PERFORMANCE SIMULATION OF A MOBILE-IP EXTENSION FOR OPTIMIZED ROAMING SERVICE

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SUMMARY

IETF RFC 2002 originally introduced the wireless Mobile-IP protocol to support portable IP addresses for mobile devices that often change their network access points with the Internet. The inefficiency of registration process, mainly within the handoff management of this protocol, produces large end-to-end packet delays, since all registrations take place after roaming the mobile node into a foreign subnet, and further degrades the system efficiency due to packet losses between subnets. The criterion to initiate a simple and fast full-duplex connection between the home agent and foreign agent is a very important issue to be considered by a work.

In this paper, a workaround was developed, mapping the roaming behavior to Mobile-IP registration process to present the feasibility of designing and modeling a CIA: communication inter-agents procedure, as an extension to the basic Mobile-IP. It supposes an early registration of mobile node to a subnet predicted to roam into, to reduce the roaming duration and eliminate packet losses. Analytical results of corresponding state-transition diagram, as a function of network parameters, are presented. The heuristic of configuration file during practical setup session for registration parameters, on Cisco platform Router-1760 using IOS 12.3 (15)T is created. Finally, stand-alone performance simulations results on Simulink Matlab, within each subnet and also between subnets, are illustrated for reporting better end-to-end packet delays. Results verified the effectiveness of our Mathcad analytical manipulation and experimental implementation. It showed much lower values of end-to-end packet delay for Mobile-IP using CIA procedure. Furthermore, it reported packets flow between subnets, i.e., no more gaps for data losses.

Keywords: *Cisco platform, delay optimization, mobile-IP capabilities, performance simulation, registration process, roaming, state-transition, wireless computer networks*

1. INTRODUCTION

In contrast to wireless mobile network, the term wireless Mobile-IP (MIP) [1]-[4] network in this context implies that wireless network is based on handling the IP packets of high bit rates between mobile users, such as business travelers with portable computers of some sort (e.g., Laptops). Basic MIP protocol that was originally introduced in IETF RFC 2002 to support portable IP addresses for mobile devices, which often change their network access points with the Internet, encountered some inefficiencies, basically within three main categories according to each step of mobility resource management (MRM) process: location management, routing management, and handoff management. Adding to which here, inheriting from the handoff management between networks, the registration process (RP) [1]-[4], one of the MIP three basic capabilities.

When a mobile host (MH) leaves its present subnet, connection with the Internet or the forwarded traffic from its home agent (HA) must be switched to another agent in the foreign neighboring subnet in order to maintain packets receiving. This operation is referred to as roaming. Roaming, then, is the service during which the **C**ommunication links between MHs and agents are maintained; and adequate connection quality should be ensured within the network when MH travels from the coverage area of one HA to that of a foreign agent (FA). The need for optimized roaming service may also arise for a number of other reasons (e.g., roaming accumulation). Roaming is normally subnet to subnet (inter-subnets or **I**nter-**A**gents in different subnets), and roaming may occur many times during a mobility. It is therefore essential that the roaming procedure should be simple, fast and place minimum loading on the network capacity. The roaming procedure may involve consultations between the HA and nearby FA to the MH. Consequently, the criteria to initiate a full-duplex between the HA and FA, to reduce the roaming duration, is a very important issue to be considered by a work in this paper.

In roaming service, the mobile node (MN) uses an authenticated registration procedure to register its current location with a FA, in order to acquire a new IP address, care-of-address (CoA), to still in contact with the Internet and to inform it's HA of its CoA in order that HA forwards its IP traffic. In this registration procedure is the gap, which causes our problem under study; that is the packet losses (PLs) [5] while roaming. Therefore, PL is based on the aspect of MIP-RP. The basic RP involves four steps:

1. The MN requests the forwarding service by sending a registration request to a selected FA that MN will use.

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2. The FA relays this request to the MN's HA.
3. The HA either accepts or denies the request and sends a registration reply to the FA.
4. The FA relays this reply to the MN.

As we can see, the RP, one of the three core capabilities of the basic MIP protocol, is inefficient, since all the registration steps take place after the MN already roamed into the destined foreign subnet (FS) with an Internet connection Interruption [5] and with no forwarding service yet and just waiting until performing a successful registration. Furthermore, the registration request must first be routed from the FA, which resides in the FS, to the HA, which resides in the home subnet (HS) while both of MN and FA are in the same subnet, but not in the HS (i.e., they have to ask for a permission from the HA, which either accepts or denies the request). Therefore, registration request experiences unnecessary delay in initiating forwarding service to the MN and in turn causes PLs.

In this paper, a workaround is developed, mapping the roaming behavior to MIP-RP. This led to specify the registration procedure of basic MIP protocol as a framework for us, around which we present a feasibility of designing and modeling an intelligent procedure, *CIA: communication inter-agents*, extension to the basic MIP. This procedure platform is based on a *Triple-R sequence* (*RRR: requesting, registering, and then roaming*) that supposes an early registration of MN, to a subnet predicted to roam into, using HA-based registration and EqR-policy (*equilibrium roaming-policy*) [6], as a cost-effective solution to reduce the roaming duration, eliminate the PLs, and bridge the gap between subnets, an area that until now has been largely neglected [2]. The state-transition diagram of the modeling-scenario is manipulated for the system throughput and end-to-end packet delay (EtE-D), and analyzed using equilibrium point analysis (EPA). The heuristic of configuration file during the practical setup session for registration parameters, on Cisco platform Router-1760 using IOS 12.3 (15)T is created. Finally, we illustrate the performance simulation results for reporting better EtE-Ds, using Simulink Matlab, to verify the effectiveness of our Mathcad analytical manipulation, and experimental implementation.

2. CIA PROCEDURE

Essentially, if a MH wishes to roam into a FS, then there must be an authenticated registration procedure [2], [4], shown in Fig. 1, to inform its HA of its CoA and register itself with the FS. This is performed in MIP according to a registration signaling capability.

Simply, our signaling CIA procedure is as follows: Once a MH has recognized that it will roam into a FS (some sort of intelligence) and before it goes outside it's HS area, it should initiate registering by sending a registration request to the nearest HA directly. By default, the nearest HA from MH at this moment will be the nearest from the border of intended FS and it is easily to be recognized by any MH according to the discovery process, which is practically applied with cell information (CI) service.

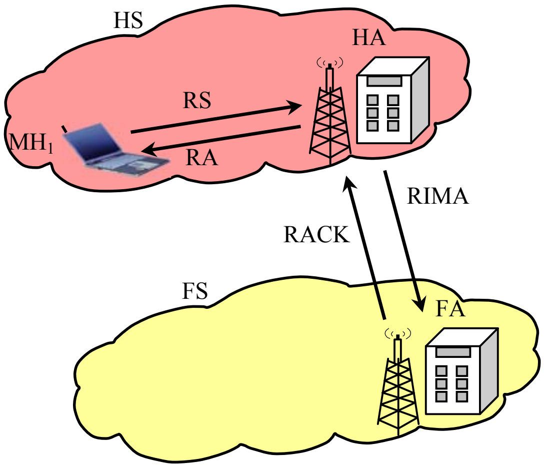

Fig. 1 Registration procedure for roaming in MIP

- **R_1 (Requesting):** In CI service, the MH starts RP by sending a special router solicitation (RS) [2]. This solicitation assists in finding the nearest point of attachment for the roaming node. In the request, MH provides only its permanent IP address and an identifier, which uniquely identifies destined FS.

The HA in turn performs the choosing process of the FA, on behalf of the MH, from it's mobility binding cache (MBC) according to an equilibrium building block strategy (i.e. EqR-policy) [6].

- **R2 (Registering):** Once this nearest HA determined the FA and the temporary IP address, it sends a router advertisement (RA) back to the MH as an acknowledgment (ACK), with its temporary IP and IP of the chosen FA.

After that, HA also sends a roaming initiate message alert (RIMA) to the chosen FA. This message, shown in Fig. 2, contains only both permanent and temporary IP addresses of the MH. The message is encapsulated (or tunneled) within an IP packet whose source and destination addresses are the addresses of HA and FA, respectively, with an expiration time T_L. When the FA receives the alert, it checks it's own cache for updates to process the registration packet, and waits for a waiting time, T_W, until receiving a message alert, whose source and destination are the temporary and permanent addresses of MH and FA, respectively, from the MH that it successfully reached the FA's coverage area.

We can notice that all the previous steps take place while the MH stills in the way to the FS without any loss of time, as possible, where the ideal case is when $T_W = T_P$. After that, FA sends a roaming acknowledgment (RACK) to the HA, informing that it accepted successfully the MH in its subnet.

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IP source address of HA
Permanent IP address of MH_1
Temporary IP address of MH_1
Expiration time T_L
IP destination address of FA

Fig. 2 Mobile-IP registration packet for CIA procedure

- **R3 (Roaming):** Consequently, the HA updates the mobility binding of MH and sends out a broadcast roaming initiate (RI) with the gratuitous address resolution protocol (ARP) [7] to the network. This signal informs the whole network that this node is going to perform a roaming and updates the ARP cache of all hosts and routers that currently have an ARP cache entry for that MH.

This allows the forwarding service to be initiated directly from the HS to FS and establishes a full-duplex connection between the HA and FA, whenever it is needed, to the MH, to enter the on-line state as shown in Fig. 3.

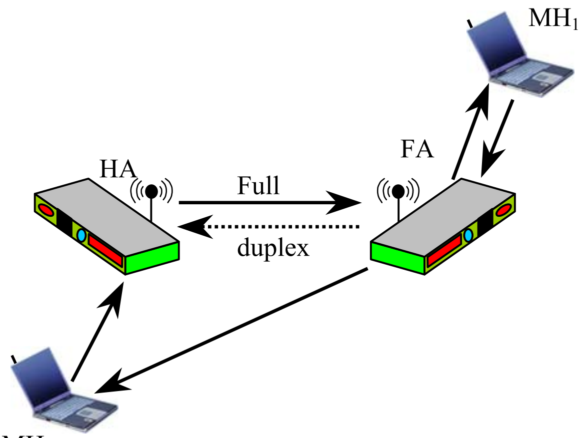

Fig. 3 Full duplex connection between HA and FA

3. CIA MODELING SCENARIOS

As shown in Fig. 4, each agent is modeled as a single server partially queue, with two classes of arrivals, where these two arrival processes are independent. Our modeling challenge is to distinguish between these two types of messaging across the serves that perform the agent functions as follows:

1. Messaging for initiating the roaming service of a MH from the HS to a FS. This type has no queuing and is referred as Class-1, which corresponds to registration requests that initiate the roaming of a MH. Costs due to increased traffic of this type are not considered, since it is expected that these messaging packets will consist of a small percentage of the overall network traffic.
2. Messaging due to the Internet connection or the forwarding service of traffic to a MH. This type must suffer from queuing according to the Markov-modulated Poisson process (MMPP) [8] and is referred as Class-2, which corresponds to data packets to be encapsulated and tunneled to the FA to be forwarded in sequence to the MH.

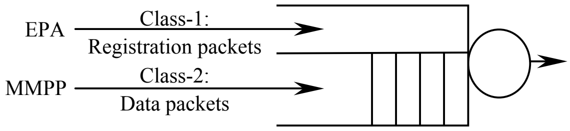

Fig. 4 Modeling the agent

Class-1 requests have a preemptive priority over Class-2 ones, to produce a flexibility of operations and accelerate the process of initiating the full-duplex connection.

Our system model employs the following assumptions:

1. **Agents (A):** Consider mobile Internet is comprised of subnets. Each subnet is defined as a collection of agents and MHs grouped together to achieve required levels of performance and reliability. The total number of network agents (both of HAs and Fas) is *A*.
2. **HA-FA pair:** For modeling reliability purpose we characterize an instance of roaming service by the origin (HA) and destination (FA), and vice versa, of the connection setup, that is by an HA-FA pair. The system reliability here is defined that the probability of deadlock is being minimized.
3. **Mobility Binding Cache (MBC):** It is a cache of mobility bindings of MNs, maintained by each node to be used in tunneling datagrams to MNs. This function is already defined in basic MIP protocol for all agents, adding to which here also the MHs We require also all MHs to maintain a binding cache. This MBC is to be previously configured on each node (MHs/ HAs/ FAs) for containing the IPs of all nodes allover the whole network. MBC entries are being updated periodically by a gratuitous ARP every a time-period η.
4. **No queuing:** Our messaging type is Class-1, which corresponds to registration requests that initiate a roaming of a MH. This type of traffic has no queuing since it has a preemptive priority over Class-2 traffics.
5. **Propagation time (T_P):** The propagation time of message alerts, ACKs, gratuitous ARP requests or replies between nodes is the same, and it is of 100 ns for mobile wireless channels [9], [10].
6. **Fetching time (η):** It is the fetching time of data from the MBC. In other words, it is the choosing time of a FA and temporary IP from MBC entries, or it represents the updating time of MBC entries of the MN inside HA. Each of

these operations takes a fixed amount of time, η units, where $\eta < T_P$.

7. **Bernoulli distribution:** Tokens arrive at each HA from a MN according to a Bernoulli process with a sent-registration-request arrival probability π; i.e., at any slot, the HA with an empty slot can have a token arrival from a MN with probability π. On the other hand, tokens arrive at each HA from a FA according to a Bernoulli process with a received-registration-request arrival probability β; i.e., at any slot, the HA with an empty slot can have a token arrival from a FA with probability β.
8. **Acknowledgment probability (γ / γ'):** It is the probability of getting/sending an acknowledgment from/to the FA, respectively, to start the forwarding service of traffic and it is the same for all the resource AS/AS´ stateplaces from the 1^{st} to T_L^{th} ones, where $\gamma = \gamma'$.
9. **Token length ($1/\delta$):** Tokens are typed objects that represent the information managed by the system. Token length, for a token departure probability δ, is geometrically distributed with the average token length being $1/\delta$ units.
10. **Optimization factor ($1/T_W$):** Optimizing the roaming service for minimum PLs is measured and controlled by the wasting time T_W between agents, until the MN reaches the FA coverage area, (in time units) where $T_W \geq T_P$.
11. **Expiration mechanism (T_L):** The expire parameter is number of seconds (in time units) to send the message-alert registration requests before expiration. The default is 120 s and the range is 1 to 3600 for Cisco platform. If no reply is received, agent sends another registration request after the interval expires. The default is 10 s. The range is 1 to 3600, where $T_L > (2T_P + T_W)$.
12. **Neglected times:** Forming times for message alerts, ACKs, and checking the MBC are negligible, because all its entries are already defined, it contains no data, and it is included in the T_W in parallel, respectively.

The benefit of our CIA model is that it is generalized to also accommodate the FAs to increase the possibility of initiating a full-duplex connection setup, for the development of affordable and scalable platform for roaming service, by decreasing the network EtE-D.

4. STATE-TRANSITION

We will take an abstract transmission model and trace the route of a signal through the MIP network, using suitable values for model parameters. The state-transition diagram for the CIA modeling-scenario is shown in Fig. 5 [11]. An agent can be in any stateplace and remains in that stateplace for a geometrically distributed amount of time, based on the token length (where token lengths are used to model connection holding times of circuits in the CIA procedure), if it is in the on-line stateplace, *OLS*, or a fixed amount of time (one unit) if it is in any other stateplace. Presence of token in a previous stateplace triggers transition to the next stateplace. Thus, transitions implement the activities of the system, while stateplaces are data warehouses that store information until some transition will need it.

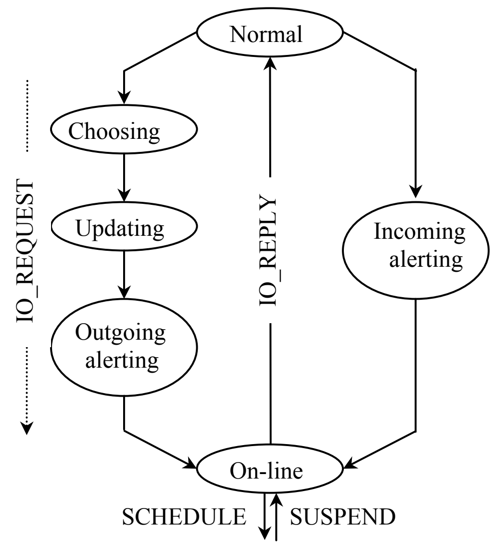

Fig. 5 State-transition diagram

5. CIA PERFORMANCE MANIPULATION

The aspect of MIP deals with the MH registration, where MH is configured with the address of one, more or all HAs. In this case, applying the EPA principle [6] in which it is assumed that the system is always at an equilibrium point of the Markov chain of network states, the total number of network agents (A) will be represented of a Markov chain of the number of agents in each state with a multidimensional state space vector, as follows in (1).

$$A = \begin{bmatrix} A_{NS} \\ A_{CS} \\ A_{US} \\ A_{AS} \\ A_{OLS} \end{bmatrix} = \begin{bmatrix} A_{NS_1} & A_{NS_2} & \cdots & A_{NS_\eta} \\ A_{CS_1} & A_{CS_2} & \cdots & A_{CS_\eta} \\ A_{US_1} & A_{US_2} & \cdots & A_{US_{(2T_P+\eta)}} \\ A_{AS_1} & A_{AS_2} & \cdots & A_{AS_{2T_P+T_W+T_L}} \\ \cdots & \cdots & \cdots & A_{OLS} \end{bmatrix} \quad (1)$$

These HAs may become the bottleneck when there are large numbers of MHs roam in the network and in turn, it is difficult to manipulate this system using Markov techniques [8] because of the very large state space. Therefore, we analyze the system with the aid of EPA [6], as a unified and powerful strategy for dynamic behavior evaluation of complex packet broadcast networks for performance evaluation.

Since all HAs are identical, we will study the state-transition diagram at a single HA (in our case is HA: 147.175.10.1) with a FA (in our case is FA: 147.175.20.3), and aggregate the effect on the total number of agents in the network. The aggregation of communication between the HA and FA, as a unit of all agents, will provide the flow equations for each state, such that the numbers of agents in stateplaces are defined with originating to agents in NS_1:

A : Total number of network agents.
A_{NS} : Number of network agents in normal state (*NS*).
A_{CS} : Number of network agents in choosing state (*CS*).
A_{US} : Number of network agents in updating state (*US*).
A_{AS} : Number of network agents in sent alerting state (*AS*).
$A_{AS'}$: Number of network agents in received alerting state (*AS`*).
A_{OLS} : Number of network agents in on-line state (*OLS*).

It can be obtained [6] that these numbers of agents are given by (consult Fig. 5):

$$A_{NS_K} = C^{K-1} \cdot A_{NS_1} \qquad for\ K = 1,2,...,\eta \tag{2}$$

$$A_{CS_K} = \pi \cdot \left(\frac{1}{1-C}\right) \cdot \left[1 - C^{\eta}\right] \cdot A_{NS_1} \qquad for\ K = 1,2,...,\eta \tag{3}$$

$$A_{US_K} = \pi \cdot \left(\frac{1}{1-C}\right) \cdot \left[1 - C^{\eta}\right] \cdot A_{NS_1} \qquad for\ K = 1,2,...,2T_P + \eta \tag{4}$$

$$A_{(AS/A\dot{S})_K} = \frac{1}{2} \cdot V \cdot \left[1 - C^{\eta}\right] \cdot A_{NS_1} \qquad for K = 1,2,...,2T_P + T_W \tag{5}$$

$$A_{(AS/A\dot{S})_{2T_P+T_W+K}} = \frac{1}{2} \cdot V \cdot (1-\gamma)^{K-1} \cdot \left[1 - C^{\eta}\right] \cdot A_{NS_1} \qquad for K = 1,2,...,T_L \tag{6}$$

$$A_{OLS} = \frac{1}{\delta} \cdot V \cdot \left[1 - (1-\gamma)^{T_L}\right] \cdot \left[1 - C^{\eta}\right] \cdot A_{NS_1} \tag{7}$$

$$;\ Common\quad term:\ C = \left[1 - \frac{\pi + \beta}{V}\right] \quad and \quad V = 1 + \pi\beta$$

- ***Normalized Throughput*** **($\overline{Th}$):** For our network, the number of network agents in on-line state, A_{OLS}, is further calculates the number of active agents. In turn, it represents the throughput of network as a function of different network parameters, upon which the Internet connection or forwarded traffic during roaming will be monitored and controlled for optimized efficiency and better performance. $\overline{Th}$ is defined as the fraction of agents in the active state .

$$\overline{Th} = \frac{No.\ of\ \ active\ \ agents}{Total\ \ No.\ of\ \ agents} = \frac{A_{OLS}}{A} \tag{8}$$

- ***End-to-end Delay (EtE-D)*:** It is defined as the time from a message readiness at a MH until the time that message completes its transmission. This consists of [2] the time required to initiate the registration request-packet in the MH (η), the propagation delay for the special RS (T_P), the time required to re-form the registration packet at the HA (η), the propagation delay for the RA (T_P), the propagation delay for the RIMA (T_P), the time required to check the MBC for updates at the FA (η), waiting time until receiving a message alert from the MH (T_W), the propagation delay for the RACK (T_P), the propagation delay for the RI (T_P), the time until an ACK is received (T_{ACK}) with a geometric distribution, and the message transmission time ($1/\delta$).

As we are intended only in establishing a full-duplex connection between HA and FA and that during this establishing, the message transmitted is only the registration request-packet, with no data is included, then its transmission time is to be neglected. The EtE-D is reduced as in (9):

$$EtE-D = 2 \cdot (\eta + T_P) + T_W + \gamma \cdot \sum_{K=1}^{T_L} K \cdot [1-\gamma]^{K=1}$$
$$;\gamma = \frac{1 - \beta \cdot (A-1)}{\left[\frac{1 + 2\cdot\pi\cdot(T_P + \eta)}{\pi + \beta} + T_P + \frac{T_W}{2} + \frac{1}{\delta}\right] \cdot 2 \cdot \beta \cdot (A-1) - T_P + 1} \tag{9}$$

where
δ : Message departure probability.
π : Sent-registration request-arrival probability.
β : Received-registration request-arrival probability.
γ : Robability of receiving/sending an acknowledgment.
η : Fetching time of data from the MBC (in s).
T_L: Expiration time of registration request (in s).
T_P : Propagation time between nodes (in s).
T_W: Wasting time between agents (in s).
EtE-D: End-to-end packet delay (in s).

6. PRACTICAL IMPLEMENTATION

The following heuristic is of the configuration file that was created during the setup session for registration parameters, on Cisco [12] platform Router-1760/Dram-64 MB/Flash-32 MB using IOS 12.3 (15)T with an access point Cisco Aironet-1230G and a client card with series Cisco Aironet-350G. The IOS 12.3 (15)T was chosen because it is very important to match the native virtual LAN (VLAN) across the link. In the Cisco IOS software versions earlier than 12.1(3)T, we cannot define the native VLAN explicitly, as the encapsulation native command under the sub-interface is not available.

In our practical case under study, the HS has five MHs on interface Ethernet1 [7] (sub-subnet 147.175.10.0) and five on virtual sub-subnet 157.175.10.0. So, there are two MH groups. Each MH has one security association. The HA has an access-list to disable roaming capability by mobile access router 147.175.10.15. Our mobile access router is a router that operated as a MN defined in MIP specification, which allowed a router to roam, as MN: 147.175.10.14, away from its HS and still provide connectivity for devices on its subnet. The 157.175.10.0 group cannot roam in areas where the subnet is 147.175.90.0. The 147.175.10.0 group has a lifetime of 1 hour (3600 s). On the other side, the FA is providing service on a serial interface 1/0.

We progressed through the System Configuration until we came to the registration items that we intended to change. The registration items were configured to set the maximum registration lifetime value of 90 s. The following configuration command script has been created when we implemented practically the sequence of our CIA procedure on wireless MIP protocol:

```
Router# setup
--- System Configuration Dialog ---
!...
! Configuring global parameters:
Enter host name [Router]:
!...
Configuring interface parameters:
!...
router mobile
!
! Foreign Agent Router Configuration
ip mobile foreign-agent care-of serial1/0
!
interface serial1/0
ip address
ip irdp
ip irdp holdtime 30
foreign-agent 147.175.20.3
Care-of addr 147.175.20.25
ip mobile secure foreign-agent 147.175.20.3 spi
100 key hex 12345678123456781234567812345678
ip mobile foreign-service
!...
! Home Agent Router Configuration
ip mobile home-agent
!
! Define which hosts are permitted to roam
ip mobile home-agent broadcast roam-access 1
!
! Define a virtual network
ip mobile network MyJet virtual-network
157.175.10.0 255.255.240.0
!
ip mobile host 147.175.10.14 mobile-network
ip mobile mobile-network MyJet 147.175.10.0
255.255.240.0
!
! The next five lines specify security
associations for mobile hosts on Ethernet1
!
! Deny access for this host
access-list 1 deny 147.175.10.15
!
! Deny access to anyone on network 147.175.90.0
trying to   ! register
access-list 2 deny 147.175.90.0
!
ip mobile host 147.175.10.14  interface Ethernet1
!
! Define which hosts are on Ethernet 1, with
lifetime of 90 ! sec
ip mobile host 147.175.10.11 147.175.10.15
interface Ethernet1 lifetime 90
!
! Define which hosts are on the virtual network,
and the    ! care-of access list
ip mobile host 157.175.10.11 157.175.10.15
virtual-network 157.175.10.0 255.255.240.0 care-
of-access 2
!
! The next five lines specify security
associations for     ! mobile hosts on virtual
network 157.175.10.0
!
register <--- NEW
!...
!
!...
! Mobile Router (MN) Configuration
router mobile
ip mobile router
address 147.175.10.14 255.255.240.0
home-agent 147.175.10.1
mobile-network Ethernet1 <- NEW
! Define Mobile Router Registration parameters
ip mobile registration-lifetime
register lifetime 90
show ip mobile router registration
Mobile Router Registrations:
Home agent 147.175.10.1:
    Registration accepted 04/12/06 08:48:07, On
    Ethernet1
 Care-of addr 147.175.20.25, FA addr
 147.175.20.3, HA addr 147.175.10.1, Home addr
 147.175.10.14
 Lifetime requested 00:02:00 (90), Granted
 00:02:00 (90)
    Remaining 00:01:36
    Flags sbdmgvt, Identification
    BE805B64.AFE88540
    Register next time 00:00:36
    Extensions: <- NEW
        Mobile Network Add 147.175.20.0/20 <- NEW
        MN-HA Authentication SPI 100 <- NEW
!
!...
Ctrl-z
Router#
```

As shown in the above configuration output, while the MH: 147.175.10.14 is still detecting its HA for mobile subnets 147.175.10.0/20 inside the HS, it registers by sending out a request to that HA. The request was accepted. The HA authenticated the registration, bind it to a FA and provided it a CoA from the FS for mobile subnets 147.175.20.0/20. In addition, HA injects the mobile subnets 147.175.10.0/20 associated with the MH into the HA routing table.

7. PERFORMANCE SIMULATION RESULTS

We illustrate simulation results, using Simulink Matlab, to verify the effectiveness of our Mathcad analytical manipulation, and experimental implementation. The whole EtE packet delays inside and between subnets, with (downward fluctuations) and without (upward fluctuations) CIA procedure, in MIP are shown in figures 6 to 10. Also, the average EtE packet delay between subnets for MIP-CIA is shown in Fig. 11.

For the following figures 6-10, End-to-end packet delay "*EtE-D*" versus time "T_W". *A=100 agents, Unit*=1 μs, π=0.005 msg/unit, β=0.005 msg/unit, $1/\rho=10^5$ μs, η=0.01 μs, T_P=0.1 μs/km, $T_L>(2T_p+T_w)$.

Vertical : End-to-end packet delay (10^{-3} s)
Horizontal: Time (s)
Upper : MIP without CIA
Lower : MIP with CIA

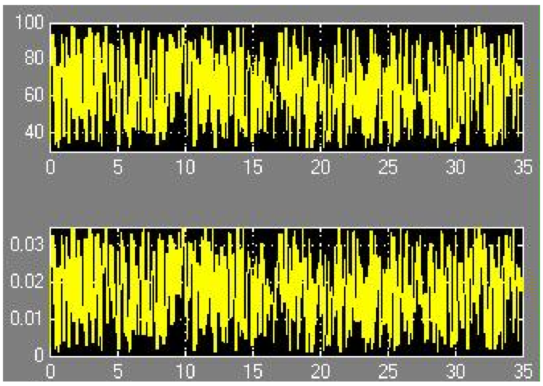

Fig. 6 End-to-end packet delay "*EtE-D*" versus time "T_W" inside the HS

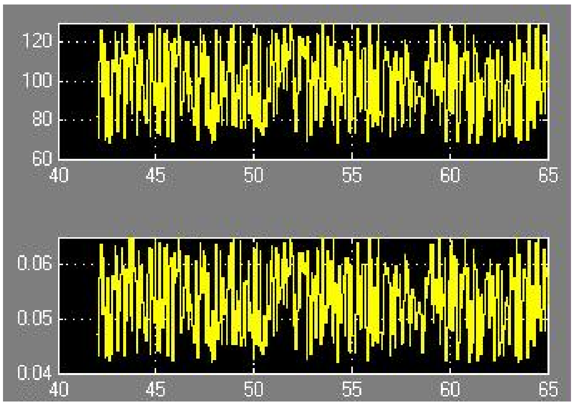

Fig. 7 End-to-end packet delay "*EtE-D*" versus time "T_W" inside the FS-1

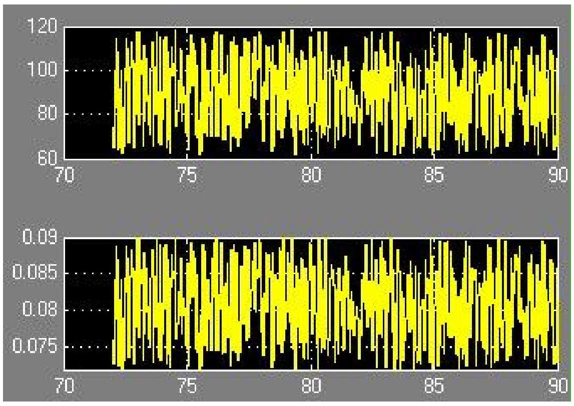

Fig. 8 End-to-end packet delay "*EtE-D*" versus time "T_W" inside the FS-2

We can observe that, with the time changes, the EtE packet delays change accordingly. In the case of MIP with CIA procedure, we notice that (shown in figures 6-8) the EtE packet delay is always much lower (better) than the delay without [13] CIA procedure, no matter what the subnet is HS or FS. When the MH is still inside the HS or moves to the FSs, the maximum EtE packet delay with CIA procedure (shown in Fig. 6) is much smaller (better) than the minimum EtE packet delay without CIA procedure. When the MH moves to the FS-1 and FS-2, the maximum and minimum EtE packet delays (shown in Fig. 7 and Fig. 8) with CIA procedure increases, but still much lower than the same ones without CIA procedure, respectively. Connection interruption between subnets HS and FS-1 (shown in Fig. 9) was completely eliminated, i.e. there is a packet flow for MIP-CIA between the times 35 s and 42 s, when MH moves out of the wireless HS and enters the coverage area of FS-1, whereas for MIP without CIA procedure there is no packet flow between these times. Also, connection interruption between subnets FS-1 and FS-2 is completely eliminated, i.e. there is a packet flow for MIP-CIA between the times 65 s and 72 s, when MH leaves FS-1 and enters the coverage area of FS-2, whereas for MIP without CIA procedure there is no packet flow between these times (shown in Fig. 10). This means no more gaps for PLs between subnets.

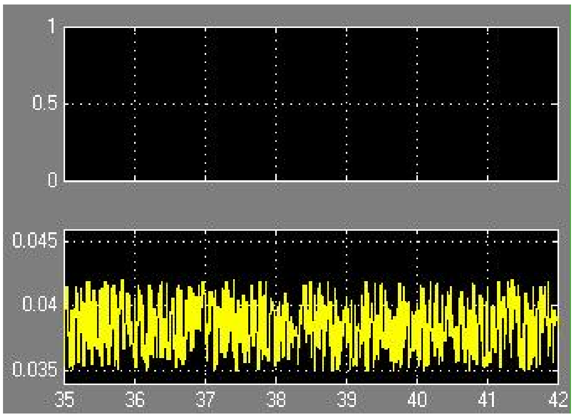

Fig. 9 End-to-end packet delay "*EtE-D*" versus time "T_W" between subnets HS and FS-1

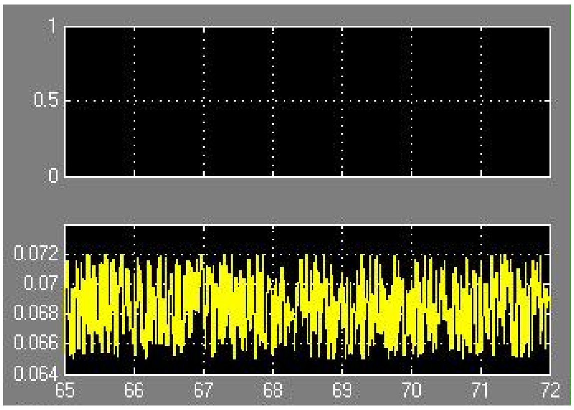

Fig. 10 End-to-end packet delay "*EtE-D*" versus time "T_W" between subnets FS-1 and FS-2

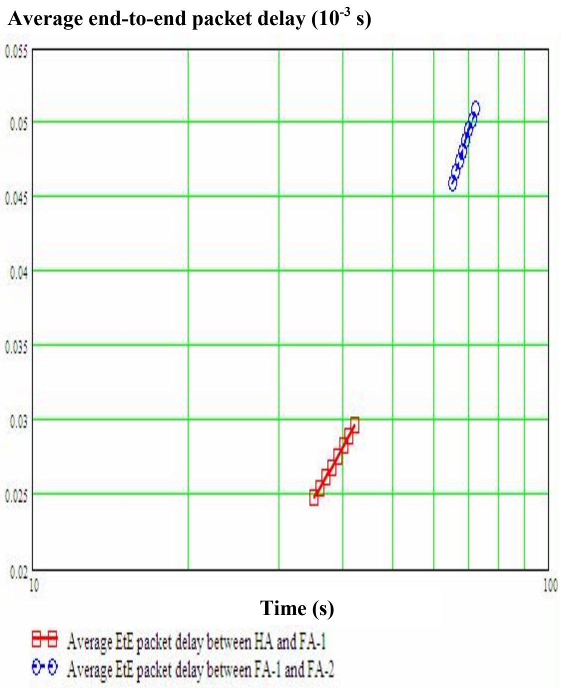

Fig. 11 Average end-to-end packet delay "*Average EtE-D*" between subnets versus time "T_W", for MIP-CIA. *A=100 agents, Unit*=1 μs, π=0.005 msg/unit, β=0.005 msg/unit, $1/\rho=10^5$ μs, η=0.01 μs, T_P=0.1 μs/km, $T_L>(2Tp+Tw)$

1	2	$1.0000155 \cdot 10^{-3}$	$7.0711775 \cdot 10^{-4}$
5	6	$5.0001072 \cdot 10^{-3}$	$3.5356097 \cdot 10^{-3}$
9	10	$9.0002805 \cdot 10^{-3}$	$6.3641594 \cdot 10^{-3}$
13	14	0.0130005	$9.1927666 \cdot 10^{-3}$
17	18	0.0170009	0.0120214
21	22	0.0210013	0.0148502
25	26	0.0250018	0.0176789
29	30	0.0290024	0.0205078
33	34	0.033003	0.0233367
37	38	0.0370038	0.0261656
41	42	0.0410046	0.0289946
45	46	0.0450055	0.0318237
49	50	0.0490065	0.0346528
53	54	0.0530076	0.037482
57	58	0.0570087	0.0403112
61	62	0.0610099	0.0431405
65	66	0.0650113	0.0459699
69	70	0.0690127	0.0487993
73	74	0.0730141	0.0516288
77	78	0.0770157	0.0544583
81	82	0.0810173	0.0572879
85	86	0.0850191	0.0601175
89	90	0.0890209	0.0629472
T_W=	$T_L(T_W)$=	$D(T_W)$= --EtE Delay--	Av. $D(T_w)$= --Av. EtE Delay-

Tab. 1 Wasting times "*Tw*", corresponding expiration times "T_L", end-to-end packet delays "*EtE-D*", and average end-to-end packet delays "*Av. EtE-D*"

8. CONCLUSIONS

We considered the roaming service in wireless MIP networks, in which the basic MIP protocol was originally introduced in IETF RFC 2002 to support portable IP addresses for mobile devices that often change their network access points with the Internet. This protocol encountered some inefficiencies, basically within three main categories according to each step of MRM process: location management, routing management, and handoff management. Furthermore, the inefficiency of RP, one of the MIP three basic capabilities, is interrupting the Internet connection and causing the PLs problem of forwarded traffic while roaming. Reasons for the need of optimized roaming service were mentioned. Consequently, the criteria to initiate a simple and fast full-duplex connection between HA and FA was a very important issue to the centric of all aspects in this work, as a cost-effective solution to reduce the roaming duration, eliminate the PLs and bridge the gap between subnets, an area that until now has been largely neglected.

In this paper, a workaround was developed, mapping the roaming behavior to MIP-RP, which we specified as a framework for us, around which we presented a feasibility of designing and modeling an intelligent registration procedure, *CIA procedure (communication inter-agents)*, extension to the basic MIP. This procedure platform is based on a Triple-R sequence (RRR: requesting, registering, and then roaming) that supposes an early registration of MN to a subnet predicted to roam into, using HA-based registration and EqR-policy, to reduce the roaming duration and eliminate the PLs. The state-transition diagram of the modeling-scenario was manipulated and analyzed using the EPA for system throughput and EtE packet delay. The heuristic of configuration file during the practical setup session for registration parameters, on Cisco platform Router-1760 using IOS 12.3 (15)T was created. Finally, we illustrated the performance simulation results for reporting values of EtE-D, using Simulink Matlab, to verify the effectiveness of our Mathcad analytical manipulation, and experimental implementation.

Results show that, connection interruptions between subnets were totally eliminated and packets flow was reported between subnets, i.e., no more gaps for PLs. The packet flow continues, no matter whether the MH is inside a subnet or roaming between subnets. Wherever it has a point-of-attachment, to be served and still connected to the Internet and forwarded traffic from its HS, with much lower EtE packet delays (see Tab. 1), and without any packet losses. The analytical performance results as a function of different network parameters were presented as convincing evidences and realistic cornerstone, upon which the Internet connection or forwarded traffic during roaming will be monitored and controlled, whereas the simulation results illustrate the effectiveness of CIA procedure in MIP protocol for optimized efficiency.

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