Evaluation of Mobile IP Regional Registration with Fast Optimized Smooth Handoff

Hla Myo Tun, Hein Thura Aung and Zaw Min Naing

Abstract- Mobile IP is one of the solutions for connecting mobile nodes without breaking ongoing communications. Mobile IP uses two IP addresses: one is home address and another is care-of address which is used when the mobile node is moved to another network. Although original mobile IP can support seamless roaming, it still has many problems such as packet loss during handoff and handoff latency. Those problems usually effect on the performance of mobile IP. In mobile IP regional registration, a Gateway Foreign Agent (GFA) is added at just one hop away from foreign networks. Registration process within the same domain does not need to connect with the home agent and the GFA performs as local home agent for the mobile node. In Fast Optimized Smooth Handoff (FOSH), the foreign agents share information of mobile nodes by sending binding updates to each other. By sending registration request message to all entries in the Cache, the mobile node can perform an early registration. In our proposed method, FOSH mechanism is applied to mobile IP Regional Registration in order to reduce the number of packet loss that is lost at foreign agents during handoff. 'Network Simulator Version 2' (NS2) is used to implement the proposed method and output trace file is manipulated in order to evaluate the performance of mobile IP in terms of packet loss and packet delay. The number of hops between the home agent and the mobile node and the speed of the mobile node is varied as the functions of the performance of the mobile IP in terms of packet delay and number of packet loss.

Index Terms: Mobile IP, Regional Registration, Wireless Communication, Network Simulator 2

I. Motivation

Mobile IP performs three main functions which are Agent Discovery, Registration and Tunneling once the MN enters into a new network. During agent discovery process, the MN determines whether it is at home network or foreign network by checking agent advertisement messages from the agents. If it is not at home network, it registers with the new FA and get the care-of address. In the registration process, the FA also notifies the HA of the new location of the MN. In the mean time, the HA intercepts all data packets that are sent to the MN from other nodes and after registration, the HA creates a tunnel to the MN and sends all data packets that it intercepts. While the MN is away from its home network, it always receives data packets through the tunnel. When it sends data to other nodes, it uses normal routing protocol and sends directly to the CN. It is the duty of every HA to intercept all data packets and forwards them to the MN whether it is at home network or foreign network [1]. In this way, the MN can maintain the ongoing communication with other nodes even it moves away from its home network.

However, the mobile IP technology is still not at an acceptable state as the new technology for mobile networks in term of performance. It still has problems in security, handoff latency, encapsulation overhead, routing mechanism and signal load on networks. Thus several extensions are added to the original mobile IP in order to improve the performance. The MN registers with the HA every time it moves away from its home network, and so this causes signaling burden on the agents and network. Moreover, the signaling delay will also decrease the performance of Mobile IP if the distance between the MN and the HA is too far. Mobile IP Regional Registration (Mobile IP RR) [2] is one of the extensions to the original mobile IP to reduce those signaling load and delay. Mobile IP RR introduces a new entity which is called Gateway Foreign Agent (GFA) between FAs and the HA. The GFA acts as a local representative of the HA and administers a group of FAs. Thus the GFA introduces a network hierarchy to the MN in the visited network. The address of the GFA is advertised in the domain by the FAs and if the MN enters the domain for the first time, it uses the address of the GFA as its new care-of address when it registers its new location to the HA. When the MN moves within the domain, it does not need to register its new location with the HA but with the GFA only. In this way, the signaling load on both visited network and the home network are reduced and makes the registration process faster.

In mobile IP data transmission process, when the MN sends data to CN, it sends directly to the CN whereas when the CN sends data, it sends to the MN via the HA. That causes triangular routing, increases the number of lost packets and makes the mobile IP performance inefficient if the distance between the CN and the MN is small but the MN and the HA is large. Optimized Smooth Handoff [3] can reduce those problems by sharing binding updates among FAs, the HA and the nodes (both the CN and the MN) and buffering packets in FAs that are sent to the MN while it is moving from one network to another. In OSH mechanism, when the MN registers with the new FA, it also notifies the new FA to send

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its new location to the previous FA by using previous foreign agent notification which is added to the Registration Request message. So, the previous FA can update the current care-of address of the MN with the new FA and the previous FA can now redirect the data packets to the MN. When the HA and the previous FA receive the binding update from the new FA, it also forwards the binding updates to the CN in order for the CN to be able to send data directly to the MN. In that way, triangular routing problem can be avoided. Although, the OSH mechanism tries to reduce the number of lost packets, it is also important to consider the buffer size of the FAs. Moreover, if the MN takes longer to find a new FA when it leaves from a network, the buffered packets at the previous FA will overflow. In order to avoid this problem, sending agent advertisement Messages more frequently and more FAs provided are possible, but sending messages too many will burden the network traffics and more coverage area will tend to more hardware equipment requirement which means more cost.

Fast Optimized Smooth Handoff [4] enhances the performance of the original OSH by introducing Neighbors Cache in the FAs. In OSH mechanism, the buffered packets are forwarded to the MN from the FAs only when the MN has established connection with the new FA. That causes the sequence of the packets out of order which may cause jitter, and delays the arrival of the packets. In FOSH mechanism, each FA has a neighbor cache which stores the addresses of the adjacent connectable FAs. That neighbor cache is stored in the neighbor advertisement List of the MN when the MN registers with a FA. When the MN moves to a new network, it broadcasts the registration request message to all the addresses of the FAs in its neighbor advertisement List. In that way, the MN doesn't need to wait for the Agent Advertisement message from the FAs and an earlier connection can establish between the MN and the newly visited FA. That makes the handoff process faster and reduces the number of lost packets during handoff.

In our research, we intend to improve the performance of the Mobile IP Regional Registration by combining with FOSH mechanism. Mobile IP RR can effectively reduce the number of lost packets by adding a GFA but it still suffers from the packet loss during handoff. Moreover, by combining with FOSH, in the hierarchical topology of Mobile IP RR, an early registration process can be occurred and this will make the number of lost packets less than ever.

II. Proposed Method

In our research, Mobile IP Regional Registration (Mobile IP RR) is integrated with FOSH method in order to improve the performance of original mobile IP. Mobile IP Regional Registration can reduce the signaling cost and number of lost packets. However, the performance of Mobile IP RR is still not acceptable as it still has problems of packet loss as there is no information sharing among FAs along with the movement of the MN. Moreover, the MN has to wait for the Agent Advertisement messages and this situation cause unnecessary handoff delay and packet loss. FOSH method can provide a faster handoff method and thus reduce the number of lost packets during handoff. So, FOSH method is applied in mobile IP Regional Registration topology so that the existing FOSH will become more realistic, efficient and have a better performance in terms of packet loss, signaling cost and handoff latency. The details of proposed method are as follows.

A. Topology

Figure.1 shows hierarchical topology of the network in our research. As seen in Figure, there is one GFA, one HA, FAs and MN. The GFA is a local administrator of several FAs in the proposed topology. The FAs are grouped in the same domain which is under the administration of GFA. Each FA is identified by the network prefix as part of the internet address. The MN, the GFA, the FAs and the HA are assumed to support security and authentication among each other. The HA is the traffic source of MN in our proposed network topology. The HA will send data continuously to the MN while it is moving from one FA to another.

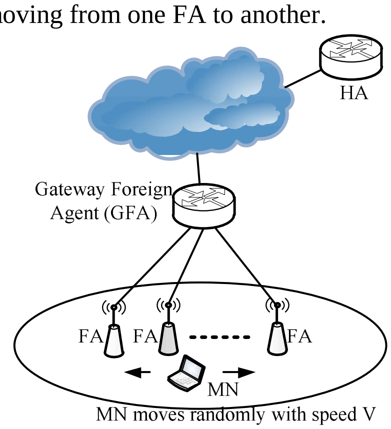

Fig.1. Networking Topology of Mobile IP Regional Registration with FOSH

B. Mobile IP Regional Registration (Mobile IP RR) with FOSH

As in FOSH method [4], FAs and MN in our proposed network topology will have neighbor caches. Those Neighbor Caches store the addresses of FAs that are adjacent to each other. In order to be able to store the addresses of FAs in Neighbor Caches, the adjacent FAs must be connectable with each other regardless of whether they are physically close or not. Using the addresses in neighbor caches, the FAs will send agent advertisement messages to all entries in neighbor caches to notify its adjacent FAs of its presence and mobility services. The FAs that receive those advertisement messages will store them in their neighbor advertisement List. Each FA uses that

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particular neighbor advertisement List and includes all the addresses in the List in its agent advertisement message when they broadcast them for mobile nodes. In that way, the MN will be advertised for not only the availability of its visiting FA but also of the adjacent ones. Figure.2 and 3 show how the MN is advertised for the availabilities of the adjacent FAs.

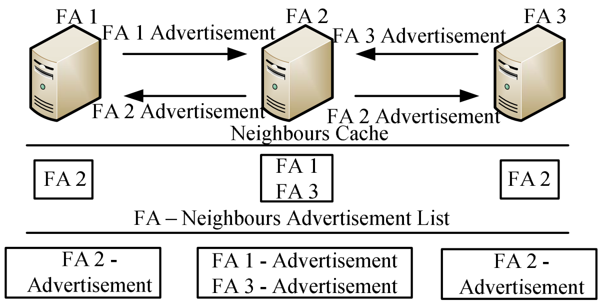

Fig.2. Advertisements for Adjacent Availabilities of FAs

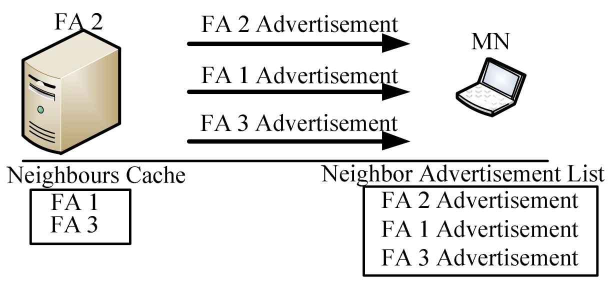

Fig.3. Advertisements to the MN

The MN is moving within the domain that is under the control of the GFA while receiving data from its HA. FAs within the GFA domain will transmit agent advertisement messages periodically to notify any MN that enters its coverage area of their presence and available mobility services. Once the MN enters the domain and receives those advertisement messages, it registers its new location with its HA via the current FA and GFA. It uses the address of GFA as its new care-of address in registration process with its HA so that regional registration can be performed [2]. That care-of address is not changed as long as the MN is moving to different FAs within the same domain and only regional registration is required to be processed when the MN enters new FA area. The Internet will be connecting the GFA with the HA and the number of hops between them will be varied as a factor of performance evaluation. The more hops between them, the longer registration time the MN takes.

The MN registers its new point-of-attachment with its HA via GFA and FA for the first entrance into the domain. However, subsequent movements of the MN within the domain will be regionally registered with only GFA via visited FAs [2]. After regional registration process with GFA, the newly connected FA is informed by the MN to send binding updates which includes information of its new location to the previously connected FA by using previous foreign agent notification extension [4]. Then, after the previous FA receiving the Binding Update message, the previous FA extracts the message and stores the source IP address (the address of new FA) in its neighbor Cache and will forward all data packets sent to the MN that it buffers during the handoff time to the MN via the new FA. In the mean time, the new FA can store the address of the previous FA in its neighbor Cache. In this way, the adjacency of the FAs is revealed by the movement of the MN and both the new FA and the previous FA store binding updates of each others' in their neighbor Cache. Figure.4 shows how the FAs share information with each other.

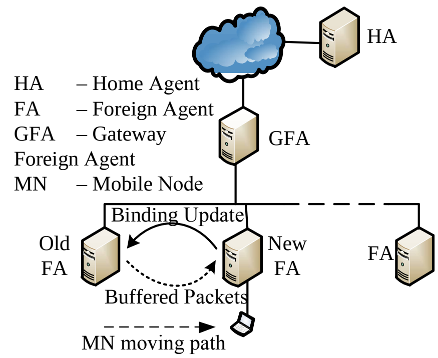

Fig.4. Information Sharing between Previous FA and New FA

Not only the FAs store advertisement messages in their neighbor advertisement Lists, the MN also has neighbor cache and stores advertisement messages in its neighbor advertisement List. When the MN enters into a new FA area, it will send registration request messages to all FAs in its Neighbor Advertisement List. If the visited FA is already one of the entries in neighbor advertisement List, the MN can establish a faster registration as it does not need to wait for Advertisement messages from FA. After having sent all request messages, the MN clears its neighbor cache. The newly connected FA refills the neighbor cache of MN with newly updated entries. With the help of entries in neighbor cache, the MN can establish a fast registration process with new FA.

There are two conditions for the MN in possibility of establishing faster registration process with new FA in our proposed method. As in FOSH technology, fast registration procedure is able to be occurred only when the address of visited FA is in MN's neighbor advertisement List. So, if the MN has already the address of newly visited FA in its neighbor advertisement List, the MN can save time for awaiting agent advertisement message and thus faster registration process is occurred. Otherwise, the MN has to wait for Agent Advertisement message from FA as in normal Mobile IP technology. Figure.4 shows the signaling diagram for the proposed method.

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In Figure.4, we assume that the MN moves from old FA to a new FA. As the MN does not have information about the new FA in its List, it waits for agent advertisement message from new FA as in normal mobile IP protocol. Once the MN has received Advertisement message, it registers with new FA. However, Figure.5 shows the signaling diagram of MN in which case the MN already has the address of new FA in its neighbor advertisement List. So, it does not wait for agent advertisement message from new FA and it sends registration request message once it enters into the area of new FA.

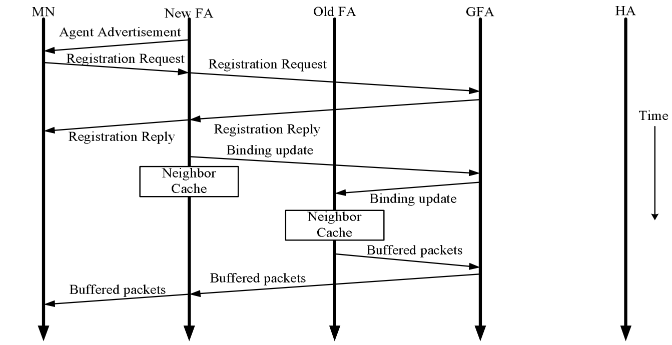

Fig.5. Signaling Diagram of the Proposed Method

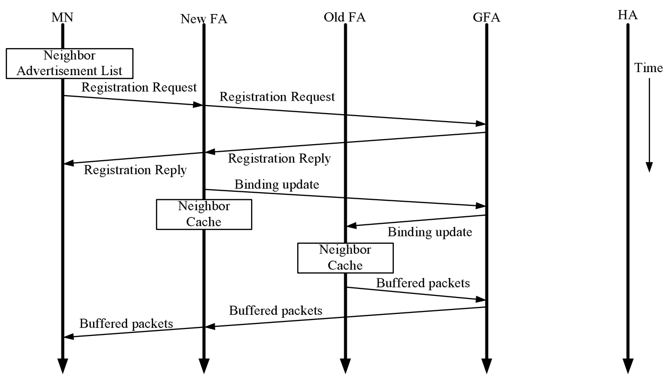

Fig.6. Signaling Diagram of the Proposed Method

Our proposed method is supposed to reduce the signaling delay and number of lost packets during handoff. However, in our proposed method, the FAs share binding information about the movement of MN. In order to share that information, they have to send and receive messages with each other. That means extra data packets are injected into the network and the traffic of the network is burdened more than that of normal Mobile IP. So, as one of the perimeters in assessing overall performance of Mobile IP, the total signaling load in the network will also be simulated and measured to acquire a better and more complete performance evaluation.

III. Simulation Model

NS2 is a discrete-event simulator, where actions are associated with events rather than time. An event in a discrete-event simulator contains execution time, a set of actions, and a reference to the next event. Figure.5 shows the concept of discrete-event simulation in which events are interlinked and forming a chain of events on the simulation chronology. As it is event-driven simulation, time between a pair of events cannot be always constant. When the simulation starts, events in the chain are executed from left to right. Simulation in NS2 consists of two main stages [09Iss]: network configuration and simulation. In network configuration stage, a network is designed and built with an initial chain of events which are scheduled to occur at a certain time (e.g., start CBR (Constant Bit Rate) at 1 second). In simulation stage, NS2 moves along the chain of events and executes each event chronologically [5,6].

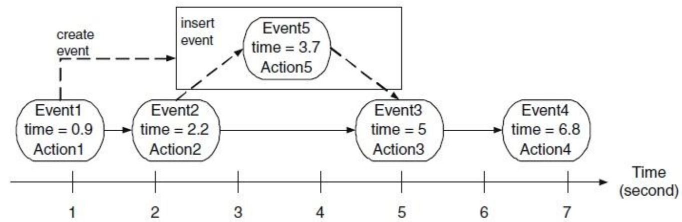

Fig.7. Event-driven Simulation

A. *Simulation Topology of Proposed Method*

The network topology is designed before the simulation has started. In our network topology, there are from three to eleven mobile nodes, two GFAs for two domains, one HA, one CA and eight FAs. The World Wide Web (www) is assumed to be the separator between home network and foreign networks. Each four FAs will make one wireless domain which is administered by each GFA. The CN is attached to a wired domain and sending packets to the mobile nodes by using TCP and FTP. The mobile nodes will be moving from one FA to another within different domains while they are receiving packets sent from the CN. Figure.6 shows the hierarchical topology of the proposed method. Figure.7 shows the distribution of FAs in each wireless domain.

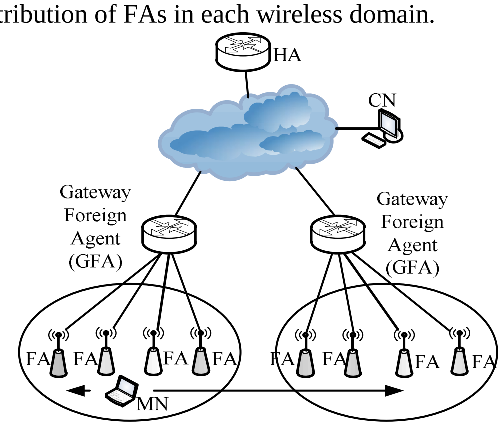

Fig.8. Hierarchical Topology of Proposed Method

As our proposed method, the mobile nodes will move around different FAs and when they enter into a new domain, they will register their new locations with the HA while using the address of GFA as their new care-of address. Roaming to

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different FAs in the same domain does not need to register with the HA but with the GFA instead as in mobile IP regional registration. Along with the movement of the MN, the FAs will share the information of the MN and the availabilities of their adjacent FAs by sending bind updates to each other. Then those FAs will store the addresses of other FAs that are physically interconnected with each other in their neighbor Advertisement Lists. When they broadcast advertisement messages, those FAs will broadcast all addresses of FAs that are stored in their advertisement lists. The MN will store those advertisement lists in its neighbor cache. When it moves to a new network, it will send registration request messages to all entries in its cache. Early registration process can be done if the newly visited FA is in the list of the cache. If the FA is not in the list of the cache, it will wait for the agent advertisement messages as in normal mobile IP. After the registration process is done, the FA will clear the neighbor cache of the MN and fill with new entries.

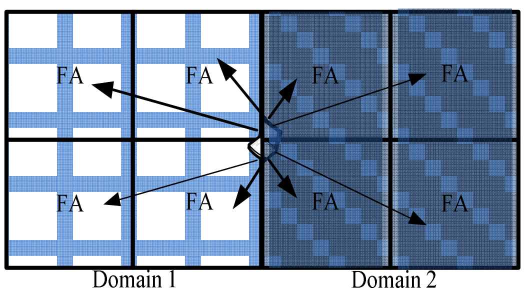

Fig.9. Distribution of FAs in Each Wireless Domain

IV. PERFORMANCE EVALUATION

The simulation result of mobile IP and mobile IP regional registration with FOSH are analyzed in terms of number of packet loss and signaling delay.

A. Simulation Environment

In the simulation environment, there will be a correspondence node (CN) which is the traffic source of the whole network. The link between CN and base station nodes uses TCP/IP and the traffic source is FTP which sends 1kbytes of packets to every mobile node in the simulation environment. In network topology, there will be up to eleven mobile nodes, one HA, eight FAs and two GFAs that administers eight FAs with two wireless domains and the CN which is the traffic source. There are one wired domain and two wireless domains.

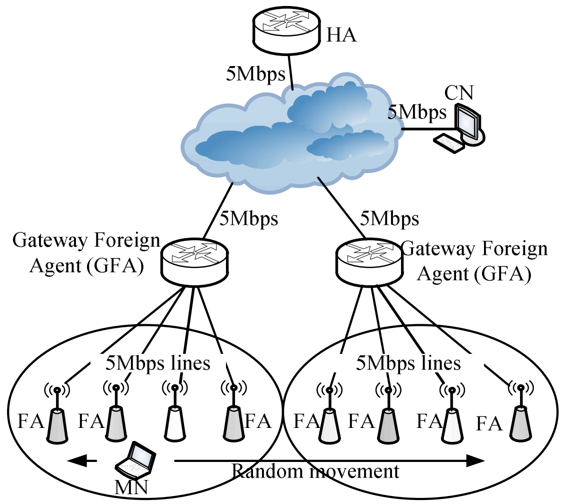

Fig.10. Network Topology of Proposed Method

The link layer of wireless domains is wireless 802.11 and routing protocol is DSDV. The entries in wired domain and base station nodes in wireless domains are linked using 5Mbps transmission rate with 2ms transmission delay. The mobile node will move randomly in different FAs with various speeds. The movement of the MNs will be described later on. The FAs will broadcast agent advertisement messages in every one second.

In order to evaluate the performance of Mobile IP and proposed method, the number of hops between HA and MNs and the speed of MNs will be varied. The performance will be checked in terms of number of packet loss and transmission delay between the sender and the receiver. Figure.8 shows the network topology of our proposed method.

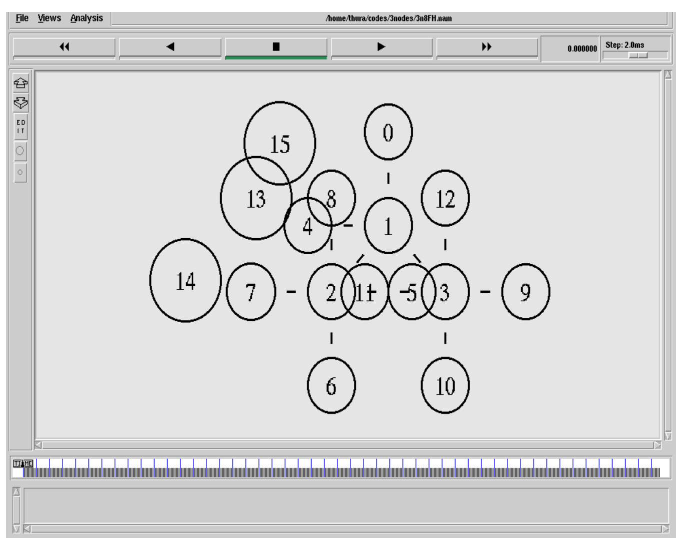

Fig.11. Visual Window of Network Animator

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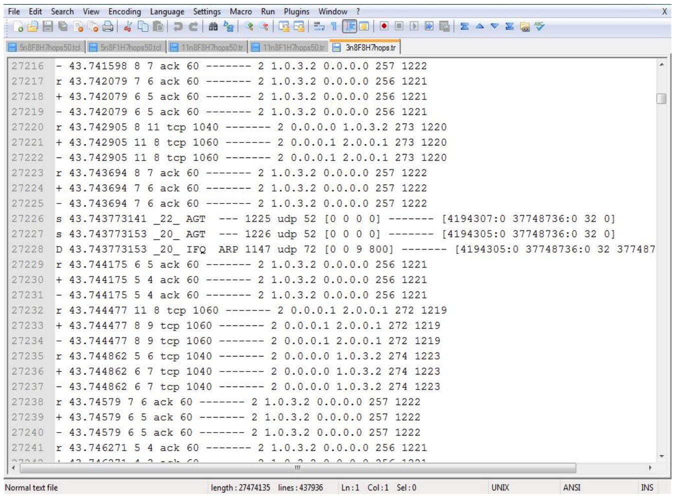

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27216 - 43.741598 8 7 ack 60 ------- 2 1.0.3.2 0.0.0.0 257 1222
27217 r 43.742079 7 6 ack 60 ------- 2 1.0.3.2 0.0.0.0 256 1221
27218 + 43.742079 6 5 ack 60 ------- 2 1.0.3.2 0.0.0.0 256 1221
27219 - 43.742079 6 5 ack 60 ------- 2 1.0.3.2 0.0.0.0 256 1221
27220 r 43.742905 8 11 tcp 1040 ------- 2 0.0.0.0 1.0.3.2 273 1220
27221 + 43.742905 11 8 tcp 1060 ------- 2 0.0.0.1 2.0.0.1 273 1220
27222 - 43.742905 11 8 tcp 1060 ------- 2 0.0.0.1 2.0.0.1 273 1220
27223 r 43.743694 8 7 ack 60 ------- 2 1.0.3.2 0.0.0.0 257 1222
27224 + 43.743694 7 6 ack 60 ------- 2 1.0.3.2 0.0.0.0 257 1222
27225 - 43.743694 7 6 ack 60 ------- 2 1.0.3.2 0.0.0.0 257 1222
27226 s 43.743773141 _22_ AGT  --- 1225 udp 52 [0 0 0 0] ------- [4194307:0 37748736:0 32 0]
27227 s 43.743773153 _20_ AGT  --- 1226 udp 52 [0 0 0 0] ------- [4194305:0 37748736:0 32 0]
27228 D 43.743773153 _20_ IFQ  ARP 1147 udp 72 [0 0 9 800] ------- [4194305:0 37748736:0 32 377487
27229 r 43.744175 6 5 ack 60 ------- 2 1.0.3.2 0.0.0.0 256 1221
27230 + 43.744175 5 4 ack 60 ------- 2 1.0.3.2 0.0.0.0 256 1221
27231 - 43.744175 5 4 ack 60 ------- 2 1.0.3.2 0.0.0.0 256 1221
27232 r 43.744477 11 8 tcp 1060 ------- 2 0.0.0.1 2.0.0.1 272 1219
27233 + 43.744477 8 9 tcp 1060 ------- 2 0.0.0.1 2.0.0.1 272 1219
27234 - 43.744477 8 9 tcp 1060 ------- 2 0.0.0.1 2.0.0.1 272 1219
27235 r 43.744862 5 6 tcp 1040 ------- 2 0.0.0.0 1.0.3.2 274 1223
27236 + 43.744862 6 7 tcp 1040 ------- 2 0.0.0.0 1.0.3.2 274 1223
27237 - 43.744862 6 7 tcp 1040 ------- 2 0.0.0.0 1.0.3.2 274 1223
27238 r 43.74579 7 6 ack 60 ------- 2 1.0.3.2 0.0.0.0 257 1222
27239 + 43.74579 6 5 ack 60 ------- 2 1.0.3.2 0.0.0.0 257 1222
27240 - 43.74579 6 5 ack 60 ------- 2 1.0.3.2 0.0.0.0 257 1222
27241 r 43.746271 5 4 ack 60 ------- 2 1.0.3.2 0.0.0.0 256 1221
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Fig.12. Output Trace File

Visual window of network animation that is generated as one of the output types from the simulation with NS2 is presented in Figure.10. After the simulation is done, a text based trace file is generated and that trace file is manipulated with awk program to get a data set and number of packet loss and signaling delay are calculated from the data set. Figure .11 shows the format of trace file with 3 mobile nodes running at different speeds with 7 hops distance between their HA.

B. Movement of MN

Instead of moving straight of MN, the MN will move to any directions randomly in order to be more realistic. The MNs will move within eight FAs with different speeds. The movement of the MNs is shown in Figure .9.

V. Simulation Results

In order to evaluate the performance of mobile IP and proposed method, the number of data hops between HA and MN is varied and the speed of the MN is also varied so that more frequent handoffs will be occurred. The performance is evaluated in terms of number of packet loss and signaling delay. The speeds of the MN is varied from $10ms^{-1}$ to $50ms^{-1}$ and the number of hops between HA and MN is set up to seven hops. In order to be more likely to reality, the number of MNs is also increased up to eleven MNs.

A. Speed

First, the number of MNs is set to three and the number of hops between HA and MN is kept constant at seven hops. Then, the speed of the MNs varied from $10ms^{-1}$ to $50ms^{-1}$.

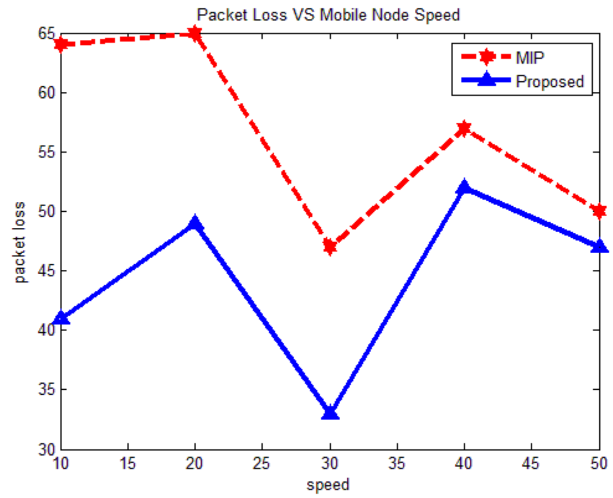

Fig.13.Packet Losses as Function of Mobile Nodes' Speed

The traffic source is CN and traffic protocol is TCP with FTP. The MNs are moving within different FAs while they are receiving packets from the CN. Figure.11 shows the graph of both mobile IP and our Proposed Method for number of packet loss as a function of mobile nodes' speed.

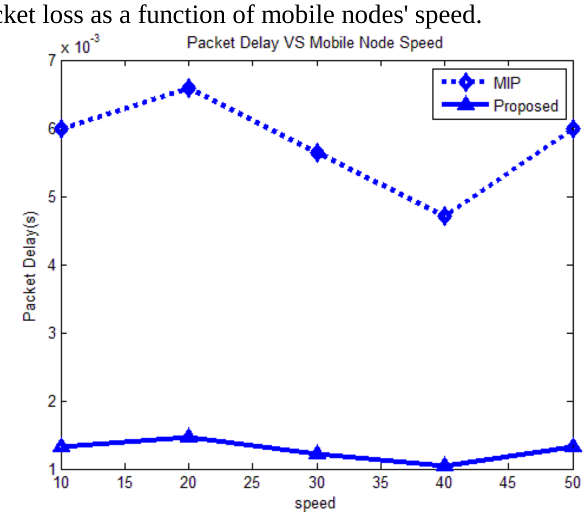

Fig.14. Packet Delay as Function of Mobile Nodes' Speed

As shown in Figure.11, the proposed method can save number of lost packets than the original Mobile IP. Packet loss is normally occurred during handoff process due to signaling delay and in the proposed method, signaling delay can be reduced by the mechanism of both Mobile IP regional registration and FOSH. Now, Figure.12 shows the graph of signaling delay as a function of speed.

B. Number of Hops

Now, the speed of the MNs will be kept constant at $10ms^{-1}$ and the number of hops between HA and MNs will be varied as a function. The number of MNs is three and the traffic source is FTP with TCP from CN and three MNs are moving within two wireless domains with four FAs in each. Table1 and 2 show the performance comparison of number of lost packets and packet delay as a function of number of hops between HA and MNs.

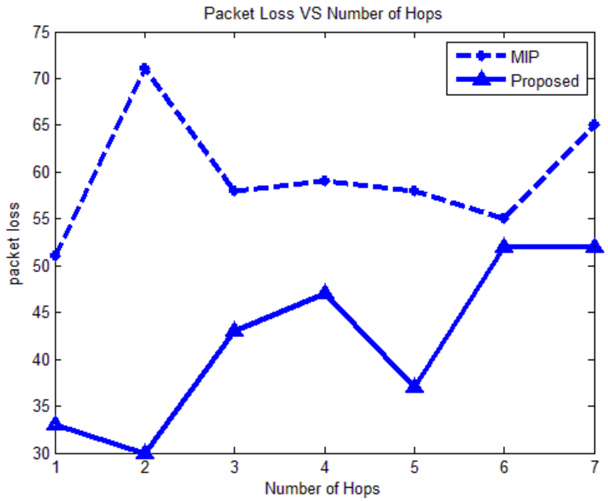

Fig.15. Packet Loss as a Function of Number of Hops

Figure 13 shows the number of packet loss as a function of number of hops between HA and MNs. As shown in Figure 13, the number of packet loss can be increased when the distance between HA and MNs is large.

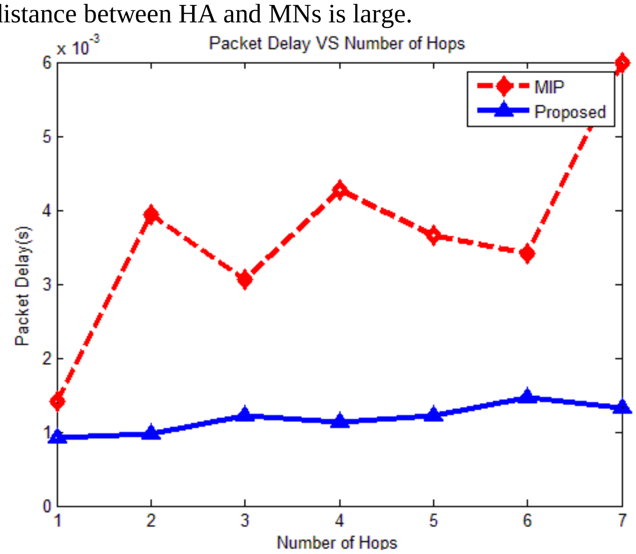

Fig.16. Packet Delay as a Function of Number of Hops

So, in the proposed method, new entities, GFAs are added and the number of packet loss is reduced. Figure 14 shows the graph of packet delay as a function of number of hops. The package delay is also reduced in the proposed method as shown in Figure 14.

TABLE I
PERFORMANCE TABLE OF PACKET LOSS AS A FUNCTION OF NUMBER OF HOPS

Number of Hops	1	2	3	4	5	6	7
MIP	51	71	58	59	58	55	65
Proposed Method	33	30	43	47	37	52	52
Saved Packets	18	41	15	12	21	3	13
Saved Packets in (%)	35.2	57.7	25.9	20.3	36.2	5.5	20

TABLE II
PERFORMANCE TABLE OF PACKET DELAY IN MILLISECOND AS A FUNCTION OF NUMBER OF HOPS

Number of Hops	1	2	3	4	5	6	7
MIP	1.4	3.9	3.1	4.3	3.7	3.4	6
Proposed Method	0.96	0.98	1.2	1.1	1.2	1.5	1.3
Saved Packet Delay Time	0.44	2.92	1.9	3.2	2.5	1.9	4.7
Saved Packet Delay Time in (%)	31.4	74.9	61.3	74.4	67.6	55.9	78.3

C. Number of Mobile Nodes

Now, the speed of MNs is kept constant at $50ms^{-1}$ and the number of hops between HA and MNs is kept at 7 hops. Instead, the number of MNs is increased and the performance of mobile IP and proposed method is evaluated.

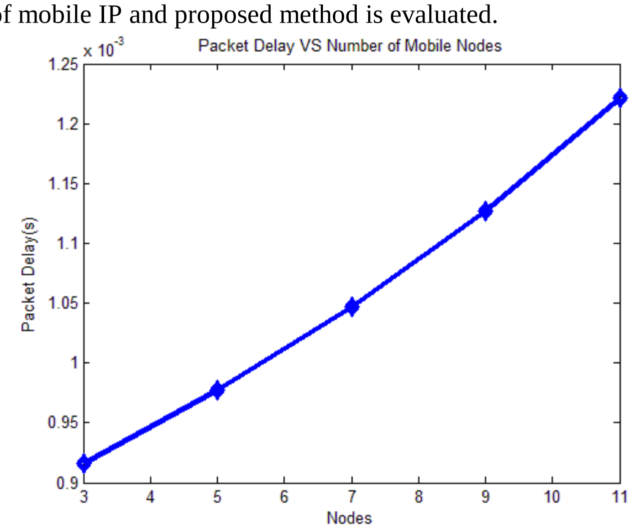

Fig.17. Packet Delay as a Function of Number of Mobile Nodes

Figure.15 shows the graph that illustrates the characteristics of packet delay with increasing mobile nodes and Figure.16 shows the graph that mentions the characteristics of packet loss as a function of number of mobile nodes.

According to the simulation results, the proposed method has better performance than original mobile IP in terms of packet delay and number of lost packets.

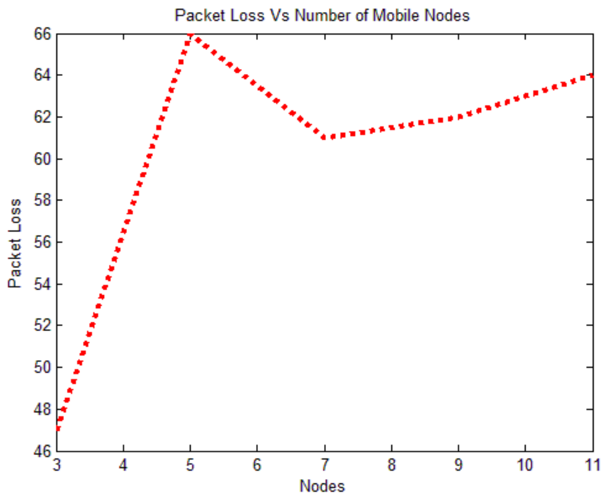

Fig.18. Packet Loss as a Function of Number of Mobile Nodes

VI. Conclusion

As the mobile IP RR does not share the information of MN among FAs, the number of packet loss may increase during frequent handoffs. So, in this research, those two mechanisms are applied together to the original mobile IP. By the mechanism of mobile IP RR, the signaling delay can be reduced and from the mechanism of FOSH, the number of packet loss can be reduced. In the simulation, popular network simulation tool (NS2) is used to evaluate the proposed method against original mobile IP. In the simulation environment, the number of hops between the HA and the MNs and the speed of MNs are varied to check the performance of the proposed method. First, the speed is kept constant and hops are varied and due to simulation results, the proposed method has a good result. Then, number of hops is kept constant and speed of MNs is varied. In that simulation, the proposed method can save signaling delay and number of lost packets. At last, the number of mobile nodes is increased and the performance of the proposed method is evaluated in terms of packet delay and number of packet loss.

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