# Integration of FHAMIPv6/Diffserv/MPLS/Load Balancing Algorithm

Jesus Hamilton Ortiz
Closemobile Research & Development SL:

Bazil Taha Ahmed
Autonomous Madrid University

Juan P. Pantoja
Campinas State University - UNICAMP

**Abstract**

This paper discusses the Quality of Service metrics in the integration of FHAMIPv6/MPLS/Diffserv protocols. These metrics are analyzed using the load balancing algorithm in the presence of network congestion. The metrics used are delay, jitter, and throughput. These metrics are analyzed when a handoff occurs in the ad hoc network. The results obtained show that the load balancing algorithm is a great option in the integration to optimize the Quality of Service in ad hoc and hybrid network when a handoff occurs.

***Keywords:*** *QoS, FHAMIPv6, MPLS, Diffserv, Handover, Handoff.*

## 1. Introduction

With the FHAMIPv6/MPLS integration [3][4][8][9][10][11] we intend to provide Quality of Service in ad hoc networks and propose solutions to some of the challenges in ad hoc and hybrid ad hoc networks, for example, the routing problem, the signaling problem, safety, etc. On the other hand, with this work we try to recover the standard protocols designed to provide Quality of Service and the discarded to be used in ad hoc networks (MPLS, Diffserv, and RSVP). To achieve this it was necessary to modify the protocols source code and adapt them to the special mobile characteristics of ad hoc networks, it was also necessary to adapt of NS-2 simulator versions (this simulator will be used because it is open source and for the experience we have working with it) [2], so that all protocols can work with the same version, as the protocols are designed in different versions and do not work in all versions of the simulator.

One of the main motivations for this work are the ad hoc networks challenges and the great interest researchers have on them, with our tests we intend to make a contribution to the limitations that this type of networks have. There are many challenges in ad hoc networks, we do not pretend to solve all of them, but we look forward to providing a more standard solution, as the best known solutions focus on a very particular subject, but at the same time neglect many aspects of this limitation, each solution is for a particular solution, we will resort to standards known and defined by the IETF (Diffserv, RSVP) as a starting point. In order to do this, a change in the protocols characteristics and standards will be required taking into account the network's mobility characteristics.

In the FHAMIPv6/MPLS/Diffserv integration case, the FHAMIPv6 protocol [3][4][8][9][10] was designed to provide hierarchical addresses in an ad hoc network, but not to provide Quality of Service, as the FHMIPv6 protocol is not designed to be used in ad hoc networks, for this reason this extension version emerged. In order to provide Quality of Service, FHAMIPv6 and MPLS were integrated, (this integration provides End-to-End Quality of Service and allows the adjustment of the IPv6 protocol extension in ad hoc FHAMIPv6 mobile networks), due to the compatibility between IPv6 and MPLS at the headers processing level, decreasing the amount of processing load. In Diffserv´s case, it allows us to segregate End-to-End traffic flows and to provide classification and priority to each traffic, depending on the type of priority assigned in Diffserv. Once these protocols have been integrated and the work is previously done and tested, the Quality of Service degradation in a congested network is evaluated. We have used a load balancing algorithm as a mechanism for limiting the problem of Quality of Service degradation in order to optimize End-to-End traffic or to maintain the minimum Quality of Service requirements for certain traffic by default. The metrics evaluated are chosen because they are the most sensitive when a handover or handoff occurs, our tests have been performed in an ad hoc network and in a hybrid network, the Quality of Service metrics have been measured on a handoff in the presence of a congested network so that when the Quality of Service algorithm is used, it allows the problem of network congestion to be neutralized.

## 2. Background

A. MPLS&Diffserv

MPLS and the Differentiated Services model: the mechanisms of MPLS traffic classification and its ability to establish LSPs, which allows it to provide different services to different types of traffic, depending on its specific needs. It is evident therefore that MPLS is not an alternative to the Differentiated Services model, but on the contrary, MPLS can be used as a support of the Differentiated ‘Services [2] [11] LSPs that can carry multiple OAs, so the EXP field in MPLS header tells the LSP the PHB to be applied to each packet (contains the information on the service of the packet on its discard probability).

LSPs that only transport one OA, so that each LSR deducts the treatment that each packet should receive based exclusively on the value of the label, while the drop probability is indicated in the EXP field of the MPLS header or in the specific mechanism of discarding that in the link level encapsulation.

MPLS allows network administrators to flexibly translate the Bas in LSPs, introducing several Bas in a single LSP or establishing for each BA.

B. MPLS in IPv6

In IPv6, due to the existence of a label field in the IPv6 header. This field opens the possibility of using some fields of the IPv6 header to transport the information contained in the MPLS header, making unnecessary the generic header of the MPLS, which could represent savings on bandwidth and an improved efficiency.

The coding of the fields in the MPLS header in IPv6 header could be:

The MPLS label field can be encoded in the label field of the IPv6 header, since both fields have the same length (20 bits).

The TTL field of MPLS, can be encoded in the field "Hop Limit" of the IPv6 header.

The Experimental Bits and MPLS S field could be coded in the "Traffic Class" field of the IPv6 header, where the EXP BITs would occupy the bits with more weight and the S field would occupy the bit with less weight. [6][7][8][9].

The FHAMIPv6 protocol created as an extension to support hierarchical addresses in MANET networks, but FHAMIPv6, is not a protocol to provide quality of services in such networks. For this reason in the following paper it necessary integrates FHAMIPv6 and MPLS in order to provide QoS in Ad hoc networks. In order to achieve the communication source to destination was necessary modify the protocol FHMIPv6 obtaining FHAMIPv6 protocol. In the chapter [3] described with detail the new protocol (FHAMIPv6) starting from FHMIPv6 protocol. The goal is to achieve successful communication from source to destination using hierarchical addresses in ad hoc networks. [3].

C. Load Balance Algorithm in MPLS Description

The description of this algorithm has been divided in two stages. The first calculates an optimal flow allocation in terms of the average delay. The algorithm solves the problem of determining the paths that can be used and then assigns the traffic to the paths according to the congestion. The algorithm´s approach to solve the first problem is as follows [1]:

In a network consisting of N nodes. A pair of nodes (m, n) can be connected by a direct link with a bandwidth equal to $b_{(m, n)}$. The total number of links is denoted by L and the topology is denoted by T, this is a set of pairs of nodes. Being (AERnxl) the matrix for which $A_{(i, j)} = -1$ if the j link goes to node i, 1 leaves it and 0 otherwise.

Traffic demand is X given by $d_{(i, j)}$ matrix, where i, j are the input-output nodes respectively. $R_{(i, j)}$ ERn is a vector for each (i, j) pair such that $R_{(i, j)}$, k=$d_{(i, j)}$, if k is an ingress node, $R_{(i, j)}$, k =-$d_{(i, j)}$, if k is an egress node, and R (i, j), k=0 for the other case. Being $X_{(i, j), (m, n)}$ the assigned traffic to the (i, j) input-output nodes in the (m, n) link. Then the total traffic on the (m, n) link is

$$X_{(m,n)} = \sum_{(i,j)} x_{(i,j),(m,n)}$$

The formula based on pairs of links that minimizes the maximum load is as follows:

$$Min\left[-\in Z + \sum_{(m,n)} w_{(m,n)} \sum_{(i,j)} x_{(i,j),(m,n)}\right]$$

Subject to the following restrictions:

$$X_{(i,j),(m,n)} \geq 0; Z \geq 0$$

$$\sum_{(i,j)} x_{(i,j)(m,n)} + C_{(m,n)}Z \leq b_{(m,n)} \; for\ each\ (m,n)$$

$$with\ b_{(m,n)} > 0, in\ each\ node\ n.$$

$$Ax_{(i,j)}^{T} = R_{(i,j)}^{T}, for\ each\ (i,j)$$

Where Z describes the minimum value of unused capacity. The last equation indicates that, for every n node, the incoming traffic of each ingress-egress pair must equal the outgoing traffic.

In the second stage once a solution is found to the x $_{(in,\ j),\ (m,\ n)}$ variable, paths for every ingress-egress pair must be found. Being T the original topology, which consists of a set of direct links. Since a pair of ingress-egress nodes only uses part of the complete topology, a new topology $T'_{(i,\ j)}$ is defined, which consists of links for which x (i, j), (m, n) is different from zero. Being $L'_{(i,\ j)}$ the number of links in the topology $T'_{(i,\ j)}$. All paths are searched for an ingress-egress pair (i, j) using a depth-first search algorithm (DFS), defined as follows.

1. Being $P_{(i,\ j)}$ an empty set of paths.
2. Finding all links (i, k) of the topology $T'_{(i,\ j)}$. Do for each link (i, k) a subset $P'_{(i,\ j)}$, which consists of nodes i and k. add $P'_{(i,\ j)}$ to the $P_{(i,\ j)}$ set.
3. If the last component of the subset $P'_{(i,\ j)}$ is an egress node j, the subset $P'_{(i,\ j)}$ is incomplete.
4. Considering a subset $P'_{(i,\ j)}$. Find all the links (k, l) where k is the last $P'_{(i,\ j)}$ node of the T' topology. Create for each (k, l) link a subset $P''_{(i,\ j)}$, which consists of all of the nodes $P'_{(i,\ j)}$ and the node l. Now replace the set $P'_{(i,\ j)}$ by the $P'_{(i,\ j)}$ in the set $P_{(i,\ j)}$. Repeat this for every subset $P'_{(i,\ j)}$, which are not complete.
5. If there is a subset $P'_{(i,\ j)}$, that is not complete, return to step 3, otherwise stop the algorithm.

As a result of the algorithm a set of possible paths $P_{(i,\ j)}$ will be obtained for an ingress-egress pair. Being $K_{(i,\ j)}$ the number of roads and being Q (I, J), the matrix, where

$$Q_{(i,j),(l,k)} = \begin{cases} 1, & \textit{if path use the link } l \textit{ of the topology } T'_{(i,j)} \\ 0, & \textit{in other case} \end{cases}$$

For each ingress-egress pair. Being $Y_{(i,\ j),\ k}$ the traffic assigned to the k path. The $Y_{(i,\ j),\ k}$s can be solved in the matrix equation

$$Q_{(i,j)}\ Y^T_{(i,j)} = x'^T_{(i,j)}, \text{ for each (i, j)}$$

Where X is the vector of traffic flows for each ingress-egress pair (i, j). The system defined by the above matrix equation can be solved or undetermined, because the number of paths differs from the number of links. Finally, if an element of the solution matrix Y (i, j), k differs from zero, the ingress-egress pair uses the k path, otherwise it does not. So reducing these paths from the set of paths P (i, j) the current set of paths is obtained.

## 3. Scenario description (Integration and Algoritm)

The goal of the simulation was to analyze QoS metrics in the FHAMIPv6/Diffserv/MPLS integration under the influence of a load balancing algorithm based on congestion. The metrics analyzed were: delay, jitter and throughput.

The figure below illustrates the simulated scenario: this represents an environment in which a mobile node (AMN) communicates with an ACN using CBR traffic; the node has an Ad-Hoc Home Agent (AHA). On the other hand during the simulation the AMN moves between two access points (APAR and ANAR) to study the effects of the handoff on QoS metrics.

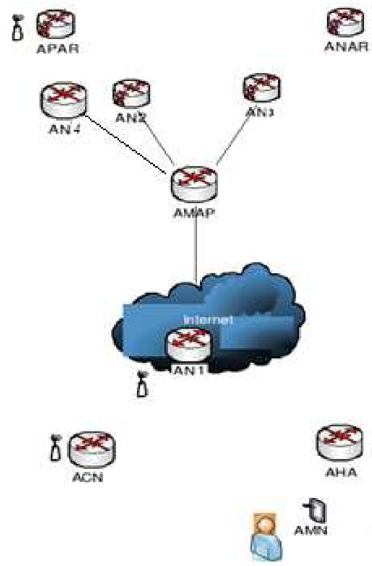



Fig. 1 Simulation scenario FHAMIPv6/Diffserv/MPLS

As shown in the figure above, there are wired links in the core network, their description is presented in Table 1.

Table 1: Description of wired links

| Link | Class | Delay [Ms] | Bandwidth [Mb] |
|---|---|---|---|
| AN1-> AMAP | Simplex | 50 | 100 |
| AMAP->AN1 | Simplex | 50 | 100 |
| AMAP->AN2 | Simplex | 2 | 10 |
| AN2->AMAP | Simplex | 2 | 10 |
| AMAP->AN3 | Simplex | 2 | 10 |
| AN3->AMAP | Simplex | 2 | 10 |
| AMAP->AN4 | Simplex | 2 | 10 |
| AN4->AMAP | Simplex | 2 | 10 |

On the other hand, CBR traffic between the AMN and the ACN is defined in the simulation, QoS metrics are analyzed for this particular traffic.

With respect to the proposed integration, the role played by each protocol is described below: FHAMIPv6 provides mobility functions, hierarchy and fast handover while ad hoc routing capabilities are provided by AODV. Furthermore, Diffserv protocol is used to provide differentiated treatment to traffic between the AMN and the ACN so that it has a higher priority and receives a superior treatment than the IP´s best effort. MPLS is set up on the wired portion of the network to facilitate the routing task, additionally a protocol was given to the network core, and it performs a load balancing based on the congested links.

The protocols distribution in the different nodes of the scenario is as follows:
Diffserv is configured in the nodes: AN1, AMAP, AN2, AN3 and AN4, like this:
AN1: Edge Router
AN2: Edge Router
AN3: Edge Router
AN4: Edge Router
AMAP: Core Router

Diffserv is set up so that AMN could use a maximum transfer rate of 5 Mbps and will guarantee a rate of 1Mbps, if used below 1Mbps transfer, the traffic experienced a Green treatment, if the rate is between 1Mbps and 5Mbps a Yellow treatment and if it exceeded 5Mbps a Red treatment, ie high, medium and low drop precedents were used depending on the threshold of the transfer rate. Depending on the drop a virtual queue is used. In the simulation one physical queue and three virtual queues were used, each linked to a drop precedence.

MPLS was set up as follows, AN1, AN2, AN3 and AN4 nodes were settled as edge routers and the AMAP as core router. Furthermore LDP is the label distribution protocol used. Finally, the load balancing algorithm based on link congestion is run by MPLS.

Based on the above, the nodes' roles on the network have the following configuration:
- AN1: FHAMIPv6/Diffserv/MPLS/ Congestion algorithm
- AN2: FHAMIPv6/Diffserv/MPLS/ Congestion algorithm
- AN3: FHAMIPv6/Diffserv/MPLS/ Congestion algorithm
- AN4: FHAMIPv6/Diffserv/MPLS/ Congestion algorithm
-. AMAP: FHAMIPv6/Diffserv/MPLS/ Congestion algorithm
- ACN: FHAMIPv6
- AHA: FHAMIPv6
- AMN: FHAMIPv6
- APAR: FHAMIPv6
- ANAR: FHAMIPv6

## 4. Description of the simulation

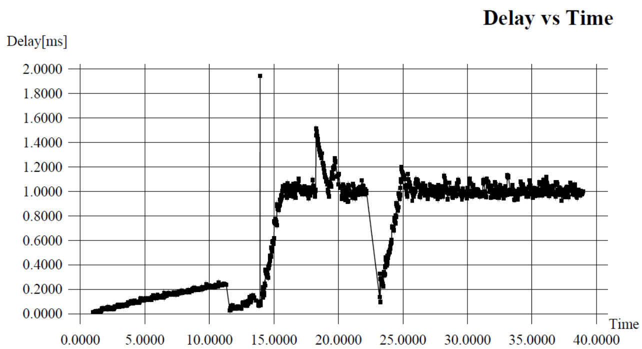
AMN is in the AHA area initially, from there it begins a CBR session with ACN at t=1s, the traffic goes in the direction AMN → ACN, then at t=10s the AMN begins its movement towards the APAR zone at 30m/s arriving there near the time t=14s. Onwards, CBR session will be carried out using the route AMN-> APAR->AN2->AMAP->AN1->ACN. Later at t=15.5s a new traffic between the ACN and AN2 begins, it congests the path used by the AMN to send its traffic to the ACN, due to this congestion MPLS runs its load balancing algorithm, as a result of this algorithm the AMN traffic will now take the route AMN->APAR->AN4->AMAP->AN1->ACN avoiding the link congestion AN2->AMAP. Then, at t=20s the AMN moves to the ANAR area at 10m/s, moments later close to t=23.25s handoff is performed and subsequently CBR session will take place following the route AMN->ANAR->AN3->AMAP->AN1->ACN. The purpose of these shifts was to analyze the QoS metrics in a direct connection (to determine as much as possible) and through access routers in order to measure the efficiency of proposed integration in the core network, further APAR displacement towards the ANAR was performed to analyze the handover effects in the QoS. On the other hand the traffic between ACN and AN2 was used to congest the link AN2->AMAP and to evaluate the effectiveness of the MPLS congestion algorithm.

## 5. Analysis of results

This section presents the results obtained from the simulation carried out.

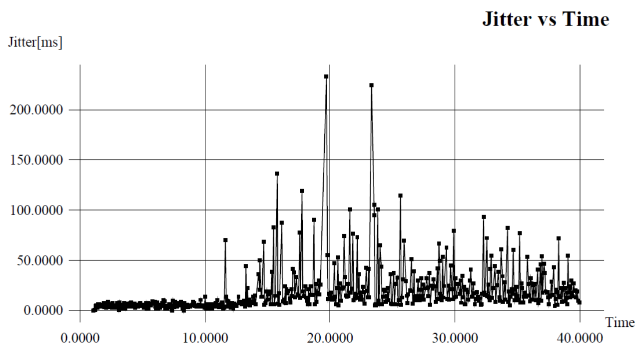
### A. Analysis of delay

The figure below illustrates the performance of the delay with respect to time. As seen in the first 10 seconds of the simulation, the delay is below 0.4 seconds, then it goes through a sharp decline and subsequent a slow increase due to the AMN movement from the AHA zone to the APAR zone. It is important to mention that despite the congestion present since the time t=15.5s, delay behavior at that time presents no alteration, that is why the congestion avoidance algorithm was successfully implemented. Subsequently, near t=23.25s the delay undergoes a decrease because the handoff takes place at that time. Then the delay is stabilized at around 1s. Finally it is noted that on average delay was 592.29ms



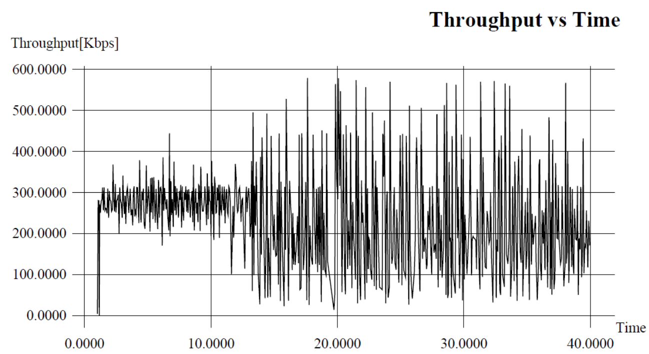

B. Analysis of jitter

Because the jitter is measured in terms of delay, the facts discussed in the previous section are applied to describe the behavior of the jitter with respect to time, which is presented in the figure below. It is noted that the average jitter obtained a value of 13.08ms.




B. Analysis of throughput

The figure below illustrates the throughput performance with respect to time. Initially this metric tends to stabilize near 300ms, later with the AMN movement towards APAR zone, throughput fluctuates on a wider range of values. It is important to mention that at t=15.5s throughput is not affected by the congestion present on AN2->AMAP link because the congestion avoidance algorithm uses theAN4-> AMAP link to avoid such congestion affecting the traffic. It is also noted that the handoff has no notable effects on the throughput, since the throughput does not change its behavior when the handoff takes place. The last 10 seconds of simulation, the behavior of the metric in question is very similar to that exhibited when the AMN is located in the APAR zone. Finally it is noted that the average throughput was 210.81kbps




## 6. Conclusions

This article introduced the integration of FHAMIPv6, Diffserv, MPLS protocols with the execution of congestion algorithm. The purpose was to analyze the behavior of QoS metrics especially at times when congestion is present on some links of the simulated topology. The simulation showed that the average delay was 592.29ms while the jitter was 13.08ms; both metrics were stable in the presence of congestion. On the other hand throughput had no changes in its behavior in the presence of network congestion or by the handoff execution. Therefore it can be concluded that the congestion algorithm that was executed in the simulation scenario is useful to keep the QoS of the network traffic in the presence of congestion

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