Performance Evaluation for Mobility Management Protocols in Cellular IP and Hawaii Mobile Networks

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ABSTRACT

Handover management is one of the most critical issues that mobility management protocols are concerned with. This process becomes even more critical in the case of Micro-mobility where the Mobile host is expected to encounter frequent handovers. Several IP micro-mobility protocols have been proposed to enhance the performance of Mobile IP in an environment with frequent handoffs. In this paper we make a details study of how the performance of the handoff schemes of two candidates for micro-mobility protocols, namely HAWAII and Cellular IP. The aim of the paper is to investigate the impact of handoffs on TCP by means of simulation traces that show the evolution of segments and acknowledgments during handoffs. Application of these models allows a comparison of two important handoff schemes: the Multiple Stream Forwarding scheme of HAWAII and the Semi-soft Handoff scheme of Cellular IP.

Keywords: *IP micro-mobility, CIP, HAWAII, handoff*

1 INTRODUCTION

Today the most world's powerful technology trends, the Internet and mobile communications. With the majority of information and new services being deployed over IP, the increasing variety of wireless devices offering IP connectivity, such as PDAs, handhelds, and digital cellular phone, is beginning to change our perceptions of the internet. Mobile data communication will likely emerge as the technology supporting most communication including voice and video. The third generation mobile radio communication systems (UMTS, CDMA2000) use a packet data transfer and switching technology as preferred solution. At the same time, the research community is investing a major effort to provide an "all-IP" end-to-end solution, commonly referred to as fourth-generation (4G) systems. 4G systems will support IP services transparently in a highly heterogeneous infrastructure independent of the underlying physical layer [1].

Mobile IP [MIP] [2] is the current standard solution designed for mobility management in IP network. It allows a Mobile Host (MH) to change its point of attachment from one access router to another. However Mobile IP is not designed to support fast handoff and seamless mobility because after each migration a local address must be obtained and communicated to the home agent (HA). This will introduce considerable delays in the handoff process due to the round-trip time between the Foreign Agent (FA) and the Home Agent (HA) during the registration process. Applied in an environment with frequent handoffs, this may lead to unacceptable disturbance to ongoing sessions in terms of handoff latency and packet loss.

Over the past several years a number of IP Micro-mobility protocols have been discusses in the IETF mobile IP working group. Most of these protocols adopt a hierarchal approach by dividing the network into domains. Mobile IP is used to support mobility between two domains called macro-mobility. While Local movements of a mobile within an administrative domain called micro-mobility. IP micro-mobility protocols are designed for environment where mobile hosts change their point of attachment to the network so frequently. Micro-mobility protocols reduce the number of registrations that an MH has to do by allowing the MH to avoid having to register with the home agent (HA) every time it moves within the same domain [5].

This has the benefit of reducing delay and packet loss during handoff and eliminating registration between mobile hosts and possibly distant HAs when mobile hosts remain inside their local coverage areas. The Cellular IP [6] and Hawaii IP [4] protocols achieve faster and more seamless local mobility support in limited geographical areas. However there are still shortcomings and inefficiencies with these protocols. The Cellular 1P protocol does not support seamless handoff when a mobile host attaches to a new access point and loses contact with the previous one. The Hawaii IP protocol can handle this situation but does not handoff as quickly as the Cellular IP protocol does. Both the Cellular IP and Hawaii IP protocols include their own handoff schemes for local mobility. Cellular IP support two handoff schemes while Hawaii IP protocols use four handoff schemes.

In this paper we present a performance comparison of the handoff schemes of two micro-mobility protocols Hawaii and Cellular IP (CIP). We show that the difference in handoff quality depending on the design of these protocols. The rest of the paper is organized as follows. The second section of this paper we describe the Cellular IP and their handoff schemes. The third section of this paper we describe the Hawaii protocols with two handoff schemes (MSF and UNF). The fourth section we then present the simulation using the ns simulator and compare some performance aspect of the MSF and UNF schemes of HAWAII and the hard handoff and Semis-oft handoff schemes of CIP. Finally Conclusion remark and future work.

2 MOBILITY MANAGEMENT

Mobility management consists of two components namely location management and handoff management [11, 12, and 13].

- Location management, this is refers to the registration or location update (LU) and paging.
- Handoff management is the most important issue in mobility management. It is refers to the ability of the network to allow a call in progress to continue as the MN continues to move and change its point of attachment.

Location management concerns the discovery of the current point of attachment of a mobile user for the delivery of incoming calls. When the MN move to other location it must informs the network of its location at times triggered by movement, timer expiration, this procedure perform by registration or location update.

In the case of mobile hosts maintaining location information in support of being continuously reachable would require frequent location updates which would consume precious bandwidth and battery power. This signaling overhead can be reduced through the introduction of paging. Mobile hosts are expected to typically operate on batteries with limited lifetime. This makes it important to save idle mobile hosts from having to transmit frequent location update messages. This requires explicit support from networking protocols, such as the ability to track location approximately and the ability to page idle mobile hosts. Idle mobile hosts do not have to register if they move within the same paging area. Rather, they only register if they change paging area.

Handoff management is performed in three steps. The first stage is the initiation, in which the MN changes its point of attachment with a base station, it sends request to the current base station for handoff to the target BS. Then the connection generation follows and the network must find new resources for the handoff connection and perform additional routing operations. Finally the third step is the data flow control, where the delivery of the data from the old connection path to the new one is maintained according to the service agreement.

In cellular environment there two kinds of handoff, the first one (Intracell) when the MN moves to a new AP belonging to the same subnet, it performs a Layer2 handoff. The second (Intercell) when the MN moves to anew AP belonging to another subnet, it performs a Layer3 handoff.

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3 CELLULAR IP

The Cellular IP [5, 6 and 7] is a proposal to the IETF made by researchers from Colombia University and Ericsson. A Cellular IP network consists of interconnected Cellular IP nodes. A Cellular IP node that has a wireless interface is also called a Base Station. Mobility between gateways is managed by mobile IP while mobility within access networks is handled by Cellular IP. Cellular IP access networks are connected to the Internet via gateway router. Mobile hosts attached to an access network use the IP address of the gateway as their Mobile IP care-of address. Figure 1 illustrates the path taken by packets addressed to a mobile host.

3.1 Routing and Paging

The Cellular IP base stations emits beacons on regular basis, this allows the mobile host to locate their nearest base station.
When a Mobile host finds its nearest base station it has to register to this cellular IP network and sends a Route Update message to its connected base station, this route update message is routed internally in the cellular IP network from the base stations to Cellular IP Gateway by using a hop-by-hop shortest path routing mechanism. As the route

update message travels to the gateway via base stations, route cache mappings are created in the base station, the path taken by these packets is cached by all intermediate base station. These cached routing maps are also used for packets destined for the Mobile host.
The routing entries in the Cellular IP nodes are soft state. In order not to lose its routing path, a mobile host has to refresh its routing entries periodically. In Cellular IP this is done by a regular data packet or by sending a route update message if the mobile host has no data to transmit [6].

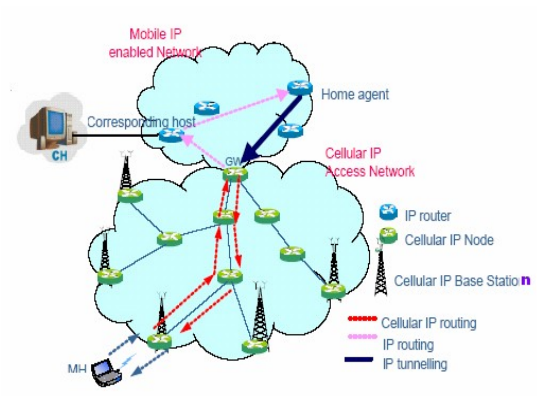

Figure 1Cellular IP access network

If the mobile host wishes to maintain these mapping but not transmit data it can send a special Internet Control Message (ICMP). A typical example of this is when a mobile host receives UDP stream of packets on the downlink but has no data to transmit on the uplink.
When a mobile host changes to a new base station it must send a route update packet, which contains authentication information, to its new Base Station, this will modify the Route cache mappings. Since data packets do not contain authentication information and hence they cannot modify the route cache mapping but only refresh the mappings. Packet send by Corresponding host to mobile host are first routed to the host HA and then tunneled to the gateway. The gateway detunnels packets and forwards them toward a base station. Inside a Cellular IP network, mobile hosts are identified by their home address, and data packets are routed without tunneling or address conversion.
Mobile hosts that are not actively transmitting or receiving data but want to stay reachable for incoming packets, have the opportunity to let their route cache entries time out and to maintain paging cache entries. The difference between the route cache and the paging cache is that paging caches are not necessarily maintained on each Cellular IP node and have longer timeout values. Paging caches are also updated and refreshed by any packet sent by the mobile host. When an incoming call is detected at the gateway, a paging message is transmitted to the mobile host's current paging area to establish the call. The mobile host receives the paging packet; it moves to active state and creates its Route Cache mappings as shown in Figure 2

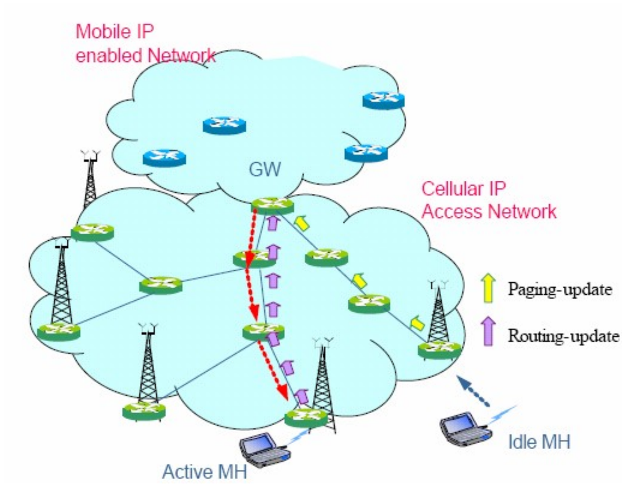

Figure 2 Paging Update/Routing Update

If a Cellular IP node, that does not maintain a paging cache, receives a downlink packet for a mobile host for which it has no routing entry in its route cache, it broadcasts the packet to all its downlink neighbors. A node that has paging cache but has no mapping in it for the mobile host discards the packet. Idle mobile hosts do not have to register if they move within the same paging area. Rater they only register if they change paging area. In order to remain reachable mobile hosts transmit paging-update packet at regular intervals defined by paging-update time.

3.2 Handoff Scheme in Cellular IP

The Cellular IP support three types of handoff scheme, hard handoff, indirect handoff and semi-soft hand off. In Cellular IP a handoff is always initiated by the mobile host. Mobile host listen to beacons transmitted by base station and initiate handoff based on signal measurements by sending a route update packet to the new base station.

3.2.1 Cellular IP hard handoff

Cellular IP hard handoff is based on simple approach that trades off some packet loss in exchange for minimizing handoff signaling rather than trying to guarantee zero packet loss. When Mobile hosts switches to a new base station, it send a route-update packet to the new base station, hence it has stopped listening to the old base station. Packets that are traveling on the old path to the old base station will be lost. No packets are transmitted along the old path once the route-update massage has created a new mapping at the cross-over base station that point toward the new base station.

3.2.2 Cellular IP Indirect handoff

The [8] indirect handoff based on some wireless technology can not listen to the current base station while sending a route-update packet to the new base station. It assumed the network can obtain the IP address of the new base station. When the mobile host decides to make a handoff instead of sending a route-update packet to the new base station directly, it sends the packet to the current base station. This packet will have as its destination IP address, the IP address of the new base station. The old base station forwards this packet with a flag indicating indirect handoff to the gateway. The gateway delivers the packet to the new base station using normal IP routing.

3.2.3 Cellular IP Semi-soft handoff

On the semi-soft handoff the mobile host switches to the new base station, transmits a route update message with a flag indicating the semi-soft handover while listening to the old base station. The route update message reconfigures the route caches on the way to the gateway router and adds an entry to the cache of crossover node. Downlink packets for the specific mobile host are duplicated and sent along paths, the new one and the old one. After a fixed amount of time, the mobile host finally migrates to the new base station and then sends another route update message to complete the semi-soft handover.

This second route update message sets up a proper path to the new base station and stops the cross-over node duplicating packets. If the path to the new base station is shorter than to the old one, some packets may not reach the mobile host. To overcome this problem, packets sent along the new path need to be delayed. A mobile host may get some duplicate packets or detect a loss of few packets. To prevent this delay device can be used to keeps the packets looping a specified time before sending them towards the MH through the new route. This delay ensures data stream on the new route does not get ahead of the stream traveling the old route. A delay device mechanism, located at the crossover node, should provide sufficient delay to compensate for the time difference between the packets travelling on the old and new paths.

4 HAWAII

The Hawaii [4] Handoff-Aware Wireless Access Internet Infrastructure was proposed to the IETF by researchers from Lucent Bell Labs. Like in Cellular IP, HAWAII responsible for the micro-mobility within a domain while the macro-mobility is handled by Mobile IP.

4.1 Routing and Paging

In HAWAII a hierarchy based on domains is used. The gateway into each domain is called domain root router (DRR). A HAWAII domain comprises several routers and base stations running the HAWAII protocol, as well as mobile hosts. When the Mobile host enters into a foreign domain the mobile host is assigned a co-located care-of-address. The mobile hosts keep its network address unchanged while moving within a domain. The Corresponding Node (CN) and the Home Agene (HA) do not need to be a ware of the host's mobility within this domain. A mobile host in a HAWAII environment runs a standard Mobile IP protocol. Therefore mobile host in the Hawaii domain exchanges only MIP control messages with the network, while the routing within a Hawaii domain is realized with UDP-based Hawaii messages. Hawaii messages are never forwarded outside the domain, not even to the MH. The MH must support a bit modified way to handle some MIP messages.

There are three types of HAWAII path setup messages: power-up, update and refresh. On power up a mobile host sends a Mobile IP registration request message to the corresponding base station. The base station then sends a HAWAII path setup power-up message to the domain root router which is processed in a hop-by-hop manner. On all routers on its way to the domain root router this power-up message adds a routing entry for the concerned mobile host. The domain root router finally acknowledges this path setup power-up message to the base station which finally notifies the mobile host with a Mobile IP registration reply. Thus, the connectivity from that domain root router to the mobile hosts connected.

The routing entries in the routers are soft-state, i.e. they have to be refreshed periodically by path setup refresh messages, which are sent independently by each network node and which can be aggregated.

Routers, not passed by a path setup message related to a mobile host; do not have any knowledge about its whereabouts. Whenever a router receives a packet for such an unknown mobile host, e.g. from another mobile host within the domain, it uses a preconfigured default interface pointing towards the domain root router. This packet will be forwarded in this direction until it will arrive at a router knowing a route to the addressed host. In worst case this will be the domain root router. Mobile hosts in standby state only have to notify the network on a change of paging area and not on each base station handover. When a packet arrives for a mobile host in standby state, the network has to page it before it delivers the packet. This paging induces the mobile host to switch to active state immediately. For using Hawaii's paging support, it is necessary to have link-layer paging functionality on the wireless link which means that the mobile host is able to identify its paging area and to detect paging requests.

A typical solution for identifying the paging area is, that base stations periodically send beacon signals including the paging area identities on a broadcast channel, so a mobile host listening to this channel can easily detect a change. The paging requests of the base stations can be sent on separate paging channels to which the mobile hosts are listening.

The network has to maintain paging information for each mobile host and has to deliver paging requests for these hosts up to the base stations from where on link-layer paging mechanisms are responsible. One way to achieve this HAWAII relies on the IP multicast routing protocol. Each paging area is assigned a multicast group address and all base stations within that paging area join this multicast group.

4.2 Handover Mechanisms

Four alternative setup schemes control handoff between access points. The appropriate path setup scheme is selected depending on the service level agreement (or operator's priorities among QoS parameters, e.g., eliminating packet loss, minimizing handoff latency, and maintaining packet ordering). The four path setup schemes can be classified into two classes. The first class includes two forwarding path setup schemes: MSF and an alternative the SSF schemes. The second class includes two non forwarding schemes: the UNF scheme and MNF scheme [3].

4.2.1 Forwarding path setup schemes

In these path setup schemes, packets are first forwards from the old base station to the new base station before they are diverted at the crossover router. We define the crossover router as the router closest to the mobile host that is at the intersection of two paths, one between the domain root router and the old base station, and the second between the old base station and the new base station.

As mentioned above two variants of forwarding schemes in HAWAII are proposed, one that works with standard IP routing tables to update the host-based entries and another scheme where the IP routing table is extended to accommodate interface-based information.

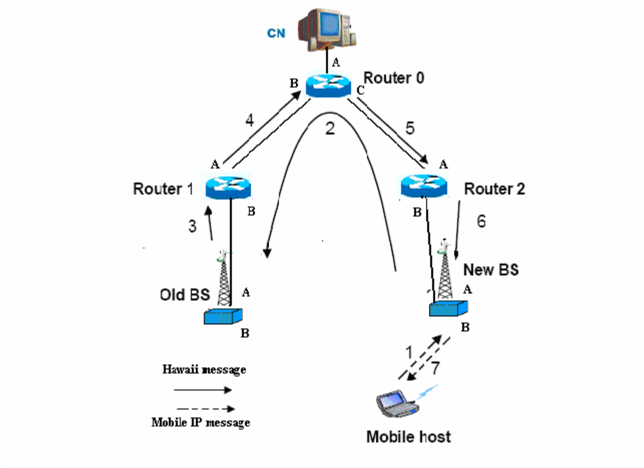

Figure 3 Hawaii path setup scheme MSF

These schemes are known as Multiple Stream Forwarding (MSF) and Single Stream Forwarding (SSF). In the following the MSF scheme analyzed in this paper is describe. The MSF scheme is illustrate in Figure 3.

When handoff occurs the mobile host loses contact with the old base station and at the same time MH sends a Mobile IP registration message (Message 1) to new base station. The new base station then sends a HAWAII path setup update message (Message 2) directly to the old base station. This message contains the new base stations address. The old base station performs a table look-up for a route to the new base station and determines the interface, interface A, and next hop router, Router 1. The old base station adds forwarding entry for the mobile host IP address with outgoing interface set to interface A. From now on the old base station forwards all data packets, including packets arrived after the handoff and stored in a forwarding buffer at the old base station to the new base station according to the new forwarding entry. The old base station then forwards Message 3 to Router 1. Router 1 performs similar actions and forwards the message 4 to Router 0. Router 0, the cross-over router in this case, changes the forwarding entry that results in new packets being diverted to the MH at the new base station. It then forwards the message towards the new base station. Eventually Message 6 reaches the new base station that changes it's forwarding entry and sends an acknowledgment of the path setup message to the MH, shown as Message 7

Note that this order of updating the routers can lead to the creation of multiple streams of disordered packets arriving at the MH. For example, during transient periods newer packets forwarded by Router 0 may arrive at the MH before older packets forwarded by Router 1 which might in turn arrive before even more older packets forwarded by the old base station. This scheme can also result in the creation of transient routing loops (for example, after old base station has changed its entry to forward packets but before the Router 1 processes Message3). However, note that the disordered streams and routing loops exist for short periods of time. The main benefit of this scheme is that it is simple and results in no loss.

The BSs use a forwarding buffer for each MH in order to store the packets to be forwarded in the handoff procedure. All packets addressed to a MH are stored in the buffer (even after being transmitted to the MH). This allows that packets sent to the MH but lost because the MH moved out of coverage, will have the opportunity to reach the MH when forwarded to the new BS. Furthermore, the forwarding buffer is provided with a time out mechanism such that the buffer holds a packet only for a limited time period. When the path setup update message arrives at the old BS, all packets outstanding in the buffer for which the time out is not expired are forwarded to the new BS.

4.2.2 Non-forwarding path setup schemes

In these path setup schemes, as the path setup message travels from the new BS to the old BS, data packets are diverted at the cross-over router to the new BS, resulting in no forwarding of packets from the old BS.
There are two variants of the Non-Forwarding scheme, motivated by two types of wireless networks. The Unicast Non-Forwarding (UNF) scheme is optimized for networks where the MH is able to listen/transmit to two or more BSs simultaneously for a short duration, as in the case of a WaveLAN or Code Division Multiple Access (CDMA) network. The Multicast Non-Forwarding (MNF) scheme is optimized for networks where the MH is able to listen/transmit to only one BS as in the case of a Time Division Multiple Access (TDMA) network. In the following the UNF scheme analyzed in this paper is described. The UNF scheme is illustrated in Figure 4. In this case, when the new BS receives the path setup message, it adds a forwarding entry for the MH's IP address with the outgoing interface set to the interface on which it received this message. It then performs a routing table lookup for the old BS then forwards Message 2 to Router 2. This router performs similar actions and forwards Message 3 to Router 0. At Router 0, the cross-over router in this case, forwarding entries is added such that new packets are diverted directly to the MH at the new BS. Eventually Message 5 reaches the old BS that then changes its forwarding entry and sends an acknowledgment, Message 6, back to the MH.

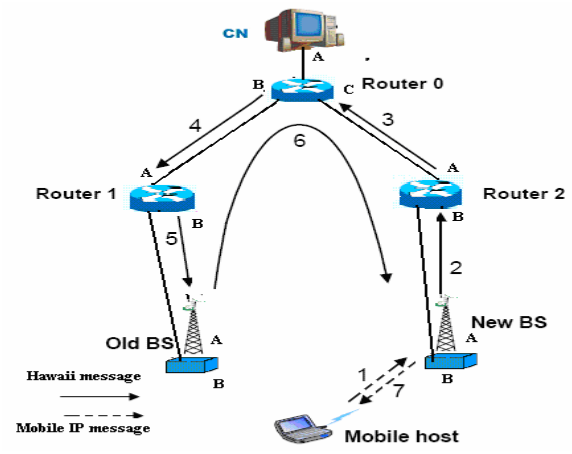

Figure4 Hawaii path setup scheme UNF

5. Simulation Model

To compare different handoff schemes performance, we implement both hard and semisoft handoff of Cellular IP and multiple stream forwarding (MSF) and unicast nonforwarding (UNF) of Hawaii. We used the Columbia IP Micro-Mobility Software (CIMS) [11] based on version 2.1b6 of network simulation [10]. The platform used for the simulation is shown in Figure 5.

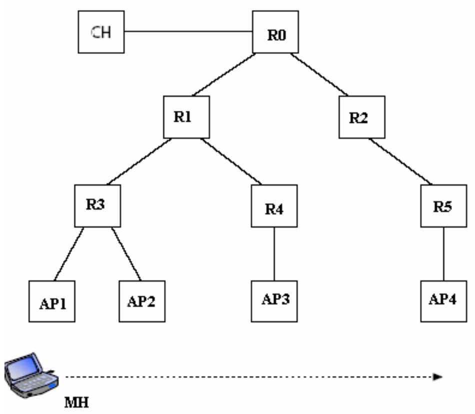

Figure 5 The Simulated network topology

In this network the base station broadcast their beacons at interval of 1 s. The connection between wired nodes uses a 10 Mb/s duplex link with 2 ms delay. Mobile host connect to access point using the ns-2 carrier sense multiple access with collision avoidance (CSMA/CA). The results were obtained using a single mobile host moving between access points (AP1-AP4) at a speed of 20meter/s, the overlap area is 30 m. We compare these schemes for UDP and TCP applications with regarding to delay, packet lost and throughput. During the simulation mobile host receives UDP packets transmitted by CH consist of 210 byte at 10 ms interval. The Reno congestion control was used for TCP with packet size 1460 bytes. The full time for the simulation is 70 second.

6 RESULTS

6.1 UDP Performance

While mobile host making handoff when moving between access points (AP1-AP4) and vice versa and during the simulation time the mobile host performs 6 handoffs in total, the first handoff occurs at 6.14 second, while the last one at 53.08 second. We use UDP probing traffic between the CH and MH and we observe for higher data rates. In each case, the same scenario applied: CBR (constant bit rate) traffic packet size was 210 bytes and the mobile host moved at a speed of 20 meters/second and the full time for the simulation is 70 Second. The number of packet losses for Hard and Semi-soft handoff schemes respectively. Under the Hard handoff scheme, 5 packets were lost during the handoff as shown in Figure 6, while in Semi-soft handoff under the same conditions, by contrast, no packets at all were lost because the mobile host able to listen to two base stations simultaneously for a short duration. In this way those packets which lost in hard handoff scheme during the establishment of new link are saved and arrive at the mobile host.

Therefore as the mobile host moves faster it spends less time in the overlap region so the packet loss increases. The packets lost under MSF Hawaii were 5 packets during the handoff this is depend on the buffering as increasing the buffering time results in increasing the number of packets being buffered and forwarded until loss eliminated as in our simulation the buffering time is 5 ms, while under UNF results in 20 packets were lost. This lost depend of the packet size as the higher data rate the greater the packet loss. For UNF and Hard handoff the delay related to the packet delay between the APs and the cross-over node.

6.2 TCP Performance

Handoff latency is proportional to the round-trip time between mobile host and Crossover router. When the mobile host handoff is completed over shorter handoff distances, the time in which packets can be lost is shorter, resulting in fewer packets lost in total compared to longer handoff distances. The delay for the four micro-mobility shown in Figure 7a and 7b, and from this figure we can observe that the MSF have the maximum delay.

This increase in the delay time is due to the use of buffers for storing and re-directing the packets from the old base station to the new base station.

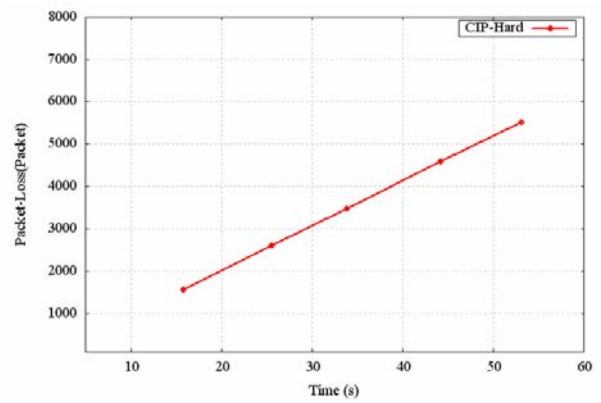

Figure 6 UDP Packet lost CIP-Hard handoff

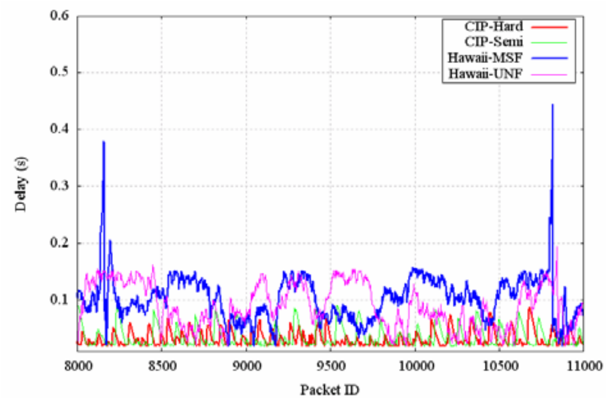

Figure 7a. Packet Delay

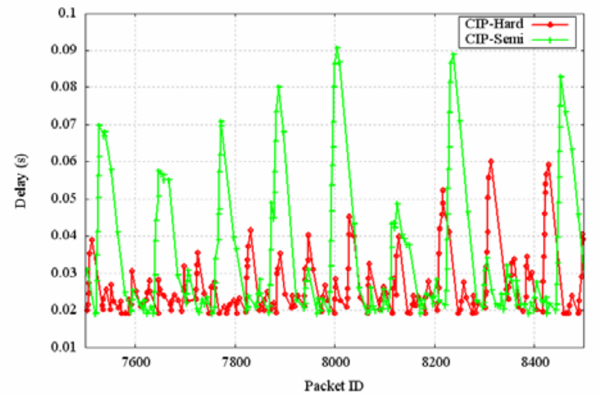

Figure 7b. Packet Delay

In the next experiment we study the impact of handoff performance on TCP throughput. The mobile host performs handoffs between AP1 and AP4 and via versa. The average TCP throughput at the mobile host for all handoff schemes is shown in

Figure 8 and Figure 8. We observe that the performance of TCP degrades as the handoff frequency increases, due to packet loss. As the handoff rate increases TCP has less time to recover from loss. This forces TCP to operate below its optimal operational point From Figure 8 we can observe that semi-soft handoff reduces packet loss and significantly improves the transport throughput in relation to the hard handoff scheme, this performance results associated with using the large buffer. In contrast to the semisoft handoff for UDP traffic, packet loss is not entirely eliminated with TCP.

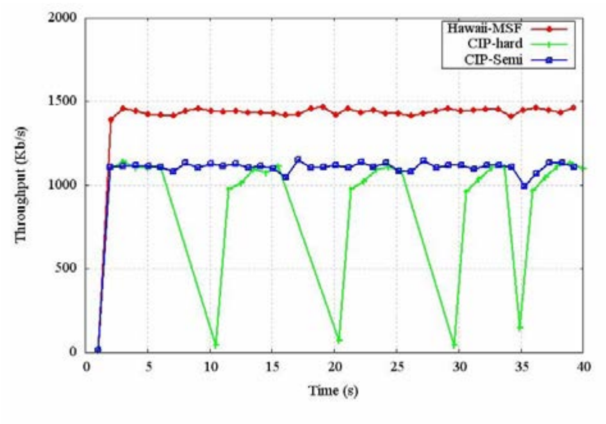

Figure 8 TCP Throughput

From Figure 7 we can observe that semi-soft handoff reduces packet loss and significantly improves the transport throughput.

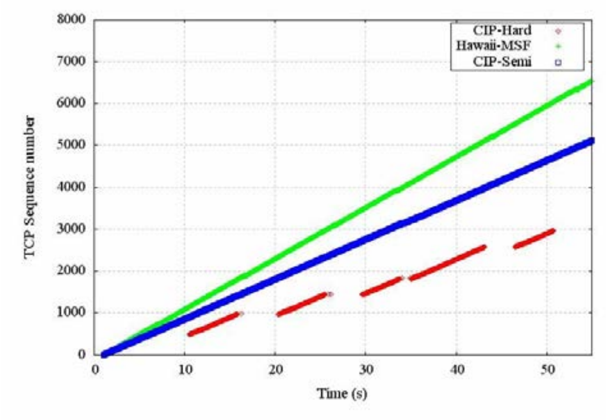

Figure 9 TCP sequence number

From Figure 9 we can observe that semisoft handoff reduce packet loss, the Figure shows that the packet loss in the CIP hard handoff caused by the handoff results in a TCP timeout. The degradiation caused by packet loss increase with increasing handoff. As each handoff packets get lost when the MH switches between AP1 to AP4.

Even using semisoft handoff losses packet can occur, remember that the time between beacons are generated is 1 second. Therefore it can occur that MH receives the beacon from the new base station triggering the handoff after crossing the overlapping area. The advantage of MSF over UNF is that in Hawaii MSF the protocols tries to a voide losing the packets outstanding at the old base station when the connection is switched to the new base station. This is accomplished by forwarding these outstanding packets to the new base station. When using Hawaii with the UNF path setup scheme the MH is able to listen to both the new and the old base station. This scheme and CIP with semisoft handoffs have only small differences in the handoff procedure that is not relevant for their performance evaluation.

7 CONCLUSION

In this paper, we discuss the handoff issue in Mobile IP thoroughly and analyze the key factors that affect MH's handoff performance. The great the handoff distance, the more packet loss results in all handoff schemes in Cellular IP. If the handoff delay is less than the time that the mobile host spent in the overlap region then the Semi-soft handoff scheme has the best performance for Cellular IP protocol. In a Cellular IP network the number of hops from source to destination is constant since all routing-update packets must reach the gateway. However in Hawaii, nodes upper than Crossover router are not involved when handoff is happening. Therefore Hawaii is more reliable and, compared with Cellular IP, has less control signalling in the nodes upper than the Crossover router compared to Cellular IP.

The longer handoff delay in the Hawaii handoff scheme causes greater packet loss than in Cellular IP handoffs. Comparing packet loss numbers for UDP applications in Cellular IP and Hawaii; at higher handoff rates the performance of both the forwarding and the nonforwarding schemes in Hawaii is worse than that of all handoff schemes in Cellular IP. The MH in semisoft must able to send route update packet to new station while listening to the old base station, whereas in MSF scheme the MH switches instantaneously from the old base station to the new base station. It is shown Cellular IP needs less buffers than Hawaii, and the Cellular IP semi-soft can eliminate packet loss but it may cause packet duplicated. Cellular IP employs special signaling even for mobile host while Hawaii keeps Hawaii signaling apart from mobile hosts.

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