PetriNets Manipulation to Reduce Roaming Duration: Criterion to Improve Handoff Management

Hossam el-ddin Mostafa, and Pavel Čičak

***Abstract*—**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 to the Internet. The inefficiency of this protocol mainly within the handoff management produces large end-to-end packet delays, during registration process, 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, to reduce the roaming duration, is a very important issue to be considered by a work in this paper. State-transition Petri-Nets of the modeling scenario-based CIA: communication inter-agents procedure as an extension to the basic Mobile-IP registration process was designed and manipulated. 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 from 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 lower values of end-to-end packet delay for Mobile-IP using CIA procedure. Furthermore, it reported packets flow between subnets to improve packet losses between subnets.

***Keywords*—**Cisco configuration, handoff, packet delay, Petri-Nets, registration process, Simulink.

I. Introduction

WHEN a mobile host (MH) leaves its present subnet [1], the connection with 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 is the service during which the **C**ommunication links from 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 arises due to packet losses (PLs) between subnets when the MH registers with another subnet, and also due to 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, and 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 is a very important issue.

The registration process (RP), one of the three core capabilities of the basic Mobile-IP (MIP) protocol [1]-[4], is inefficient, since all the registration steps take place after the mobile node (MN) is already roamed into the destined foreign subnet (FS) with an Internet connection Interruption 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) whereas 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, the registration request experiences unnecessary delay in initiating forwarding service to the MN and in turn causes PLs.

In this paper, we highlight a MIP extension, CIA procedure: communication inter-agents. 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 [5] registration and EqR-policy (equilibrium roaming-policy), 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. The state-transition Petri-Nets of the modeling scenario is manipulated and analyzed, for the system end-to-end packet delay (EtE-D). 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

Manuscript received January 15, 2006. This work was financially supported by the Slovak Science Grant Agency, VEGA, No. VG 1/0157/03, with Cisco wireless labs at FiiT-STU Bratislava, under the project entitled “Methods and tools for development of the secure networked and distributed mobile computer systems and their management II.”

H. Mostafa was with the Department of Electronics and Electrical Communications Engineering, Faculty of Electronic Engineering, Menoufia University, Egypt. He is now with the Department of Computer Networks and Systems, Faculty of Informatics and Information Technologies, Slovak Technical University, Ilkovičova 3, 842 16 Bratislava, Slovakia (phone: +421-2-654 295 02; fax: +421-2-654 205 87; e-mail: eng_hosam@fiit.stuba.sk).

Pavel Čičak is with the Department of Computer Networks and Systems, Faculty of Informatics and Information Technologies, Slovak Technical University, Ilkovičova 3, 842 16 Bratislava, Slovakia (phone: +421-2-654 295 02; fax: +421-2-654 205 87; e-mail: cicak@fiit.stuba.sk).

created. Finally, we illustrate the performance simulation results for EtE-D, using Simulink Matlab, to verify the effectiveness of our Mathcad analytical manipulation, and experimental implementation.

II. CIA Procedure

Essentially, if a MH wishes to roam into a FS, then there must be an authenticated registration procedure [1]-[4], shown in Fig. 1, to inform its HA of its care-of-address 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 the MH at this moment will be the nearest from the border of the 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.

- **R_1 (Requesting):** In CI service, the MH starts the 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, the MH provides only its permanent IP address and an identifier, which uniquely identifies the destined FS.

The HA in turn performs the choosing process of the FA, on behalf of the MH, from it's MBC according to an equilibrium building block strategy (i.e. EqR-policy) [5].

- **R_2 (Registering):** Once this nearest HA determines the FA and the temporary IP address, it sends back a router advertisement (RA) back to the MH as an acknowledgment (ACK) with its temporary IP and IP of the chosen FA.

After that, the HA also sends a roaming initiate message alert (RIMA) to the chosen FA, 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 time T_W until receiving a message alert, whose source and destination are the temporary and permanent addresses of the 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, the FA sends a roaming acknowledgment (RACK) to the HA, informing that it accepted successfully the MH in its subnet.

- **R3 (Roaming):** Consequently, the HA updates the mobility binding of the MH and sends out a broadcast roaming initiate (RI) with the gratuitous address resolution protocol (ARP) [6] to the network. This signal informs the whole network that the node is going to perform a roaming and updates the ARP cache of all the 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 the 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.

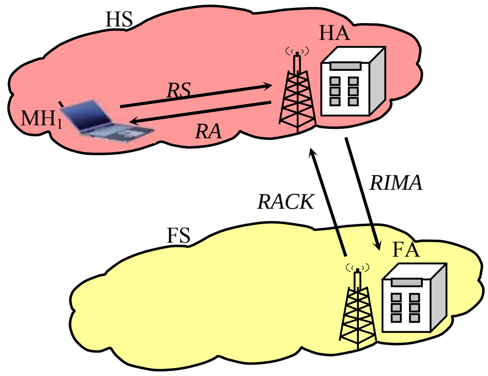

Fig. 1 Registration procedure for roaming in Mobile-IP

III. State-Transition Petri-Nets

The state-transition Petri-Nets for the CIA modeling scenario is shown in Fig. 2 [7]. 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. The presence of token in the previous stateplace triggers transition to the next stateplace. Thus, transitions implement the activities of the system, whereas stateplaces are data warehouses that store information until some transition will need it.

We will take an abstract transmission model and trace the route of a signal through the MIP network using suitable model parameters. 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), as shown in Fig. 2, and aggregate the effect on the total number of agents in the network.

IV. End-to-End Delay

End-to-end Delay (*EtE-D*) is defined as the time from a message readiness at a MH until the time that the message completes its transmission. This consists of 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 ($1/\delta$).

The aggregation of communication between the HA and FA, as a unit of all agents, will provide the total EtE packet daely. It can be obtained [8] that this delay is as follows in Equ. 1(consult Fig. 2): As we are intended only in establishing

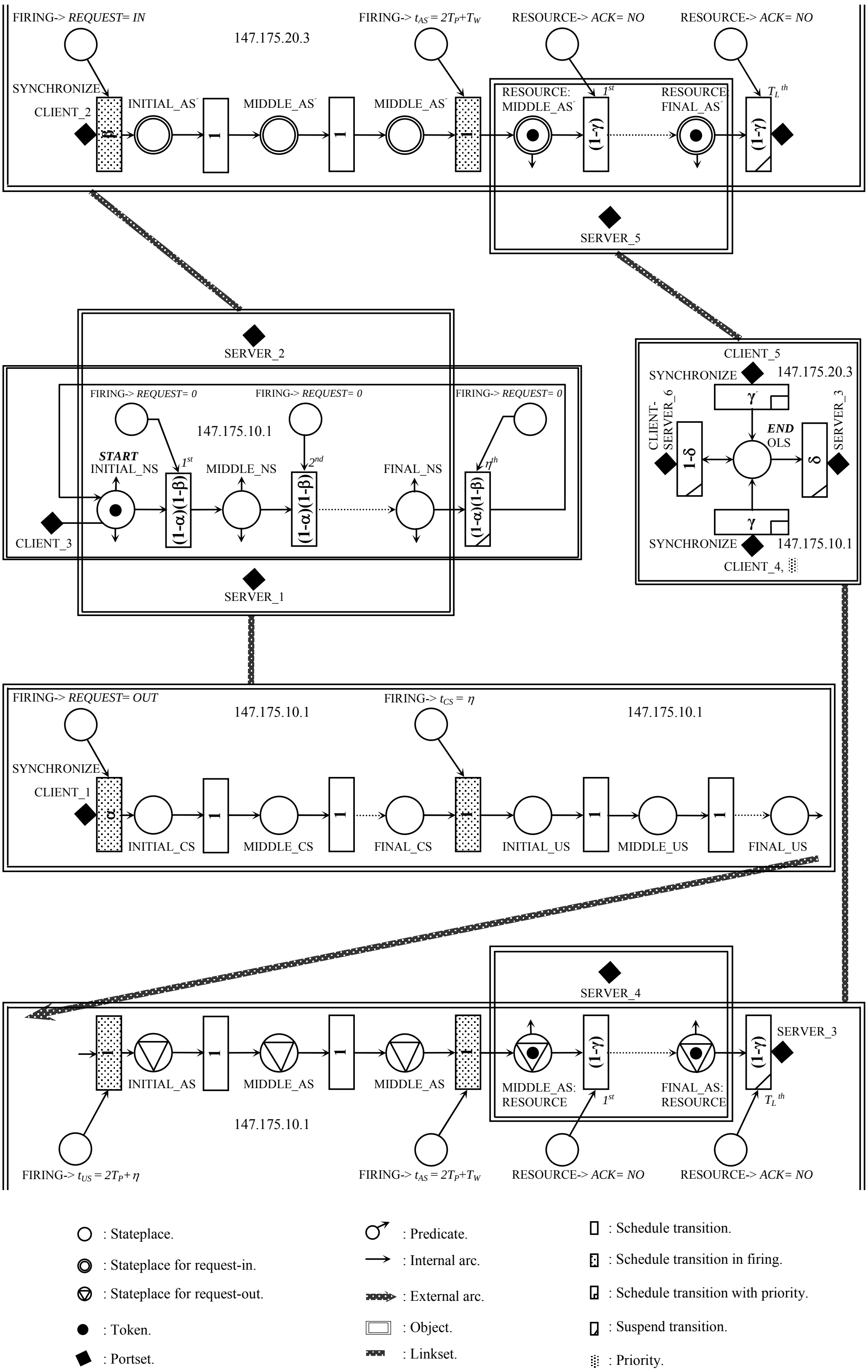

Fig. 2 State-transition corresponding Petri-Nets

a full-duplex connection between the 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 to:

$$EtE\ \ D = 2\cdot(\eta + T_P) + T_W + \gamma \cdot \sum_{K=1}^{T_L} K \cdot [1-\gamma]^{K=1} \quad (1)$$

$$;\gamma = \frac{1-\beta\cdot(A-1)}{\left[\frac{1+2\cdot\pi\cdot(T_P+\eta)}{\pi+\beta} + T_P + \frac{T_W}{2} + \frac{1}{\delta}\right]\cdot 2\cdot\beta\cdot(A-1) - T_P + 1}$$

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

V. Epxperimental Implementation

The heuristic of configuration file that was created during the Setup session for registration parameters, on Cisco 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 [9].

In our practical case under study, the HS has five MHs on interface Ethernet1 [6] (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. The mobile access router is a router that operates as a MN defined in MIP specification, which allows 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 sec). 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 item that we intended to change. The registration item was configured to set the maximum registration lifetime value of 90 sec. 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.

VI. 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 delay and EtE packet delay between subnets, with (downward) and without (upward) CIA procedure, in MIP are shown in figures 3 to 7.

For the following figures 3-7, 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/ρ=100 ms, T_P=0.1 μs/km, η=0.01 μs, T_L>*(2Tp+Tw)*.

Upper: MIP without CIA. Vertical: EtE-D (sec) X 10^{-3}
Lower: MIP with CIA. Horizontal: Time (sec)

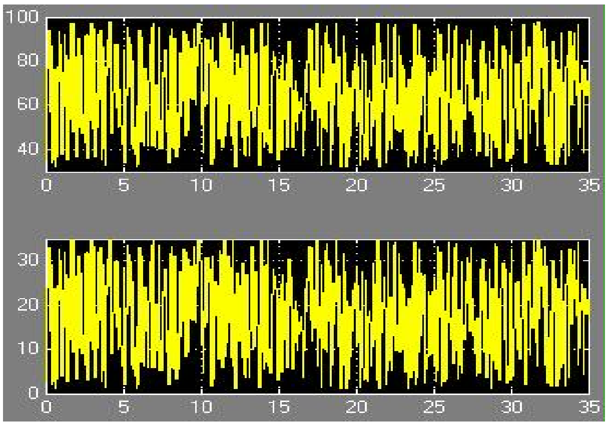

Fig. 3 End-to-end packet delay "*EtE-D*" versus time "T_W". inside the HS

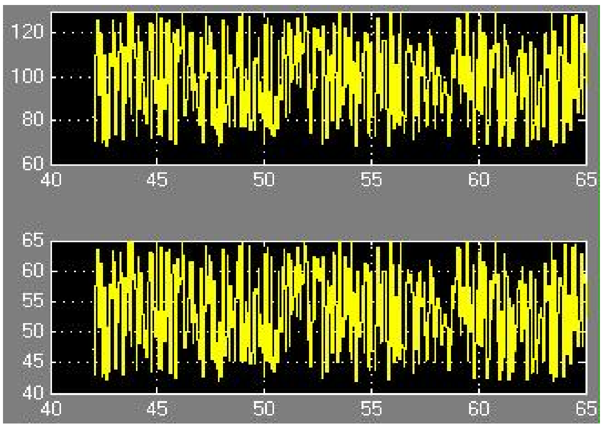

Fig. 4 End-to-end packet delay "*EtE-D*" versus time "T_W". inside the FS-1

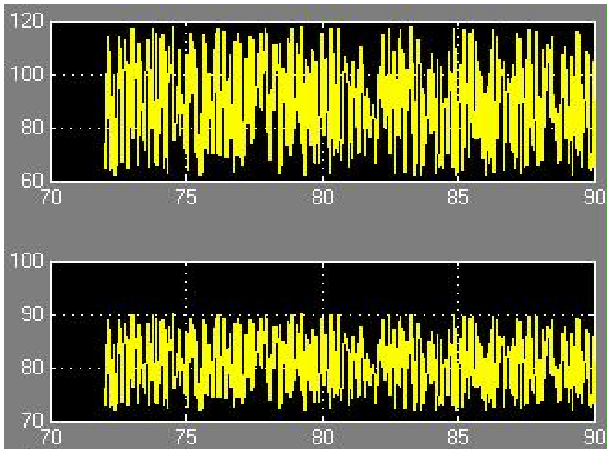

Fig. 5 End-to-end packet delay "*EtE-D*" versus time "T_W". inside the FS-2

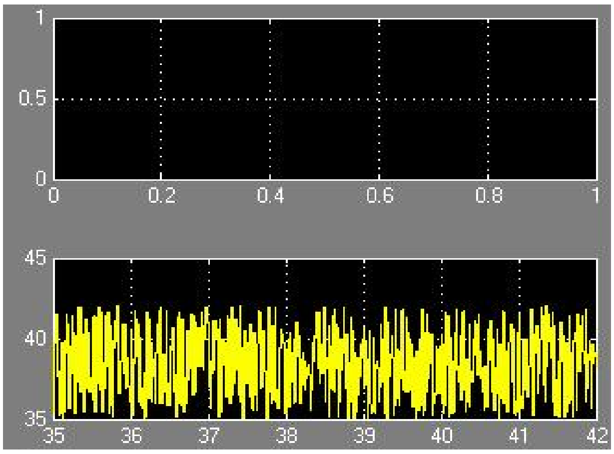

Fig. 6 End-to-end packet delay "*EtE-D*" versus time "T_W". between subnets HS and FS-1

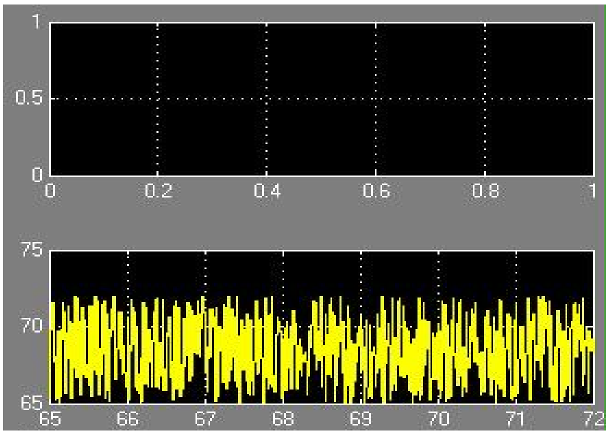

Fig. 7 End-to-end packet delay "*EtE-D*" versus time "T_W". between subnets FS-1 and FS-2

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 3-5) the EtE packet delay is always lower (better) than the delay without [10] CIA procedure, no matter what the subnet is HS or FS. When the MH is inside the HS, the minimum EtE packet delay with CIA procedure (shown in Fig. 3) is much smaller (better) than the EtE packet delay without CIA procedure. When the MH moves to the FS-1, the maximum and minimum EtE packet delays (shown in Fig. 5) with CIA procedure decline lower than the same ones without CIA procedure, respectively. PLs between subnets HS and FS-1 (shown in Fig. 6) were completely eliminated, i.e. there is a packet flow between the time 35 sec and 42 sec, 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, PLs between subnets FS-1 and FS-2 is completely eliminated, i.e. there is a packet flow between the times 65 sec and 72 sec, 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. 7).

IV. Conclusion and Future Work

We considered the roaming service in wireless MIP networks, in which the basic MIP protocol was originally introduced in the IETF RFC 2002 to support portable IP addresses for mobile devices that often change their network access points to the Internet. It 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 the HA and FA was a very important issue to the centric of all aspects in this work, as a cost-effective solution to eliminate the PLs and bridge the gap between subnets, an area that until now has been largely neglected.

In this paper, we highlighted the *CIA procedure (communication inter-agents)* as an extension to the basic MIP-RP. 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 Petri-Nets of the modeling scenario was manipulated, for system 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 EtE-D, using Simulink Matlab, to verify the effectiveness of our Mathcad analytical manipulation, and experimental implementation.

Results show that, the PLs between subnets were totally eliminated. The packet flow continues, no matter whether the MH is inside a subnet or roaming between subnets, as shown in figures 6 and 7. Where ever 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 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 illustrated the effectiveness of CIA procedure in the MIP protocol for optimized efficiency.

References

[1] J. Jue and D. Ghosal, "Design and Analysis of a Replicated Server Architecture for Supporting IP-Host Mobility," *ACM Mobile Computing and Communications*, Revue, 2(3):16-37, 1998.
[2] A. Jamalipour, *The Wireless Mobile Internet: Architectures, Protocols and Services*, John Wiley & Sons Ltd, England, 2003.
[3] C. E. Perkins, "Mobile IP," *IEEE Commun. Magazine*, vol. 35, no. 5, pp. 84-99, May 1997.
[4] William Stallings, *Mobile IP*: http://www.informit.com/, Oct 2001.
[5] H. Mostafa, "Home agent-based decentralized user-mobility with EPA-selection", *IIT.SRC-2005 student research conference proceedings,* FiiT-STU, Bratislava, Slovakia, Apr. 2005, pp. 103-107.
[6] W. R. Stevens, *TCP/IP Illustrated, Volume 1: The Protocols*, Addison-Wesley Professional Computing Series, 1994.
[7] ARTIS Software Corporation, "Extentions to Petri Nets," *Telecom and Datacom Engineering Solutions*, USA, 2001.
[8] L. Kleinrock, *Queueing Systems*, *Vol. I: Theory*. New York: Wiley, 1975.
[9] Cisco website: http://www.cisco.com/go/mobile_ip/, 2004.
[10] H. Chen and L. Trajkovic, "Simulation of Route Optimization in Mobile IP," *proceedings of 27th annual IEEE conference on local computer networks (LCN'02), workshop of wireless local networks*, Tampa, FL, USA, Nov. 2003.

Hossam el-ddin Mostafa has got the B.Sc. degree: in electronics and electrical communications engineering (EECE) at the Faculty of Electronic Engineering– Menoufia University (FEE – MU), Menoufia, Egypt in 1997; Dipl.: in Information Technology and Computer Networks (IT&CNs) at the Information Technology Institute (iTi), the CABIENT, Cairo, Egypt in 1999; M.Sc.: in EECE from the FEE-MU, Menoufia, Egypt in 1999; and finally finished the MPhil.: in Optical Computer Networks (OCNs) at the FEE -MU, Menoufia, Egypt in 2002.

He is a university academic & technical teaching assistant and scientific researcher at EECE Dept., FEE-MU, Egypt; while he is working toward the Ph.D. degree at Department of Computer Networks & Systems, Faculty of Informatics & Information Technology-Slovak Technical University (FiiT–STU), Bratislava, Slovakia, in wireless Mobile Computer Networks (MCNs), as a scholarship doctorand, from 2003. Up-till-now, he has 9 publications in international technical and military conferences proceedings in Slovakia, Singapore, and USA. His research interests include designing, modeling and evaluating architectures and protocols for DWDM-OCNs and Wireless-MCNs.

Pavel Čičak is an associatiom professor and a director of Cisco labs at the Dept. of Computer Networks and Systems, FiiT-STU, Bratislava, Slovakia.