

Analytical Approach of Proxy-LMA Mobility System in Heterogeneous IP-based Mobile Networks

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Abstract

Mobile users want to be provided with uninterrupted network services when they navigate on the Next-Generation (NG) wireless networks. For that, interlocking with a heterogeneous network is important, but there have been few studies on the method for guaranteeing global mobility. Thus, this paper proposes the Proxy-LMA technique, the mobile IP-based global inter-networking system, to enhance global mobility and interoperability within the Next-Generation (NG) network environment. The purpose of the proposed Proxy-LMA system is to expand the boundary of the mobility with regards to the existing mobility management protocol (PMIPv6 and MIPv6) in order to guarantee global mobility and interoperability within the heterogeneous network environment. The results of the performance evaluation showed that the proposed Proxy-LMA system was more efficient than other methods from the standpoint of signaling cost and delay in the heterogeneous network environment.

Keywords: *Next-Generation wireless systems; Proxy Mobile IPv6; Global roaming; Mobility management; Proxy-LMA.*

1. Introduction

As the Internet communication networks converge and service providers are engaged in fierce competition to provide faster network services, consumers want to be offered fast and high quality services. To satisfy the desires of consumers, it is essential to provide uninterrupted heterogeneous inter-network service. As part of those efforts, the IP-based Next-Generation (NG) wireless network (NGWN) has come under the limelight. The major purpose of the NGWN is to integrate the heterogeneous network system, build perfect infrastructures to offer uninterrupted high speed Internet service, and satisfy the requirements of users through the evolution of wireless communication for low cost and high quality services [1]. Recently, the mobile communication system pursues broadband and mobility and is evolving into the digital convergence service system, which combines communication, broadcasting, and the Internet. In addition, the integration of

various wireless terminals has resulted in the increased demand of users for the undisrupted services anytime and anywhere while they are moving. To achieve those objectives, NGWN still has many problems that need to be resolved. As part of those efforts, various groups of IETF (Internet Engineering Task Force) are pushing ahead with the international standardization in relation to the future Internet [2]. Particularly, there have been actively ongoing discussions about the protocols related to the MIPv6-based mobility with an aim to ensure services are offered by various Internet service providers, such as different protocols, or backbone, etc., in the heterogeneous environment, not the mobility inside specific network.

The MIPv6 protocol does not support the mobility when MN (Mobile Node), the host-based mobility protocol, does not support the MIPv6 protocol, and the host-based mobility protocol is directly involved in the mobility as the HA (Home Agent) and MN exchanges the message when MN performs the handoff. As a result, many problems arise from the signaling between MN and HA as well as the increase in the amount of resources being used in the wireless section [3]. For that reason, PMIPv6 (Proxy MIPv6), the network-based mobility protocol, was proposed in order to resolve the problems in the existing host-based mobility protocol. Specifically, PMIPv6 is not involved in the process of transmitting the message of certain IPv6 mobility protocols when MN performs the handoff. Instead, the network processes it [4]. PMIPv6 has higher cost-effectiveness in terms of the signaling cost compared to MIPv6. However, the efficiency related to the global mobility outside the LMA (Local Mobility Anchor), which is defined in PMIPv6 was not taken into consideration [5].

Fig. 1 below shows the configuration of heterogeneous networks in this paper. In [5], it can be found that the movement within the heterogeneous network requires more network traffic and signaling, compared to the movement in the existing domain. As previously mentioned, PMIPv6, which is the latest issue among the mobility management protocols recommended by IETF, recommends that only the local mobility in the domain be supported, not the global mobility.

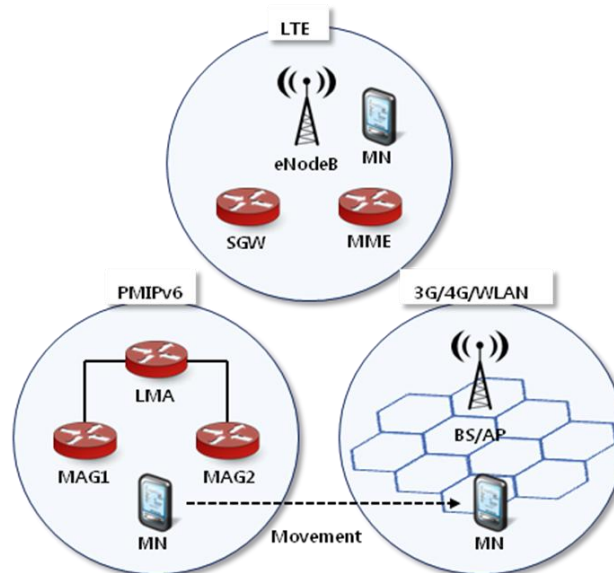


Fig. 1. Architecture of heterogeneous mobile networks.

Thus, this paper proposes the method that uses the Proxy-LMA gateway to ensure global mobility between heterogeneous networks. The purpose of the proposed Proxy-LMA gateway is to minimize global handoff overhead and the location management cost, which arise between the heterogeneous networks while

maintaining the characteristics of different networks. In other words, it minimizes the occurrence of signaling, when the overhead occurs in heterogeneous networks.

This paper consists of the following Chapters: Chapter 2 discusses the research related to global mobility management; Chapter 3 explains the proposed technique for global mobility management. In addition, Chapter 3 and 4 evaluate the performance of the proposed technique through a mathematical approach, and present the results. Finally, Chapter 5 draws the conclusion.

2. Background and related work

Mobile users in the Next-Generation (NG) wireless network system can go through various subsystems realized by different technologies and protocols when communicating. The mobility management technique, proposed in this paper, can be largely divided into location management and handoff management based on the entity on each network [6, 7]. Generally, handoff management is defined to be the technology that enables the uninterrupted service of the application hierarchy being used in the movement by the MN between the location section (or cell or domain) [9].

2.1 Overview of PMIPv6

PMIPv6 is a protocol that provides the session continuity for all hosts through IP mobility, regardless of whether MIPv6 protocol is embedded or not, and is a network-based mobility management protocol that requires only the modification of equipment on the network side. PMIPv6 was added to include the new functional elements called LMA and MAG (Mobile Access Gateway). As the PMIPv6 technique does not require the IP mobility protocol to be embedded in the MN, which has limited functions and resources, no practical problems occur such as the increased power consumption of the MN or the increased consumption of resources in the wireless section due to various signaling traffic in the process of handover. Any types of MN are capable of handover when moving in a network, even if they do not have the IP mobility function. For PMIPv6, the entity on the network, not the MN, is responsible for location management. In other words, the MN records the current connection point of the MN to ensure that the session can be transmitted to the MN.

It saves the location information in the form of DB (database) in the network entity, such as MAG and HA/LMA, etc., on the local domain to indicate the current location of the MN [8].

In PMIPv6, the handoff stage is divided into 3 stages, and the procedures are specified below. The first stage involves the identification of the mobile user (MN-ID), which requires the handoff in the MAG. In the second stage, the movement to other domains is informed to the MAG of other domains and the information related to the movement is renewed through the routing of this information in order to prevent the occurrence of handoff and disruption with regards to service in the network. The final stage involves the control of data flow to ensure that the existing data transmission service is maintained in the connection path that has been newly created. However, all measures proposed above are limited to the location domain of a specific network [9, 10]. Although the PMIPv6 protocol provides the handover function, problems, such as the disruption of session, etc., occur if the MN performs the handover through the interface using different access technologies such as wireless LAN or WIMAX. However, MN or the global mobility of users must be taken into account to ensure that different backbones, protocols and services offered by service providers can be used in NGWN', not the internal roaming of a specific network.

2.2 Support for global mobility using the MIH

MIH (Media Independent Handover) is the handover technology that came under the spotlight for the first time in the mobility management protocol, and is a technology being standardized by IEEE 802.21 WG (Working Group) in order to provide uninterrupted handover in heterogeneous networks. What has to be given the most consideration in case of MN movement to the heterogeneous network is the fulfillment of QoS (Quality of Service) as a result of the handover. For that, IEEE 802.21 WG recommends the MIH standard technology for the uninterrupted vertical handover service between heterogeneous networks [11]. MIH enables the MN, which has multiple wireless interfaces, to select the best network connection type that can be automatically used without the intervention of the user, and provides Event Service, Command Service, Information Service, etc., to ensure the flexible handover of the session between heterogeneous networks and media.

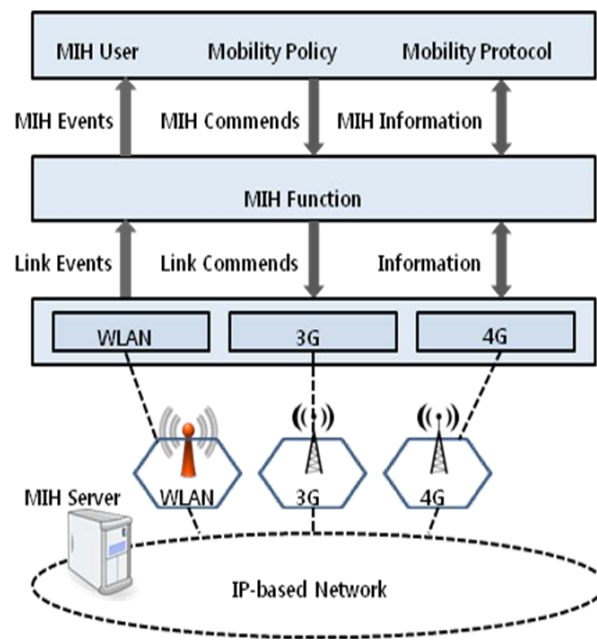


Fig. 2. MIH-based Heterogeneous Network Topology

Recently, MIH technology is being expanded to support the handover to the NGWN network in an attempt to conform to the trends toward the convergence between broadcasting and communication. Task group (TG) is set up under IEEE 802.21 WG to proceed with the standardization of the concerned technologies. In addition, MIH information service defines the MIH information service, the separate network object, which provides various heterogeneous networks adjacent to the current location before the movement of the MN, so that the information concerning various heterogeneous networks adjacent to the current network where the MN is located and the information about the handover policy can be utilized for the handover. Using this MIH event, the upper-rank mobility management protocol minimizes the delay and packet loss in the handover of the heterogeneous wireless network, thus providing high quality service to the users. However, MIH technology is currently undergoing standardization and encounters difficulty in realizing the application service and authentication procedures. Although researches have been conducted to devise the measures that can help ensure uninterrupted provision of services to the MN based on MIH, there has not been clear definition and adequate solutions for handover among heterogeneous networks.

2.3 Support for global mobility between MIPv6 and PMIPv6

As previously explained, PMIPv6 is a protocol that only considers the support for local mobility. Thus, there is a limit in supporting global mobility. For that, measures have been presented to use it with MIPv6, which enables the global mobility [13]. For example, that is the case wherein the support of local mobility is enabled by the PMIPv6 while the support of global mobility is enabled by MIPv6. Similar researches present the FHMIPv6-MIPv6 technique [14]. However, there may be a difference, depending on whether the MN provides support, if MIPv6 and PMIPv6 are used. Basically, PMIPv6 can support all MNs. However, MIPv6 can be used only when the MN provides support. Particularly, there may be a problem that MAG has to report all current local IP prefixes in order to support MIPv6 or report HNP to support PMIPv6. To resolve such problems, the BCE (Binding Cache Entry) of PMIPv6 and the BCE of HA need to be shared. However, if the MN moves towards the MIPv6 domain from the domain, there may be a problem that the binding information has to be managed regardless of the domain. In establishing the heterogeneous network, building PMIPv6 and MIPv6 in one area (cell) will unavoidably lead to a decrease in cost-effectiveness as the efficiency will decline in comparison with the cost.

3. Proposed Proxy-LMA System

The technique proposed in this paper provides both interoperability and global mobility in heterogeneous networks when the MN moves. This paper presents the method for using the Proxy-LMA (Global Mobile IP-based Internetworking System) gateway in order to minimize the cost arising from the global handover. Specifically, Proxy-LMA gateway is set to be directly and mutually connected for the adjacent subsystem and therefore can access the subsystems on both sides. Fig. 3 shows an example of interconnection for the 3 subsystem networks. The mobility management technique proposed in this paper can be largely divided into location management and handoff management based on each network entity [6, 7]. For PMIPv6, the entity on the network, not the MN, is responsible for location management. In other words, the current connection point of the MN is recorded to enable the transmission of session to the MN. In relation to the current location of the MN, the location information is stored, in the form of database, on the network entity such as MAG and HA/LMA, etc., on the local domain [8]. Handoff management means the technology enabling the uninterrupted application hierarchy service, which is being used by the MN in the movement between domains. The proposed Proxy-LMA gateway ensures the conversion of message for the signaling message and serves as the gateway to convert the message among the cells in order to facilitate the protocol conversion. For that, it supports the function for the conversion into the two interfaces.

In the first place, Proxy-LMA gateway determines the ID information (MN-ID) of the MN, which creates the request for registration in case of movement among other domains, along with the expected path of movement. The expected path of movement may differ, depending on the configuration of the network that is adjacent. It designates the interface related to the buffering procedure for the registration and the handover request message, and performs the processing procedure such as saving as well as the packet awaiting the processing, etc.

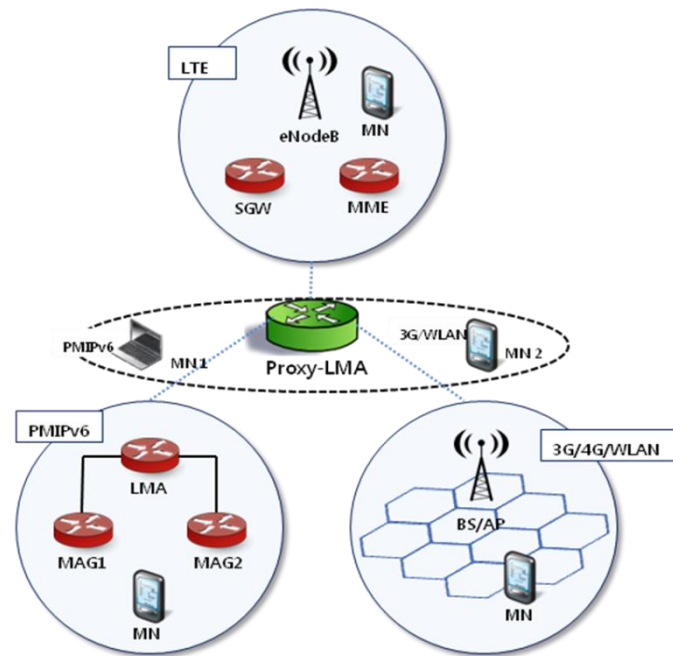


Fig. 3. Proxy-LMA Architecture in Heterogeneous Networks

The conversion function of Proxy-LMA gateway is as follows:

- ① Converting the message among the heterogeneous networks and maintaining the signaling format
- ② Maintaining the location information of mobile users after the location registration or renewal, thus providing the function to search for the location information anytime
- ③ Transmitting the session and transmitting the signaling information safely
- ④ Performing the authentication of mobile users to ensure the transmission of security data

Furthermore, the proposed Proxy-LMA gateway is the upper-rank entity on the network located in the adjacent network, and provides the interlocking with the MIP-based service. In addition, the service, based on the location area, requires the use of many DB for global mobility management among heterogeneous networks. Generally, HA/LMA forms the network that includes many MAGs.

The operation scenario of Proxy-LMA gateway is as follows. Mobile users can move to many subsystems realized by different technologies and protocols in the heterogeneous network environment. Each subsystem saves the information form, which uses its own registration procedure, in the entity DB on each network that manages the mobility. Proxy-LMA gateway, which is based on such information, performs the procedure for transmitting the message among the heterogeneous networks by considering the mobility of the MN, enables the search for user's roaming information by adjusting the format, and controls the error to ensure secure transport. For such a scenario, two procedures regarding registration were proposed before. Another is the single registration (Single Registration, SR) procedure, and the other is the multiple registration (Multiple Registration, MR) procedure [17]. The single registration method is for registering in HA/LMA or MAG, the single system, anytime to show the current location. The multiple registration method is the method by which the MN registers the current location in the entity that exists in many subsystems anytime while each subsystem, which manages the mobility of the MN, is not integrated. However, this registration procedure may cause excessive traffic in each entity of the network, thus affecting the quality of the network service.

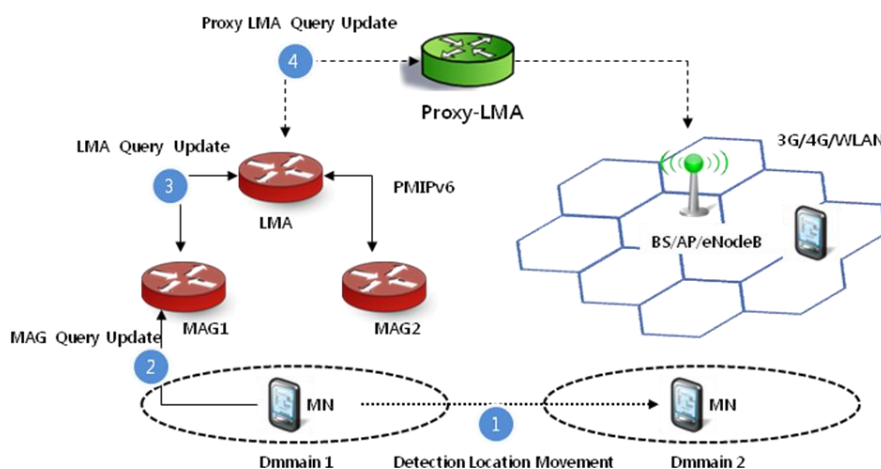


Fig. 4. Location Update Procedures of Proxy-LMA Architecture

Fig. 4 shows the diagram of the procedure related to the proposed registration process. As the MN has to renew the current location through the moved domain, the Proxy-LMA gateway needs to flexibly convert different maximum message sizes and address the designation technique. For that, the maximum segment size is defined to be the maximum segment size required for performing the conversion without any change in the basic network characteristics. It supports the function of converting the low speed data to high speed data when the packet transmission speed of two networks is different. In other words, it is like processing through the buffering in the Proxy-LMA gateway based on the DB(database) which is stored in the entity on each network, depending on the size of RSS(Received Signal Strength), by the nature of wireless. To ensure global mobility among heterogeneous networks, the performance needs to be defined due to the registration/renewal and transmission as part of the task to define the size of traffic that is generated during the movement of the MN. In fact, the handover procedure has to be undergone after the renewal of the location if the MN moves. Fig. 5 shows the procedure in case of the movement in a heterogeneous network and illustrates the process of global handover. The global handover procedure in heterogeneous networks is not very different from the registration procedure, which was explained before. In the first place, the MN, which received the data through HA/LMA and MAG of domain 1, moves from domain 1 to domain 2. If movement of the MN is detected, MAG of domain 1 transmits the GM_PBU (Global Movement Proxy Binding Update) message to the top-ranked HA/LMA. The message is transmitted to the Proxy-LMA again in order to notify the movement of the MN and the occurrence of global handover. Later, the movement of the MN to the HA/LMA of the heterogeneous network in the neighboring domain 2 is monitored, and then the GM_PBU message is transmitted to MAG. The receiving status during the movement of the MN is transmitted to the Proxy-LMA. In the meantime, the Proxy-LMA sets the two-way tunneling between domain 1 and domain 2, and constantly provides feedback on the movement of the MN and saves it. After the two-way tunneling is set, the RS (Router Solicitation) message is transmitted through MAG and HA/LMA to inform that the movement of the MN is completed. Finally, the Proxy-LMA, which received the GM_PBA (Global Movement Proxy Binding Acknowledgement), changes the destination address to LMA regarding domain 2 in order to optimize the message route. No problem arises from the constant tunneling, unlike the existing tunneling method, and the cost of transmission does not significantly increase even if the handover occurs continuously if the message route is optimized.

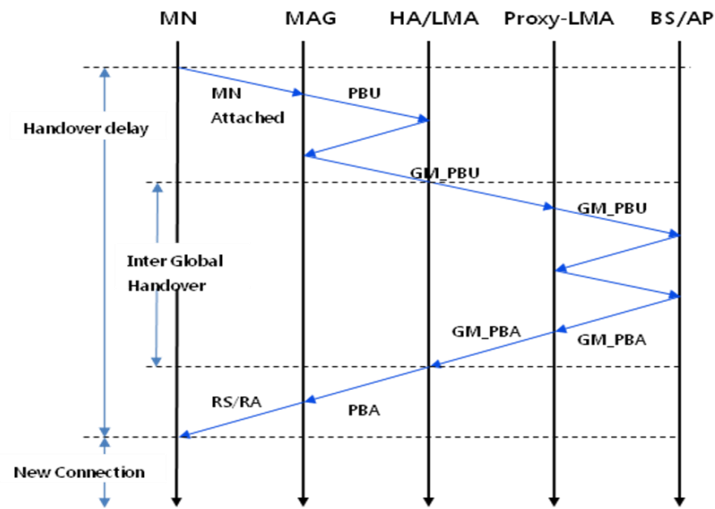


Fig. 5. Proxy-LMA Handover

4. Performance evaluation

In this Chapter, the average response time for the query will be analyzed, as well as the average query execution and information renewal ratio in each DB stage during the global roaming.

4.1 Parameter

This section defines the two adjacent networks as subsystem i and subsystem j for the evaluation of performance, and assumes that the Proxy-LMA is located between those heterogeneous networks. The parameters are defined as shown in the Table 1.

Table 1. Parameter definitions for each subsystem i

Parameter	Definition
N_{MAG_i}	number of $MAGs$ in subsystem i
ρ_i	user density in subsystem i
v_i	average speed in MAG_{ix} ($x=1,..N_{MAG_i}$)
A_i	total area of subsystem i
λ_{out_i}	average traffic generated by each MT of subsystem i (calls/second/terminal)
λ_{in_i}	average incoming traffic to each MT of subsystem i (calls/second/terminal)
$\tau_{req_e}^M$	query rate at the functional entity e using method M (e stands for $MAG_{ix}, LMA_i, Proxy-LMA$, whereas M stands for SR, MR or NM)
$\tau_{update_e}^M$	update rate at the functional entity e using method M

4.2 Evaluation of query and update rates

The traffic pattern, which is generated during the global roaming, consists of the registration, registration cancellation, transmission request, and transmission request transfer signal. This traffic is divided into the query execution and information renewal from the standpoint of the DB task [18]. First, the evaluation of the query execution and information renewal ratio is based on the mobility model that considers the speed and direction of the mobile user, the DB record of the user's movement, etc. [19].

This paper evaluates the query execution and information renewal by referring to the fluid flow model. Based on this mobility model, mobile users of subsystem i are assumed to be uniformly distributed along the movement direction $[0, 2\pi]$ and moving at an average speed of v_i . If we assume that the mobile users are uniformly distributed in subsystem i at a density of ρ_i and the boundary of subsystem i is L_i , the ratio of the mobile users who are moving from subsystem i to subsystem j can be derived in the following way.

$$r_{ij} = \frac{\rho_i v_i L_i}{\pi} \quad (1)$$

If each network (i.e., MAG, HA/LMA or Proxy-LMA) is modeled using the M/G/1 queuing system [20], the average query execution and information renewal ratio in the DB stage can be determined. In particular, the SR method shows the average arrival rate of Proxy-LMA and the entity of each network during the task, which is performed for the system movement of the internal system through [17], as follows.

$$\tau_{req_MAG_{ix}}^{SR} = N_{MAG_i} [r_{ji} + (\lambda_{out_i} + \lambda_{in_i}) \rho_i A_i] \quad (2)$$

$$\tau_{update_MAG_{ix}}^{SR} = N_{MAG_i} (r_{ij} + r_{ji}) \quad (3)$$

$$\tau_{update_MAG_{ix}}^{SR} = N_{MAG_i} (r_{ij} + r_{ji}) \quad (4)$$

$$\tau_{req_MAG_{jx}}^{SR} = N_{MAG_i} r_{ij} + N_{MAG_j} [2r_{ji} + (\lambda_{out_j} + \lambda_{in_j}) \rho_j A_j] \quad (5)$$

$$\tau_{update_MAG_{jx}}^{SR} = N_{MAG_i} (r_{ij} + r_{ji}) + 2N_{MAG_j} r_{ji} \quad (6)$$

$$\tau_{req_LMA_{ix}}^{SR} = N_{MAG_i} [r_{ji} + \lambda_{in_i} \rho_i A_i] \quad (7)$$

$$\tau_{update_LMA_{ix}}^{SR} = N_{MAG_i} (r_{ij} + r_{ji}) \quad (8)$$

$$\tau_{req_LMA_{jx}}^{SR} = N_{MAG_i} r_{ij} + N_{MAG_j} [r_{ji} + \lambda_{in_j} \rho_j A_j] \quad (9)$$

$$\tau_{update_LMA_{jx}}^{SR} = N_{MAG_i} (r_{ij} + r_{ji}) + N_{MAG_j} r_{ji} \quad (10)$$

$$\tau_{req_Proxy-LMA}^{SR} = N_{MAG_j} (r_{ij} + \lambda_{in_j} \rho_j A_j) + N_{MAG_i} (r_{ji} + \lambda_{in_i} \rho_i A_i) \quad (11)$$

$$\tau_{update_Proxy-LMA}^{SR} = N_{MAG_i} (r_{ij} + r_{ji}) + N_{MAG_j} \rho_j A_j (\lambda_{out_j} + \lambda_{in_j}) \quad (12)$$

Here, N_{MAG_i} and N_{MAG_j} shows the number of each MAG in subsystem i and j . Under the same condition, the average query execution and information renewal ratio in each DB can be obtained through the

algorithm proposed in [13] in relation to the MR method. Using, the MR method, the entity of each network can be also modeled through the M/G/1 queuing system. The average query execution and information renewal ratio in the entity for each stage of the DB is specified below [17].

$$\tau_{req_MAG_{ix}}^{MR} = N_{MAG_i} [r_{ji} + (\lambda_{out_i} + \lambda_{in_i}) \rho_i A_i] + N_{MAG_j} \lambda_{in_j} \rho_j A_j \quad (13)$$

$$\tau_{update_MAG_{ix}}^{MR} = N_{MAG_i} r_{ji} \quad (14)$$

$$\tau_{req_MAG_{jx}}^{MR} = N_{MAG_i} [2r_{ji} + (\lambda_{out_j} + \lambda_{in_j}) \rho_j A_j] \quad (15)$$

$$\tau_{update_MAG_{jx}}^{MR} = N_{MAG_i} r_{ji} + 2N_{MAG_j} r_{ji} \quad (16)$$

$$\tau_{req_LMA_{ix}}^{MR} = N_{MAG_i} [r_{ji} + \lambda_{in_i} \rho_i A_i] + N_{MAG_j} \lambda_{in_j} \rho_j A_j \quad (17)$$

$$\tau_{update_LMA_{ix}}^{MR} = N_{MAG_i} r_{ji} \quad (18)$$

$$\tau_{req_LMA_{jx}}^{MR} = N_{MAG_j} [r_{ji} + \lambda_{in_j} \rho_j A_j] \quad (19)$$

$$\tau_{update_LMA_{jx}}^{MR} = N_{MAG_i} r_{ji} + N_{MAG_j} r_{ji} \quad (20)$$

$$\tau_{req_Proxy-LMA}^{MR} = N_{MAG_j} \lambda_{in_j} \rho_j A_j + N_{MAG_i} (r_{ji} + \lambda_{in_i} \rho_i A_i) \quad (21)$$

$$\tau_{update_Proxy-LMA}^{MR} = N_{MAG_i} r_{ji} + N_{MAG_j} \rho_j A_j (\lambda_{out_j} + \lambda_{in_j}) \quad (22)$$

In the proposed approach, the query execution and information renewal message arrival in each DB follows the Poisson process, and the average arrival rate for each entity is expressed as follows.

$$\tau_{req_MAG_{ix}}^{NM} = r_{ji} + (\lambda_{out_i} + \lambda_{in_i}) \rho_i A_i \quad (23)$$

$$\tau_{update_MAG_{ix}}^{NM} = r_{ij} + r_{ji} \quad (24)$$

$$\tau_{req_MAG_{jx}}^{NM} = r_{ij} + (\lambda_{out_j} + \lambda_{in_j}) \rho_j A_j \quad (25)$$

$$\tau_{update_MAG_{jx}}^{NM} = r_{ij} + r_{ji} \quad (26)$$

$$\tau_{req_LMA_{ix}}^{NM} = r_{ji} + \lambda_{in_i} \rho_i A_i \quad (27)$$

$$\tau_{update_LMA_{ix}}^{NM} = r_{ij} + r_{ji} \quad (28)$$

$$\tau_{req_LMA_{jx}}^{NM} = r_{ij} + \lambda_{in_j} \rho_j A_j \quad (29)$$

$$\tau_{update_LMA_{jx}}^{NM} = r_{ij} + r_{ji} \quad (30)$$

$$\tau_{req_Proxy-LMA}^{NM} = r_{ij} + r_{ji} + \lambda_{in_i} \rho_i A_i + \lambda_{in_j} \rho_j A_j \quad (31)$$

$$\tau_{update_Proxy-LMA}^{NM} = r_{ij} + r_{ji} \quad (32)$$

4.3 Determination of the response time

Through (2) to (31) in regards to the expressive formula above, the average arrival rate λ_e of the

message in each network entity e (MAG, HA/LMA or Proxy-LMA) can be obtained. Suppose that the probability that the message, which arrived at network entity e , will be the information renewal message $P_{update_e}^M$, and that the probability that this message will be the query execution message is $P_{req_e}^M$. Then, the probability $P_{req_e}^M$ can be expressed as below, when the M method is used.

$$P_{req_e}^M = 1 - P_{update_e}^M = \frac{\tau_{req_e}^M}{\tau_{req_e}^M + \tau_{update_e}^M} \quad (33)$$

Here, M shows the proposed method (i.e., SR, MR, or NM), and e shows the functional entity (i.e., MAG, HA/LMA or Proxy-LMA). As each entity was modeled through the M/G/1 queuing system, the response time for the query execution or information renewal can be checked. In order to obtain better information, HA/LMA is assumed to be caching the data replicated from MAG in the environment with the probability of P [17, 18]. As a result, the effect on global roaming can be analyzed when various probability P is applied. If we assume that we know the average delay time for the query execution or information renewal processing in each network entity and if such average delay time is expressed as $P_{req_e}^M$ and $P_{update_e}^M$, the average delay time for processing the message in an entity e can be expressed as follows.

$$E(T_{pr_e}) = P_{req_e} T_{pr_{req_e}} + P_{update_e} T_{pr_{update_e}} \quad (34)$$

Then, the delay time for the second temporal point can be expressed as below [20].

$$E(T_{pr_e}^2) = P_{req_e} T_{pr_{req_e}}^2 + P_{update_e} T_{pr_{update_e}}^2 \quad (35)$$

Using the Pollaczek-Kintchine formula [20], the delay time in processing each network entity can be expressed as follows.

$$W_e = \frac{\lambda_e E(T_{pr_e}^2)}{2[1 - \lambda_e E(T_{pr_e})]} \quad (36)$$

Here, λ_e represents the average message arrival rate (query execution and information renewal message arrival rate) in the network entity e . Furthermore, the response time for the query execution is determined by the variable P (the probability that the required information is in MAG). T_x is represented by assuming the delay in the transmission between MAG_{ix} and LMA_i as 'constant'. $T_{pr_MAG_{ix}}$ and $T_{pr_LMA_i}$ are represented as the average delay in processing for MAG_{ix} and LMA_i , and $W_{MAG_{ix}}$ and W_{LMA_i} are represented as the average delay in waiting for MAG_{ix} and LMA_i , respectively. The response time is defined to be the weighted sum of the query execution in MAG_{ix} and LMA_i based on the signaling traffic related to

the DB execution and mobility [19]. In other words, the response time of subsystem can be expressed as below.

$$T_{res_i} = p(W_{MAG_{ix}} + T_{tr_MAG_{ix}}) + (1-p)(2T_x + W_{LMA_i} + T_{tr_LMA_i}) \quad (37)$$

Here, T_{res_i} is the average delay time in responding to the query when the mobile user is located at subsystem i .

4.4 Numerical results and analysis

To analyze the signaling traffic generated in the global roaming, the expected number of the signaling message, which is exchanged per second in the M-LMA/M-HA or the Proxy-LMA stage, and the average response time for the query execution in subsystem i are also evaluated. In the first place, the query execution and information renewal speed of M-LMA/M-HA or Proxy-LMA are evaluated on the basis of the behavior regarding the mobile user. In the infrastructure system roaming, the behavior of the mobile user is characterized by Local Call-to-Mobility Ratio (LCMR). Here, LCMR means the ratio of ‘the number of changes in the mobile terminal location’ to ‘the number of generated calls’. In addition, the behavior of the mobile user in the global movement is characterized by the Global Call-to-Mobility Ratio (GCMR). Here, the GCMR means the ratio of ‘the number of the mobile user’s handoff execution among the systems’ to the ‘number of generated calls’. The mobile users are assumed to be moving between i and j in heterogeneous network (PMIPv6 and MIPv6) in order to compare the approach, proposed in this paper, with SR and MR methods. The parameters of respective subsystems are summarized in the Table 2.

Table 2. Parameters for global roaming analysis

Parameter	Subsystem i	Subsystem j
Number of $MAGs$	6	4
Cell area (km^2)	0.04	36.0
Average speed (km/h)	5.0	20.0
Number of HA/LMA	1	1
λ_{in} ($call, second, terminal$)	8.333×10^{-4}	5.556×10^{-5}
λ_{out} ($call, second, terminal$)	5.556×10^{-4}	2.778×10^{-4}

Generally, the query execution and information renewal rate in M-LMA/M-HA or Proxy-LMA decreases through the GCMR anyway. In other words, more query execution/information renewal tasks are performed based on the time unit as the mobile users perform an increasing number of roaming between the systems when the ratio of calls are fixed (when the response to the request is constant). Fig. 6 and 7 show the results.

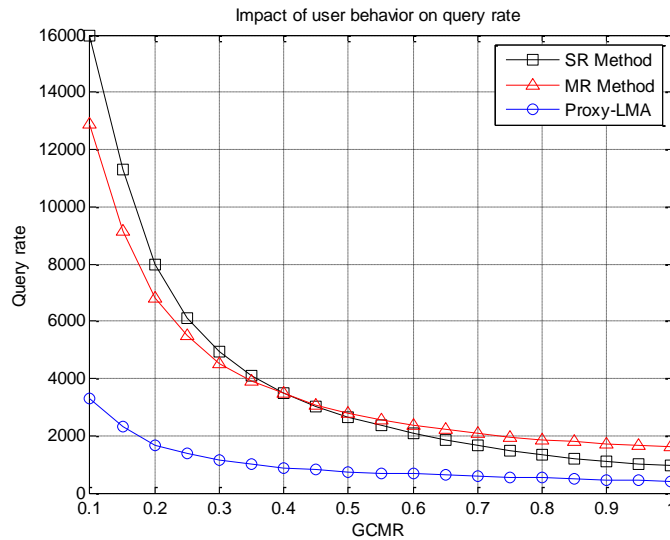


Fig. 6. Impact of user behavior on query rate.

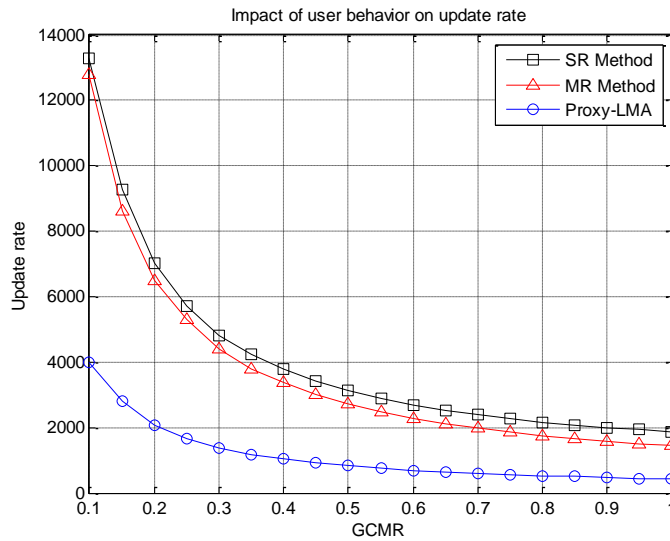


Fig. 7. Impact of user behavior on update rate.

This shows that the proposed approach brings about significant improvement from the perspective of query execution and information renewal in global roaming, compared to the SR and MR methods. Meanwhile, the MR method led to a greater decrease in the query execution rate, compared to the SR method, when $0.1 < \text{GCMR} < 0.4$. However, the MR method was found to be inefficient, compared to SR method, when GCMR was larger. For each method, the changes in system response time were investigated, as well as the query execution and information renewal rate based on user distribution, in M-LMA/M-HA or Proxy-LMA stage. For that, the user distribution in subsystem i was set from 0.1 to 95%. Fig. 8 and 9 show that the average query execution and information renewal rate of M-LMA/M-HA or Proxy-LMA decreases if the ratio of mobile users increases in subsystem i .

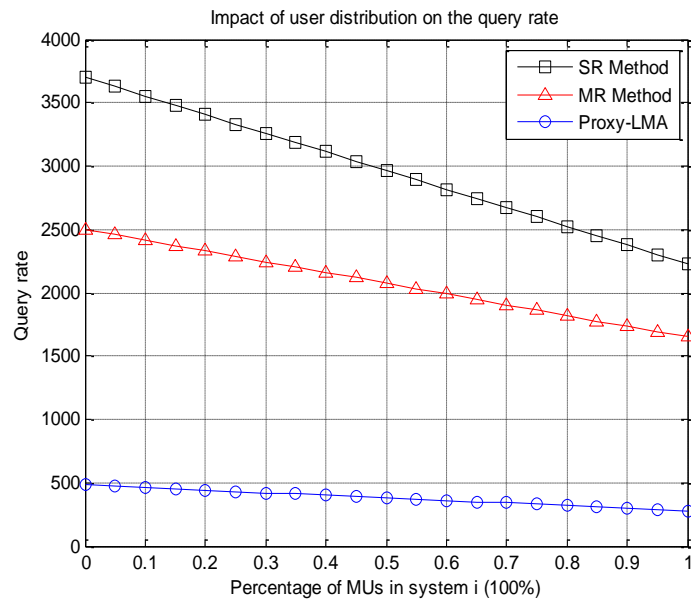


Fig. 8. Impact of user distribution on the query rate.

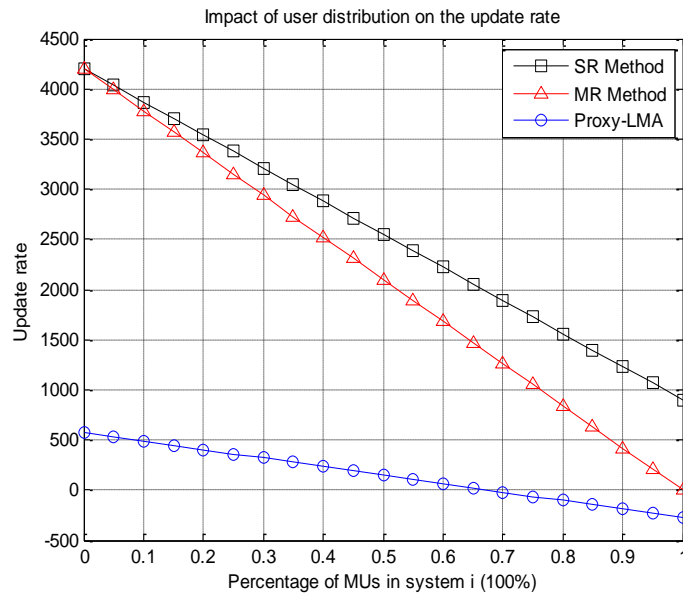


Fig. 9. Impact of user distribution on the update rate.

This means that better services can be provided if mobile users are concentrated in a subsystem. Fig. 10 shows that the proposed approach significantly reduces the response time, as well as the query execution and information renewal rate, in M-LMA/M-HA or Proxy-LMA.

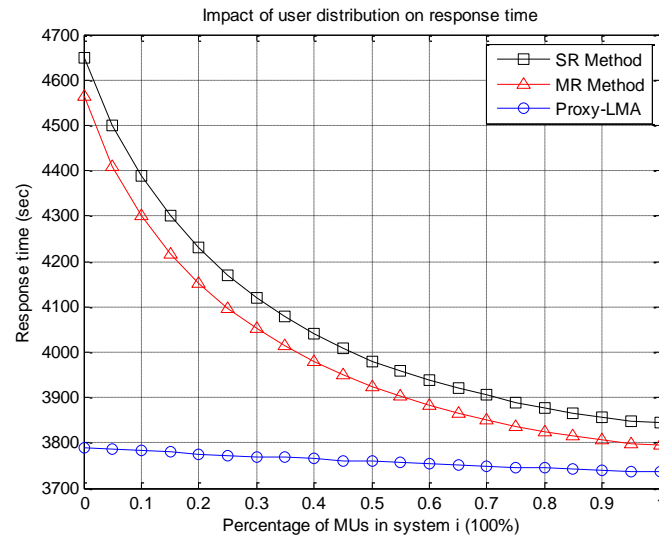


Fig. 10. Impact of user distribution on response time.

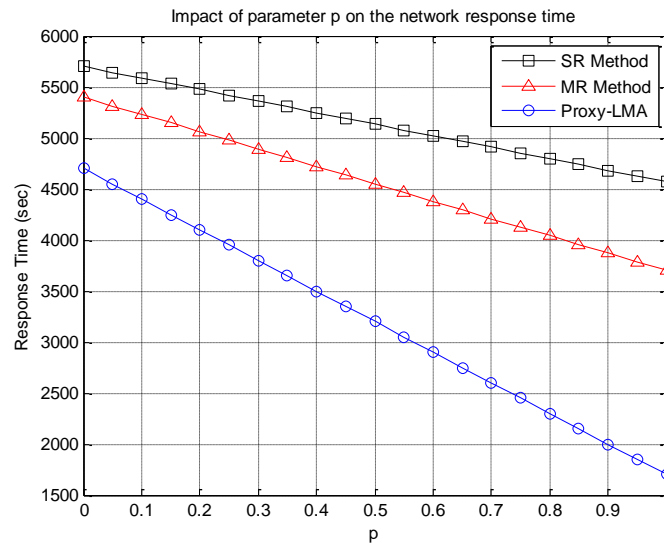


Fig. 11. Impact of parameter p on the network response time.

Based on the results, the changes in the query execution, information renewal rate, and response time can be compared based on the user distribution in MAG, HA/LMA, and the Proxy-LMA stages on each network. The following evaluates the effect of the location management policy on the response time. For that, the average processing delay time of MAG and LMA/HA is defined as 10ms for MAG and 10ms for LMA in the query execution. For information renewal, MAG is defined to be 20ms and LMA is defined to be 30ms. The probability P of discovering the information, which is requested upon the query execution, is changed. The results presented in Fig. 11 show that the response time is in inverse proportion to probability P . In other words, the network response time is reduced if more location information is retrieved from MAG. Additionally, the results demonstrate that the approach, proposed in this paper, can reduce the response time in the value of P ($0 < P < 1$).

5. Conclusions

Until now, most studies on the NGNW considered only the domain within one mobility management protocol. However, there have been few studies that looked into the heterogeneous network environment, the procedure for exchanging the signaling messages, and cost reduction, etc. The heterogeneous environment, which was examined in this paper, also has many constraints, and particularly was found to have several problems such as the limit in mobility, the upswing in the signaling cost, and the prolonged handover delay, which is the weakness of each network. In order to resolve such problems, this paper proposed the Proxy-LMA gateway method based on PMIPv6 and MIPv6 to reduce the signaling cost and handover delay. The results of performance evaluation show that the Proxy-LMA gateway method, proposed in this paper, is more beneficial in terms of the reduction in network traffic, fast response time generation and fast user location determination, fast query execution and information renewal, etc., compared to SR, MR and others. Thus, it was confirmed that the proposed method could ensure global mobility and interoperability within a heterogeneous network environment. Future studies need to be conducted in relation to the security requirements in order to ensure efficient control of various security-related variables arising from the movement of users and various control messages that are generated from the handover between heterogeneous networks.

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