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Improving Vertical Handover Performance of Real Time Applications over Heterogeneous Wireless Networks

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ABSTRACT
The Wireless network, applications and devices have been dramatic changes in throughout the last decade. Several issues related to the heterogeneity of such wireless environment were handled, namely the mobility management, resource allocation, security, quality of service and transparent handover. In fact, to meet the increasing demands of mobile users, the next generation wireless systems form a relay of cooperatives of heterogeneous wireless technology that allows users to be connected anytime and anywhere. Wireless networks can integrate various heterogeneous radio access technologies as GSM, UMTS, WLAN, Wimax etc... The main promise of interconnecting these heterogeneous networks is to provide high performance in achieving a high data rate and support real time applications. In this Paper performance analysis of UMTS-WLAN integration network is performed and the vertical handover latency delay was improved by using the Network Simulator NS2 to model and simulate different scenarios by focusing on real-time traffic such as VoIP.

General Terms
Vertical Handover Latency, Quality of services

Keywords
UMTS, IEEE 802.11, Mobility management.

1. INTRODUCTION
Future mobile networks will most likely be based on a packet-switched architecture with a diversity of access technologies. With such architecture, the 3G mobile networks can easily be extended by other IP based wireless access technologies like Wireless Local Area Network (Wireless LAN) or worldwide interoperability for Microwave Access (WIMAX).

Interworking of the wireless networks requires different mobility management, security and QoS mechanisms to be harmonized and integrated into a common architecture. Different choices of these mechanisms lead to several interworking approaches that can be organized into two groups: IP-based and UMTS-based. In the IP-based approach, the networks remain independent of each other and potentially belong to different administrative domains. Only the subscriber information management can be common for the networks. In the UMTS-based approach, the WLAN is embedded in the UMTS network. The UMTS control protocols are reused within the WLAN. The WLAN data traffic is routed via the UMTS core network. This solution is suitable for a single, 3G operator.

The important point in the vision presented above is that the user expects the transparent operation of applications and network services, despite its mobility. However, in most cases, terminals and applications can not continue to operate without additional operations such as reconfiguration of IP addresses and other network settings. This reconfiguration causes the interruption, hence the implementation of vertical Handover. Two major factors that affect the handover performance are the handover delay and packet loss which consequently affect the performance of the network throughput during handover period. Many researchers have proposed mobility management techniques to solve the handover related issues. The mobility management is mainly operated at IP layer. However, the mobility management using a single layer may not be sufficient to fully reduce handover delay or to support the advanced handover mobility requirements. The design of mobility solutions across heterogeneous networks with low handover delay is a challenge because each access network has its own mobility.

2. BACKGROUNDS
In [2] S. Rizvi, A. Asif, N.M. Saad, Nasrullah A. & M. Z. Y. conclude there paper that for both cases, their results demonstrate that the performance of the integrated UMTS and WLAN is far better in the case of GGSN-WLAN than that of SGSN-WLAN internetworking, for all of the applied applications and measurement parameters. This is because the WLAN 1AP [8] needs to have some additional capabilities to process UMTS messages; the SGSN-WLAN integration requires more processing and latency for the communication. Whereas for GGSN-WLAN, a simple IEEE 802.11b WLAN AP is required; therefore, GGSN-WLAN requires no additional tasks for communication. They also set as objective of future research, the evaluation and optimizations of the vertical handoff decision algorithms and the maintenance of a seamless mobility, when the user is moving across the heterogeneous wireless networks.

In [3] R. Pries, D. Staehle, P. Tran-Gia and T. Gutbrod conclude the paper by presenting the value of the complete handover that can be performed within 750 ms and the blackout time with no connection lasts only 100 ms.

In contrast to the above mentioned research efforts, the prime concern of this paper is to study the evaluation and optimizations of the vertical handoff delay without Blackout time and to maintain a seamless mobility, when the VOIP user is moving across the heterogeneous wireless networks.

In vertical handoffs ([2]UWoff), i.e., handoffs between radio access networks which are representing different technologies, an additional delay is occurred to disconnect from the current serving radio access network, and to connect to the target radio access network. Therefore [3], correct time to initiate an UWoff request and selection of the best available target

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[1] Access Point
[2] Vertical Handover UMTS toward WLAN

network among the range of available network are crucial. Moreover, minimizing the vertical handoff delay is an important factor to avoid packet loss and degradation of services during UWoff.

2.1 Heterogeneity

Heterogeneous Networks will be based on a federation of multiple networks of different operators and technologies. On one hands, this leads to increased affordability of ubiquitous communication, as the user has full freedom to select technology and service offering and the investment needs for new networks are reduced.
On the other hand, networks will have to integrate the capabilities of different technologies to an end-to-end, seamless and secure solution for the user. Ambient Networks take a new approach to embrace heterogeneity visible on different levels, such as link technologies, IP versions, media formats and user contexts [4]. Diversity of access links, especially of links provided by mobile networks, is supported by a generic link layer concept, which will efficiently enable the use of multiple existing and new air interfaces. Heterogeneous Networks also consider the implications of heterogeneous wireless systems on the overall network, especially the impact on end-to-end QoS and multimedia delivery. In particular, the novel concept of network composition will include the negotiation between different networks regarding their capabilities, e.g. regarding quality of service.

2.2 Mobility Management

Mobility can be divided into several kinds of mobility, depending on the actor of movement. Movement can be:

- Personal – A person moves from one network-connected device to another,
- Node – A node (i.e. mobile terminal) changes its point of attachment to the network. Network mobility is a special case of node mobility,
- Application – A networking application is migrated from one network-connected device to another network-connected device,
- Session – This related to Application mobility. A networking session is moved from one networking device to another or
- Service – Services that are available for a subscriber at one network location are made available at the new location where this subscriber moves.
- In this paper the Node mobility is used to study the vertical Handover UWoff between UMTS and WLAN.

2.3 Vertical Handover

The vertical handoff [5] process involves three stages. The first is the network discovery. In this phase, Mobile Nodes (MN) periodically searches if there are some other different types of wireless networks and take these discovered networks as candidates. The second is the handoff decision phase where MNs compare the state of the current network with candidates, and select one as the handoff target from them according to a certain criterion. The last is the handoff implementation phase where MNs execute the handoff actions and associate with the newly authenticated network.

3. UMTS IN NS2

UMTS is a 3G mobile communication system where the radio interface is based on Wideband Code Division Multiple Access (WCDMA). Radio frequencies allocated for UMTS are 1900-2025 MHz and 2110-2200 MHz [10].
UMTS is among the first 3G mobile systems which offer wireless wideband multimedia communications over the Internet Protocol (IP) and as such, it allows mobile Internet users to access a variety of multimedia contents available on the Internet in a seamless fashion at data rates up to 2 Mbps indoor and 384 Kbps outdoor.

- Radio Propagation Models Implemented in Ns2:

The radio propagation models implemented in ns are used to predict the received signal power of each packet. At the physical layer of each wireless node, there is a receiving threshold. When a packet is received, if its signal power is below the receiving threshold, it is marked as error and dropped by the MAC layer. Up to now there are three propagation models in NS2, which are the free space model1, two-ray ground reflection model and the shadowing model.

- Free space model: The free space propagation model assumes the ideal propagation condition that there is only one clear line-of-sight path between the transmitter and receiver. H. T. Fries presented the following equation to calculate the received signal power in free space at distance from the transmitter.

$$P_r(d) = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} \quad (1)$$

Where Pt is the transmitted signal power, Gt and Gr are the antenna gains of the transmitter and the receiver respectively. L is the system loss, and lambda is the wavelength the free space model basically represents the communication range as a circle around the transmitter. If a receiver is within the circle, it receives all packets. Otherwise, it loses all packets.

- Two-Ray Ground reflection model: A single line-of-sight path between two mobile nodes is seldom the only means of propagation. The two ray ground reflection model considers both the direct path and a ground reflection path. It is shown that this model gives more accurate prediction at a long distance than the free space model. The received power at distance is predicted by

$$P_r(d) = \frac{P_t G_t G_r {h_t}^2 {h_r}^2}{d^4 L} \quad (2)$$

Where Pt is the transmitted signal power, Gt and Gr are the antenna gains of the transmitter and the receiver respectively. L is the system loss and ht and hr are the heights of the transmitter and receiver antennas respectively.
The equation shows a faster power decrease with an increase in distance. However, the two-ray model does not give a good result for a short distance due to the oscillation caused by the constructive and destructive combination of the two rays. Instead, the free space model is still used.

- Shadowing model: The free space model and the two-ray model predict the received power as a deterministic function of distance. They both represent the communication range as an ideal circle. In reality, the received power at certain distance is a random variable due to multi path propagation effects, which is also known as fading effects. In fact, the above two models predicts the mean received power at distance. A more general and widely-used model is called the shadowing model.

4. SIMULATION

NS2 is a simulation tool for data networks. It is built around a programming language called [3]Tcl which is an extension. From the perspective of the user, the implementation of this simulator is via a Programming step that describes the network topology and the behavior of its components, and then comes the stage of simulation itself, and finally the interpretation of the results. This last step can be supported by a tool appendix called Nam that allows visualization and analysis of the simulated elements.

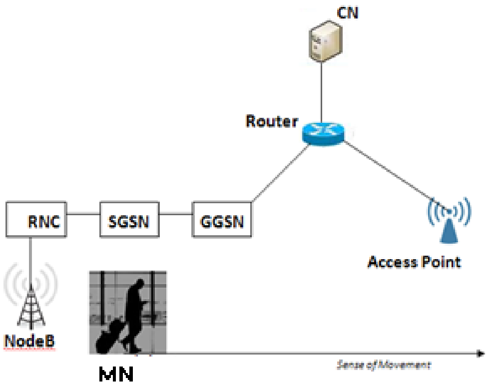

Fig. 1: Scenario Topology

Topology and Scenario

We suppose that the MN is located within the reach of UMTS network, knowing that the Node B is 500 m distant from the 802.11 access point. The rays of UMTS and WLAN cells are respectively 500 m and 250 m. We analyze the performance of vertical handover by the user that moves with an average speed of 40 km / h from the UMTS network to the WLAN, in terms of bandwidth, Packet loss, transmission delay (time of arrival of packets) and handover latency, knowing that the type of traffic used is VoIP whose characteristics are shown in the Table 2. Fig.1 illustrates the simplified diagram of the simulation topology.

The work is divided into three phases: pre-simulation, simulation and post simulation:

- Pre-Simulation: This first phase consists in setup and configures the simulation network parameters such as the global simulation parameters, Mobile node and UMTS parameters and finally parameters for real time application such as VOIP.
- Simulation: This phase involves the execution of the main program for example: handover.tcl and from the files defined in the pre-simulation phase.
- Post simulation: This step is to filter trace files to extract the results of the simulation.

Handover.tcl code to generate in addition to the main file trace.tr, three log files on which we will build later to analyze the performance of UMTS-WLAN Vertical Handover.

[3] Tool Command Language

The project does not focus on ad hoc networks, so the use of a tracking algorithm support in infrastructure mode is required, hence the necessity to use the protocol NOAH: NO Ad-Hoc Routing Agent (NOAH) is a wireless routing agent that (in contrast to [4]DSDV, [5]DSR,) only supports direct communication between wireless nodes or between base stations and mobile nodes in case Mobile IP is used. This allows simulating scenarios where multi-hop wireless routing is undesired. NOAH does not send any routing related packets.

In Fig.1 a multi-mode interface supporting UMTS and WLAN (802.11a/b/g) for a user (MN) must be equipped with a dual-mode terminal filling both the [6]UE function with a [7]USIM card and the function of [8]STA equipped with a wireless card 802.11, and this, to establish a connection with the CN (Correspondent Node is the VOIP server). Tight coupling configuration is used to integrate the 802.11a/b/g networks at the same level as the UMTS's [9]GGSN. A router interconnects UMTS's GGSN to WALN's access point (802.11a/b/g). Because the simulated results reveal that the GGSN-WLAN integration performance is better than the [10]SGSN-WLAN integration for all the applied applications and measurement parameters.

Network Parameters

Table 1: Mobile Terminal Parameters

Mobile terminal Parameters	Pt_(MN)	Pr_ (MN)	P_idle (MN)	Wired Routing
Assigned values	0.20 W	0.125 W	0.005 W	OFF

Table 2: VOIP Parameters

Codec VoIP	VoIP packet size	Inter-packets Interval
G.711	160 Bytes	20 ms

5. SIMULATION RESULTS AND DISCUSSIONS

This section of the paper consists of simulating the vertical Handover between the two heterogeneous wireless networks UMTS / WLAN, by adopting the model of the city as a model of mobility in an urban area.

This model consists of a highway system and a set of cells.

• The diameter of a cell varies between a few hundred meters to several kilometers.

4 Destination-Sequenced Distance Vector
5 Dynamic Source Routing

6 Mobile Equipment
7 UMTS Subscriber Identity Module
8 Station
9 Gateway GPRS Support Node
10 Serving GPRS Support Node

Performance Vertical Handover UMTS-WLAN will be analyzed in terms of three key points:
• The end to end consumed bandwidth by the mobile terminal
• the rate of packet loss during the handoff
• the transmission delay of the packets during the handoff

5. 1 Bandwidth

We simulated the bandwidth received by a single mobile terminal, which moves with an average speed of 40 km / h from the UMTS network to the 802.11 network.

Fig.3 shows the evolution of the throughput offered by UMTS and 802.11a/b/g as function of time during the UWoff for a single device and without implementing the Quality of services. The Throughput offered by the UMTS network for a single user using VOIP traffic with an average of 1.7 Mbps is also shown in the Figure3. On the other Hand the Throughput offered by 802.11a network can go up to 5.4 Mbps, but makes a drop for a few seconds. These drops are due to the mobility of the user which performs the Doppler Effect in the frequency domain and the spread of the delay in the time domain, thus affecting the quality of the received signal by the terminal.

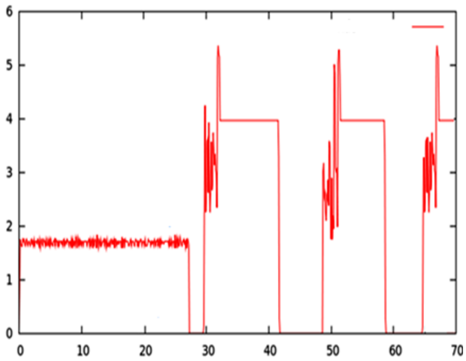

Fig 2: Pre-Simulation Throughputs

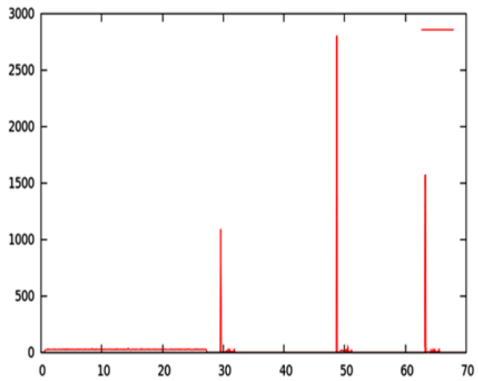

Fig 3: Packet Loss before Optimization

Within the 802.11b coverage, the average level of packet loss is 26 packets; given that the number of packets generated is 9973 which gives a loss rate of 0.26% also meet the constraint of VoIP loss rate.

Besides the records of received throughput from different WLANs networks we also trace the evolution of packet loss and the transmission delay both as a function of time during the UWoff.

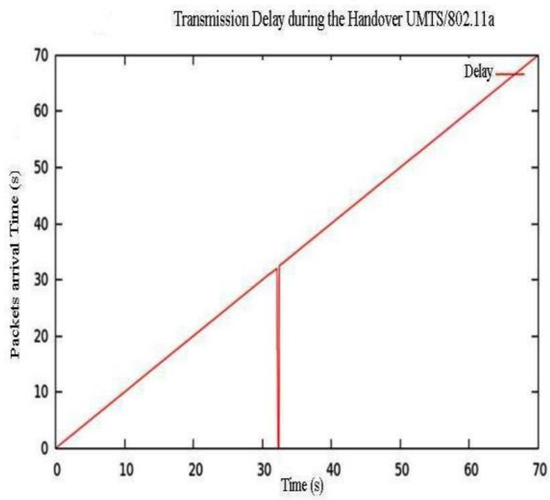

Fig 4: Transmission Delay

We can observe in Figure 5 that the transmission delay is proportional to the period of the simulation, but drops very fast to zero during interval of time when the user execute the Handover UWoff. This is because the mobile terminal receives more packets from the old base station (Node B) during this period by establishing a new connection to the Access Point 802.11b.

It can be observed in Fig.2 that the Handover latency of the UWoff takes a period of 1866 ms, which can be restrictive for VoIP traffic as this duration exceeds the acceptable value within 150 ms for VoIP traffic.

The result demonstrates that we must improve the performance in order to guaranty for the VOIP user better quality of services to establish a better call session with the VOIP server and without interruptions.

5.2 Threshold based Optimization

Based on the threshold values (Table 3) we could define the exact time of the UWoff. On the other hand the performance requirement for the VOIP mobile user is reached and we can see in Fig.5 that the Throughput received by the MN is stable in both cases:

- When the mobile connects to UMTS network
- When the mobile gain respectively access to the different 802.11a/b/g networks.

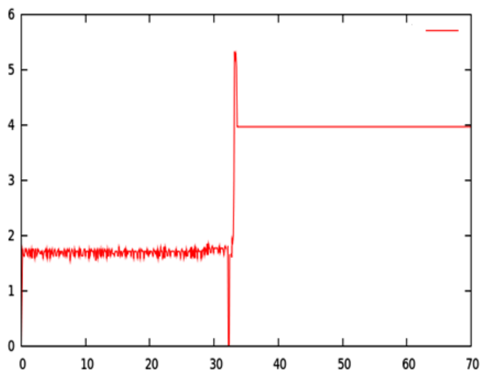

Fig 5: Throughputs after First optimization

Table 3: Adjusted Parameters

Parameters	RXThresh (UMTS)	CSThresh (UMTS)	CSThresh (802.11a)	RXThresh (UMTS)
Old values	1e-16 W	4e-18 W	2.31e-12 W	1e-16 W
New values	1e-16W	4e-18W	0.31e-12W	1e-16W

Table 4: Comparison of Handover Latencies

Vertical Handover	UMTS-802.11a	UMTS--802.11b	UMTS-802.11g
Hanover Latency before Optimization	1860 ms	1428 ms	620 ms
Hanover Latency after Optimization	76 ms	58 ms	86 ms

5.3 Method and Quality of services

After applying the quality of service we can make the following remarks:

Decrease in packet loss, especially during the handover latency and it remains relatively insignificant elsewhere. The new values of packet loss rates:

- The loss rate is within the reach of UMTS: 0102%
- The loss rate during the handover latency is: 2.57%
- The loss rate is within the reach of 802.11b: 0067%

5.4 Change the queuing Algorithm to [11]SFQ instead of [12]Drop Tail:

From Fig. 7b can be observed that after applying the Quality of services, the VoIP dual-mode equipment effectively switch from UMTS original access network to the 802.11b WLAN visiting network, but this time the handover execution occurs at 30.1(from previous scenarios predefined execution time) in instead of 32.6 seconds. It means that the mobile has become more sensitive to the detection of the carrier in the coverage of transmission delay for a Bi-mode mobile user that runs real time Application such as VOIP. Such solution is adequate for environment, where WLAN network extends the radio network coverage of UMTS, for example in case of ISPs, where it is very difficult to deploy UMTS network everywhere, or where the cost of the deployment of UMTS network is expensive.

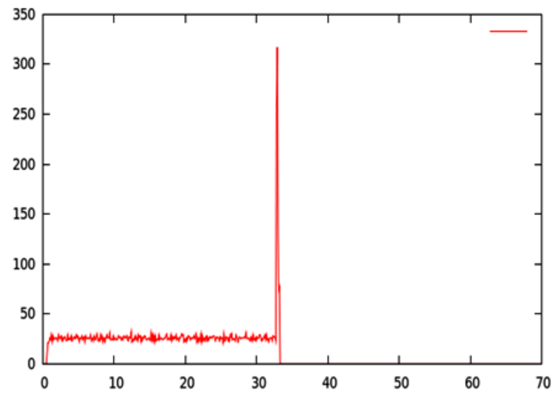

Fig 6: Packet Loss after second optimization

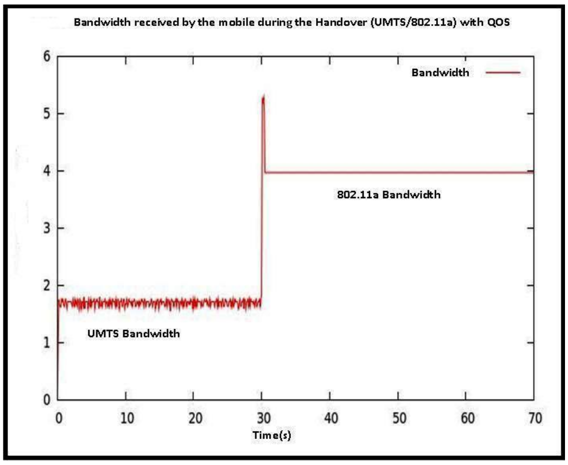

Fig 7: Throughput received form the mobile terminal

In Fig.7 can be observed that the handover did not result in any throughput interruption and almost all sent packets were delivered.

Table 5: Adjusted Parameters

Parameters	RXThresh (UMTS)	CSThresh (UMTS)	RXThresh (WLAN)	CSThresh(WLAN)	1CWmin(Old value 31)	1CWmax(Old value 1023)
Assigned Values	0.9e-16 W	3.9e-18 W	3.30e-10W	1.20e-11W	2	15

[11] Stochastic Fairness Queuing
[12] simple queue management algorithm

It can also observed in Fig.6 that the Handover latency of the UWoff is 76 ms, presenting a value significantly lower than (1866 ms) that previously found in Fig.5.

802.11a network offer a stable throughput during the simulation time that can reach a value up to 5.4 Mbps. A summarization of the handover latency values is presented in Table 5.

The delay is canceled after the execution of handover for very short periods, but this time is due as we previously mentioned to the presence of the Doppler Effect caused by user mobility.

In Fig. 6 the packet loss is higher during the handover latency; this is due to the rupture of connection between CN and MN during this particular period in which the terminal registers a new address (care-of-address) via Mobile IP, when changing the location from the home network (UMTS) to the foreign network 802.11b.

Within the UMTS coverage, the packet loss is lower and the average value of 27 packets loss and knowing that the total number of packets generated in this range is 15,911 packets, resulting in a loss rate of less than 1%, namely 0169 %, responding to the VoIP QoS constraint in terms of packet loss rates.

Impact mobile speed on the performance

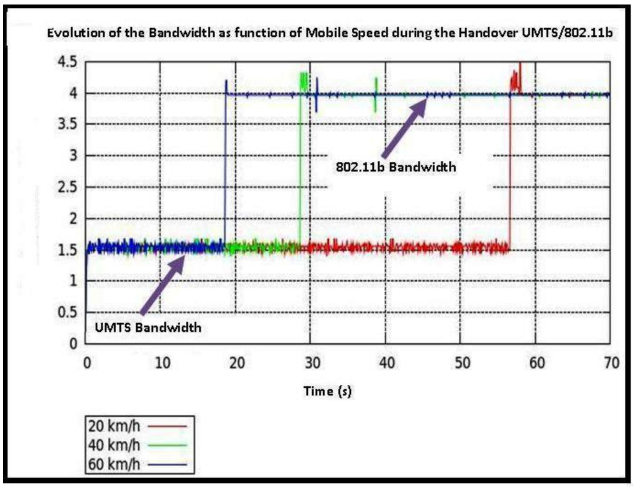

Figure 8: Mobile Throughput by different speed

Table 6: Hanover Execution Moment vs. Mobile Speed

Speed of the Mobile	The Moment of Handover execution
20 km/h	56,7 s
40 km/h	28,7 s
60 km/h	18,6 s

Note well that if we increase the speed of the mobile terminal, it happens, that the mobile quickly attach to the Wireless network 802.11b, considered the best signal quality (rate) than the UMTS network. This means that the Handover between the two heterogeneous technologies happens earlier, if the mobile increase his speed moving from UMTS network toward to the WLAN network (Figure 8.).

There is no influent of the mobile speed on the result; the optimization parameters are also valid for different speed of the mobile Terminal.

5.5 Analysis of Performance after increase in number of mobile terminals

Once the latency of the vertical Handover for the mobile Terminal is optimized, in the following sections we will increase the number of mobiles in four scenarios:

Scenario 1	5 Mobile Nodes using VoIP
Scenario 2	10 Mobile Nodes using VoIP
Scenario 3	15 Mobile Nodes using VoIP
Scenario 4	20 Mobile Nodes using VoIP

Scenario 1: In UMTS coverage, MN1 which is close to NodeB, has the largest amount of bandwidth (0.68 Mbps), the MN5 is first one that execute the Vertical Handover. MN 1, that is far away form the AP 802 .11b, executes at least the UWoff.

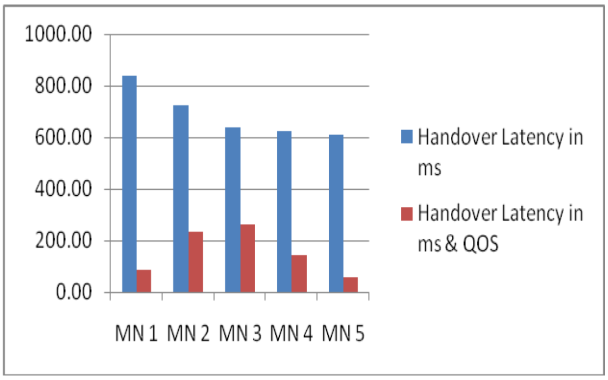

Fig 9: handover Latencies Scenario 1

Packet loss rate is higher during the latency of the Handover and it reaches the maximum in case of the MN1, which execute the Handover at least

Scenario 2: Figure 10, you see, that increases the number of mobile devices, the number of packet losses also increase, but this number is higher during vertical Handover latency, as can be seen in the green curve in Figure 11.

Figure 10 confirms affirmations of scenario 1, namely whether the mobiles terminals pass through the heterogeneous network UMTS /WLAN, the number of packet losses is low respectively in the coverage of UMTS and WLAN, but in the overlapping area, where vertical Handover occurs, the percentage of packet loss is greater, in particular, if the number of mobile devices increases. Comparing scenario 1 with scenario 2, the maximum packet loss rate is 25% of scenario 2, which is higher than 9% in scenario 1.

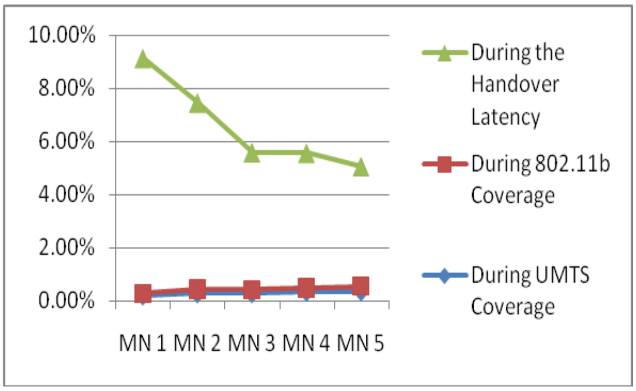

Fig 10 packet loss rate during Handover latency Scenario 1

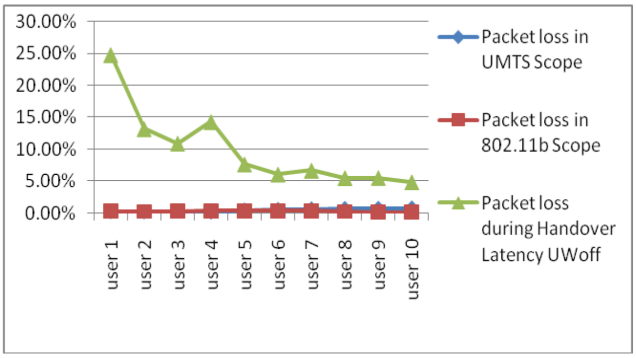

Fig 11: packet loss rate during Handover latency Scenario 2

Scenario 3: The scenario parameters optimization and application of service quality have given good results in terms of Handover latency, the throughput and packet loss. Even if the results are not better that those where the number of devices was small. From 15 mobile users, there are stations that do not have sufficient performance to communicate with the VOIP server, because the UMTS network share the available bandwidth on the number of participating nodes in the network, in addition to that the Near-Far Effect prevent NodeB to listen to distant stations.

Figure 12 shows that the packet loss rate for terminal MN3 reached the maximum of 33.8%, which means that, if we increase the number of mobile devices, the packet loss rate and bandwidth will receive unacceptable values. Thing that needs to be corrected by the deployment of more access points in the network, in order to serve all mobile devices and to improve the performance of the heterogeneous UMTS-WLAN wireless network.

Scenario 4: after increasing the number of Mobile users running VoIP at 20, the end-to-end throughput received by all users is not stable and there is very poor performance that can be explained by the Near-Far Effect, which is caused by interference between mobile nodes within CDMA system. This phenomenon is generally solved by dynamic adjustment of power of the transmitters, but it is not our purpose at the moment, but our research axis, is to focus on solution to reduce the vertical Handover latency.

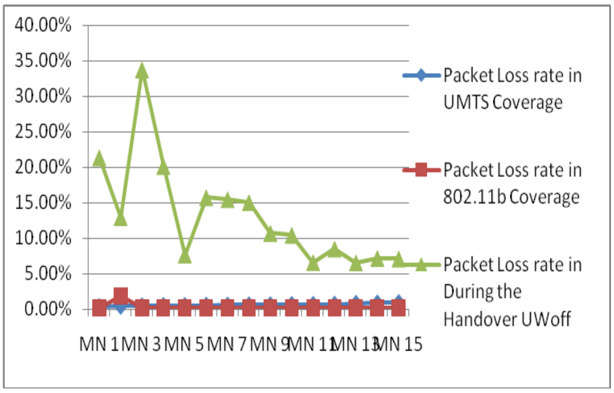

Fig 12: packet loss rate during Handover latency Scenario 3

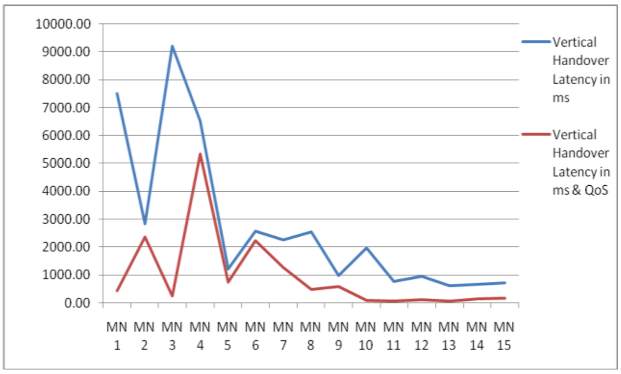

Fig 13: Comparison of Handover Latencies scenario 3

There is also a reduction of the transmission delay of the terminal MN 15, especially during the UWoff latency. In the UMTS coverage, the MN14 receives only about 60 kb of bandwidth, which is less than the bandwidth required by a VoIP application using the codec G.711 (64 KB). It should be noted also that if we apply the quality of service, the MN 8 terminal is served by the UMTS network since the received bandwidth reaches values of 0.08 Mbps, while the number of VoIP MN 8 can communicate with the server.

This article was developed to define software architecture capable of supporting the vertical Handover between WLAN and UMTS networks. We therefore identified challenges technology between the two network technologies and put in value the role of Mobile IP in the execution of the process of the Handover when mobility of a dual-mode mobile terminal between heterogeneous networks UMTS and WLAN is required.

In addition to the technological challenges, added to practical challenges related to the software Simulator NS - 2 for modeling of the scenario of Handover between UMTS and WLAN networks for the implementation of the NOAH routing protocol that was developed for the infrastructure mode support. Consecutively to the analysis of these practical challenges, a model of development was proposed in order to simulate a scenario that supports different types of applications between a UMTS NodeB and an access point for different 802.11 standards, as well as deal with the impact of the steady increase in the number of mobile on the performance of Handover UWoff (UMTS/802.11b). Finally, the vertical Handover scenario simulation issues related to the time of switching between UMTS and WLAN (says the Handover latency) networks as well as the packet loss rate during the UWoff (Handover UMTS toward WLAN). On the other hand, vertical Handover scenario of between UMTS and WLAN networks modeled highlights the QoS requirements more or less acceptable in terms of packet loss and transmission delay for real-time such as VoIP applications.

6. CONCLUSION

The results of the simulated scenarios indicate that the proposed method was efficient to optimize the vertical Handover latency, for a mobile user running the real time application, voice over IP, between UMTS and WLAN networks. According to previous researches, this value is a hundred milliseconds; our approach has proved a value of 58 milliseconds. The performance of the heterogeneous networks could only be optimal, if the number of active users, who are sharing the bandwidth within a radio cell of a UMTS antenna; is limited.

As perspective we suggested other aspect that can affect the latency of the vertical Handover latency between heterogeneous wireless such as security and signaling aspects.

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