

Analysis of Seamless Handoffs in Mobile IP

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Abstract: Mobile IP is the IETF's default standard for provision of mobile communication. An issue related to the QoS of Mobile IP is the Handoff procedure, which results in more latency and data loss for moving nodes. This is primarily due to the delay in Registration process, slower movement detection and longer path taken by the data to reach the Mobile Node. This issue needs to be addressed so that seamless handoffs can be realized in order to meet the QoS constraints. In this work the MIP handoff has been analyzed by means of ns2 simulations for both TCP and UDP types of traffic. Primary focus has been to analyze and compare the performance of a mobility routing table based improved handoff scheme that aims at minimizing the handoff delay with the standard handoff procedure in MIP. Results show that the mobility routing table based scheme improves instantaneous throughput by 25 to 35 % during the handoff, resultantly the average throughput has also increased. Moreover, the packet delay has also reduced by 20 to 30 % consequently reducing data loss during the handoff.

Key words: Mobile IP, Mobility, Seamless Handoff, Quality-of-Service (QoS), Third-Generation (3G)

INTRODUCTION

Wireless networks are rapidly evolving towards 3G and beyond. These networks will use IP for addressing, which means that a node's IP address will be its identity anywhere on the Internet (Anand R. Prasad, 2005). When the node is mobile it will use Mobile IP outside its Home Network. Moreover, 3G networks and beyond will support high data rate transfers making live Video conferencing and high speed voice and data convergence a reality. This will give users the flexibility of roaming within a particular wireless network or outside of it while still retaining their permanent IP addresses. For example MIPv4 is currently being deployed on a wider scale for cdma2000 networks. In such networks MNs will move quite frequently, making corresponding handoffs quite fast. Although, MIP is the solution for mobility in future networks, it does not handle handoffs in a seamless manner. This is primarily because for each handoff to take place successfully the MN would have to register itself with the home agent (HA), and frequent registrations would result in loss of en-route packets.

It has been proposed that MIP is suited for mobility on a wider scale, while on a micro level micro-mobility protocols are well suited. This is because an MN mostly moves more frequently within a domain. And as the micro-mobility protocols follow a hierarchical model they are well suited for scenarios where frequent handoffs are involved. In such protocols registrations to the HA are avoided as long as the MN is in the same sub-network. Before delving in to the mechanics of the various approaches that focus on minimizing the handoff, it is imperative to have a look at the handoff procedure itself.

This paper focuses on giving a brief overview of the handoff procedure and some of the common handoff minimization techniques. After this we have analyzed the standard MIP scheme and a mobility routing table based approach using ns2 simulations. The mobility routing table handoff approach is based on the previous work carried out in (Wei Wu., *et al*, 2002) and this work is an extension and confirmation of the results presented in (Wei Wu., *et al*, 2002). After introduction in Section I, Section II focuses on the mechanics of the handoff, Section III discusses the various approaches in order to minimize the handoff, Section IV presents the simulation details and results and finally the conclusion is presented in Section V.

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2. Overview of the Handoff:

In this section we present an overview of the handoff procedure. A handoff is performed when a mobile node (MN) moves from coverage area of one Foreign Agent (FA) to another. The handoff procedure though quite intricate is elaborated in some detail in the preceding paragraph.

For simplicity we are considering the L3 handoff. The following steps are involved in an L3 handoff:
L2 Handoff: An MIP handoff occurs as a result of an L2 handoff between two IP networks. As Mobile IP functions independent of the lower layers so L2 (Link Layer) handoffs occur in the first stage. The MN therefore can be connected to two FAs at one time.

Movement Detection: An MN can detect that it has moved to an area which is covered by another FA if it receives Agent Advertisement from another FA. Movement detection algorithms are covered in some detail in (Perkins, C., 2002). Only the advertisement from new FA might not be necessary for a handoff, an increased Bit Error Rate, or a weak link with the present FA may also prompt the MN to look for another FA. As stated previously, since MIP is independent of lower layer handoffs so movement detection relies on the L3 mechanisms.

Registration: The MN has to successfully register its new care of address (CoA) with the HA. This can be summarized as follows:

1. MN receives agent advertisement from new FA.
2. It requests registration through FA.
3. FA sends registration request of new COA to HA.
4. HA responds with registration reply to FA with acceptance/rejection messages.
5. FA replies to MN indicating successful/unsuccessful registration.

The above steps conclude that each stage in the handoff procedure increases the over all latency in the handoff procedure. This affects the performance of real time applications like voice over IP (VOIP) thus undermining quality of service (QoS) of the MIP. However, the real killer is the "registration" itself.

The various micro-mobility protocols (Valko, A.G., 1999; Ramjee, R., *et al.*, 1999; Gustafsson, E., 1999) are well suited for achieving seamless or near-seamless handoffs. All these protocols follow a hierarchical model and are similar in this respect.

3. Handoff Minimization Techniques:

In this section we present some of the techniques that focus on minimizing the handoff itself.

A handoff comprises of the following three stages: an L2 handoff, Movement detection and the Registration process. So the overall latency of the L3 handoff is the cumulative sum of these three stages. This explicitly means that to minimize the overall time all three stages should be minimized.

Micro-mobility protocols follow a hierarchical architecture. These protocols have a single point of entry/exit. This means that all data in/out flow occurs from that very single point. It is perceived that a MNs movement would be mostly restricted within a domain, and frequent handoffs within that domain can be handled locally. Inter-domain handoffs however, would work via the MIP itself. So at a micro level micro-mobility protocols work well whereas at the macro-level the MIP is sufficient enough to fulfill the requirements. The handoff procedure in these micro-mobility protocols is now discussed.

Cellular IP: Cellular IP (Campbell, A., 2000; Valko, A., 1999; Andrew, T., 2000) (CIP) uses a single entry point called as CIP Gate Way (CIPGW) to control inward and outbound traffic. All the network elements, which are accessed from this gateway, are considered as a part of this domain. Cellular IP allows two types of handoff, i.e. *hard handoff* and the *semi-soft handoff*.

HAWAII: The handoff aware wireless access internet infrastructure (Ramjee, R., *et al.*, 1999a, Ramjee, R., *et al.*, 1999b) (HAWAII) also follows a hierarchical model. The gateway in this case is called the *domain root router (DRR)*. HAWAII scheme provides transparency to MN's since it tends to use the traditional MIP schemes for inter-domain mobility (Jochen Schiller, 2004). When a host enters the HAWAII domain it is allotted a co-located CoA. The gateway i.e. the DRR in this case does not perform de-capsulation of packets, instead it only routes the packets to the MN. However for routing, HAWAII uses a different mechanism.

HMIPv6: The Hierarchical management MIPv6 (Soliman, H., *et al.*, 2005) (HMIPv6) is an extension of the MIPv6 (Johnson, D., 2004) that aims at minimizing handoff latency by establishing a hierarchical structure. Micro-mobility support is provided by mobility anchor point (MAP) for a domain. A domain can have one or more MAPs. A MAP acts as an HA for the MNs. A number of Access routers (AR) are used within a domain to form a hierarchy. An MN has two IP addresses i.e. On-link care of address (LCOA) and Regional care of address (RCOA). The LCOA is the IP address granted to an MN by its AR whereas, RCOA is the

MAP address. The MAP receives inbound traffic for an MN that it is serving, encapsulates it and sends it over to the MN's current address (LCOA). Local movement updates are handled by binding updates (BU).

As discussed in Section 1, handoff latency is the result of the three process i.e. registration, movement detection and L2 handoff. In HMIPv6 the overall latency is the overall sum of Movement Detection latency, CoA configuration latency and the Binding update latency. The MIPv6 Fast Handover (Koodli, R., 2005) can also be used with HMIPv6 (Soliman, H., *et al*, 2005).

Route Optimization: In the classical MIP model packets are sent from the CN to the HA. The HA after performing a routing table lookup encapsulates these packets in a new IP header (towards the MN's CoA). These are received by the FA, which after de-capsulation delivers them to the MN. On the reverse path the packets may follow the same route or may even go directly to the CN directly. This type of communication has a number of drawbacks. Firstly, the packets have to travel a longer path, which results in more latency. Also during handoff more packets are lost since data traverses a longer path towards its destination. This is called the Triangular routing problem and is shown in Fig 1.

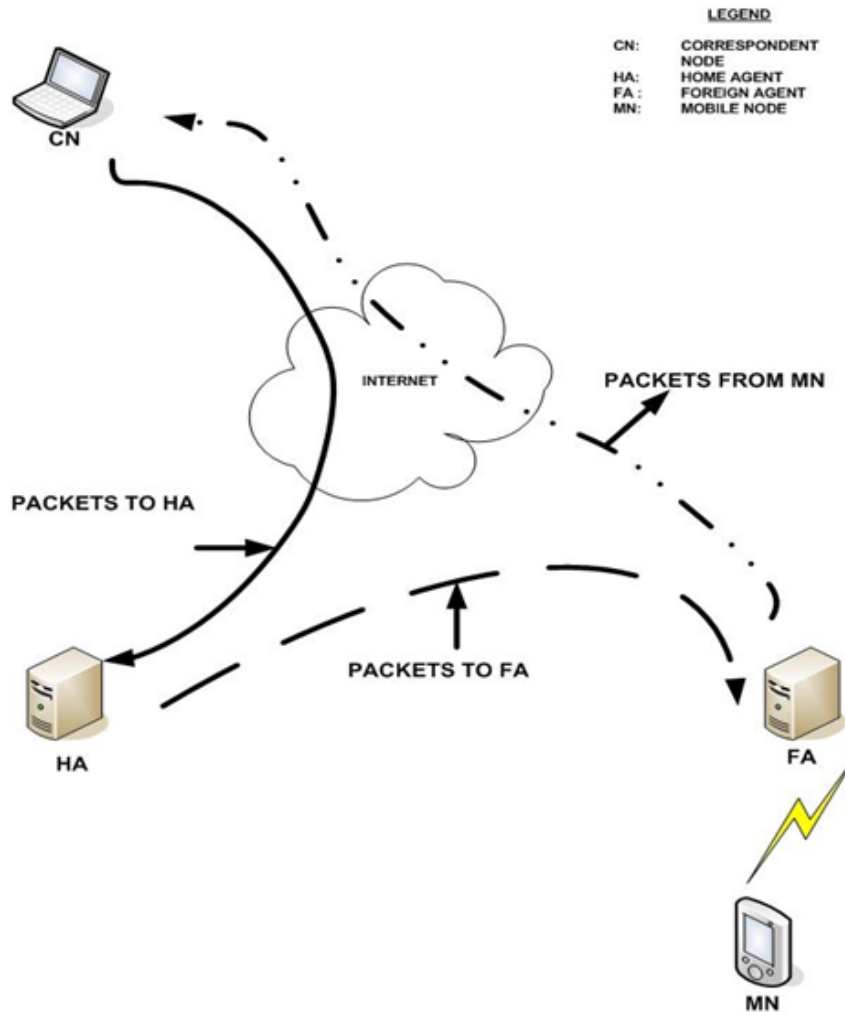


Fig. 1: Triangular Routing

4. Simulation Study:

In the mobility routing table scheme, the central idea is the creation of a Mobility Routing Table (MRT) in the FA, HA and the CN's Router. This has three fields comprising of the MN's permanent IP Address, the Care of Address and a numeric N-field. This is shown in Figure 2.

IP Address	Care of Address	N-Field
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Fig. 2: Mobility Routing Table

After a handoff is executed successfully and the MN has registered with the new FA, it sends a MRT entry to the HA, the HA on the other hand sends this entry to the CN's Router. From then the data routing decision from the CN to the MN is taken by the Router and so the HA is totally circumvented. It is important to note that this scheme works only after the handoff. That is before the handoff the data will travel to the MN via the HA, as in case of normal MIP. The N-field simply increments by a value of one at each handoff. Details of Flow Chart showing the handoff process from oFA to nFA and the packet delivery processes in the modified MIP scheme are shown in Figures 3 and 4, respectively.

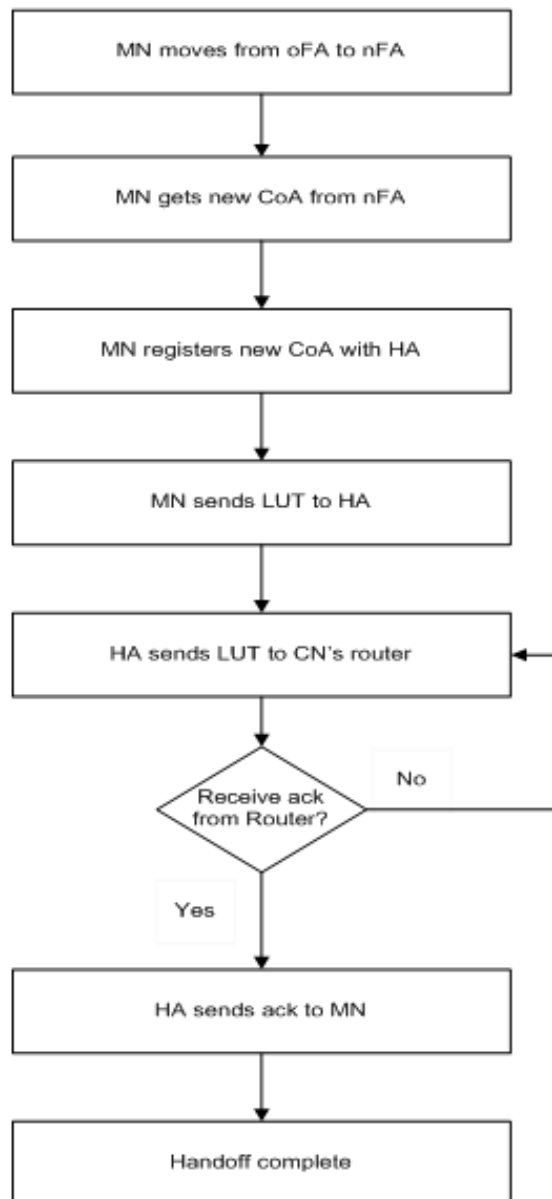


Fig. 3: Handoff process

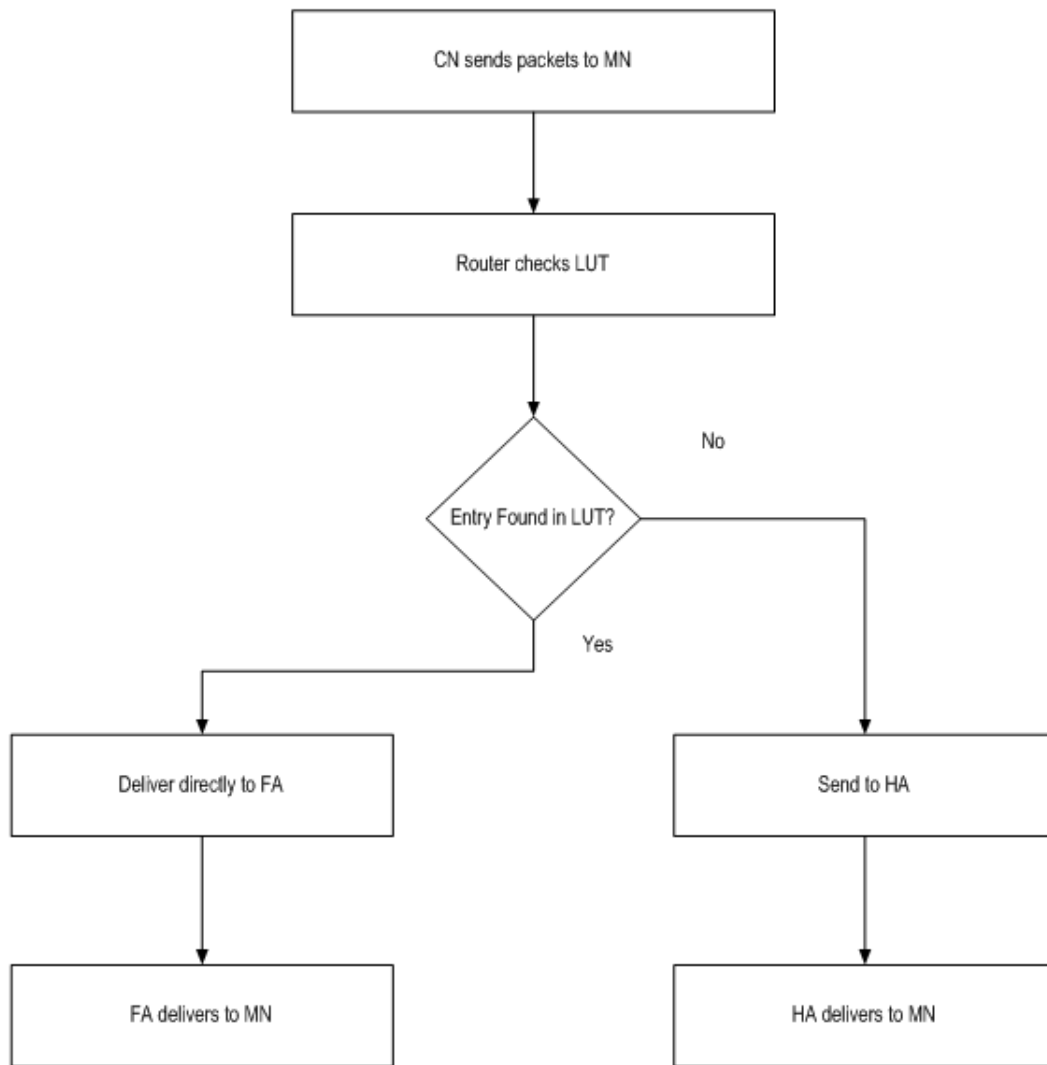


Fig. 4: packet delivery process

4.1 Simulation Scenario 1:

In this scenario the area in which the nodes are based is 670 x 670 M. One HA and two FAs have been configured. The FAs and HAs have a radius of 150 M. These can be called as Base Stations for convenience. The base stations have overlapping areas of coverage. This means that at the boundaries there signals overlap, this will help the MN decide about handoff once it reaches the boundary of an HA or FA. In this experiment TCP traffic has been used to analyze the results. The MN is initially configured to be attached with the HA and then it moves to the FA1 and FA2 where two handoffs take place. The nodes moves from HA towards FA1 with a speed of 15 m/s and stops there for 10 seconds. After that it moves from FA1 to FA2 with a speed of 10 m/s. The scenario is shown in Figure 5.

4.1.1 Simulation Results, Scenario 1:

The simulation results for scenario 1, with normal MIP are shown in Figure 6. The Figure 6 shows the instantaneous throughput (kbps) of TCP traffic as a function of time (seconds). It can be seen that when the handoff occurs there is a sharp dip in the throughput at that instant. And after the completion of the handoff the throughput again goes to its normal value. The two deep dips denote two handoffs, which the MN does while moving from HA to FA1 and then to FA2. In Figure 7, simulation results for the MRT based MIP are shown. It can be clearly seen from Figure 7 that there is a marked increase in the instantaneous throughput

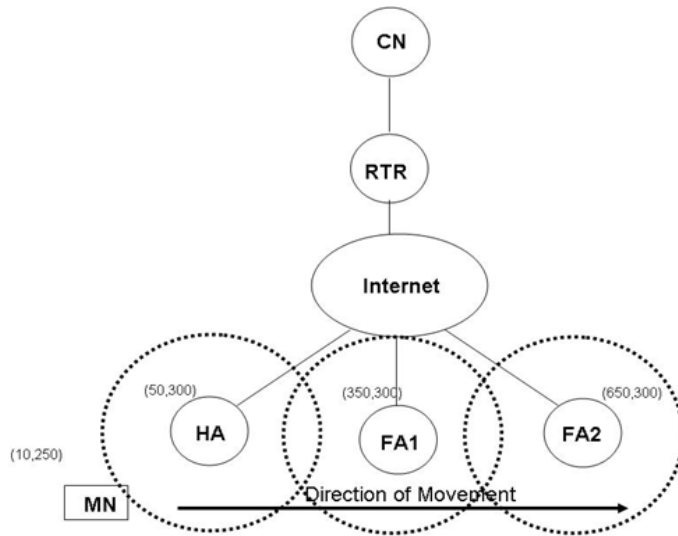


Fig. 5: Simulation Scenario

during the handoff as compared to the results for normal MIP. This is because in the MRT based MIP data travels a shorter path and consequently less data is lost during handoff. Also the improved scheme results in lower latency. All the results for scenario 1 are presented in Table 1.

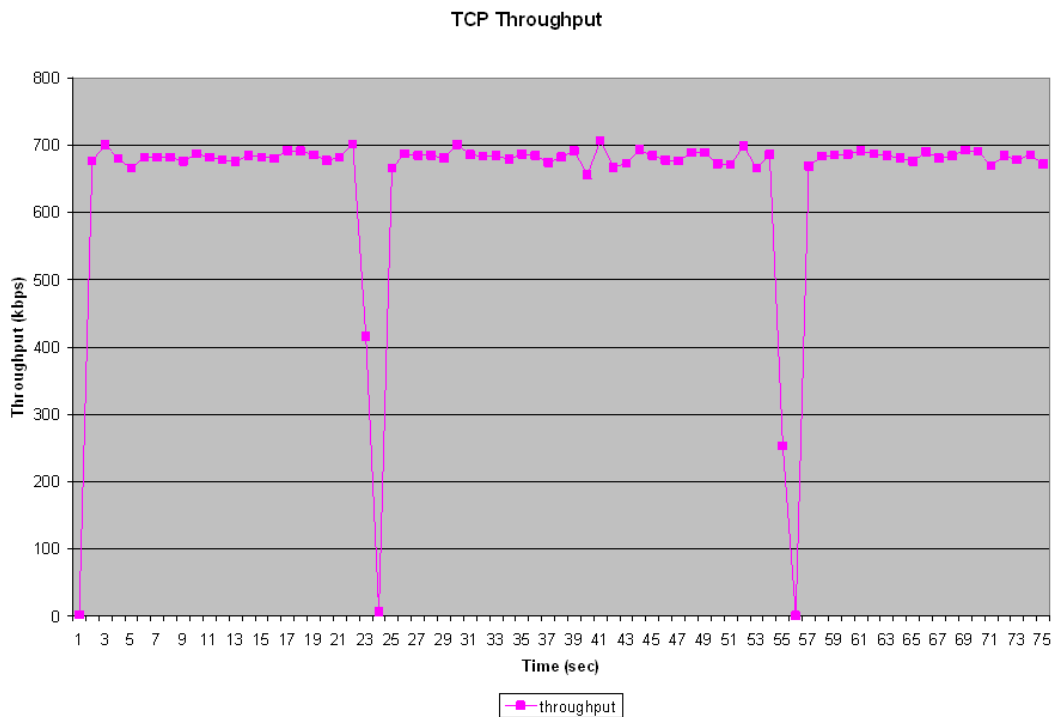


Fig. 6: Normal MIP based handoff results (TCP)

Table 1: Improved Results

Statistic	Normal MIP	MRT Based MIP	Improvement	Percentage
Avg Throughput (kbps)	819	840	21.361	3 %
Instantaneous Throughput 1 st Handoff (kbps)	0	270	270	33 %
Instantaneous Throughput 2 nd Handoff	6	201	195	23 %
Average Delay (msec)	49.24	31	18.24	37 %

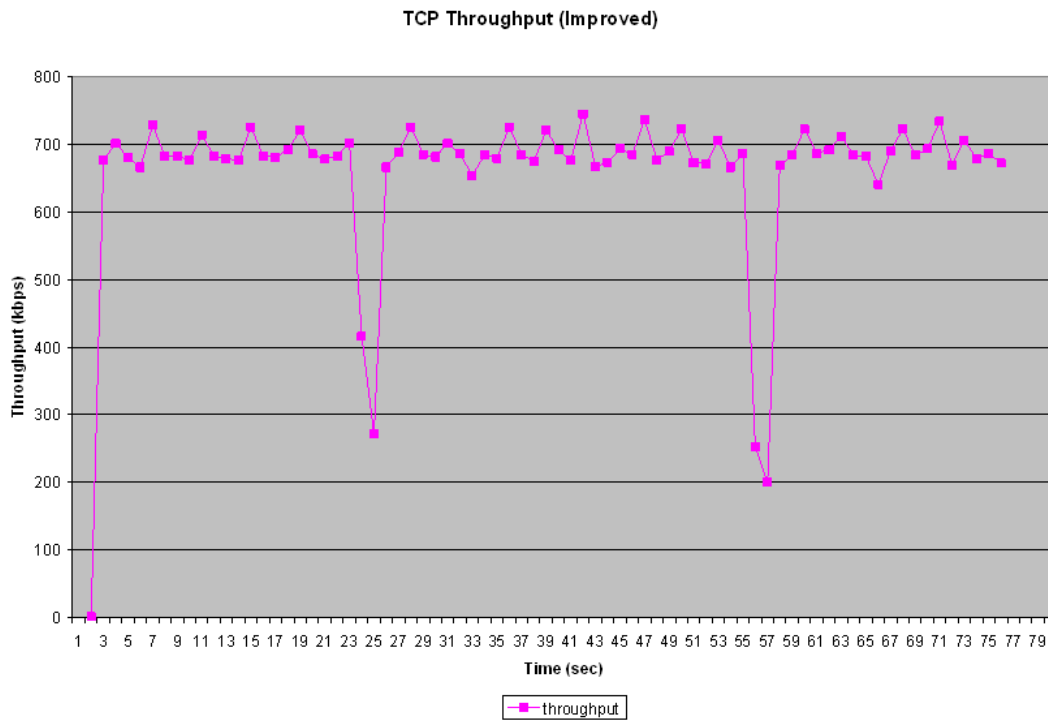


Fig. 7: MRT based MIP handoff results (TCP)

4.2 Simulation Scenario 2:

For simulation scenario 2, same network topology is considered as for scenario 1 as in Figure 5. Here, real time traffic with UDP as transport protocol is being used. The MN was made to move in a similar fashion between one HA and two FA2, so the MN did two handoffs. The motion of the MN was controlled so that it does not move in a random fashion; rather it was made to move in one direction. The simulation results are shown in Figure 8 and Figure 9.

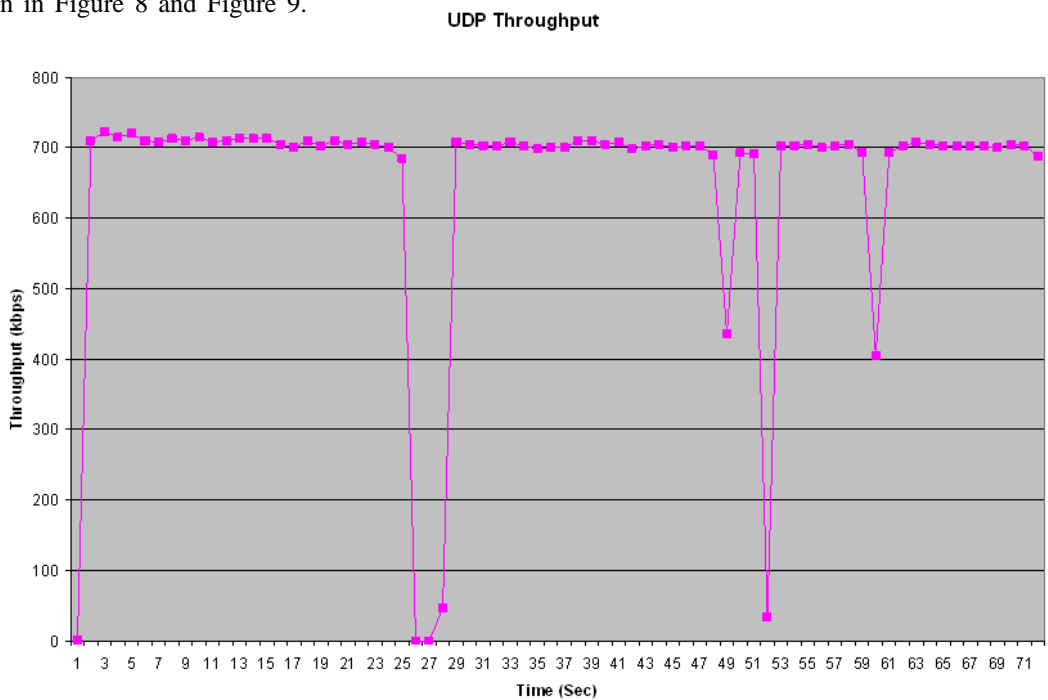


Fig. 8: Normal MIP handoff results (UDP)

It can be clearly seen by comparing the results in Figure 8 and Figure 9 that for UDP type traffic, the handoff delay and consequently the achieved throughput are significantly improved as was the case for TCP type traffic. All the results for scenario 2 are depicted in Table 2.

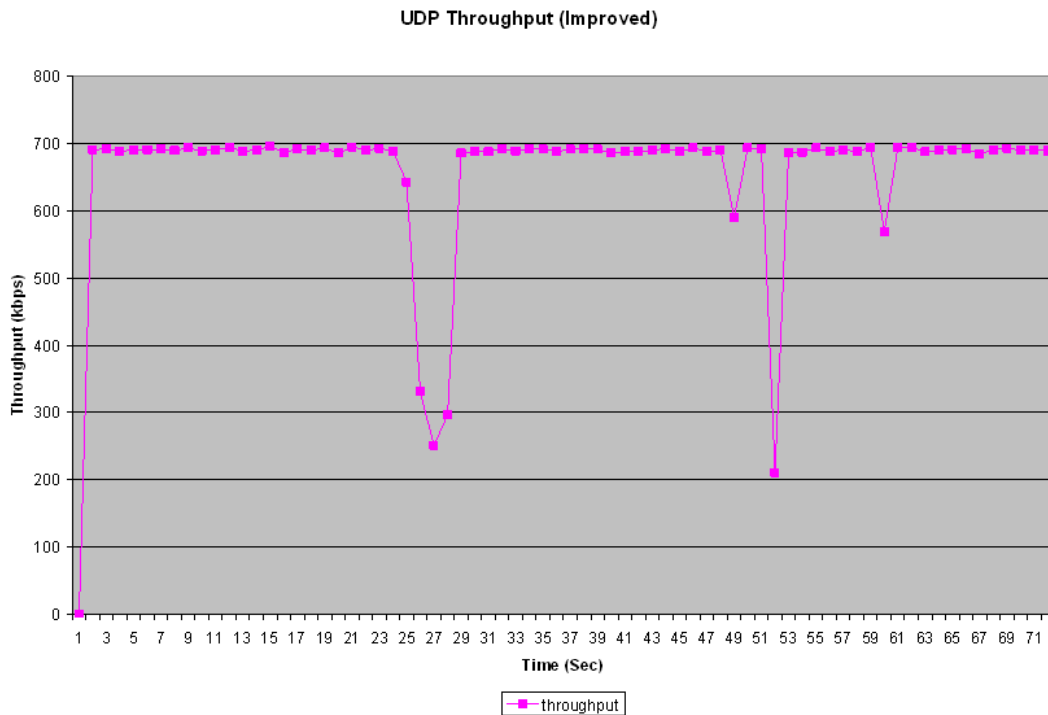


Fig. 9: MRT based MIP handoff results (UDP)

Table 2: Results Scenario 2

Statistic	Normal MIP	MRT Based MIP	Improvement Factor	Percentage
Average Throughput (kbps)	781.4	806	24.8	3.2 %
Instantaneous Throughput 1 st Handoff	0	250	250	31 %
Instantaneous Throughput 2 nd Handoff	34	201	167	21 %
Average Delay (msec)	56.88	34.6	22.3	39 %

5. Conclusion:

In this research work we aimed at analyzing the handoff procedure in MIPv4 with a view to subsequently improve upon it. As MIP is the protocol that is going to be used for future networks like 3G and beyond which are going to support real time multimedia applications like VoIP and video conferencing so it is imperative that the protocol be robust and reliable in all respects to support such services.

It was also found that the overall handoff delay was closely linked to the different stages involved in the handoff. In other words each stage contributed to the delay, so in order to improve the handoff each one has to be dealt with separately. The micro-mobility protocols which exploit the notion of not having to resort to frequent registrations stood out as far as the Registration process was concerned. Similarly, a faster movement detection required L2 triggers in order to speed up the process of movement detection. The Route Optimization solution on the other hand provides a shorter route but overwhelms the MN itself with frequent Binding Update messages. Routers on the other hand lack support for MIP specific routing. The idea of involving the Router in the MIP operation was new and genuine, and therefore, it was chosen.

For the purpose of Simulation, ns2, well known event driven Simulator was chosen. The handoff procedure was simulated for four different scenarios involving firstly, one and then two MNs. Both TCP and UDP types of traffic was used in the simulations. Handoffs were done by the MN between HA and the FA in order to study its behavior. The end to end delay as well as instantaneous and average throughputs of the simulations was recorded for the standard MIP. It was found that the instantaneous throughput deteriorated drastically at the handoff in all the cases. The end to end delay of the data packets was also recorded. Finally the mobility routing table based scheme which relies on shorter path to the MN was analyzed. The same scenarios of the

simulations were run on the modified protocol. It was found that the end to end delay reduced by at least 30% and at the most 45%. These reading are indeed quite encouraging. It was also found that data loss during the handoff improved quite substantially, in the range from 25% to 35%. Finally, a marginal improvement was also observed in the average throughput of the overall simulation.

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