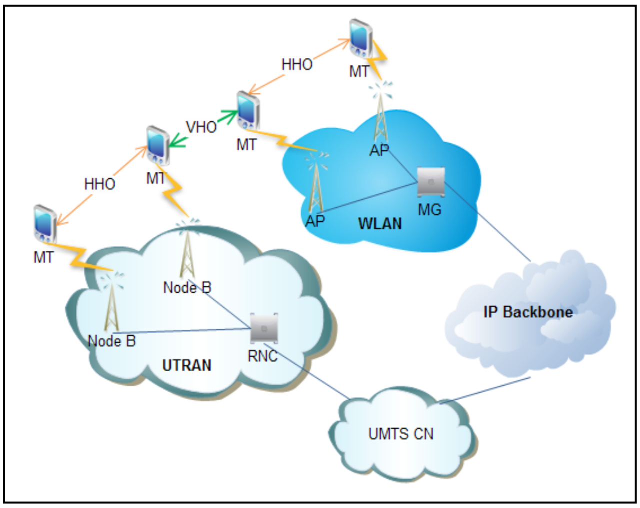


FIGURE 1 HORIZONTAL AND VERTICAL HANDOVER

Figure 2 shows an example of Heterogeneous Network where a vertical handover is very important. For example, a mobile phone equipped with a WLAN and a high-speed cellular technology for Internet access like

3G and WiMAX have to often choose among these available access networks technologies.

In general, WLAN is suitable in low mobility and provides higher speed, while cellular technologies typically provide more ubiquitous coverage but few throughputs capacity. When the user starts his streaming session in WLAN, Vertical handover will help him to switch to 3G or WiMAX in case he loses the WLAN signal. So the user has the possibilities to transfer his session among these technologies. In the context of heterogeneous wireless networks, the challenge of vertical handover is to help mobile client to switch from one network technology to another without interruption.

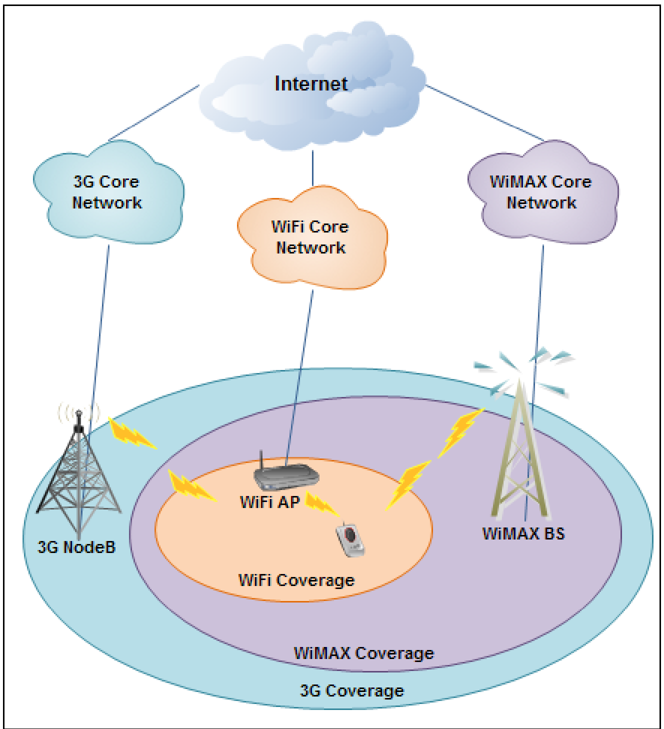


FIGURE 2 HETEROGENEOUS WIRELESS NETWORK

As reported in [1], [2], [3], [6], [9], [10] and [11] heterogeneity implies that different access technologies have very different characteristics in terms of bandwidth, packet loss, waiting time, latency and data link layer etc... These big differences will require an intelligent architecture to support heterogeneity and offer a continuity of service during handover.

In this paper we show how our tested "*HAVE-2W3G*" architecture [20] supports the MIH specifications [27]. In addition we show the server side of "*HAVE-2W3G*". Also concerning the performance aspect, we will discuss the received interarrival time of TCP traffic while moving from one network technology to another.

So, the challenges concerning heterogeneous network will be resolved if the following key issues are considered: (i) Seamless mobility across heterogeneous networks, (ii) Application adaptation to maximize the end user's perceived quality and (iii) Adaptation to network dynamics such as wireless channel errors and congestion.

In this paper we focus mainly on the first key issue. The suggested architecture and its implementation provide a Vertical Handover support to guarantee seamless mobility. The rest of this paper is organized as follows: section 2 presents problem requirements. Section 3 presents the related works about heterogeneous test-bed. Section 4 presents an overview about MIH. Section 5 presents the suggested architecture and its implementation. The section 6 presents the test-bed configuration and the section 7 evaluates the performance of the proposed architecture. Finally, section 8 concludes the paper.

Problem Statement

Emergency scenario is one of the scenarios where a vertical handover is very important. In case of telemedicine, and particularly in the context of rescue after an accident, the emergency operation must setup by using networks technologies to help personnel in emergency site to collaborate with the specialist(Correspondent Node, CN) located in the hospital to offer an emergency medicine during the evacuation to the hospital of injured victims in critical situation. A wireless network connection must be established between the emergency personals and the specialist for collaboration. This collaboration is possible through voice and video data application launched in the mobile device of the emergency agent. By using a streaming application, the specialist and the agent will collaborate as they are in the same place.

Due to the limit of coverage of wireless networks accesses, a mobile client device used by emergency personnel must support multiple technologies; Also, with the help of *HaVe-2W3G* module integrated in mobile client device, the mobile client device has the possibility to choose automatically or manually the best technology anywhere and anytime. The route between the place of the intervention and the hospital could be covered by many types of wireless access networks depending to the Telecommunication operator. At each moment, the MN will choose the best connection to assure the communication with the specialist doctor.

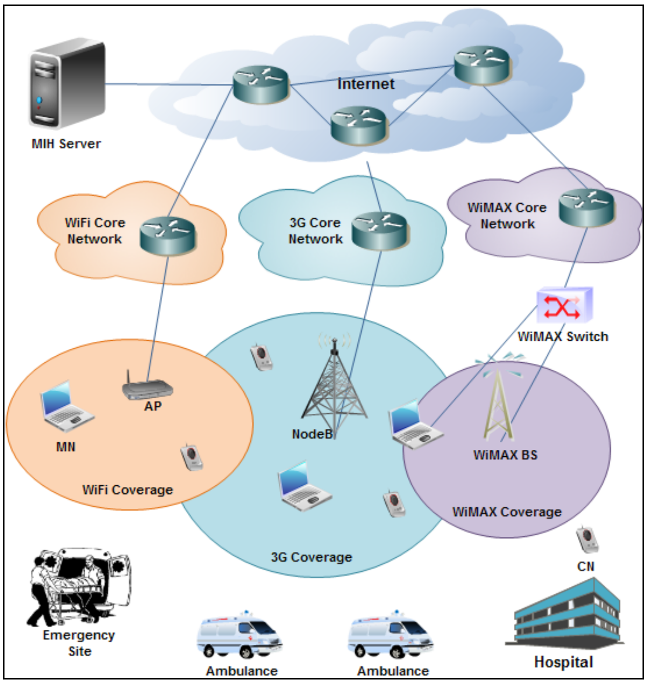


FIGURE 3 *HAVE-2W3G* USER INTERFACE

In our scenario showed in Figure 12, from the accident site, the mobile client of the emergency has only the possibility to access the WiFi through a hotspot and 3G connection. The route between the hospital and the accident place is covered by the 3G. The hospital which is destination is covered by these three networks accesses (WiFi, 3G and WiMAX). As result, Mobile client device has to maintain connection with the specialist doctor during the intervention operated in the ambulance through streaming collaboration. In this case, the lost of network connection will cause a great problem.

The mobile client device select in each step between the emergency site and the hospital the best network connection so that at least it keeps the communication with the specialist and also get a better QoS. In case of telemedicine, we know that 3G in his current version cannot offer a high throughput capable to support a high quality of video unless if the video has a low quality.

Related Works

To face theses challenges of heterogeneous network access, several approaches that facilitate this handoff have been proposed. These approaches enable application session to be transferred from one network to another without interruption. They use a selection criterion based on the network which provides better quality of service in term of bandwidth, latency, coverage and so on. Also, the quality of experience (QoE) providing the perception of the service in the user side is more and more used to perform a better vertical handover decision. In general, the published works responding to the challenges of vertical handover follow three approaches: the simulation, analytical approaches and the test-bed implementation.

Concerning the simulation approach most of works were implemented in NS-2 simulator [22] and Opnet [23].

Authors in [25] propose a network selection mechanism that takes quality of experience into consideration for decision making. It is a user-based and network-assisted approach. They use the quality of experience of ongoing users in candidate networks as an indicator to select the best network for connection. They have implemented and tested the mechanism in network simulator NS-2. Their obtained results illustrate that with a QoE-aware mechanism, the proposed scheme improves throughput in 3G networks but do not ameliorate in the WiFi. Normally, the throughput minimum value in WiFi networks when QoE-based algorithm is used must be the same when Vertical handover decision is priority-based. But, the scheme proposed does not perform better in order to guarantee the throughtput even the notion of QoE helps mobile node to achieve a better quality of service for application after a Vertical handover. Also WiMAX network was not used.

Jakimoski et al. propose in [8] the performances evaluation of Vertical Handovers for Multimedia Traffic between WLAN, WiMAX and 3G Mobile Networks using NS-2 simulator. Their work give a thorough analysis of the vertical handover processes in IEEE 802.21 standard and permit to understand the correlations between the vertical handover duration, throughput performance and delay during the handover process and dependence of these parameters from the traffic type (voice, video) and mobile terminal speed. Also Michail et Al [28] proposed middleware architecture based on the Media Independent Handover (MIH) in order to support multimedia services across inter-technology nodes in a seamless manner and with minimum perceived QoS degradation. Their proposed architecture was evaluated through NS-2 simulator.

As analytical approach, the authors in [21] present a performance analysis of vertical handover latency for IEEE 802.21-enabled PMIPv6 (Proxy Mobile IPv6). They evaluate the performance of PMIPv6, PFMIPv6, and IEEE 802.21-enabled PMIPv6 in view of handover latency. They study also the impact of the layer 2 attachment delay handover from WLAN to Mobile WiMAX and show that, the layer 2 attachment delay varies depending on the target network. So, few works are implemented as testbed in real networks environment.

As testbed implementation, Qinxue Sun et al. [1] establish a testbed which includes the different wireless heterogeneous access network technologies: WLAN, GPRS and TD-SCDMA to ensure vertical handoff. The solution proposed doesn't integrate technologies like WiMAX and 3G. Additional time is added because of translation of IPv4 to IPv6 and vice versa. Also, the tested application (ftp and ping) are not timing constrained.

In [5], the authors propose a Seamless IP diversity based on Generalized Mobility Architecture (SIGMA); they implemented a mobility management scheme at the transport layer. This scheme can be used with any transport protocol that supports IP diversity to implement vertical Handover. Like in [1], they also did not provide or refer to a viable architectural framework in which the selection mechanism can work. They did not support a WiMAX network connection and the data traffic consists in ftp packets and did not show what happens while only using streaming traffic.

Wan-Seon et al. [7] propose an implementation of the IEEE 802.21 Media Independent Handover (MIH). They evaluate the performance of MIH through experiments in integrated 802.11/802.16e networks. The implementation doesn't take into account 3GPP technologies and IPv4 despite of the enormous number of clients.

Busanelli et al. proposed in [24] present experimental results based on the implementation of a real testbed with commercial WiFi (Guglielmo) and UMTS (Telecom Italia) Italian deployed networks. Based on a RSSI and hybrid RSSI/goodput VHO algorithm, their testbed experienced a long handover times. They use a non coupling scenario where the two connected networks are communicated through internet and no through a Telecom Operator gateway. Their approach doesn't provide a new method comparable to the existing approach like MIH. They used only two network technologies: WiFi and UMTS and do not take into account WiMAX networks. Our approach reduces this handover delay and has also WiMAX as the third proposed network.

Most of the proposed solutions do not take into account all the existing network technologies. The interconnection implemented between these networks is a tightly-integrated system where networks are connected through the gateway of an operator and not through the internet. This solution obliges the client to get a service only through one operator. In our approach, we propose an architecture taking into account three networks access (WLAN, WiMAX and 3G).

These accesses are interconnected through internet. This approach gives the client the possibility for each network access technology to be subscribed to the telecommunication operator giving the best quality of service. A testbed is also implemented to evaluate our architecture in a real environment.

Media Independant Handover

Because of the abundance of Multiradio devices and access technology as seen before, IEEE has proposed a standard way to integrate all existing network access and handover approach named IEEE 802.21. This heterogeneous framework MIH (Media Independent Handover) aims to develop a common functionality for handover to bridge these access networks via a media independent handover in order to fulfill homogeneous or heterogeneous handovers. As shown in Figure 4, one of the goals of MIH (Media Independent Handover) is to connect these different existing approaches to provide a seamless Handover.

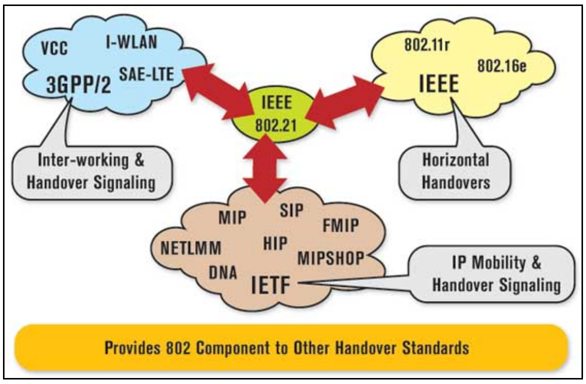


FIGURE 4 IEEE802.21 FRAMEWORK

The standard supports algorithms enabling seamless handover between networks of the same type as well as handover between different network types. The standard provides information to allow handing over to and from cellular, GSM, GPRS, WiFi (802.11), Bluetooth and WiMAX 802.16 networks through different handover.

In order to ensure service continuity between heterogeneous networks, IEEE802.21 has defined MIH mechanism that helps to optimize Handover process between IEEE802, 3GPP and 3GPP2 networks. IEEE802.21 define a logical entity, MIHF (MIH Function) see Figure 5, whose role consist on mobility management and ensuring the handover process. MIHF is a layer between layers 2 and 3 at the mobile node and at the network entity.

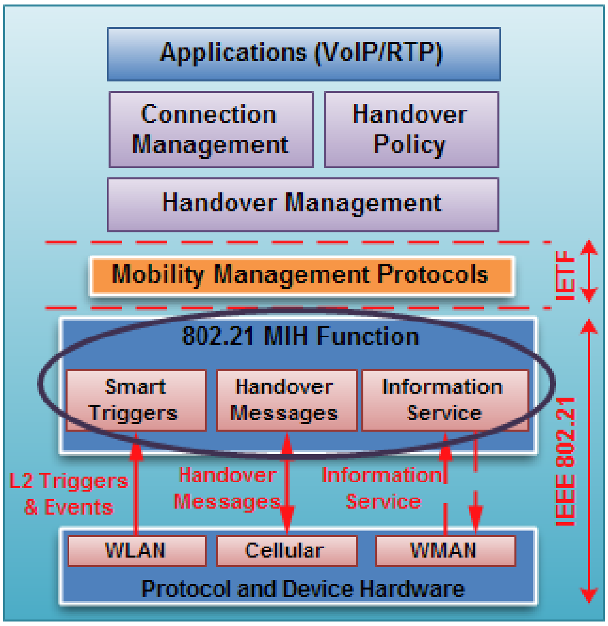


FIGURE 5 ARCHITECTURE MIH

IEEE802.21 presents a media independent interface. MIHF supports different services. These services aim to determine the need for handovers, to initiate the handovers, and to decide a target network for a mobile node.

The standard 802.21 offers a framework that enables seamless handover between heterogeneous technologies. This framework is based on a protocol stack implemented in all the devices involved in the handover.

Figure 6 shows the placement of MIHF within the mobility management protocol stack, and the different services present in the standard.

The defined protocol stack aims to provide the necessary interactions among devices for optimizing handover decisions. The standard draft defines a new link layer SAP that offers a common interface for link layer functions is independent of the technology specifics. For each of the technologies considered in 802.21, this SAP is mapped to the corresponding technology-specific primitives. Also the MIH function collaborates with the mobile IP protocol to ensure service continuity after the handover.

FIGURE 6 IEEE802.21 ARCHITECTURE

IEEE802.21 defines three primary services: MIES (Media Independent Event Services), which may came from the MAC layer, PHY or the MIH Function. They provide information corresponding to dynamic changes in link characteristics, link status, and link quality.

MICS (Media Independent Command Services): They refer to commands issued from upper to the lower layers, they enables to manage and control link behavior.

MIIS (Media Independent Information Services), which allows stations to collect information on homogeneous or heterogeneous networks existing within a geographical area.

In general, as shown in Figure 7, the handover is defined as a three-step process [17]: handover initiation, handover preparation and handover execution. The scope of IEEE 802.21 is to cover handover initiation and handover preparation where functionalities include network discovery, selection, and handover negotiation in the former layer 2 and layer 3 connectivity in latter. On the other hand, remaining functionalities such as handover signaling, context transfer and packet reception fall into handover execution.

But the Handover Execution is not taken into account in the aim of IEEE 802.21. So, MIH gives the possibility to the operator or service provider to define their own mechanism of Handover.

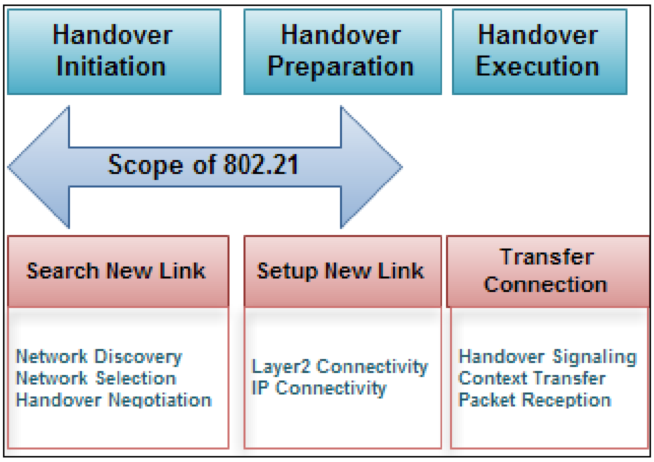
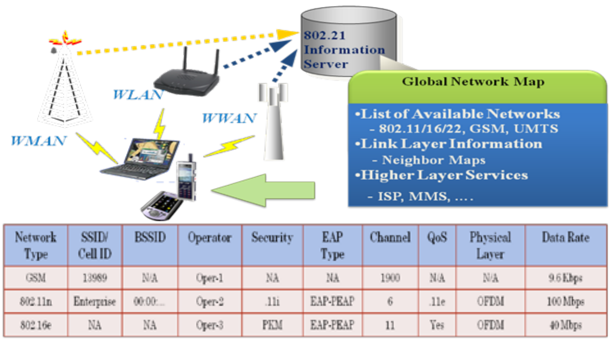


FIGURE 7 HANDOVER THREE-STEP PROCESS

The IEEE introduces also a special server MIES(see Figure 8) to stock information about Point of Attachment (PoA): Node, Base station, BTS, Access Point to help mobile node to choose the best access network during Handover decision. It's contain the information about : the list of available network, Geo-location of Point of Attachment (PoA) , operator identity, Roaming partners, cost of indication for service/network usage, security, quality of service, etc ….



Network Type	SSID/ Cell ID	BSSID	Operator	Security	EAP Type	Channel	QoS	Physical Layer	Data Rate
GSM	13989	N/A	Oper-1	NA	NA	1900	N/A	N/A	9.6 Kbps
802.11n	Enterprise	00:00:...	Oper-2	.11i	EAP-PEAP	6	.11e	OFDM	100 Mbps
802.16e	NA	NA	Oper-3	PKM	EAP-PEAP	11	Yes	OFDM	40 Mbps

FIGURE 8 IEEE 802.21 INFORMATION SERVER

Handover decision is a co-operative feature with respect to triggers and neighbor information as detailed in Figure 8. Mobile Node consults this table before taking a decision in which network to switch. As described in section II, many methods has been proposed before to resolve vertical handover problem [6], but MIH is to be stable and open to all system.

Architecture and Implementation

HaVe-2W3G Architecture

To help a mobile node to select the candidate network available in its environment, and to ensure the session continuity during a handover, we suggest an architecture which takes into account the user and the network context to guarantee the quality of service that the user subscribes to.

HaVe-2W3G, as shown in Figure 9, is composed of two parts: Mobile client side and server side. Firstly, in the Mobile client side, *HaVe-2W3G* is a three layers architecture that enables seamless handover between heterogeneous access network technologies. The three layers are: 1) A Driver Management layer, 2) A Discovery and Monitoring layer and 3) A Selection and Handover Execution layer.

By comparison to the MIH standard, the "*Driver Management layer*" and "*Discovery and Monitoring layer*" are comparable to the first and second layer of OSI model located under the MIHF Function layer in the MIH architecture. The QOSFC component is the implementation of The MIHF function witch offer many function to the upper layer component for Handover Execution. In our case, HEC component realize the MIH users. In the MIH, the MIH users (Mobile IP, SIP or other manager component) interact with the MIHF functions in order to execute handover.

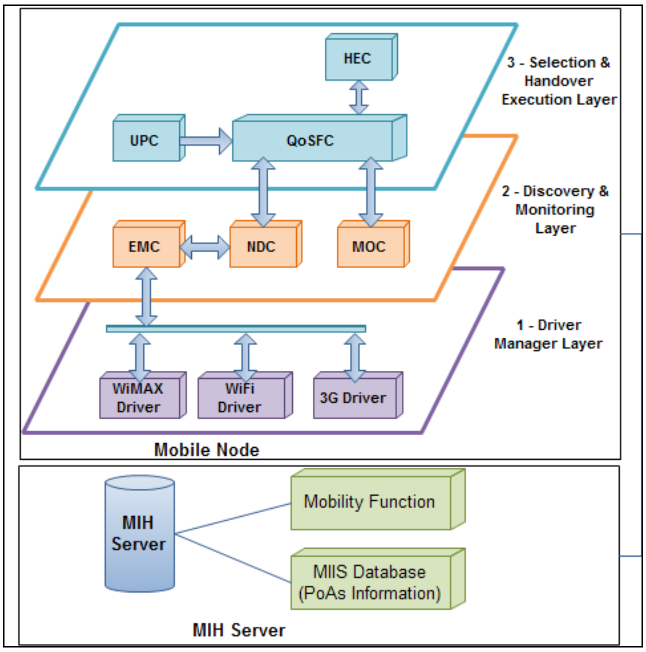


FIGURE 9 *HAVE-2W3G* ARCHITECTURE

According to our architecture, the first layer consists in The Driver Management layer which contains the device drivers of the network cards integrated in a Mobile Terminal. In the suggested architecture, drivers of the WLAN, the 3G and the WiMAX networks are stored in this component. The DMC layer is mainly aimed to manage different networks cards and provides services to the layer above. If the user installs a new card, the corresponding driver will be placed in this component. All installed drivers are located in the Kernel space. Particularly in Linux OS, users can not access directly kernel space. The only way to access these drivers information is through system call. The system call is an interface between a user-space application and a service that the kernel provides. Because the service is provided in the kernel, a direct call cannot be performed. Each driver provides functions defined in the Linux kernel accessible through system calls.

The second layer is The Discovery and Monitoring layer which is composed of three components: Event Management Component (EMC), Network Discovery Component (NDC) and Monitoring Component (MOC). Like in MIH standard, this layer is located at the second layer of OSI model and interacts with the QoSFC component.

The Event Management Component (EMC) manages the events generated from different interfaces drivers in the Mobile Node. This component is implemented in the Kernel space to report specific events that indicates any change in link characteristics, link status or link quality on local or remote entity. Especially, the EMC filters such events and passes only those related to link state. During a communication a network interface triggers one among the following messages like in MIH standard: the link up message, the link down message and a link going down message. These messages are collected through the EMC and sent to the Network Discovery Component (NDC). Regular kernel functions are mapped directly into EMC API to receive or send event to the NDC component.

The Network Discovery Component (NDC) gathers those filtered messages from the EMC. The NDC is also responsible for discovering the available Point of Attachment (PoA) to the neighboring networks. This component helps the mobile node to know the potential candidates PoAs for handover. This component is also present in MIH standard at the MIHF layer as an agent to discover network (Neighbor discovery). The NDC module is used to provide Layer 3 movement detection. APs and BSs periodically send RAs (Route solicitation) to inform the MNs about the network prefix. Like the Neighbor Discovery in MIH, the NDC agent located in the MN receives these RAs and determines if the message contains a new prefix and informs the QoSFC.

The Monitoring Component (MOC) monitors and evaluates the wireless channel conditions. The MOC manage parameters related to link behavior and handovers. It collects information like the network performance, the signal strength, link layer throughput, link quality, loss rate and contention rate. It provides collected information from link layer to the MIH user layer for an eventual handover initiation. The MOC keeps the Mobile Node informed about his connectivity to the associated PoA and the available resources in the device. With the MOC, it is possible to implement a complex parameter needed by the QoSFC for decision. All the parameters needed by the QoSFC are implemented in the MOC component. Through *RTnetlink*, MOC collect and control networks parameters. *RTnetlink* is a subset of Netlink which provides for full-duplex communication between kernel modules and user-space processes through *PF_NETLINK* sockets [18]. RTnetlink offers a possibility to get, set all networks configurations parameters located in the kernel side. Informations like: network layer, link layer setting, and gateway setting. Also, *ETHTOOL* a linux command is used by the MOC to display or to change Ethernet card settings. As in MIH, this component permits to the low layer to receive command from QoSFC or MIH user like Mobile IPv4. The command passes from MOC to different driver through *skel_ioctl* command.

The third layer, The Selection and Handover Execution layer is made of three components: the User Preference Component (UPC), the Quality of Service Function component (QoSFC) and the Handover Execution Component (HEC).

The User Preference Component (UPC) stores the information about the preference of the user. Here, such a user explicitly describes the characteristics of the preferred network to be attached to. This network may have few loss, high bandwidth and cheap connecting cost. The system decision will select the most appropriate network interface according to the user's preferences. The UPC is implemented as a form in which the client fills parameters values corresponding to the expected quality of service. The setting configuration of UPC is variable according to the used service (video, voice…). The corresponding parameters of UPC can be: the losses rate, the quality of video, the price of connection, and the preferred network. The UPC is implemented in the user space in XML format.

The Quality of Service Function component (QoSFC) component selects the most appropriate interface by using the information coming from UPC, MOC and NDC. The QoSFC is the implementation of the MIHF function in *Have-2W3G* architecture. It collects information from many components for handover decision. In Linux OS, we implemented this component at user space so that we can modify parameter and use them at the upper layer, particularly in HEC component. In this QoSFC, we also implemented a decision algorithm to select the best network. This decision algorithm is based on the throughput offered by each network access technology. The target network is the one which interface maximizes the session throughput.

We use the maximum function to select the better network according to the bandwidth provided. We denote H as a set containing all network access that a Mobile Node will receive as information coming from NDC and MOC.

Here, H = {WiFi, WiMAX, 3G} The function Th_X that return Throughput of an access technology x where $Th_x >= 0$. So, the selection function is defined as:

$C_{Interface} = \{x / Th_X = Max_H (Th_Y)\}$, which equals to the network connection with the high throughput. This function selects the network with the high bandwidth. This function will be executed only if there is at least one network access.

The Handover Execution Component (HEC) receives a notification from QoSFC about the selected network. After deciding to perform a handover to a new access network, the HEC executes such handover by switching all the active sessions to the selected network. The switching process of the active sessions will be realized as follows: once the HEC receives a message informing about the selected network, it notifies the MIH server while providing the IP address of the new selected network. Then the HEC establishes a tunnel with the MIH server, the later will forward the incoming packets holding the previous IP address, to the mobile Node using the selected network IP address. The HEC implementation is the extension of the Mobile IP protocol. Particularly, in this testbed the HEC extends MIPv4 by adding the possibility of vertical handover.

Our architecture works in the context where there is not an implementation of MIH modules in the operator equipments (PoA, router and so …) and then, the unique way of collaboration between the Mobile client and the Telecommunication operator is done through the MIH server.

In the server side, MIH server is located in the IP backhaul of the Telecommunication operator who provide the vertical handover services. MIH server contains many modules that have been defined in the MIH standard. In our case, due to the fact that the PoA have not an integrated MIH module, the server MIH are called to offer more information to the MN for vertical handover. For that, the MIH server contains two modules: a mobility function module and MIIS server. A mobility function module implements a MIHF function and a Home Agent

The MIHF function is responsible of collecting information like events and command services coming from the MN in the network. The information request about neighboring PoA is received through MIH Function. MIH function requests then to the MIIS database information about PoA in the MN's neighborhood and send back the response to MN. Mobile client collect uses directly the MIIS server which is a database integrated in the MIH server to collect information about neighboring PoA (Point of Attachment). MIIS server offers to the Mobile client useful informations for Handover initiation. The MIIS database is implemented in Mysql and contains information about PoA.

The Home Agent tracks the movement of the MN and registers every Mobile client which uses a vertical handover service. The HEC inside the mobile node communicate with the HA to transfer all actives sessions of a MN in the new network in case of handover. The HEC also sends to the HA all events about disconnection and/ or connection so that HA will update the status of the MN.

Vertical Handoff and Tunneling Process

The communication between the mobile node and the MIH server is ensured using the Mobile IPv4 (MIPv4) [12] protocol. Initially when the Mobile Node (MN) is turned on, it sends a registration request to its Home Agent (HA) which is running in the MIH server. The HA sends a registration response to the MN. This registration of the mobile node within the MIH server will be useful for keeping contact with the mobile node once it moves to another available network. After receiving the response, the MN begins the communication with a Correspondent Node (CN). CN can be a streaming data server or another Mobile Terminal.

Figure 10 shows sequence diagram of the interactions between mobile nodes while resolving the handover.

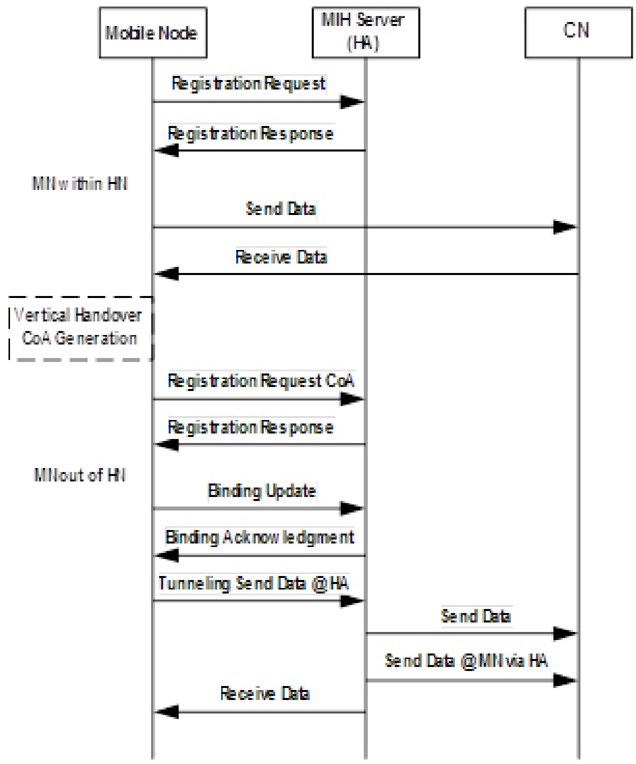


FIGURE 10 VERTICAL HANDOVER SEQUENCE DIAGRAM

When a mobile node detects other access networks and one of them is selected as the most appropriate one (according to the decision algorithm mentioned in the description of the QoSFC component in the previous subsection), then the PoA (e.g. a Base Station in a WiMAX Network) assign an IP address to the mobile node within its new position. Such IP address corresponds to the care-of-address (CoA) in MIPv4. The assigned address will be registered to the MIH server. This CoA changes at every new point of attachment. It is obtained by several ways and the most typical one is through an agent (DHCP) stores in the PoA of each network access. In this scheme, the MN initiates the registration request while still receiving packets on the old link and after receiving the *Care of Address* (CoA) it starts receiving the packets on the new link

If a CoA is generated successfully, then a tunnel is set up by sending a binding update (BU) message to its Home Agent (HA) and waiting for receiving a Biding Acknowledgement (BA) message. After receiving BU response, the MN establishes a tunnel with the MIH server to ensure session continuity.

A tunnel is created by providing a virtual interface in the mobile node side and a virtual interface in the MIH server side. All packets sent by the mobile node within the selected network, to a peer node, will be encapsulated by the mobile node virtual interface before being sent to the virtual interface of the MIH server. An original packet holds the address assigned initially. Such a packet will be encapsulated within a new IP packet using the care-of-address (CoA). Then the MIH server will decapsulate the received packets and forwards the original packet to its final destination. Figure 11 shows the packet encapsulation – decapsulation

For example if the WLAN belongs to the Home Network (HN), when the MN switches to 3G, it must establish a tunnel to the MIH Server. Without this tunnel all new packets after the handover will be lost because the MN will not be reached.

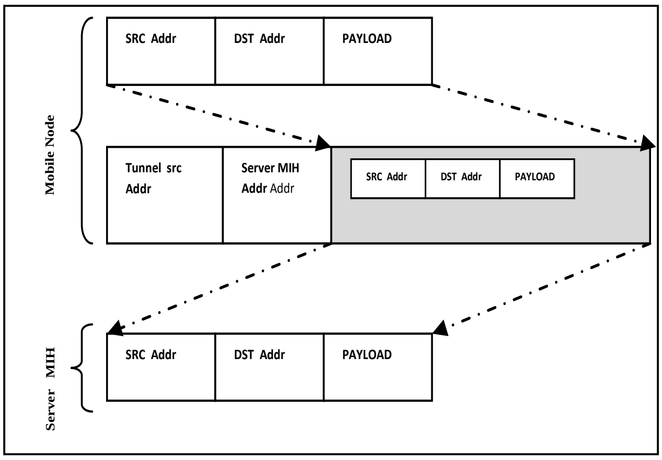


FIGURE 11 IP-IP ENCAPSULATION

The Test-bed Configuration

The implementation of our suggested architecture is implemented in real environment. This hardware configuration was provided by *"Meditel"* Telecommunication operator in Morocco.

We have 3 access networks: WLAN, WiMAX and 3G. WLAN is obtained via the WLAN access point (AP). The cellular 3G network infrastructure currently in use is the Meditel's production 3G network.

In this configuration.Our test-bed is composed with two computers: one Toshiba Laptop Pentium IV as a mobile client and a HP Desktop Pentium IV as a MIH server. The Mobile has three networks cards that can access the WLAN, WiMAX and CDMA2000 network. The mobile client is equipped with three cards of each network technologies (WiFI, 3G, WiMAX). The mobile clients get a WiFI connexion through WLAN AP Cisco Linksys WAG54G with is integrated WiFi card Prolink 100 Mbps PCI Adapter. It has also donglet 3G Huwai

E-220 to access to the 3G services provided by Meditelcom and also WiMAX - Ethernet adapter to access Meditel Telecom WiMAX service located near the central building of Meditel. The WiMAX is wired. The WiMAX Base Station shares the access through the WiMAX switch by which the mobile node (MN) is connected. The mobile node, Toshiba laptop Pentium IV, runs on *Linux Ubuntu*, equipped with these three access interfaces and it has also a possibility to switch from one network to another. The Mobile client is equipped with HaVE-2W3G software which helps him to perform vertical handover among these three networks accesses technologies.

The implementation of MN client side is based on our software architecture described earlier. We implemented the client by using linux kernel library combined with C network library to collect information in the physique layer and provide to the different components in need. For example, the driver manager layer collect all the driver of each network access card and offer specific function to the upper layer to manage Vertical Handover. All components were implemented by using a linux kernel 2.6.30.10. The Linux kernel compiled to support the mobile IP Protocol and to offer a possibility to modify network card driver's source code. The MN communicates with the server of mobility (MIH server) to facilitate seamless handover among heterogeneous networks. The MIH server helps the mobile node to maintain the continuity of service by establishing the tunnel if MN moves out its Home Network (HN). The server also is implemented in Linux.

The MN works as follows: when the MN is turned on, the user activates the Vertical handover procedure to handle the vertical handover management in the MN side. The MN discovers the available networks around and selects the best one based on the proposed algorithm in QoSFC. If MN moves out of the current network to a new Network, for example from WLAN to 3G, it establishes a tunnel between MN and the MIH server to ensure its session continuity. But if the selected network is from the Home Network, communication with the server is established without tunnel.

The tunnel we use here is IP-IP encapsulation. In this configuration, only the WLAN play the role of the Home Network. Consequently, if the MN chooses another access network for example 3G access network, it will establish a tunnel with the server. We use streaming server as Correspondent Node. The choice of this application is due to the fact that streaming media is one of the fastest growing online content delivery mechanisms today. The Mobile Node consults online TV provided by server which is connected with the mobile node through the internet. The steaming server uses TCP as a transmission protocol. Therefore, the Correspondent Node could also be a mobile terminal communicating with mobile client through a VoIP or game application.

In all, our solution reproduces MIH components like event services, command services and information services. But we also improve our architecture in client side by introducing the monitoring entity which sends information characterizing the system (System configuration, CPU, Network parameters …) to the upper layer for handover decision. Also the client use preference which allows the system to choose the network by taking into account them.

Our architecture overcomes the problem of seamless network implementation by enabling a variety of application to be implemented because the architecture is not handy and have not great latency. There is no need of user intervention and the MN always selects the best connection.

HaVe-2W3G User Interface

To help a mobile client to use of proposed solution, we have provided a user interface as shown in Figure 12 which allows a mobile client to select the Vertical handover functional mode. Through this interface, the user has a possibility to launch a vertical handover process and select the mode which corresponds to his context. There is two mode of connection: manual mode or an automatic mode. The manual mode gives the user the possibility to select the interface in which he wants to continue his communication. For example, when the user want to leave the office where he was connected on WLAN and return home. He will explicitly choose to move to 3G interface. This handover is made before the first connection collapse.

If the client selects the automatic mode, HaVe-2W3G set up a automatic mode process. In this mode, the user gives to the system the control of the handover. By using the algorithm of selection, the system selects the best interface and transfer the session without interruption. The automatic mode is more adaptive to the context of ubiquitous network. The graphical interface also offers to the client the possibility to visualize information about available network, quality of signal, bandwidth and so on. It also gives a possibility to the client to uses the tunnel during communication.

FIGURE 12 *HAVE-2W3G* USER INTERFACE

Experimental Results

To evaluate our architecture, we use a real existent environment of telecommunication operator in Morocco. The mobile client is connected to WLAN Access Point where many users are also connected. The same case with the WiMAX networks used as networks connection in Meditel siege. Also, the mobile client is connected to the UMTS networks covering all the area around Meditel building. The NodeB has the capacity to support more than 300 users. We perform different test inside Meditel building and move around the building for mobility. The mobile client is connected with the video server located in France and all the communication after leaving our networks cross the internet to reach the streaming server.

Compared to the evaluation performed in [7], the data traffic of their proposed architecture was note evaluated in a scalable environment where packets are routed through internet and also there is only one user or mobile client using all the bandwidth. Also, the handover performance evaluation performed in [24] does not take into account the scalability of the networks and separate the security phase handover phase with the security phase which is integrated in the authentication phase of the handover. So, our evaluation reflects a real case where the mobile client is not the only users in the networks and also the traffic is influenced by many parameters like: the delay caused by internet, the heterogeneous traffic and the numbers of users connected in each networks Access Points.

We analyze the performance of *HaVe-2W3G* with streaming traffic using TCP protocol. The streaming server is located in France and mobile client located in Morocco is obliged firstly, to use internet network to attend the server where many clients are also connected and use concurrence each one from other and secondly to share the channel with other subscribers at Meditel. During evaluation, we collect a same traffic through Wireshark software [20]. Wireshark capture in real-time packets exchanged between mobile client and the streaming server and also between the mobile client and the MIH server, from all these three networks cards. Also other packets like ARP packet or DNS request packet were also captured. All this traffic was filtered and used with gnuplot software to trace graphs. The packets were captured. The experiment was realized by switching automatically the mobile client from one network to another.

We measure different parameters to evaluate the performance of our architecture: throughput, handover latency, and packet inter arrival time.

In our context, *Throughput* is the amount of data moved successfully from the streaming server to the mobile client. *Handover latency* is the time take the mobile client to move from the last connect network to the new one.

Delay is the duration that takes a packet to move from the streaming server to the mobile client

Packet inter arrival time is time difference between two packets arrived at the received through the same network interface of the mobile client

Figure 13 presents the TCP throughput measurement of the scenario illustrated in Figure 12. It is clearly shown that WiMAX provides more throughput than WLAN and 3G. MN receives more data when it is connected in WiMAX network. Because our algorithm of selection is based on the throughput and the quality of signal received, WiMAX network will be always the preferred network and followed by the WLAN network.

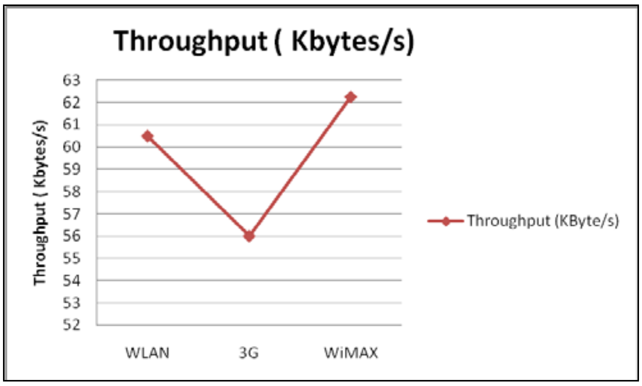


FIGURE 13 WIRELESS NETWORKS ACCESSES VS THROUGHPUT

The handover latency as shown in Figure 14 describes clearly that 3G latency is greater than WiMAX and WLAN. MN spends more time to switch in 3G networks than other networks like WLAN. This handover duration will impact on the streaming traffic sent through 3G network interface and probably be the source of session failure in case of real-time application like VoIP. Also, compared to the Handover latency results presented in [24] our architecture provide the minimum duration.

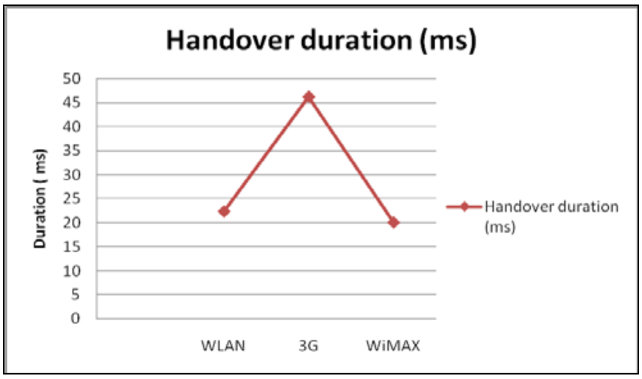


FIGURE 14 WIRELESS NETWORKS ACCESSES VS HANDOVER DURATION

In Figure 15, we see clearly the continuity of session between WLAN and WiMAX networks. Normally, without Vertical Handover mechanism, Mobile Node will interrupt its session when it moves out of WLAN coverage. MN has fewer throughputs in WLAN than in WiMAX. This difference between WLAN and WiMAX is clearly seen trough the graph.

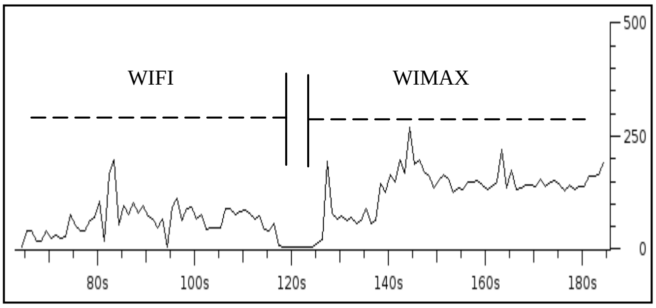


FIGURE 15 NUMBER OF PACKET VS TIME

The Figure 16 presents the RTT variation before and after the handoff of the MN from WLAN network to 3G network. The RTT evolution increase when the MN switches from WiFi Network to 3G network but remain constant in WiMAX network. The variation of RTT in the 130th seconds is due to the redirection of the packet when the MN performs handoff from WLAN network to 3G network. This change shows clearly that HEC (Handover Execution component) keeps session during handover and redirects all the corresponding packets to the destination without losses.

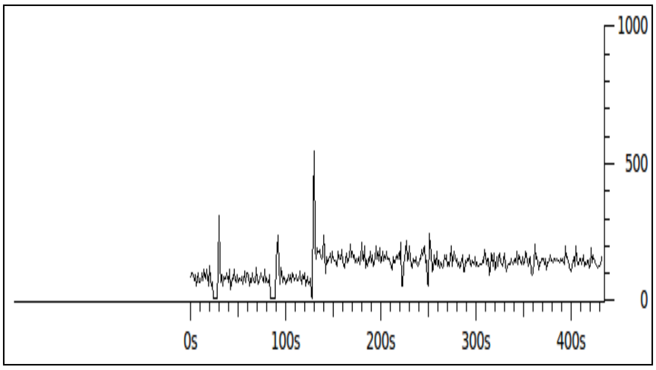


FIGURE 16 RTT VS TIME OF CAPTURE

Figure 17 present the received packet interarrival time of TCP traffic sent with a constant bit rate. In Figure 17 the interarrival duration when the Mobile Node is connected to the WiMAX network is greater than when the MN is in WLAN network and 3G networks. So, all packets sent through WiMAX network take more time than in WLAN and 3G networks. The high variation of interrarival time is caused by losses that are recovered, either at the MAC or at the transport layer.

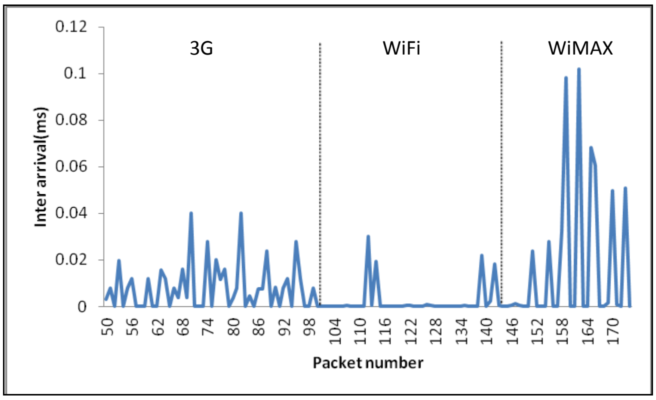


FIGURE 17 TCP PACKET SEQUENCE VS INTERARRIVAL(MS)

Furthermore, it is clear that WLAN present the best arrival time than WIMAX and the 3G networks. Also, the received packet inter arrival time in 3G Networks presents the best arrival time than WIMAX. Others tests were performed with Skype. The interruption of service caused in Skype was due to the long time caused when the network switch from 3G to WiMAX because of the long latency handover. The 3G network causes more latency so that the transfer of voice session takes more time than tolerated latency. A WiMAX network interface has not detected in time a route to the Internet gateway and provokes the connection failure. But from WiMAX to 3G or WiFi to 3G/WiMAX and vice versa, the communication was realized without interruption.

Conlusion

In this paper we presented our architecture *HaVe-2W3G* and its implementation which guarantees an interworking between heterogeneous networks. This implementation provides a tunneling mechanism to ensure the continuity of a session while processing a Vertical Handover. The suggested architecture provides a set of components organized in three layers. Such components allow the management of the active networks drivers and their associated events. These components offer the mobile node the possibility to monitor its resources and its network performance. *HaVe-2W3G* allows the mobile node to select the appropriate network while managing the Vertical Handover process. Our implementation was made in a real environment integrating components of the core network of Meditel (a telecom operator). An evaluation was performed using a streaming content form a server linked to internet.

An important of our testbed plateform is the preservation of service continuity while skipping from one network to another.

Our architecture proposes also more functions than MIH: monitoring of the system resources, user preferences module and handover decision component using multiple criteria.

In future work, we plan to consider the QoS and the Quality of Experience (QoE) parameters related to the user services in addition to those related to the network (signal strength) in order to offer a more powerful algorithm for Vertical Handover Decision. We also need to increase the density of the network and replace the laptop with a mobile handset using other kinds of operating systems like Android. Another important point consists in evaluating the performance of the suggested solution by considering a more realistic scale in terms of mobile users.

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