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Location-Awareness Management in IP-based IMT Network Platform (IP^2)

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ABSTRACT

IP^2, as an extended concept of the next generation IMT network, is a concept of basically supporting mobility using two steps of IP address (i.e. IPha (IP Host address) and IPra (IP routing address)) in IP backbone network. Current IP^2system has a shortcoming of excess usage of network resources caused by sending paging messages to all cells in LA (Location Area) in paging procedure. Considering the evolving direction of network, which is taking mobility with various speed and integration of devices into consideration, this shortcoming must be overcome. In this paper, we proposed a method to reduce time and memory for paging by maintaining current information of MN (Mobile Node) not in Active state with proxy server. Performance evaluation based on NS-2 simulations has shown that the efficiency of network resources is improved in the proposed method.

Key words: Next generation IMT network, IP^2, Location-awareness, Paging, Proxy server

1. INTRODUCTION

Next Generation IP-based IMT Network Platform (IP^2) network, which is an important concept of IP-based system convergence, was designed to support mobility basically [1-4]. The mobility provides various and new services, which were not possible in conventional infra, as well as seamless services while terminals or users are moving. NTT DoCoMo supposed, designed and has been testing new network architecture taking mobility into consideration for Mobility Managing in NCPF (Network Control PlatForm). In IP^2 network, signaling messages in network tend to significantly increase resulted from unpredictably frequent move of users and from more and gradually complicated terminals. Consequently, radical decrease of quality is caused when handover, roaming, network convergence and device convergence are to be serviced. For improvement of network efficiency and performance, such as the reduction of signaling messages, IP^2 network uses Location Area Information as well as routing information to manage terminals and network shared resources more efficiently. In addition, we proposed a mechanism of maximizing the efficiency of networks by reducing unwanted overheads, which were gen-

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erated during paging procedure [5,6]. For the solution to the unwanted overheads, we firstly analyzed the cause of overheads through Location Area Information and proposed a solution mechanism. And the proposed solution scheme was compared with the conventional mechanism by mathematical modeling of paging cost and simulations of applicable scenarios.

In Chapter 2, theoretical background of IP^2 (The IP-based IMT network Platform) and conventional paging techniques were briefly described. In Chapter 3, a new paging scheme using Proxy was proposed. A mathematical model of paging cost was proposed in Chapter 4. In Chapter 5, the performance of the proposed scheme was evaluated by computer simulation. We lastly conclude this paper in Chapter 6.

2. IP^2 NETWORK

IMT-2000, which started its service in 2001, provides faster speed up to 384kbit/s in its mobile internet connection services. In the future "Beyond IMT-2000" network, the portion of mobile internet connection services will be increased significantly. Traffics of mobile communication network will also rapidly change from voice traffics to multimedia traffics [7,8]. In this network, IP-based network is essential to process multimedia traffics efficiently. User's needs are rapidly increasing and technologies are also being improved significantly to meet the needs. For an efficient transmission of large amount of IP multimedia traffics, IP^2 network is required to have an improved mobility management and supports for multiple wireless connection system, seamless and various application services. Figure 1 shows the logical configuration of IP^2 network architecture.

There are two areas in IP^2. One is IP transport network (Transport Network Layer (TNL)) which carrys packets. The other is middleware (Network Control Layer (NCL)) which is advanced control.

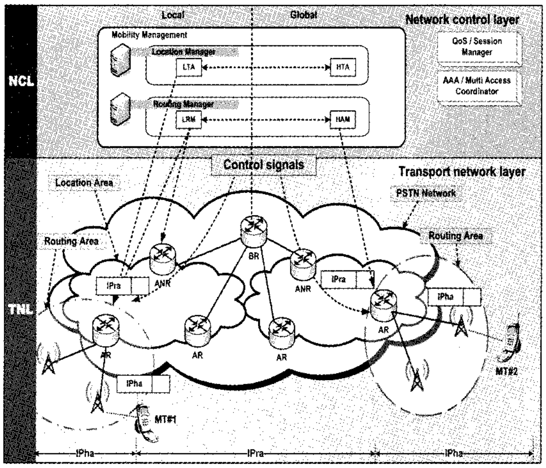

Fig. 1. Architecture of IP^2 network.

Transport Area is required for data transmission process. From a point of "IP over everything", transmission of IP packets upon various transport technologies will be evolved and IP^2 transport network will be concentrated on IP packet transmission.

The next generation operator network has to provide new services, efficient mobility management and high quality communication which will evolve independently from packet transmission functions.

Middleware is organized with NCPF (Network Control PlatForm) and SSPF (Service Support PlatForm). Transmission control and advanced service function are operated independently each other. NCPF provides management of moving, session, QoS, authentication/admission, and wireless resource. And SSPF provides contents conversion, service distribution, and location information.

3. PAGING SCHEME WITH PROXY SERVER

IP-Backbone (IP-BB) of IP^2 was designed to support mobility as a backbone network of ubiquitous network. IP-BB uses two types of IP address, which are IP host address (IPha) and IP routing address (IPra), to support free mobility of MN (Mobile Node). IPha is used between MN and AR (Access Router) and IPra is for packet transmission within IP-BB. Network structure has introduced the feature of cellular network which manages location and routing in combination. In addition, MN has two states of Dormant and Active state. Since MN in dormant state is managed by LM (Location Manager) separately, there is no need to send signals for updating location information of MN in Dormant state after the movement of the MN. Additionally, it is not required to store and manage the information of MN in CST (Cache for Source Terminal) and CDT (Cache for Destination Terminal) so that the use of network resources can be decreased [9]. MN is to change its state in three cases that MN in Dormant state sends Activation messages to AR, LM sends paging messages to MN in Dormant state and MN receives Time expire messages from AR, respectively. Paging procedure is the procedure of LM for state transition of MN from Dormant to Active state.

LM manages information of all MN within IP^2 network, conducts paging procedures and stores Location Management Table with the location of MN, which is identified as LAA (Location Area Address). RM assigns IPra to MN in Active state and manages routing address information. AR plays a role in transferring IPha of packet to IPra and in transmitting packets. AR has CST (Cache for Source Terminal), which stores IPha and IPra of MN at start point, and CDT (Cache for Destination Terminal), which stores IPha and IPra of MN at destination point [10]. LM and RM manage the information of MN location by area unit of LA (Location Area) and RA (Routing Area), respectively. Figure 2 shows the network configuration including proxy and area class of LA and RA.

Since there is no concept of dormant state in Mobile IP, location information should be updated

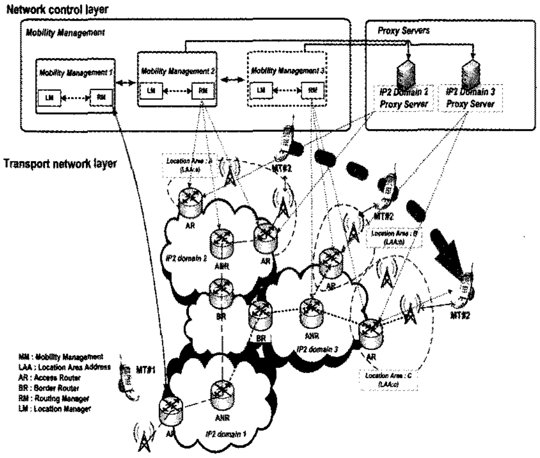

Fig. 2. IP^2 network with Proxy servers.

whenever MN moves even if there is no communication. Consequently, power consumption and waste of network resource are increased by the update messages whenever MN moves [11]. In IP^2, network resource allocation and power consumption mechanism are designed to be minimized by keeping dormant state of MN by LM. When there is a state transition, however, from Dormant state into Active state by paging, excessive network resources would be used since messages are to be flooded to all MN within an extensive area of LA. To resolve this weakness, the introduction of proxy server for paging was proposed in this paper. Since proxy server obtains the information of specified route when paging messages sent by LM are passing through the proxy server, it has more detailed location information of MN than LM does so that both AR (Access Router) and BS (Base Station) only, to which IPra of MN belongs, only receive paging packets. Consequently, network resource can be used more efficiently.

3.1 Registration of Location Information

The procedure of registering detailed location information of MN in proxy server occurs when MN joins LA for the first time or MN moves into another LA. In general, registration of the location is conducted when MN in Active state moves to another LA.

After MN in Dormant state finds that its location has changed, it sends a location registering message to BS, to which it belongs, and corresponding AR sends a location update message to LM. LM updates the entry of MN in its location management table and transmits the location registration message which is received from AR to proxy server. Then the entry of MN in proxy table is updated and the proxy server sends a location update Ack to a corresponding AR. The AR sends MN an Ack corresponding location registration request.

3.2 Paging Procedure with / without Proxy Server

Figure 3 shows paging procedure in conventional IP^2 network without proxy server. It shows that paging messages are sent through AR1 and AR2 in LAA area, to which IPha #A belongs, to all MN resulting in waste of network resource.

1) RM sends LM Paging trigger. LM searches for IPha in its location management table and finds LAA of the requested IPha. 2) LM asks paging to ARs in the area using LAA. 3) Each AR starts paging using AP (access point) which uses Layer 2 paging signal. 4) MN #1 responds by sending a paging ack and then MN starts activation procedure.

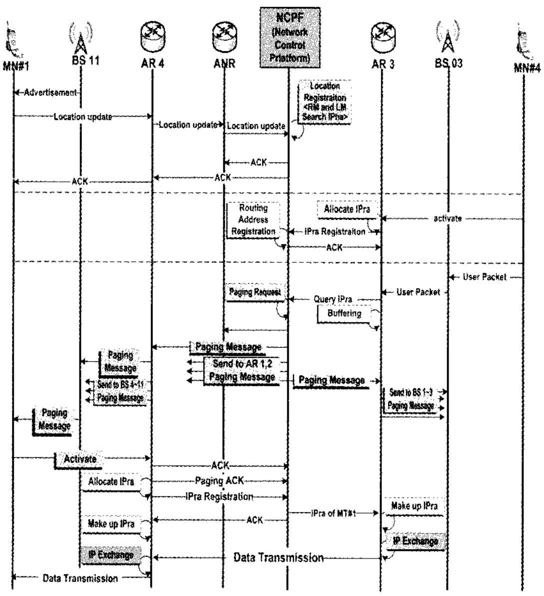

Fig. 3. Paging Procedure with No Proxy server.

Figure 4 shows paging procedure in IP^2 network with proxy server. Since the proxy server already has the current information of AR and BS, at which MN #1 is located, there is no need to send paging messages to all area of LAA. Comparing with the case of Figure 3, it can be shown that the efficiency of usages of network resources is improved very much.

1) RM sends LM paging trigger. LM searches for IPha in its location management table and finds LAA of requested IPha.

2) LM sends paging trigger to proxy server. The proxy server which received the paging trigger finds the current AR and BS in its proxy table.

3) The proxy server asks AR4 for paging by using the information found in its proxy table.

4) BS11 in AR4 starts paging through AP which uses Layer 2 paging signal.

5) MN #1 responds by sending paging ack and MN starts activation procedure.

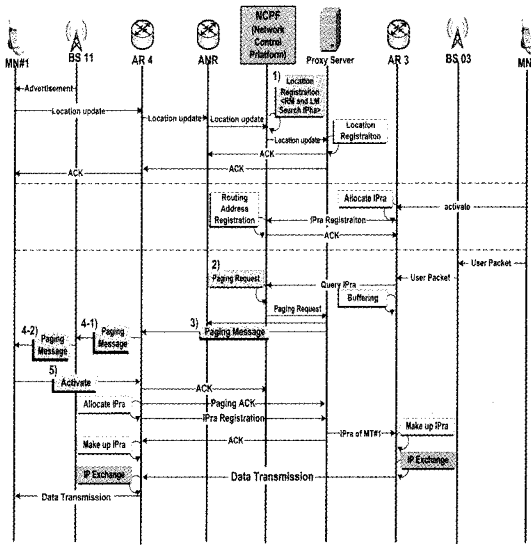

Fig. 4. Paging Procedure with Proxy server.

3.3 Mobility Support

There are 3 IP^2 domains and MN #M in domain 3 is going to send packets to MN #C in domain 1. MN #M is in Activation state and IPra is assigned to AR and RM, to which it belongs. However, MN #C is in Dormant state and IPra is not assigned to AR and RM. Only location information of MN #C is registered in LM. Mobility support procedure is as follows.

In figure 5, 1) MN #M sends the first packet to MN #C for communication. AR6 searches for IPra of destination IPha in CDT. Since there is no IPha in its table index, however, AR6 asks RM for IPra of corresponding IPha. AR6 finds there is no IPra in RM and searches if MN #C exists in Dormant state in its LM. AR6 finds there is also no information in LM and asks MM in other domains for information of IPha. AR6 finds that MN #C is in dormant state in MM#1 of domain 1 and LM starts paging procedure. Then LM asks proxy server to conduct paging to the location where MN #C is located. MN #C conducts activation procedure through paging procedure and AR1 assigns IPra to its CST and registers it to RM. AR1 sends AR6 in domain 3 the information of IPra. Then IPra in CDT is updated. The destination of the packet is changed to IPra and it sends the packets. In case of 2) MN #C, which is communicating with MN #M, moves from LAA:a to LAA:b. In this moment, since handover is a guarantee of mobility between LAs, location registration procedure has to be conducted. Through the location registration procedure, the location information of of MN #C in LM and proxy server is updated and the information of CDT of AR, at which all MNs communicating with MN #C are located.

The situation of 3) is that MN #C moves with LAA:b and new IPra is assigned to MN #C and registered to RM. Then RM updates CDT information of AR, at which all MNs communicating with MN #C are located. In case of 4), MN #C moves from domain 1 to domain 3. MN #C conducts location registration procedure and registers its IPha in LM of MM3. Location information of MN #C is deleted from LM of MM1 and RM. And then IPra is assigned to AR4 and RM and the CDT information is updated.

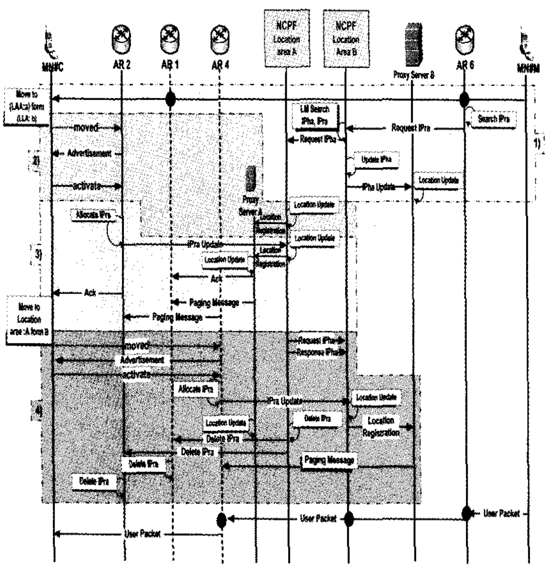

Fig. 5. Sequence of Handover.

4. PAGING COST CALCULATION

4.1 Location Management and Cost Evaluation

We assume there are NC cells in one location area. λ_i is probability that MN exists in i-th cell. ρ_i is paging load for request number in i-th cell (i = 1, 2, ⋯, NC). $\sum_{i=1}^{N_C} \lambda_i = 1 (0 \le \lambda_i \le 1)$ and ρ_i are instance values when paging process starts. One location area is divided into paging area (1 < NP < NC) of Np for the multi-step paging. And the size of j-th Paging area is nj (j = 1, 2, ⋯, NP). We will define Paging success probability of Paging Area which means a probability of a target user of an incoming call to be found in the corresponding Paging area. Paging success probability of j-th Paging area, Pj, is defined by the equation (1) below.

$$P_j = \sum_{i=m_j+1}^{m_j+n_j} \lambda_i, \quad m = \sum_{i=1}^{j-1} n_i, \quad m_1 = 0 \text{ and } \sum_{j=1}^{N_p} P_j = 1. \quad (1)$$

Paging Delay Cost means delay time until Paging is succeeded. In the equations below, $\overline{D_j}$ and $\hat{D}_j$ are Paging delay times in case of successful and failed paging, respectively. D is Average Paging delay of MN until Paging is succeeded after Paging failure.

$$D = p_1\overline{D}_1 + (1-p_1)[\hat{D}_1 + \frac{p_2\overline{D}_2}{1-p_1}] + ...(1-\sum_{j=1}^{N_p-1} p_j)[\hat{D}_{N_p-1} + \frac{p_{N_p}\overline{D}_{N_p}}{1-\sum_{j=1}^{N_p-1} p_j}]$$

$$= \sum p_j\overline{D}_j + \sum_{j=1}^{N_p-1}[(1-\sum_{i=1}^{j} p_i)\cdot\hat{D}_j] \tag{2}$$

$$\overline{D} = \sum_{j=1}^{N_p} p_j\overline{D}_j \tag{3}$$

$$\hat{D} = \sum_{j=1}^{N_p-1}[(1-\sum_{i=1}^{j} p_i)\cdot\hat{D}_j] \tag{4}$$

It is assumed that transmission time ($1/\tau$) of Paging message on Wireless link is constant in all cells. $\overline{D_j}$, which means Paging delay when Paging is succeeded in j-th Paging area, is defined by equation (5).

$$\hat{D}_j = \frac{1}{p_j}\sum_{i=m_j+1}^{m_j+n_j} \lambda_i \cdot \left(\frac{\rho_i}{\tau}\right) \tag{5}$$

Where υ_i/τ is Paging load in each cell $\hat{D}_j$, which is Paging delay in case of Paging failure, is expressed by Equation (6).

$$\hat{D}_j = \frac{\max(\rho_{m_j+1}, \rho_{m_j+2}, \ldots, \rho_{m_j+n_j})}{\tau} \tag{6}$$

In equation (3) and (5), $\overline{D}$ is determined by given location information probability distribution (λ_i) and Paging load distribution (ρ_i). For calculation of Paging Delay Cost, $\hat{D}$ is considered only. In equation (4), $\hat{D}$ can be expressed by equation (7) because of $\sum_{j=1}^{N_p} p_j = 1$.

$$\hat{D} = \sum_{j=1}^{N_p-1}[(1-\sum_{i=1}^{j} p_i)\cdot\hat{D}_j] = \sum_{j=1}^{N_p}[(1-\sum_{i=1}^{j} p_i)\cdot\hat{D}_j] \tag{7}$$

Similar to the case of equation (2), Paging load cost, which means an average number of cells searched until paging success, is defined by the equation (8).

$$L = \sum_{j=1}^{N_p}\left(p_j \cdot \sum_{i=1}^{j} n_i\right) \tag{8}$$

Therefore, overall Paging Cost (C), which is a sum of Paging delay cost ($\hat{D}$) and Paging load cost (L), can be expressed by the equation below (9).

$$C = L + \omega\cdot\hat{D} = \sum_{j=1}^{N_p}\left(p_j\sum_{i=1}^{j} n_i\right) + \omega\sum_{j=1}^{N_p}[(1-\sum_{i=1}^{j} p_i)\cdot\hat{D}_j]$$

$$= \sum_{j=1}^{N_p}[p_j\sum_{i=1}^{j} n_i + \omega(1-\sum_{i=1}^{j} p_i)\cdot\hat{D}_j] \tag{9}$$

In this equation, ω is a delay factor which priority is taken into account. Delay factor (ω) can be estimated based on the amount of Paging traffic and the condition of delay range.

4.2 Paging Cost with Proxy Server

Currently, the access mechanism of IP^2 for paging is Blanket Paging scheme, which sends Paging messages to all cells within Location Area. It has an advantage of fast response by sending Paging messages to all cells which also results in large load of the network. The mechanism for dividing Paging Area, which is called sequential Paging scheme, was designed to reduce the network load at the cost of paging delay. In this paper, we proposed a method for Paging to the current location information of MN in case of the arrival of Paging request by using a Proxy. By the method, network load can be reduced and fast response for request can be possible.

Paging cost in Sequential Paging scheme was calculated by $C = L + \omega \cdot \hat{D}$, where L is load about cells, to which Paging message is sent, until the paging is succeeded. All the cells which are searched in the previous paging are the case of failed Paging. Paging delay is occurred in the cells that failed to Paging and the total sum of Paging delay was denoted by D.

When $C = L + \omega \cdot \hat{D}$ is applied to Blanket Paging scheme, L means load about all cells with LA and D has no meaning. In case of applying $C = L + \omega \cdot \hat{D}$

into Paging scheme, both L and D is meaningless since the location information of cells is already known. However, there are errors normally generated by using proxy. The last location information of MN will be stored in proxy in case of deactivation of the MN and no location information update will be conducted until the MN is activated again. If the MN moves to another area during this period, however, the MN cannot be found. In this case, the MN can be found by blanket Paging mechanism which is used in IP^2.

It is supposed that $C_{blanket}$ is Blanket Paging cost and C_{proxy} is Blanket Paging cost with proxy. The relationship between these two costs can be expressed by the equation below.

$$C_{proxy} = \beta \cdot C_{blanket} \tag{10}$$

Where, β is a probability of moving into another area after deactivation. If MN has two states and a probability of moving from a cell to neighboring cell is denoted by p_h, β can be expressed by the equation, $\beta = \frac{1}{2} \cdot p_h$. p_h [12] can be expressed by the equation below.

$$p_h = \frac{1 - e^{-\alpha}(1-\alpha)}{2\alpha} - \frac{\alpha}{2}\int_{\alpha}^{+\infty}\frac{e^{-x}}{x}dx \tag{11}$$

Consequently, C_{proxy} can be expressed by the equation below.

$$C_{proxy} = \frac{1}{2} \cdot \left(\frac{1 - e^{-\alpha}(1-\alpha)}{2\alpha} - \frac{\alpha}{2}\int_{\alpha}^{+\infty}\frac{e^{-x}}{x}dx \right) \cdot C_{blanket} \tag{12}$$

5. SIMULATION RESULT

For performance analysis of the proposed paging technique, CIMS (Columbia IP Micro-Mobility Suite) of NS2 (Network Simulator 2) was selected to add required functions and modules of IP^2 [13]. LM of MM (Mobility Management) and the proposed proxy server were implemented and added to the basic IP paging procedures. For comparison and evaluation of paging loads, simulation environments with various sizes of LA (Location Area) and various numbers of MN were configured. The topology has 2 LA, which has 4 BS per 1 LA, and 8 BS. The following table 1 shows variables of the simulation.

The figure 6 shows the simulation results which 8 mobile terminals are moving and generating CBR packets periodically during duration of Transmission. It can be shown that the proposed method is maintaining significantly low value of the loads and the number of control packets including paging. Improved success rate of data packets transmission, which has been resulted from these low values of load and control packets, caused the decrease of drop to increase overall network transmission rate including control packets as well as data transmission rate. Local peaks in Figure 6 (a) and (d) indicate the moment of handover by moving of nodes. In this moment, the difference of transmission rate of two methods was increased. It is expected that the proposed method would have

Table 1. Simulation parameter

Parameter	value	Parameter	value
Dimension	500*500m	Router	2
Routing	NOAH	LM(Location manager)	1
Queue Len.	50	Proxy Server	1
Simulation time	20 sec	Mobile Terminal	2~8
BS(Base Station)	4	TCP packet size	1,460 bytes
CBR generation interval	0.01 sec	Duration of Transmission	0.7~5.0 sec
Default Paging Interval	0.02~0.1 sec	Default Routing Interval	0.04~0.2 sec

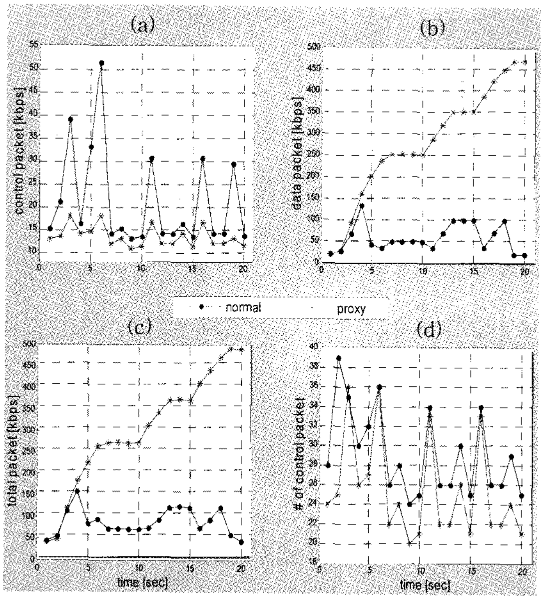

Fig. 6. Simulation Results.

benefits in real networks, which has complicated mobility and network topologies. Table 2 shows the total number of control packet transmission for paging which is generated in the overall network. It can be shown that performance improvement of about 20% has been achieved.

6. CONCLUSION

IP^2 (IP-based IMT Network Platform), as 4G network architecture, is a concept for supporting large amount of multimedia traffics generated by mobile communication in the future. In IP^2, MN has a state of Dormant or Active and data transmission is enabled after the state transition to Active state. In this paper, for reduction of waste of sharing resources in conventional methods, a method of using proxy server was proposed to help LM's paging function in IP^2 and to reduce the waste of the existing sharing resources. Since the proxy for paging maintains current location of MN, the proxy can send paging messages selectively to the current location of LA and, consequently, sharing resources of the network can be used efficiently. Since IP^2 is on the stage of progressing and not a completed model up to the present, our research works on paging will be conducted continuously.

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Table 2. Paging Load of Network (case of 8 MT)

Paging Interval	0.10	0.08	0.06	0.04	0.02
Normal (kbps)	59.102	71.387	92.129	130.684	244.922
Proxy (kbps)	47.949	57.441	73.574	103.652	196.289
Improvement (%)	23.259	24.277	25.219	26.079	24.776

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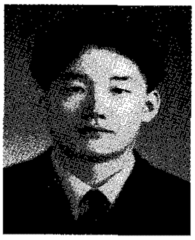

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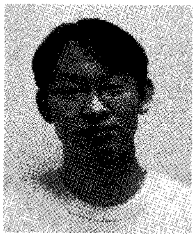

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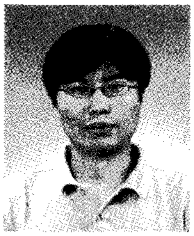

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