Performance Analysis of the Interconnection between WiMAX and UMTS Using MIH Services in MIPv6

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Summary
This article analyzes the performance of vertical handover between UMTS and WiMAX networks by defining development architecture for supporting mobility between these two technologies. First, architectures and principles of operation of networks UMTS and WiMAX are detailed and compared. Then the main protocols of mobility are considered as support of handover between UMTS and WiMAX (802.16). Finally, simulation architecture is presented followed by performance analysis modelled by the simulator NS2 in the context of connection-oriented communication.
Key words: *Networks, Wireless, UMTS, WiMAX, Handover.*

1. INTRODUCTION

In the early 21st century, mobile telecommunications systems are evolving very rapidly. The development of relevant technologies and the radical change of applications and customer requirements have led to diversification and undeniable growth in wireless communication services. Because of the simplicity and convenience of these technologies, the last decade was marked by the emergence of many wireless technologies such as Bluetooth 802.15 or WiFi (Wireless Fidelity) 802.11.
The new technical ways of radio access (UMTS, WiFi and WiMAX) are in competition with GSM. The next generation of mobile networks will allow users to use mobile broadband services capable of transmitting voice, images, data and video anywhere and anytime.
WiMAX (Worldwide Interoperability for Microwave Access) is now the network of broadband access as requested by its new performance in throughput and range. WiMAX is also known as IEEE 802.16, this standard does not cease, since its birth, knowing successive evolutions and to mark undeniable successes on the level of the services offered and the progress made in its field.
Indeed, this standard has only failed to reduce and solve the problems of remote areas deprived of ADSL (Asymmetric Digital Subscriber Line) networks and channels, but also it comes to open new opportunities by providing a highly anticipated and portability demanded by customers at the market.

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The UMTS (Universal Mobile Telecommunication System) or mobile network of third generation is a wireless mobile communication system capable of being medium, in particular innovative multimedia services, and combine the use of terrestrial and satellite devices.
With the integrated convergence between these technologies, we can provide a mobile terminal (smart phone, touch pad...) as well as WiMAX terminal (receiver) or communications transmitter via UMTS.
This dual-mode operation (UMTS-WiMAX) will move from one network to another without closing the connection.
The remainder of this paper is organized as follows: Section II is devoted to the presentation of general concepts of UMTS and WiMAX networks. In the third section, there will be detailed handover mechanisms for each system with the mobility management of both networks. The fourth part presents the modeling of horizontal handover networks of WiMAX network and vertical handover between UMTS and WiMAX. Finally, a conclusion closes this paper.

2. UMTS and WiMAX Networks

2.1 UMTS network

Universal Mobile Telecommunication System (UMTS) is also more generally the new standard of mobile telephony, called telephony of third generation or 3G. The purists prefer to use the term W-CDMA (Wideband Code Division Multiple Access) which takes again the name of the technology deployed in Europe and by certain Asian operators. This technology makes it possible to make forward more data and will allow the appearance of multimedia contents on the mobile phones such video-telephony. We will speak then rather about terminals multimedia. Thus, in addition to these technological changes, the third generation must answer the concept of quality, variety, capacity and coverage [1]. The organization ITU (International Telecommunications union) which regulates the various standards of telecommunications on a world level aimed to define a single and international standard for the third generation:

the IMT-2000. But this has failed since no less than fifteen radio access technologies have been proposed.
In the end, only 6 terrestrial radio access technologies have been kept: UTRA-FDD, UTRA / TDD, TD-SCDMA, CDMA2000, UWC-136, DECT. UMTS in turn includes the first two technologies.

2.1.1 Structure of UMTS network

A UMTS network is based on a modular and flexible architecture. Thus, these two characteristics, which make it compatible with other mobile networks of second and third generation, guarantee its evolution.
The general architecture of a network UMTS is made up of three fields (figure 1):
- The equipment user: EU (To use Equipment).
- The network of universal access: UTRAN (Universal Terrestrial Radio operator Network Access).
- The core network: CN (Core Network).

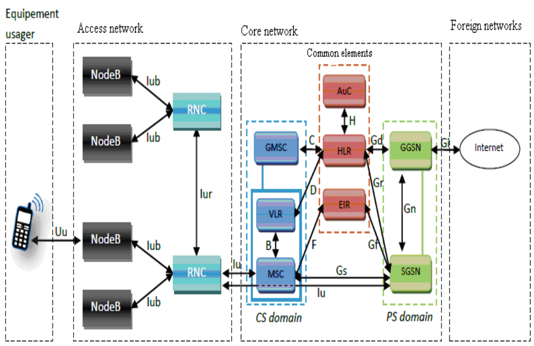

Fig. 1: Global architecture of UMTS network

a- **User Equipment:** The domain of the User Equipment (UE) includes the set of the terminal equipment.

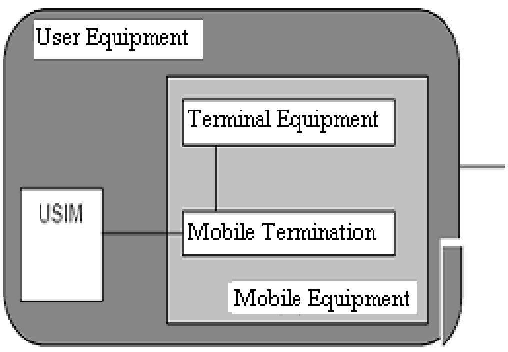

Fig. 2: User Equipment

It includes at the same time the mobile equipment and the USIM. This domain allows the user to reach the infrastructure via the Uu interface.

The mobile equipment is subdivided in two parts as depicted in figure 2:
- The Terminal Equipment (TE) is the part where information data are generated in transmission or reception processing.
- The Mobile Termination (MT) which ensures the transmission of information towards network UMTS or others and applies the functions of errors correction.

The USIM (Universal Subscriber Identity Module) is an application that manages the authentication procedures and encryption as well as services to which the subscriber has subscribed. The USIM is a card called UICC (UMTS Integrated Circuit Card). It can be used on a UMTS terminal regardless of the manufacturer usually the network operator: map combines a subscriber to one or more service providers and not necessarily the operator of the current network [2].

b- **Access Network:** The domain of the access network (as shown in figure 3) (UTRAN) provides to the Equipment User the radio resources and the mechanisms necessary to reach the core network. The UTRAN calls upon technology UTRA, with its two alternatives FDD and TDD, founded on the access method broad band CDMA.

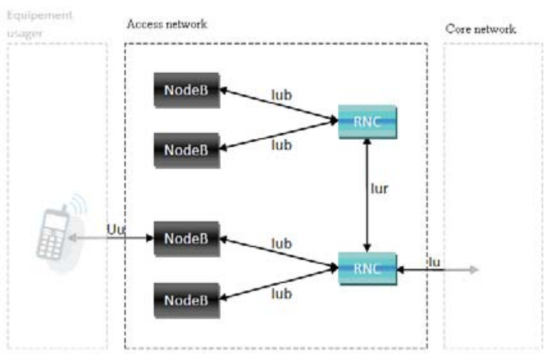

Fig. 3: Structure of Access network

c- **Core Network:** The Core Network includes all the equipment performing the functions of safety control and management of the interface with external networks (figure 4).

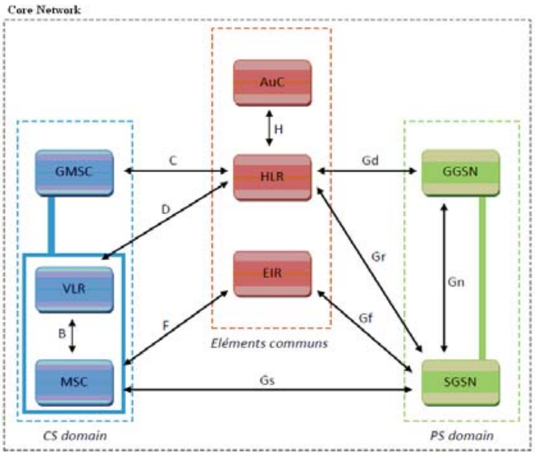

Fig. 4: Structure of UMTS core network

It is on this level that we can perceive the modularity of the UMTS network architecture. Indeed, in theory, it is possible to connect to the common core network other radio access networks (GERAN, DECT, CDMA2000, etc).

2.2 WiMAX network

Today, the wireless is increasingly present in our daily life and tends to replace the excessive use of cables. Since a few years, WiFi has revolutionized the networks but we speak already about a new technology: WiMAX (Worldwide Interoperability for Microwave Access).
Although broadband connections such as ADSL are increasing in the world, they do not allow the flexibility afforded by such a WiFi wireless network. However, WiFi allows only flow and reach very low at the same time making its use limited.
WiMAX aims to provide wireless broadband Internet in a radius of several kilometers and is intended primarily for metropolitan networks.
Figure 5 shows an example of the WiMAX network.

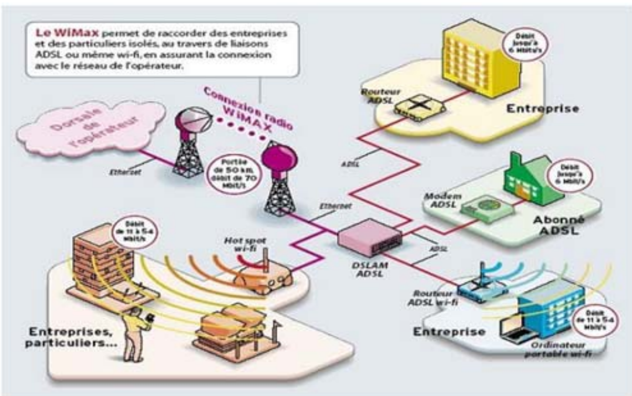

Fig. 5: Example of WIMAX network [3]

The first deployments in WiMAX are expected to allow remote areas, underserved by DSL or cable or wishing to take advantage of a wireless connection, to have a broadband Internet access. WiMAX development could therefore play an important role in the regional digital development.
With version 802.16e, WiMAX will be available for deployment in laptops with nomadic and mobile usage. Some manufacturers consider thus that the 802.16e standard constitutes an important issue for the launch of 4G mobile [4].
Mobile WiMAX opens the way for mobile telephony over IP, or more broadly to mobile broadband. The theoretical maximum throughput is 30 Mbps for a range of 2 to 4 Kilometers without obstacles.
The table below summarizes the technical characteristics of the most important standards namely IEEE 802.16, IEEE 802.16d and IEEE 802.16e.

Table 1: Technical specificities of the IEEE 802.16x various standards [4]

Parameters	802.16	802.16d	802.16e
Spectrum	10-66 GHz	< 11 GHz	< 6, 11 GHz
Channel conditions	Only LOS	NLOS	NLOS
Flow	32 to 134 Mbps at 128 MHz	Up to 75 Mbps at 20 MHz	Up to 15 Mbps at 5 MHz
Modulation	QPSK, 16-QAM, 64-QAM	256-OFDM, QPSK, 16-QAM, 64-QAM	256-OFDM, QPSK, 16-QAM, 64-QAM
Mobility	Fixed	Fixed	Nomandism
Bandwidths	20, 25 and 28 MHz	The choice between 20 and 125 MHz	As 802.16a with uplink channel to keep power
Typical cell radius	1.61 – 4.83 Kms	4.83 – 8.05 Kms	1.61 – 4.83 Kms

2.2.1 Elements of the network IEEE 802.16e

As mentioned the goal of extending "e" is to provide access nomadic / mobile.
In the IEEE 802.16e [4], there is no detailed model of reference as those presented in the section of the UMTS technology. However, the network elements are presented in a model system for mobile communications.

The model of reference is composed in groups of basic station BSs (Base Station) serving a mobile station MSS (Mobile Subscriber Station) in a given geographical sector. The BS is connected to the backbone via a cable or radio link in a manner representing the administrative affiliate network provider.
Different providers can cohabit their networks in the same areas. To ensure the procedures of Authorization Authentication and Accounting (AAA), management, the provisioning and other functions and objectives, the provider's networks can use specific servers. They are indicated under the name ASA-servers (Authentication and Service Authorization Servers) they are also responsible for these functionalities. The providers can put in application simple or several ASA-servers in a centralized or distributed way.
The following table describes the different mobile entities defined in IEEE 802.16 e.

Table 2: Relative mobility Entities in IEEE 802.16e [5]

Entities	Description
MSS	Mobile Subscriber Station contains physic and MAC layers
BS	Base Station
ASA Server(s)	Authorization Authentication and Accounting Server

The control of handover can be either localized or distributed in BSs in SAA server. Figure 6 illustrates a simple example where a user is approaching its target BS and creates a relationship with the server authentication and authorization service (ASA) [5].

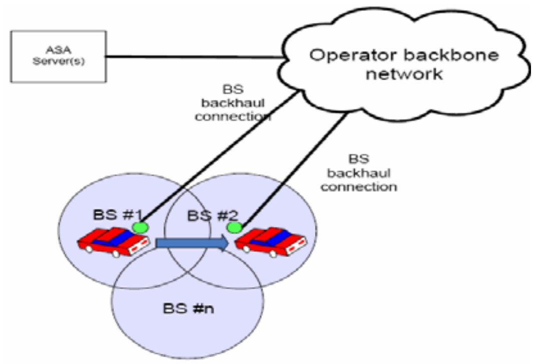

Fig. 6: IEEE 802.16e network Model [5].

2.3 Comparison between UMTS and WiMAX

Table 3 summarizes the different characteristics of both technologies.

Table 3: Comparison of UMTS and WiMAX

Parameters	UMTS	Mobile Wimax
Range	Typically 1.5 - 7 Km Pico-Cells: 50 m Micro-Cells: 500 m Macro-Cells: 7 Km	Typically 1.5 - 5 Km Pico-Cells: 100 m Micro-Cells: 10 Km Macro-Cells: 15 Km
Usage	Wireless extended network	Mobile extended network
Theoretical debit	Up to 2 Mbps (Up to 10 Mbps with HSDPA)	Up to 70 Mbps
Frequency	1800, 1900, 2100 MHz	2000 – 6000 MHz
Mobility Support	Importante Mobility: - Handover in real time (Node B/ Node B). - Support for Mobile vehicular access.	- Portable Use (Nomadic services, Limitation of layer 3 for mobile access and latency to the Handoff). - Mobility (Best effort QoS for Handoff (BS to BS)).
Modulation	WCDMA	OFDMA, FDD and TDD
Quality of Service	- Two different services real-time high. - Two different services with minimum error rate and not necessarily in real time. - Best effort service: no time constraint transmission.	- Designed to withstand constant bit rate and guaranteed. - It is intended for real-time services. - A class of service can possibly be allocated to each user connection.

3. Mechanisms of handover between UMTS & WiMAX

In this section we will detail the handover mechanisms for each system, and the mobility management of both networks, we also discuss the needs and requirements of the mobile network to support inter-system handover of UMTS and WiMAX.

3.1 Handover process

In mobile systems, the handover is a crucial process because mobile users cannot gain access to the same base station BS while moving.
The freedom to make and receive calls anywhere, at any time, creating a new dimension in human communication has often been heralded as the main advantage of new wireless systems. Handovers are the key concepts to provide mobility. It allows a user to move from one cell to another while maintaining a perfect connection and above all without interruption. In general, a handover is performed when the connection between the base station BS and the mobile terminal is more satisfying or level of traffic to a base station. The term "handover" means the entire process of deleting the existing connection and replacing it with one that will have a better connection (to the target cell). From the radio link quality obtained by

reports of measuring, the network controller is able to decide whether a handover to another cell is needed. Knowledge on the allocation of radio resources in the target cell and release of channels after the termination of the transfer are vital for a successful handover. The incapacity to establish a new connection in the target cell is regarded as a failure handover.
The delivery failure occurs in the absence of new resources in the target cell or when the radio link has dropped below acceptable levels before the call is delivered to the target cell [6].

3.2 Handover Types

The mechanism whose purpose is to allow the passage of a connection to an access point to another without interruption of service is called handover. There are two types of handover: horizontal handover and vertical handover.

3.2.1 Horizontal Handover

Horizontal handover occurs in the case of homogeneous networks (e.g. handover between NodeB of a UMTS network or between a WiMAX BS). It allows transferring traffic from one access point from one network to another access point of a network of similar technology when it comes to connection limit.

3.2.2 Vertical Handover

Vertical handover occurs in the case of heterogeneous networks. It allows transferring traffic from one access point from one network to another access point of a network of different technologies.

3.3 UMTS – WiMAX inter-system Handover

In the following, we will first describe the protocol required to support mobility between both systems UMTS and WiMAX, and we will detail the requirements for intersystem handover process. Then we will detail the handover procedure.

3.3.1 Mobile IPv6

Mobile IPv6 was initially defined as an addition to IPv4. For IPv6, the mobility support (Mobile IPv6) has been envisaged at the outset. Therefore, some problems of Mobile IPv4 have been resolved in Mobile IPv6. The major problems of the Mobile IPv4 are deployment, the triangular routing, the overhead of tunnelling and security [7], [8].

The deployment of Mobile IPv4 requires the implementation of foreign agents in each foreign network potential. This implementation suggests a reconfiguration of network coverage. The mobile IPv6 addresses this problem by eliminating all the foreign agents. It retains the ideas of home network, home agent and the use of encapsulation to route packets from the network service to the customer.

Figure 7 shows mobility management with mobile IPv6.

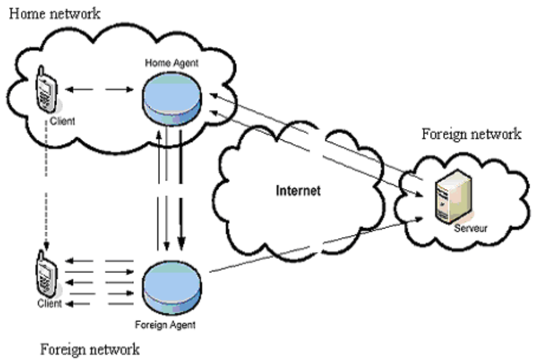

Fig. 7: Mobility management with Mobile IPv6 [7], [8]

The scenario for Mobile IPv6 is similar to Mobile IPv4 scenario. The client is initially located in its home network to a position 'A' where he established communication with a server in a foreign network through the Internet using standard IP routing mechanisms [1]. The client then changes position 'A' in the home network to 'B' in a foreign network [2].

3.3.2 Requirements of the handover

To perform inter-system handovers UMTS-WiMAX, certain requirements of the mobile terminal and network must be filled.

1) Mobile Requirements

The mobile terminal must be a dual-mode terminal that is to say equipped with a USIM for the UMTS access network and a wireless access card for access to 802.16e WiMAX network, this which allows it to operate on both networks and support handover from one network to another.

2) Network Requirements

Network interaction implies connection between UMTS and WiMAX. The UMTS network operator can provide the basis for connecting a WiMAX network. Thus we define three types of interconnection possible: the configuration tight coupling, loose coupling setup and configuration console coupling [9].

3.3.3 Inter-system Handover Procedure

The handover procedure of a mobile terminal is divided into three steps. First, some measures [10] should be conducted and compiled in a report measures. Then, a decision to handover [10], [11], [12] is taken according to the report. Finally, the handover is executed [13] if the handover decision is positive.

4. Simulation and Results

In this section, we present the simulation parameters. Then, we evaluate the performance of our achievements during the simulation.
The following figure shows the different steps of our simulation work.

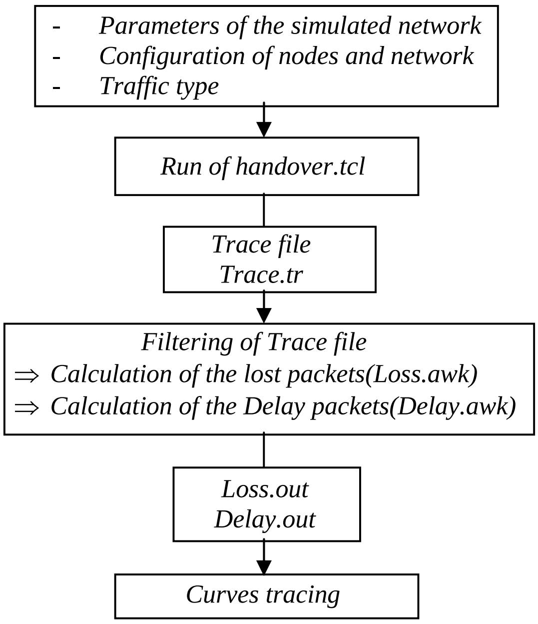

Fig. 8: Different simulation phases

4.1 Simulation parameters

4.1.1 Initial Parameters

The parameters mentioned in the table 4 are necessary for simulation.

Table 4: Initial parameters of the simulation

Parameters	Significations
Simulation time	Simulation time in second fixed at 200 sec for all simulated scenarios
Scenario size	1100 m x 1100 m
Seed	RNG (***R**andom* ***N**umber* ***G**enerator*) fixed at 1 for all simulated scenarios
Speed	Mobile node speed (m/sec)

4.1.2 Parameters of the vertical handover(UMTS – WiMAX)
We present the parameters of inter-system handover between UMTS and WiMAX. This scenario is similar to the previous scenario except that here the handover is between two BS which belong to two different technologies. In this scenario, the node multi-interface occurs so that the mobile user supports two technologies (UMTS & WiMAX) which allow it to make a handover inter-system.

a) UMTS network parameters

Table 5 illustrates UMTS parameters.

Table 5: UMTS network parameters

Parameters	significations
UmtsNodeType (rnc)	node type (is a node type **rnc**)
UmtsNodeType (ue)	node type (is a node type **ue**)
UmtsNodeType (bs)	node type (is a node type **bs**)
uplinkBW	=384kbps ; flow bandwidth UL
uplinkTTI	=10ms ; transmission time interval in UP
downlinkBW	=384kbps ; flow bandwidth DL
downlinkTTI	=10ms ; transmission time interval in DL

b) WiMAX network parameters:

Table 6 shows WiMAX parameters.

Table 6: WiMAX network parameters

Parameters	significations
Channel/WirelessChannel	channel type : wireless
Propagation/TwoRayGround	radio propagation model
Phy/WirelessPhy/OFDM	interface network type
Mac/802_16	MAC layer type
Queue/DropTail/PriQueue	Queue interface type
LL	link layer type
Antenna/OmniAntenna	Antenna model
Max_queue_size	maximum queue size
hierarchical_routing_protocol	Used routing protocol (NOAH)

4.2 Lost packets rate in function of speed

To determine the packet loss during handover, any node of the Internet transmits a stream of packets periodically to the mobile node. Before a handover is carried out, the packets are conveyed along the old road. In simulation, we suppose that Correspondent Node (CN) knows in advance the last packet which will be transmitted to reach the mobile node with its old localization. It is supposed that Correspondent Node records this packet. By receiving the recorded packet, the mobile node carries out a handover and immediately transmits a packet of updated through the new base station.
The packets sent by Correspondent Node after the recorded packet are regarded as packets lost before the arrival of the updated packet, because they are sent through the old base station.
In our scenarios, we will evaluate the average rate of the lost packets which presents the ratio of the number of the packets lost on the full number of the generated packets:

$$PLR = \frac{\text{Number of packet discarded}}{\text{Total number of packet generated}} \quad (1)$$

PLR indicates the rate of the lost packets.
The figure 9 represents the rate of the lost packets according to speed for our scenario.

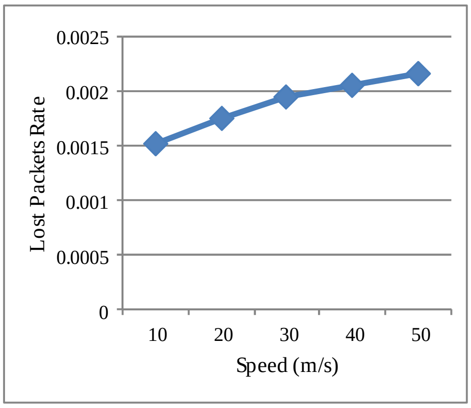

Fig. 9: Lost packets rate in function of speed

From this figure, we deduce that:
For a low mobility, the performances of the handover are satisfactory i.e. the rate of the lost packets is directly proportional with speed.
Indeed, for high speeds, the performances of the handover fall considerably.
Moreover, if we examine the files traces generated, we find that the destruction of the packets is due to the time of establishment of a new connection with the new base station where the mobile does not receive any more of the packets of the old base station.

4.3 Performance Analysis Handover WiMAX- UMTS (WUHO)

We will evaluate the performance of the WUHO handover (WiMAX to UMTS handover).
The simulated scenario is to carry traffic on the application between the node CN (Correspondent Node) and the mobile node (MN), which moves linearly in the WiMAX network to the UMTS network with a variable speed V (m/s) (see Figure 10).

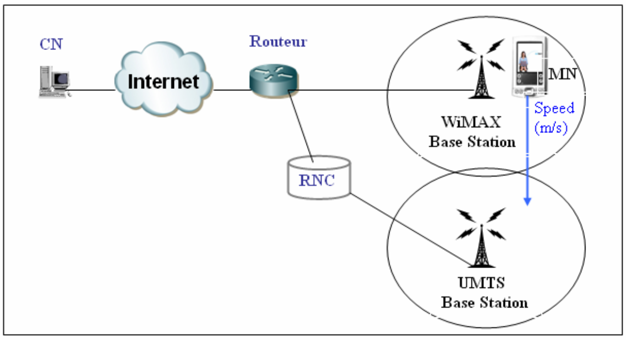

Fig. 10: Simulation Model (WUHO)

We will present the evolution of the packet transmission delay and packet loss rate versus time of the simulation for different speeds of the mobile node to implement UDP.
Table 7 presents the simulation parameters of UDP traffic.

Table 7: UDP traffic for the mobile node

Type	udp
Packet size (bytes)	500
Packet interarrival time (s)	0.02

4.3.1 Rate of lost packets

Figure 11 shows changes in the rate of packet loss over time of the simulation for different speeds.

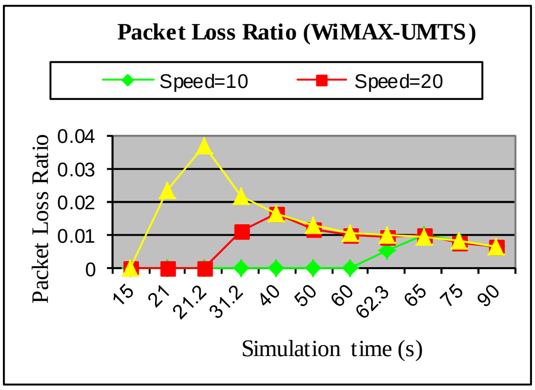

Fig. 11: Evolution of the rate of lost packets (WUHO)

From this figure we deduce that:

- For low mobility, handover performance is satisfactory. Indeed, for a speed of 10 m/s the rate of packet loss is less than 1%.
- The rate of lost packets behaves in a similar way before and after the execution of handover for both networks.
- For high speed, performance of the handover drop considerably.
- The presence of peaks during the execution of handover, which increases with speed, reaching 3,7% for a speed of 30m / s.
- The number of packets destroyed increases with speed and with the performance of the handover; in addition, if we examine the trace file generated, we find that the destruction of packets is due at time of establishment of a new location where the mobile no longer receives packets from the old base station.

4.3.2 Transmission delay of packets

The figure below shows the evolution of useful packet transmission time.

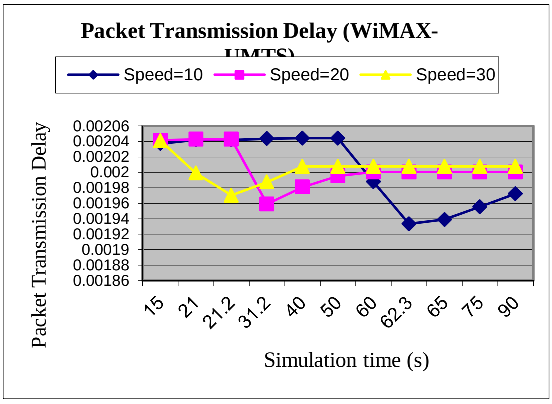

Fig. 12: Evolution of the packet transmission delay (WUHO)

This figure shows:

- After the execution of the handover, the average time of transmission is high (2 ms) for medium and high mobility.
- Decreasing the delay means that the radio link is behaving badly and some packets will be retransmitted, resulting in the need of HO.
- The average time of packet transmission decreases with the execution of the handover and slightly with speed.

4.4 Performance Analysis Handover UMTS-WiMAX (UWHO)

In this section, we assume that the mobile was originally connected to the UMTS network, as soon as it leaves the coverage area, it switches the traffic on the interface corresponding to the WiMAX (802.16 e).

We will simulate the same type of application UDP with the same simulation parameters to compare and interpret the performance of the vertical handover between UMTS and WiMAX.

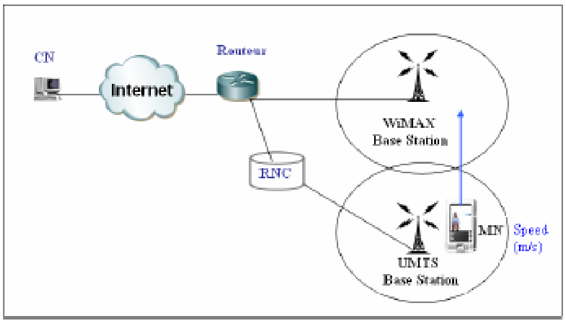

Fig. 13: Simulation Model (UWHO)

4.4.1 Rate of lost packets

Figure 14 shows changes in the rate of packet loss over time of the simulation for different speeds.

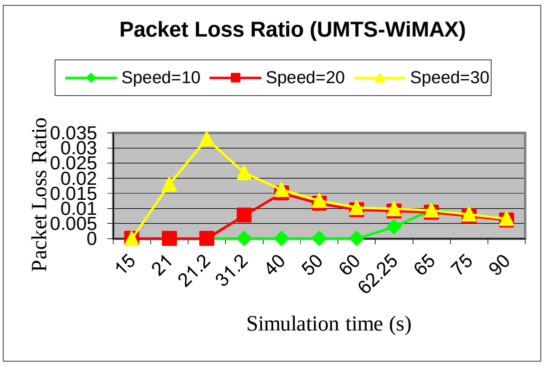

Fig. 14: Evolution of the rate of lost packets (UWHO)

From this figure, we can see that:

- In this sense, changes in the rate of packet loss are slightly lower than shown in the other direction.
- A packet loss rate is only 3,2% for high mobility.

4.4.2 Transmission delay of packets

Figure 15 shows the evolution of packet transmission time useful.

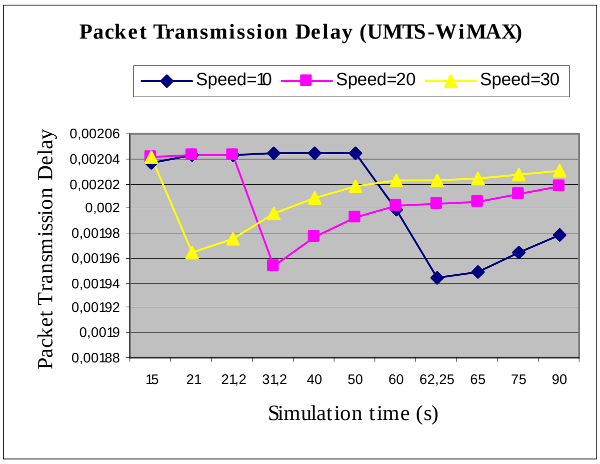

Fig. 15: Evolution of the packet transmission delay (UWHO)

The evolution of the packets transmission delay is more important to the UMTS network. It shows a latency of handovers for different speeds which is slightly higher than the results obtained in the first simulation.

5. Conclusion

In this paper, we propose a handover mechanism for moving mobiles by using MIPv6 protocol with assistance of MIH services. We considered the calculation of the lost packets rate to evaluate the performances of the inter-system handover between the two wireless networks UMTS and WiMAX.

In the study of vertical handover scenario simulation, the accent was related to the problems relating to the rate of lost packets at the time of the handover.

On the one hand, the scenario of vertical handover between UMTS and WiMAX networks modeled highlights acceptable QoS requirements during the movement of dual-mode terminal. A handover is integrated for applications of the type UDP such as the voice. On the other hand, it removes the problem of signaling load due to the mobility protocol (Mobile IPv6). This problem is likely to generate a consumption of band-width both for the operator network and the user of the mobile terminal. The user of the mobile terminal must expect a saturation of the band-width due to the frequent advertisements of routers; the network operator undergoes an important penalty by considering a high number of the base stations of UMTS and WiMAX supporting the IPv6 Mobile.

The presence of an entity handover (MIH) is important to limit the penalty. It causes delay measurement, handover decision and execution of additional failover time but significantly reduces the ads routers that act as major consumers of bandwidth.

In prospect, we advise to inter-connect several networks of heterogeneous technologies in order to obtain a terminal supporting these various technologies. We could also simulate other types of applications such as; FTP, TELNET…

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