Integration of Protocols FHMIPv6/MPLS in Hybrid Networks

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Abstract— **Currently, we are working on the integration of the FHMIPv6/MPLS protocol to provide QoS in hybrids scenarios the quality of service values were obtained when a handover occurred and the results were satisfactory. In general terms, we can affirm that during a handover, not only metrics such as delay jitter and throughput improved but also the default quality level was maintained in the integrations performed. The results obtained allowed us to identify which integration protocols were the most suitable to ensure QoS in all IPv6/MPLS network. An architectures for new generation hybrid networks is proposal, In general, the coupling between the quality of service and mobility protocols mentioned before is an excellent option to provide QoS in wireless mobile networks and, especially, in the hybrids mobile networks.**

On the other hand, we can say that, although there is no defined standard for next generation networks (4G), an all FHMIPv6/MPLS architecture will be critical in new generation wireless mobile networks, compatible with the standards proposed so far (WIMAX, advanced LTE/SAE, LTE/IMT, WiMax/IMT). The traffic used in the simulation was cbr and ftp. The simulation with ftp traffic is used in natural disaster. The tools simulation was NS-2 ver. 2.34.

Index Terms*—*FHMIPv6, Hybrid Networks, MPL, QoS.

I. INTRODUCTION

LTE/SAE consists of, the current requirement that has to be met to become the 4G standard and the most relevant concepts related to MPLS. Let's look now into the importance of supporting the LTE/SAE core with IP/MPLS[19].

The use of MPLS on LTE allows to reuse much of 2G and 3G technologies, which means a low cost per bit. In addition, MPLS can handle the IP requirements for the wide range of services it supports. Also, MPLS supports any topology, including star, tree and mesh. On the other hand, IPv6/MPLS can give IP the advanced traffic engineering, ensuring that traffic is properly prioritized according to its characteristics (voice, data, video, etc.) and the routes through the network are set up to prevent link failures. The use of differentiated services is also an important feature of MPLS, since Forwarding Equivalent Class (FEC) can perform different treatments to the services provided by IP, including an eventual integration with Diffserv contributing to provide a better Quality of Service (QoS).

In addition, because MPLS creates virtual circuits before starting the data transmission and uses special labeling, it is possible to deliver a better level of security when packets experience higher rates of transmission and processing, since the forwarding is performed according to the label without routing algorithms. This is another important aspect of IPv6/MPLS[1] in order to meet the requirements related to the throughput. Finally, MPLS promotes the simplification of the integration architecture of IP and ATM and improves the QoS experience of the users providing redundant paths to different FECs to prevent packet loss.

Currently, the 3rd Generation Partnership Project forum (3GPP) is working to complete the standard that aims to ensure the competitiveness of UMTS in the future. As a result of this work, in 2004 the Long Term Evolution project (LTE) arises, which is expected to become the 4G standard. We can find the requirements for 4G standardization in recent works like "Release 10" and "Advanced LTE" [12][14]

On the other hand, the System Architecture Evolution (SAE) is a project that seeks to define a new core component of the All-IP network called Evolved Packet Core (EPC) [3]. We can consider IPv6/MPLS and extension FHMIPv6/MPLS as part of the development of the LTE standard included in the All-IP concept that allows us to meet some requirements of LTE[6], such as end-to-end quality of service (MPLS, Diffserv, and IntServ). SAE allows interoperability with existing technologies in both the core and access networks. [15].

Due to the increasing demand of QoS by the users, it is necessary to adopt mechanisms to ensure the requirements of LTE/SAE. As it is well known, an All-IP network provides the so-called Best effort quality of service. For this reason, in order to provide QoS to the LTE/SAE network's core and to the access networks, we propose the implementation of FHMIPv6/MPLS into the Evolved Packet Core (EPC) [15]

This paper proposal the integration of the hybrids networks in order to provide QoS in new generation networks. Is proposal could be adequate for applications: military, vanet, rescue and emergency, TV-IP and commercial scenarios.

In order to achieve the integration of FHMIPVv6 and MPLS on NS-2, we proceeded as follows:

Changes in MNSv2.1 were required to make it work on NS2.32, which is the version of the simulator used in this work. The MPLS module employs RSVP-TE as the label distribution protocol since in 2003, the IETF abandoned the development of CR-LDP that used to be the protocol used in

MNSv2. In addition, we use MNSv2.1 to define MPLS nodes that support hierarchical addresses, which is totally necessary to run FHMIPv6 with MPLS that it was not previously integrated into MNSv2 and was limiting the integration between MIPv6 and MPLS.

FHMIPv6 patch for MS 2.31 was installed. He had based his patch on the previous one created by Robert Hsieh for NS 2.1b7a. NOAH is also integrated into the patch to make FHMIPv6 work with no errors. This patch was gently installed for the 2.31 version after checking that the changes included in the NS 2.32 version had affected neither FHMIPv6 nor NOAH in this version.

The paper is organized as follow:

I the introduction, II Background, III Simulation scenario with CBR, IV Analysis of metrics, V FHMIPv6/MPLS integration used in natural disaster operation, VI Simulation scenario with FTP traffic, VII Simulation Analysis, VIII FHMIPv6/MPLS vs HMIPv6/MPLS integration, IX conclusions and finally references.

II. Background

A. FHMIPv6

Fast Handover for Mobile IPv6 (FMIP) is a Mobile IP extension that allows the MN to set up a new CoA before a change of network happens. This is possible because it anticipates the change of the router of access when an imminent change of point of access is detected. This anticipation is important because it minimizes the latency during the handover, when the MN is not able to receive packets.

F-HMIPv6 was initially proposed by Robert Hsieh [20] as a way of integrating Fast handover and HMIPv6 and shows why this integration is a better option than HMIPv6 solely.

B. MPLS

An important feature of MPLS is that it provides a good balance between connection-oriented technologies to improve non IP connection-oriented mechanisms (they can only give a Best effort level of service). On the other hand, MPLS adds labels to the packets, so no routing is based on layer 3 addresses but in label switching. This allows interoperability between IP and ATM networks. It also increases the speed of the packets traversing the network because they do not run complex routing algorithms at every hop; they are forwarded considering the packet's label only. This labeling system is also very useful to classify the incoming traffic according to its higher or lower QoS requirements contracted or required.[2].

Also, since MPLS is a standard solution, it reduces the operational complexity between IP networks and gives IP advanced routing capabilities in order to use traffic engineering techniques that were only possible on ATM [21].

III. Simulation Scenario

The scenario simulated is shown in (figure 1); the MN is in the area of HA. Bandwidth configuration and delay of each link are shown below in table. The traffic used in it scenario is CBR.

TABLE I
CONFIGURATION OF THE SCENARIO

Link	Delay	Bandwidth
CN-LSR1	2ms	100Mb
LSR1-HA	2ms	100Mb
LSR1-MAP	50ms	100Mb
MAP-LSR2	2ms	10Mb
MAP-LSR3	2ms	10Mb
LSR2-PAR	2ms	1Mb
LSR3-NAR	2ms	1Mb

The traffic used was CBR since it allows to simulate audio and video in real time. These Applications have a high demand of QoS.

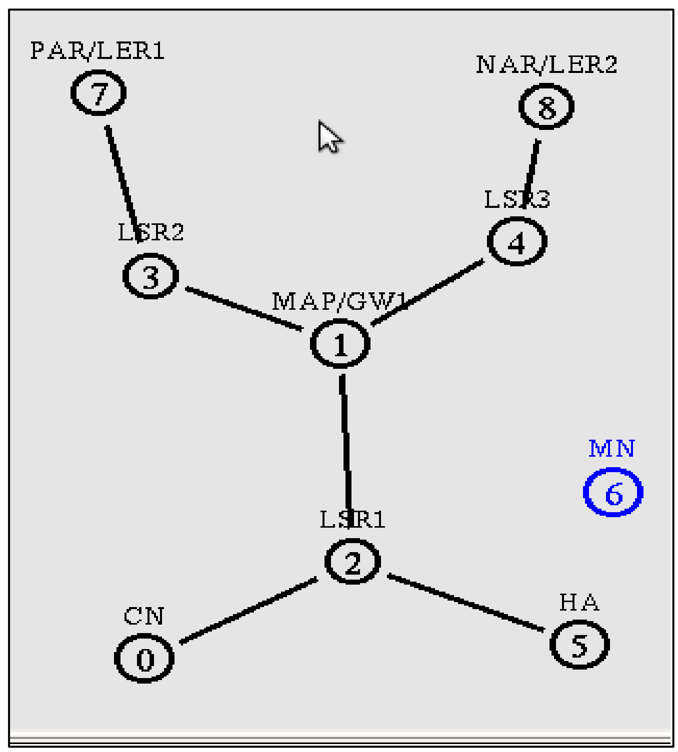

Fig 1. Scenario of simulation Fhmipv6/mpls

A few seconds later, the MN moves towards the area of PAR, as (figure 2) illustrates.

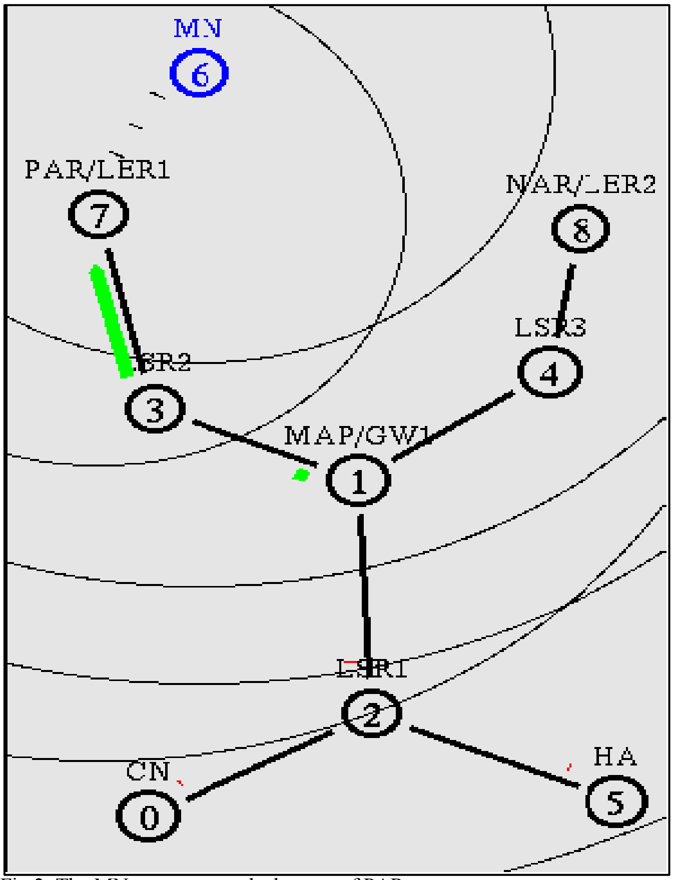

Fig 2. The MN moves towards the area of PAR

Finally, the MN moves to the area of NAR (figure 3):

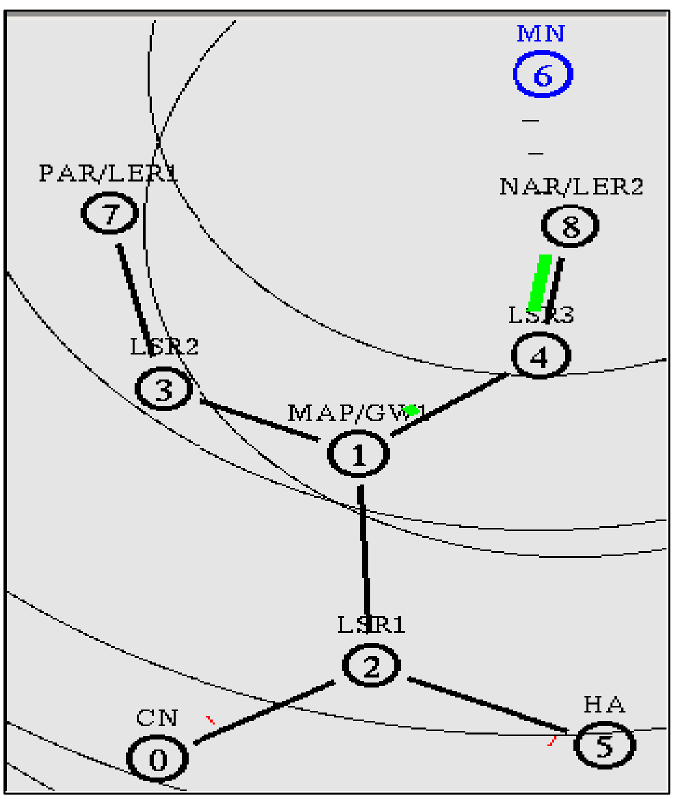

Fig 3. The MN moves to the area of NAR.

SCENARIO DESCRIPTION

Initially, the MN is located in the area of the HA. 2 seconds after the start of the simulation, the HA moves towards the area of the PAR at 100m/s, arriving at t=3.5s approximately. At t=5s, the CN begins sending CBR traffic to the MN following the route CN→LSR1→HA→LSR1→MAP→LSR2→PARMN as shown in (figure 3). Then, at t=10s, the MN starts moving to the area of the NAR at 10m/s. At the same time, the handover takes places at around t=13.12s and the MN receives one of the first packets from the NAR at t=13.14s approximately. Afterwards, the MN places in the area of the NAR at around t=17s. Finally, at t=19s, the CN stops sending traffic flow towards the MN.

IV. ANALYSIS OF QoS METRICS

The results of the integration of FHMIPv6/MPLS with CBR traffic were excellent (see figures 4,5 and 6). We present the details in the following paragraphs.

Delay analysis

The average delay of the simulation was 67.1302ms, which is good because it is only 17.1302ms above minimum delay of 50ms induced by the LSR1-MAP link. In most of the simulation the delay was between 65ms and 72ms, with a peak of about 80ms in the handover. (figure 4) Illustrates this:

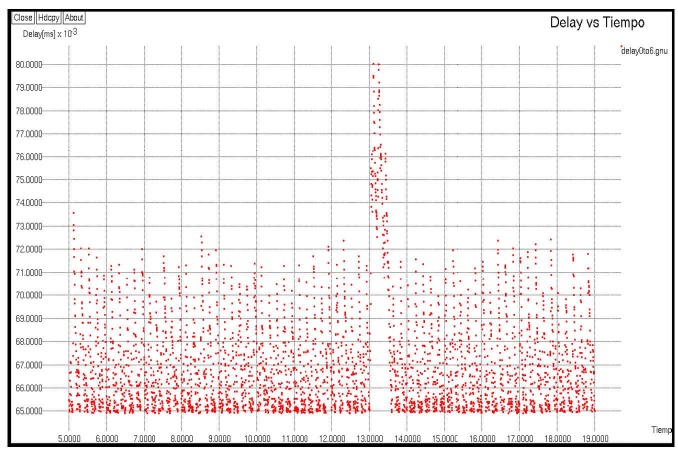

Fig 4. Delay vs time.

Jitter analysis

The behavior of the jitter was excellent, as in most of the simulation it was below 1ms and showed an average of 0.621941ms with only a few peaks that did not exceed 1.7ms. Furthermore, this metric was not affected by the handover. (figure 5) shows the results.

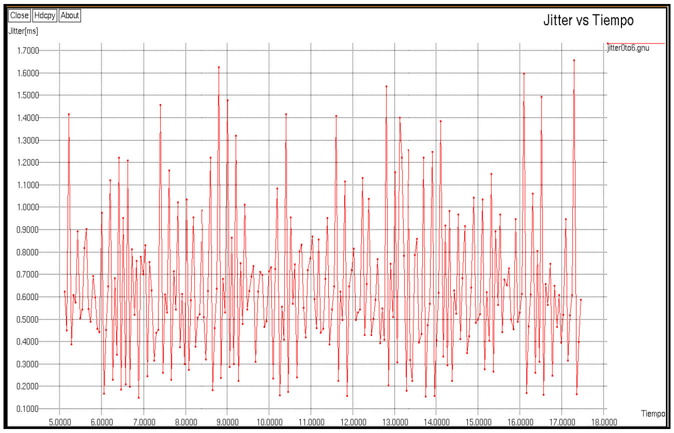

Fig 5. Jitter vs time.

Throughput analysis

The upper limit of the throughput in the simulation was 1MB, corresponding to the slower LSR2-PAR and LSR3-NAR links. Nevertheless, in most of the simulation this metric was close to 500Kbps of performance, which is positive considering the huge amount of traffic during the simulation. The average throughput was 446,049Kbps. (Figure 6) illustrates this result.

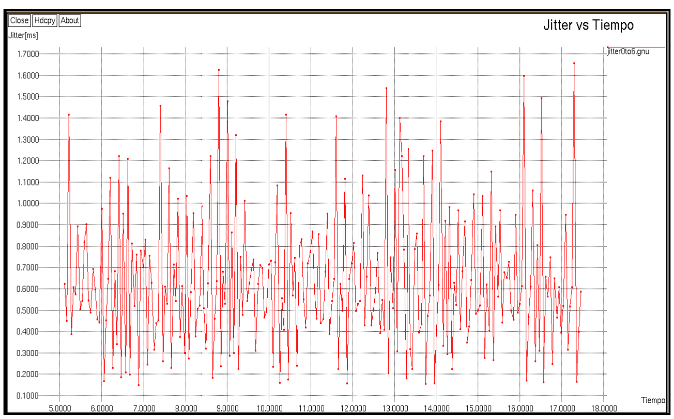

Fig 6. Jitter vs time (throughput)-

V. FHMIPv6/MPLS PROTOCOL USED IN NATURAL DISASTER OPERATION

The aim is to determine if the FHMIPv6/MPLS protocols deliver QoS in mobile sensor networks integration. These simulations are part of a future application that is being developed for hybrid networks using the FHMIPv6/MPLS protocol in rescue and natural disasters operations, which involve different emergency groups we will call communities. In order to establish a correspondence with the terms used in e-learning, this simulation only shows the integration of FHMIPv6/MPLS. The detailed explanation of these simulations in emergency or rescue situations is currently underway.

VI. SIMULATION SCENARIO

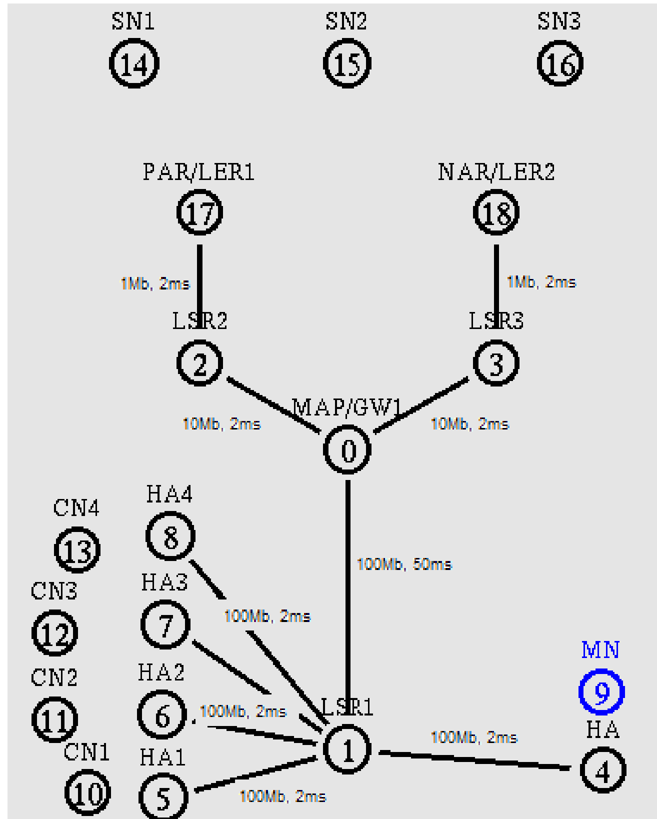

Fig 7. Scenario of simulation Fhmipv6/mpls

The simulation scenario is shown in (figure 7). It consists of an infrastructured network that connects two ad-hoc networks. At the core of the wired network FHMIPv6/MPLS protocols are used to provide QoS to packets that traverse it. The delay and the bandwidth of each link are displayed in the same figure.

The network at the top of figure 7 (formed by SN1, SN2 and SN3 nodes) consists of 3 sensors representing seismic measuring devises that send their measurements to the lower level ad-hoc network through the MN. The lower level ad-hoc network is made up of 4 communities (each node represents a community and the MN represents a community proper) as follows:

- CN1 →Ambulance
- CN2 →Fire brigade
- CN3 →Police
- CN4 →Army
- MN →Mobile community that learns as it moves around the sensors.

HA1, HA2, HA3 and HA4 nodes are the Home Agents of the CN1, CN2, CN3 and CN4 communities respectively. This means that if the MN sends a packet to the community X from the area of sensor 1 (SN1), it should follow the path MN→PAR→LSR2→MAP→LSR1→HAx→CNx, but it is not necessary that the indicator of the community matches the Home Agent because the parameter taken into account is the distance (the shortest distance). So, the community X can receive its packets from the Home Agent Z as long as it is located closer than the Home Agent X.

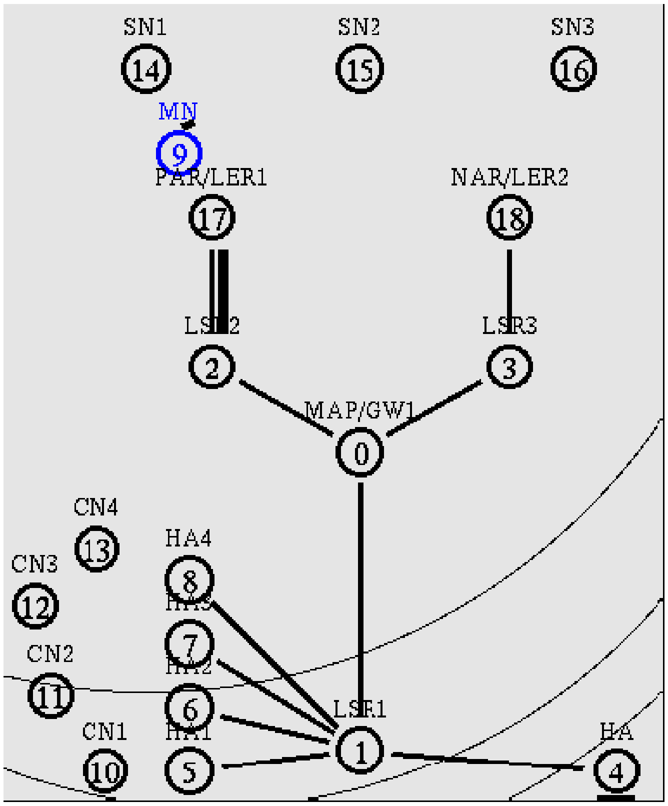

Fig 8. The MN begins moving towards the area of APAR

Subsequently, at t=7s, the MN begins moving towards the area of sensor 3 (SN3) at 10m/s, arriving at t=13s approximately, when SN3 starts sending its data to the MN. The figure below shows the moment when the MN has stopped in the area of the sensor 3:

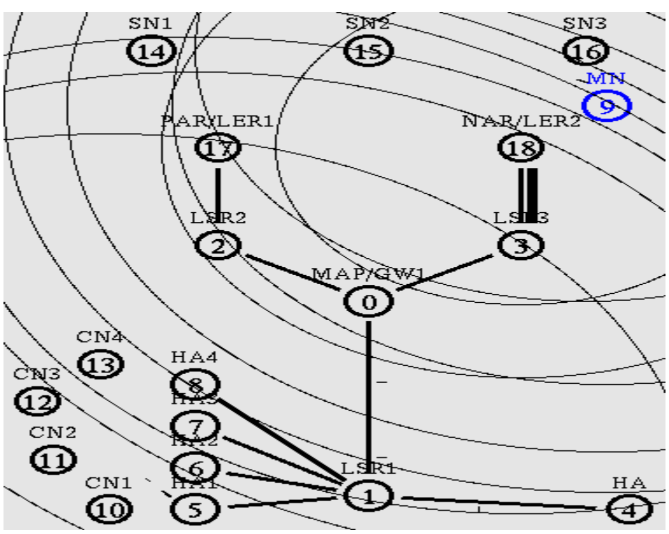

Fig 9.The MN begins moving towards the area of SN3

It is important to point out that the sensors do not detect the proximity of MN, but have been synchronized so that they behave exactly as if they did. On the other hand, while the MN moves from the PAR to the NAR, a handover occurs. Its impact on QoS metrics will be analysed later.

Finally, we should clarify that the flow of packets traversing the network are as follows: The MN sends different FTP traffic to each community. There are four TP streams from the MN traversing the FHMIPv6/MPLS network constantly. There are also two FTP flows which correspond to those generated by the SN1 and SN3 sensors respectively that reach the MN which, in turn, learns from them and informs about the different situations to the community particularly concerned.

VII. SIMULATION ANALYSIS

QoS metrics analysis

In the following sections, different QoS metrics of the scenario described above will be briefly analysed. Each metric is studied from the perspective of the MN and will take into account the four flows towards the different communities.

Delay analysis

Delay analysis of each of the four flows originated in the MN which destination is the aforementioned communities. Thereafter, the image that appears after the subtitle represents the delay in function of time.

MN→CN1 delay (Ambulance)

The average traffic delay between the MN and the ambulance community is 373.847ms. As shown in the figure below, the moment of greatest delay (about 1s) is between the 6s and 7s after the start of simulation. Note that the four FTP flows follow the common path MN→(LSR2 or LSR3)→(PAR or NAR)→MAP→LSR1, resulting in network overload. The smallest delay is about 75ms around 5s after the start of simulation and the MAP→LSR1 link has a delay of 50ms.

Additionally, we have to underline that the handover does not affect the delay because the traffic comes out of the MN, which stops sending traffic when the handover is being completed. However, metrics such as throughput and the amount of lost packets are affected by this circumstance. Henceforth, no comment on details of this metric will be mentioned since they perform similarly in most of the flows.

MN→CN2 delay (Fire brigade)

The average delay of this traffic is 331.147s with a peak of about 1.2s between the interval t=6s and t=7s; the lowest delay was recorded at about t=5s and reached 70ms approximately. We must remember that the link MAP→LSR1 has a minimum delay of 50ms.

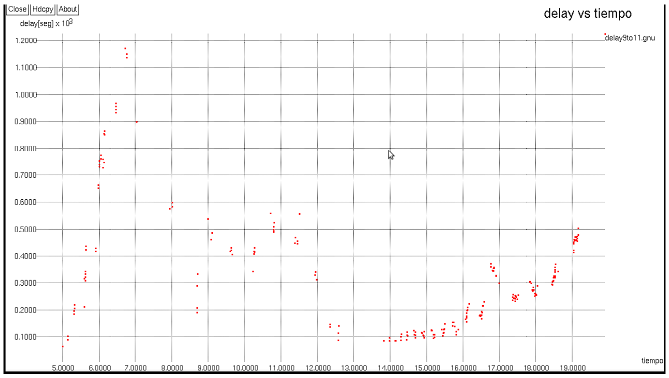

Fig 11. MN-CN2 Delay (fire brigade)

MN→CN3 delay (Police)

The average delay experienced by the police community is 256,803ms and the maximum delay, 1080ms in the same interval of the previous cases (6s-7s). Finally, the minimum delay is 80ms when the traffic flow begins.

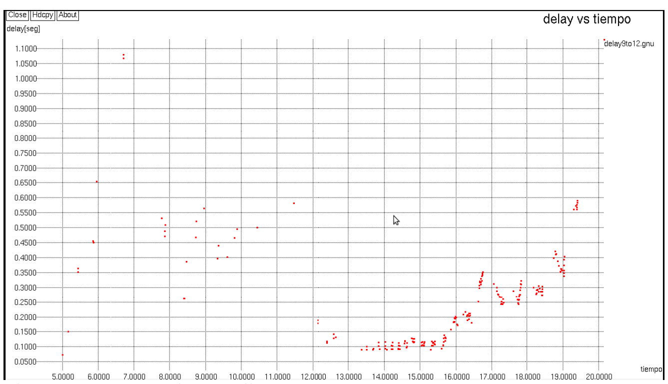

Fig 12 MN-CN3 Delay (Police)

MN→CN3 delay (Army)

In this case, the average delay is 388.314s. The maximum delay is approximately 830ms and occurs in the 6s-7s interval. Finally, the minimum delay is about 80ms and takes place at t=5s.

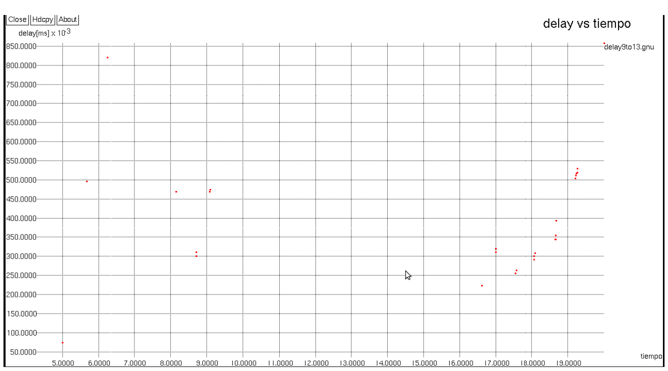

Fig13. MN→CN3 delay (Army)

Jitter analysis

The jitter presented below was calculated using the formula jitter=delay- prev_delay, where "delay" is the current packet delay and "prev_delay" is the delay of the previous packet. Thereafter, the image that appears after the subtitle represents the jitter in function of time.

MN→CN1 jitter (Ambulance)

The jitter for the traffic between the MN and the ambulance community was below 300ms in most of the simulation with a prominent peak around t=14seg of 1.2s. It is in that exact moment, when the MN stops receiving packets from the PAR and starts receiving them from the NAR, when some packets are lost. The average jitter was 135.833ms.

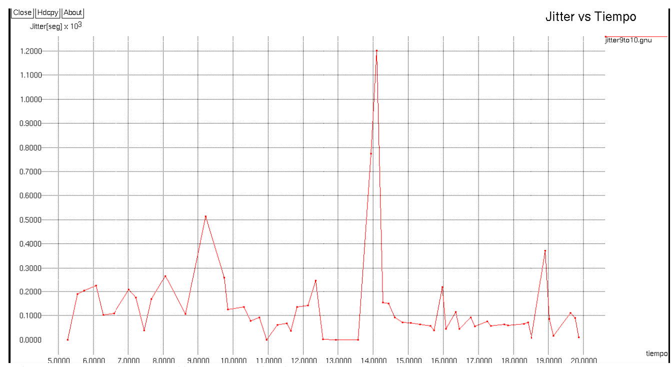

Fig 14. MN→CN1 jitter (Ambulance)

MN→CN2 jitter (Fire brigade)

The average jitter in this case was 151.509ms, with an outstanding peak of 1025ms approximately around t=14s after the start of the simulation. As shown in (figure 15), the jitter is kept under 300ms in most of the simulation.

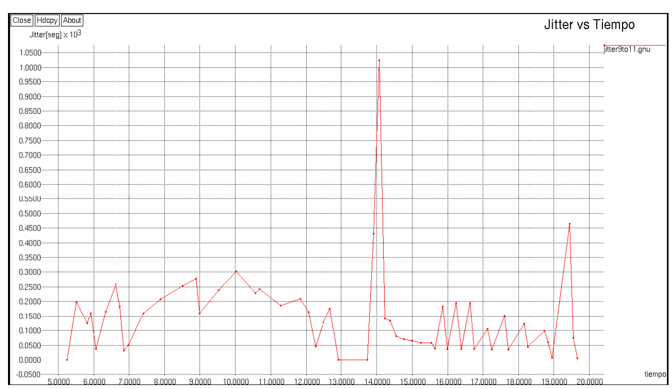

Fig 15. MN→CN2 jitter (Fire brigade)

MN→CN3 jitter (Police)

In this case, the average jitter was 134.354ms. In the course of the simulation there were several peaks. The most prominent one was between t=7.5s and t=8s with a value of approximately 880ms. Jitter, for this traffic, was more dispersed than in the previous ones.

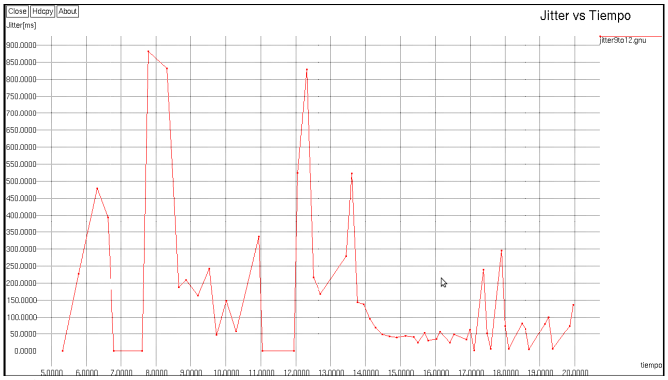

Fig 16. MN→CN3 jitter (Police)

MN→CN4 jitter (Army)

As shown in the figure below, the jitter behaves very differently from previous cases. In most of the simulation, jitter is below 300ms, but there is a peak of almost 7s. This gives an average jitter of 316.203ms.

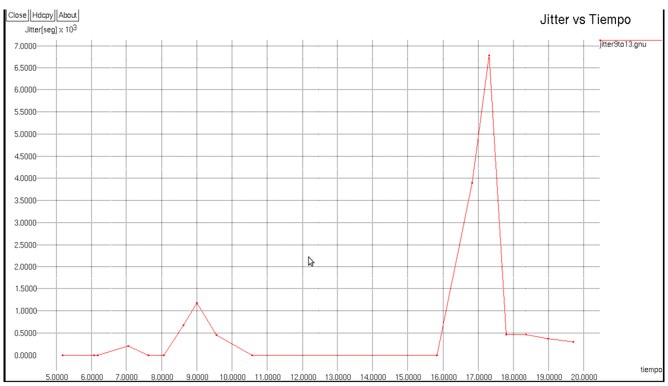

Fig 17. MN→CN4 jitter (Army)

Throughput analysis

We will analyze the throughput experienced by each of the four traffics from the MN towards any community. Thereafter, the image that appears under the subtitle represents the throughput or the TCP congestion window in function of time.

MN→CN1 throughput (Ambulance)

The average throughput is 117.056Kbps, with peaks of more than 550Kbps, which is over 55% of the link with lower bandwidth (1Mb) for PAR→LSR2 and NAR→LSR3. So the FTP traffic at its peak reached more than 55% channel usage despite sharing it with 3 additional traffic flows. Notably, in the interval (12s-14s) after the start of the simulation, the throughput dropped to zero due to packet loss as the handover took place.

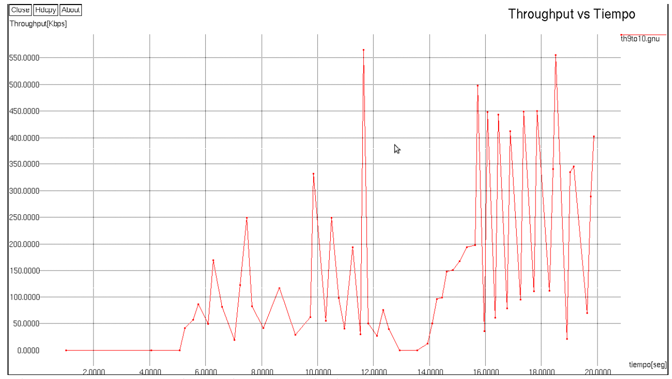

Fig 18. MN→CN1 throughput (Ambulance)

The figure below shows the evolution of the TCP congestion window (CWND) for this same traffic. The window drops correspond to the intervals 7-8, 11-12 and 13-14 when the throughput goes to zero. This shows the network overhead in the first interval and the effects of handover on the others. Window falls mean loss of packets.

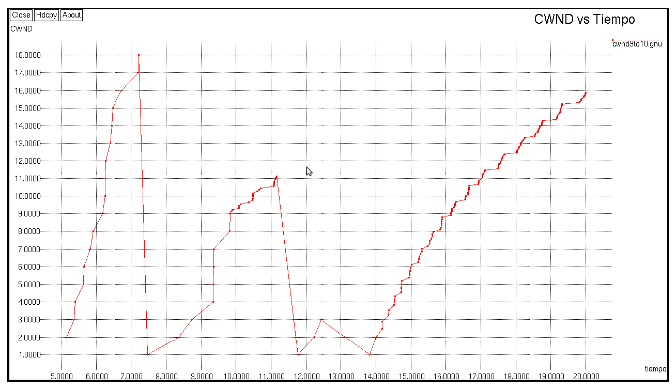

Fig 19. CWND vs Time

MN→CN2 throughput (Fire brigade)

For this traffic, the average throughput was 112.619Kbps with peaks of about 700ms, which corresponds to almost 70% of the maximum possible. As in the previous case, the throughput is zero in the interval 12-14 while the handover is completed, due to the loss of some packets.

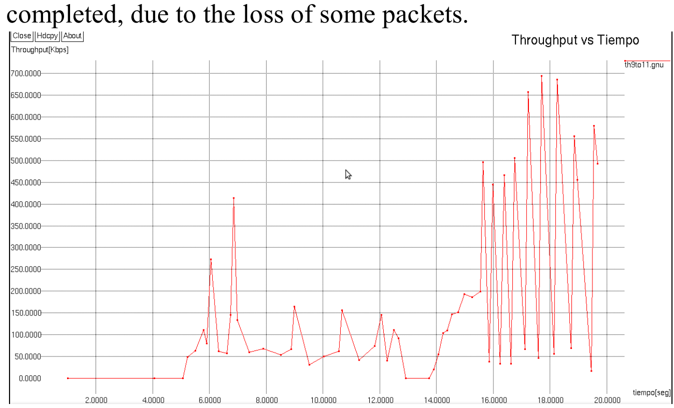

Fig 20. MN-CN2 throughput (Fire brigade)

The graphic below shows the correspondence between moments of network congestion and throughput falls. As in the previous case, window falls mean packet loss, either because of congestion or handover.

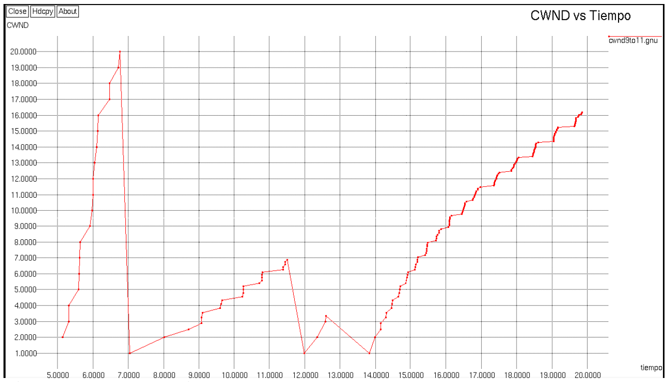

Fig 21. CWND VS Time

MN→CN3 throughput (Police)

The average throughput was 111.509Kbps, with peaks up to nearly 650Kbps. Unlike previous cases, the throughput does not fall to zero in the handover, but seconds before it occurs.

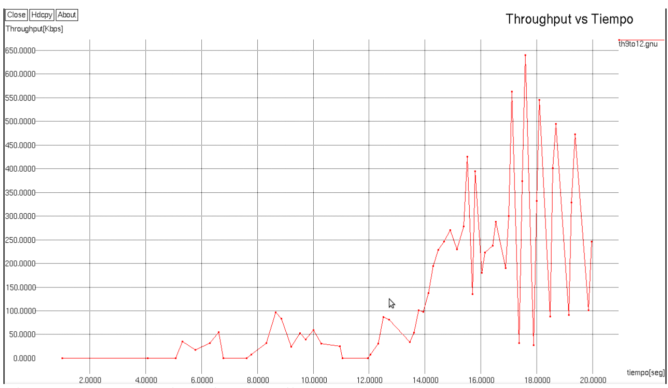

Fig 22. MN-CN3 trhoughput (police)

The figure below shows the evolution of TCP congestion window. Note that before 13.5s of the start of the simulation, the window does not increase significantly due to network congestion. However, from then on, it grows steadily. The throughput shows a similar behaviour for this traffic. Compare the picture above to the one below.

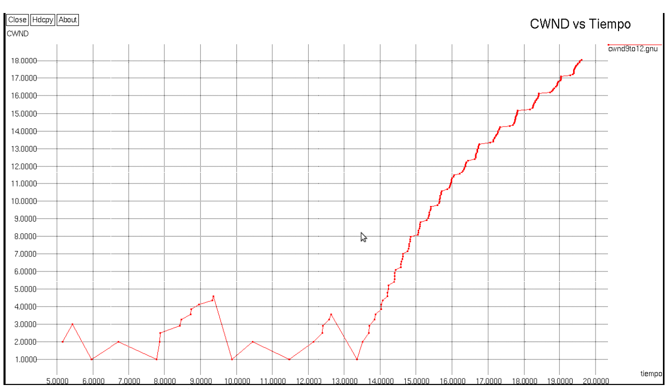

Fig 23. CWND VS Time

MN→CN4 throughput (Army)

The average throughput was 13.3333Kbps, with a peak of 46.1887Kbps. This traffic is the most affected by the the network overload.

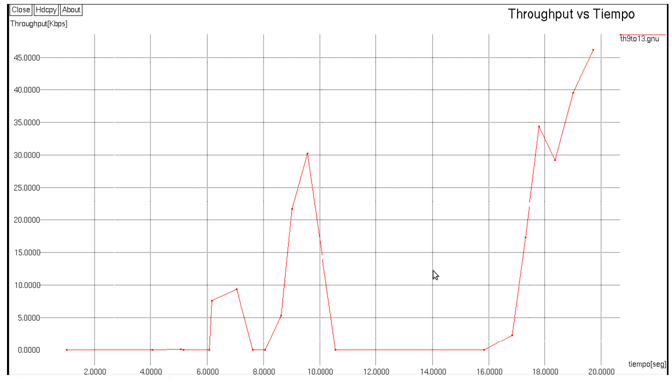

Fig 24. MN-CN4 throughput (Army)

The behavior of the TCP congestion window shown below is consistent with the throughput shown above.

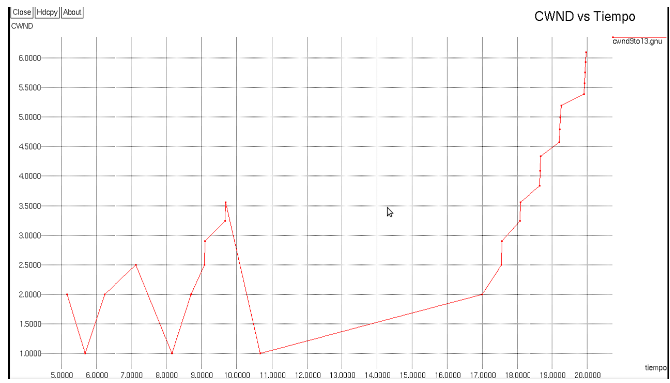

Fig 25. CWND vs Time

VIII. FHMIPv6/MPLS VERSUS HMIPv6/MPLS INTEGRATION [10]

Figure 26 shows the sequence of the packets received in the MN vs. the packets sent by the CN in HMIPv6 as well as in FHMIPv6. We can observe it is better to use FHMIPv6 to provide QoS in scenarios that require permanent handover between different points of access under the same network domain.

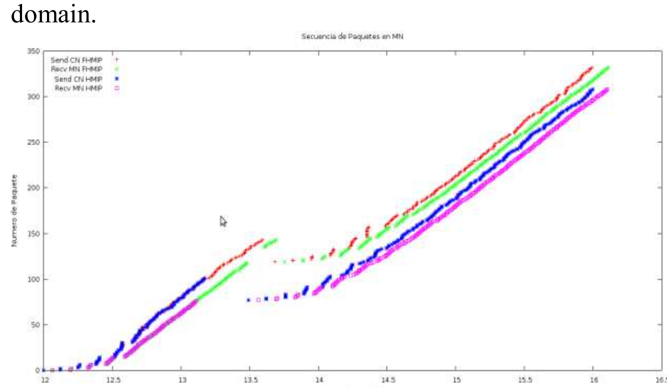

Fig 26. FHMIPv6 vs. HMIPv6

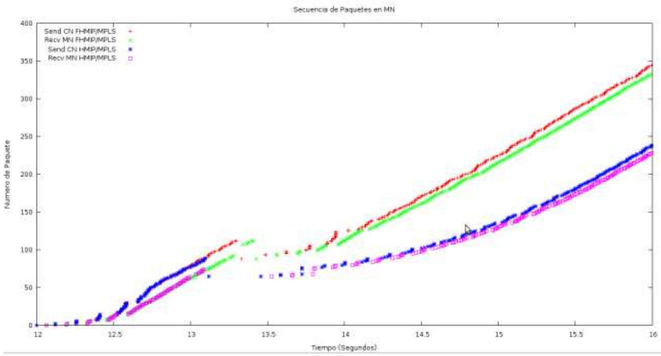

Fig 27. FHMIPv6/MPLS vs. HMIPv6/MPLS

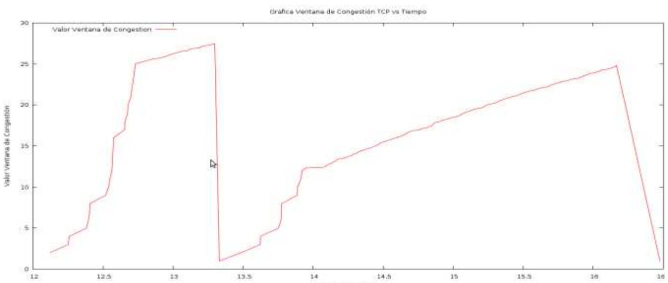

Fig 28. Congestion Window for the Integration of FHMIPv6/MPLS

As shown in Figure 27, the handover between the PAR and the NAR is much faster in the FHMIPv6/MPLS integration than in the HMIPv6/MPLS integration. This is because FHMIPv6/MPLS incorporates Fast Handover [16]. In HMIPv6/MPLS, the handover delays is around 300 ms while the FHMIPv6/MPLS integration takes nearly 90 ms. We see that the network performance is considerably increased due mostly to a faster handover (thanks to Fast Handover) and the packets are delivered also much quicker because it is integrated with MPLS. HMIPv6/MPLS manages to send around 240 packets while FHMIPv6/MPLS reaches 340. This means that the network improves its efficiency and performance by 30% approximately.

The results at the congestion window of the TCP highlight the problem of the sequence of packets mentioned in [16]. The transfer flow during the handover is interrupted and that is the reason why the value in the window falls and increases again after being registered in the NAR. In order to solve this problem in [16] it is possible to generate a redelivery of the packets between the MAP and NAR initially sent to the PAR, instead of being the PAR the one that resends them to the NAR.

IX. CONCLUSIONS

The proposed FHMIPv6/MPLS integration improves the performance of a network since the handover is completed in a shorter period of time. In other words, it can deliver more packets that the HMIPv6/MPLS integration in the same time. This evidence proves that FHMIPv6/MPLS is a very consistent candidate for 4G networks in order to improve the quality of service in IP based networks.

In this case, we performed the FHMIPv6/MPLS scenario simulation using CBR as test traffic. Various QoS metrics were analyzed, such as delay, which on average was 67.13ms; the jitter, which remained almost constantly below 1ms and throughput, which reached 446Kbps on average. On the other hand, in the course of the simulation, 3,734 packets were sent and only 180 were lost. That represents 4.82057% of all packets. Due to the excellent results we can conclude that FHMIPv6/MPLS integration improves the QoS in scenarios with CBR traffic. This simulation is headway of the implementation in VANET networks for future works. The FHMIPv6/MPLS integration is still being developed and it is necessary to test another type of traffic. In the case of TCP, there are still difficulties in achieving the registration process and we are working to identify possible causes. We hope that this integration and those made before (FHMIPv6/MPLS, HMIPv6/MPLS, etc.) allow us to provide quality of service in next generation integrated mobile hybrid networks as well as to end-to-end networks, while maintaining compatibility between different networks at access or backbone levels.

It has been shown, through the FHMIPv6/MPLS simulation integration that QoS can be offered successfully to the hybrid sensor network scenario. It was noted that the lowest average delay was experienced by the police community, which corresponds to 256.803ms. Additionally, it was found that the handover does not affect the delay of the network, while metrics such as jitter, lost packets and throughput are actually affected. On the other hand, the best average jitter was 134.354ms and corresponds to the traffic experienced by the ambulance community. It was also found that the best average throughput was around 117.056Kbps for the ambulance community and the best throughput reached almost 700Kbps, which represents 70% of the maximum possible value. This is a remarkable fact because the medium is being occupied by four different FTP traffics at the same time. Finally, 55 packages of a total of 797 are lost, that is only 6.9008% of the total amount. This loss occurs both because of the effects of congestion and handover. Finally, we conclude that the FHMIPv6/MPLS integration is adequate to support e-learning applied to sensor networks because it maintains an acceptable level of QoS metrics in order to share the knowledge of the community that moves near the sensors with other communities across the FHMIPv6/MPLS network without major problems.

Future Work:

- Compare the same scenario with FHMIPv6 without MPLS and determine how MPLS improves the QoS.
- Try a completely ad-hoc FHAMIPv6/MPLS.
- Try the same scenario with FHMIPv6/MPLS/DIFFSERV.
- Compare simulations and determine which one contributes more to the QoS.

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