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중첩된 NEMO에서의 경로 최적화를 위한 개선된 계층적 프리픽스 할당 프로토콜

노 경 택*

Improved Hierarchical Prefix Delegation Protocol for route optimization in nested NEMO

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요 약

네트워크 이동성 기본 솔루션(NEMO basic solution)의 비 경로 최적화의 문제점을 해결하기 위한 방안 중 하나로 HPD(Hierarchical Prefix Delegation) 프로토콜이 있다. 그러나 HPD는 미시적 이동성에 대한 지원을 하지 못하므로 이동네트워크노드(MNN)가 접촉점을 변경할 때마다 MIPv6 프로토콜에서와 같이 HA(Home Agent)와 통신노드(CNs)로 BU(Binding Update) 메시지를 보내야하는 문제점을 갖는다. 본 논문은 HPD에 HMIPv6 프로토콜 개념을 적용하여 nested NEMO에서의 미시적 이동성을 효과적으로 지원하는 알고리즘을 제안하였다. 이동네트워크노드는 MAP(Mobility Anchor Point) 영역 안에서 위치변경 시 가까운 곳에 위치한 MAP으로만 BU를 보냄으로써 핸드오프 과정에서 발생하는 서비스 중단이나 신호 부하를 감소시켜 HPD에서의 한계를 극복하였다.

Abstract

Hierarchical Prefix Delegation (HPD) protocol refers to a type of solution to problems inherent in non-optimal routing which occurs with Network Mobility (NEMO) basic solution. However, because HPD cannot improve the micro-mobility problems, problem surfaces each time Mobile Network Node (MNN) changes the attachment point; as happens also in a Mobile IPv6 (MIPv6) protocol in sending Binding Update (BU) messages to Home Agent (HA) / Correspondent Nodes(CNs). By applying Hierarchical Mobile IPv6 protocol concept to HPD, this study proposes an algorithm for effectively handling micro-mobility problems which occur with HPD in a nested NEMO environment. By sending BU only to nearby Mobility Anchor Point(MAP) during MNN location change within a MAP's domain, the proposed protocol will alleviate service disruption delays and signaling loads during the handover process, overcoming the limitations of HPD.

▶ Keyword : 경로최적화 (route optimization), 미시적이동성 (micro-mobility), network mobility,

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Ⅰ. Introduction

MIPv6[1, 12] encompasses not only the home address (HoA) but also care-of address (CoA) which indicate the Mobile Node's (MN) current location, and by sending BU to HA/CNs at each location change, it maintains the connection to them. However, when real-time communication or a sensitive application to potential packet loss is required, MIPv6 is severely limited. Each time MN switches its position, it must register with the HA/CNs which may be located at longdistances. During the interval between registration from one subnet to another, the connection with a CN is temporarily suspended and thus, may lead to packet loss and disruption of real-time applications such as VoIP.

HMIPv6 [2,11], an extension of MIPv6, uses a new protocol agent called MAP; conceptually, MAP acts as a regional HA. HMIPv6 comprises of Home Address (HoA) of home network, Care-of Address (CoA) of access network and Regional care-of Address (RCoA) based on MAP. Regardless of MNN's true location, HA and CN accept its location as represented by RCoA and transmit packets to the RCoA. By utilizing the binding information between RCoA and CoA, MAP forwards the data packet to the ultimate MN. HMIPv6's advantage is that, by dividing the mobility management into macro- and micro- category, it can lower the signal load and improve the handover speed during mobile connections.

On the other hand, NEMO basic solution [3] allows changes in the attached points with the internet while the nodes within the mobile networks maintain established sessions. Suboptimal routing, packet overhead and handover latency resulting from bi-directional tunnelling between MR and MR's HA occur in NEMO basic solution. Packets to MNN are first intercepted by MR's HA and tunnelled to that MR which then transmits to the MNN. Furthermore, to avoid ingress filtering, extra IPv6 header is attached to every outgoing packet and becomes further encapsulated in the process. This results in MTU's reduction and overhead increase as MR's nesting level deepens.

NEMO's shortcomings, namely the non-optimal routing and IPv6 encapsulation, can be solved by delegating Mobile Network Prefixes (MNPs) from Prefix Delegation (PD) protocol that enables MNNs to perform route optimization within the scope of the mobile network [9]. MR receives a prefix, based on PD protocol from an Access Router (AR), then, transmits the delegated prefix to its subnet. Using this prefix, the MN creates a CoA and subsequently sends the BU. This allows the MN to bypass ingress filtering and allows a direct communication with CN. Granted, PD allows for route optimization and avoidance of repeated IP header attachments between CN and MNN; however, despite the fact that 69% of user mobility is local [10], as with MIPv6, requisite transmission of BU to HA/CNs each time MN moves to a new location within the AR domain increases signaling load and handover latency problems as well as packet losses.

This study proposes applying the HMIPv6 principles to HPD protocol to not only achieve packet rout optimization and avoid ingress filtering as with HPD but also to enable a fast handover and a decrease of signaling load by improving the micro-mobility problems. The remainder of this paper is organized as follows: Related works-to-date will be cited in sections 2. Section 3 will describe the proposed route optimization mechanism using HPD with HMIPv6. Section 4 will illustrate simulation results attained from MATLAB and close with conclusion and suggestions for future works.

II. Related Work

When MR detects its own movement, it receives a prefix block by running the PD protocol. Using the prefix, MR attains a topologically correct CoA. There are various protocols as listed below for address autoconfiguration.

As one of the address autoconfiguration methods, Automatically Prefix Delegation (APD) protocol makes delegation, refreshing and return of IPv6 prefixes possible [6]. APD allows routers to request any prefix from the upstream router on the same link. When authorizing the request, the delegating router then returns a prefix and its lifetime. The ICMP prefix request message is used by the requesting router to communicate requests to the delegating router. The ICMP prefix delegation message is used by the delegating router to communicate prefix with the requesting router.

IPv6 Router Advertisement Prefix Delegation (RAPD) option in Router Advertisement (RA) messages is used for the delegation of IPv6 prefixes to simple IPv6 sites [7]. The RAPD option extends the functionality of RA messages to enable configuration of a site router. RA messages sent by a provider router can be used to assign one or more address prefixes of an arbitrary size to a site, allowing the site router to configure its network. ThisRAPD option has no functionality to support dynamic prefix leasing, refreshing and return. This means that the providing router has no way of knowing whether the delegated prefix will be used or not.

IPv6 Prefix Options for DHCPv6 proposes to use a PrefixDelegation option and Prefix Request option in the stateful configuration protocol DHCPv6 for PD [8]. The prefix requestor and delegator don't have to be on the same link, because DHCPv6 supports relay agents. Prefix Delegation option and Prefix Request option are used by delegating router and requesting router respectively. The delegating router can delegate prefixes to requesting routers through these options. It is appropriate for situations in which the delegating router does not have knowledge about the topology of the networks to which the requesting router is attached.

Among the protocols above, APD protocol is appropriate for IPv6 address aggregation architecture. Because prefixes are of variable length and multiple hierarchical layers of prefixes are allowed, it is appropriate for supporting nested NEMO. Although DHCP and RAPD are easier to implement, because prefix block is allocated even when MR sends no prefix request message, they are inappropriate.

III. Proposed Route Optimization Scheme for supporting Micro-mobility in NEMO Network

[9] is based on IPv6's stateless address configuration and APD protocol. In this scheme, IPv6 header encapsulation is avoided and route optimization achieved. Moreover, such scheme was observed to support dynamic global addressing related to the MNs of a mobile network, and makes possible the network mobility. However, despite most user mobility being local in nature [10], because a BU must be sent to HA/CNs whether macro mobility occurs or whether the micro-related movement is within the AR domain, frequent internet location change can cause unnecessary traffic increase, thereby resulting in packet losses and handover latency.

To address the above limitations, the study proposes the utilization of a scheme supported by HMIPv6

(4) in conjunction with HPD protocol (5), itself an extension of APD. The proposed algorithm provides for improving micro-mobility problems and optimal routing paths between the MNNs inside the NEMO and the CNs outside the nested NEMO.

To support this set-up, all MNNs except LFNs are assumed to use HMIPv6 protocol. Also, to improve micro-mobility problems as in HMIPv6, the access router AR(MAP), as shown connected to the internet in (figure 1), is assumed to have MAP functions. Before mobile network's MR is moved to a foreign link, because the MR must be detected to be at a home link and also because visiting downstream MR must be provided a part of an address space within the MR's network, MR's subnet link prefix will be the same as that of the delegated network prefix. For example, infigure 1, when MR2 exists in home link, MR2 will broadcast to its local link the RA message containing MAP prefix q:: and subnet prefixes q:1:: which it received from AR(MAP) and delegated prefix q:1:: which it received from HPD protocol. Furthermore, MR2 will allocate to requesting MR a longer delegating network prefix such as q:1:1::. MNNs behind the MR are composed of RCoA which use the MAP prefix from AR(MAP) through intermediate MRs and CoA based on the delegated prefix that MR, as the requesting router, received from an upstream router.

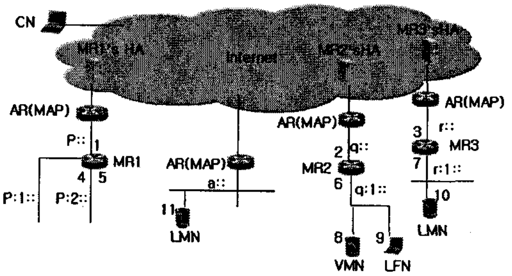


Figure 1. Mobile Router at home link

3.1 Protocol Overview

AR(MAP) broadcasts RA(MAPprefix, on-link prefix) which include prefix information option having on-link prefix and MAP option having

MAP prefix. Within the nested mobile network, all MRs (including root-MR (MR1)) except AR will be allocated delegated MNP from theupstream router, and with MAP prefix and on-link prefix, MRs will broadcast to their subnet links. The proposed protocol will be operated as shown on (figure 2.)

1. MRi will broadcast RA(MAP prefix, MNP, on-link prefix) which contains its own on-link prefix, MAP prefix received from MRi-1, and delegated MNP resulting from ICMP prefix delegation operation with MRi-1.
2. MRi+1 will form RCoA by utilizing the MAP prefix contained in the RA message from the MRi (AR: in MR1's case, the upstream router is AR(MAP)) and CoA being created from a delegated MNP.

3,4,5,6. Using HPD protocol (5), the requesting router MRi+1 will be allocated the same number of prefixes as the subnet links by the delegating router MRi. At the same time, MRi will update its routing table based on the MNPs it delegated to the MRi+1. In other words, the next hop for delegated MNPs is indicated by CoA of MRi+1. Thus, all traffic related to the allocation of MNPs is to go to MRi+1.

7. Before sending an unsolicited RA to MNN butmust send BU based on mobility management to MAP or HA/CNs. MRi+1 first sends BU(RCoA, CoA) to MAP. after receiving new MNPs from MRi, MRi+1
8. The MAP receives BU, performs DAD check, and must store this information in its Binding Cache to be able to forward packets to their final destination when received from the different CNs or HAs. MAP then sends BACK to MRi+1.

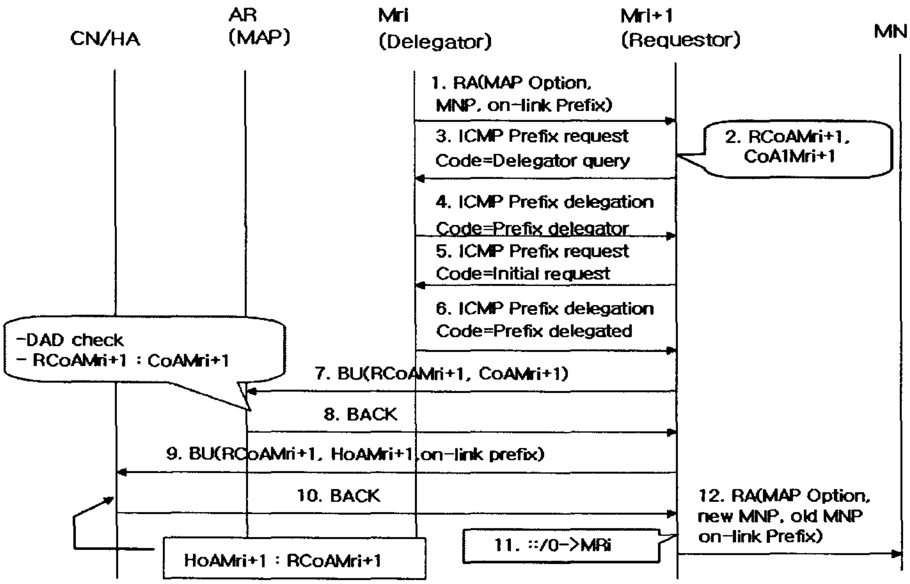


Figure 2. Proposed Protocol Overview

9,10. In macro-mobility situation, BU(on-link prefix, HoA, RCoA) is sent to its HA/CNs.Based on BU which it received from MRi+1, HA/CNs will update its binding cache then send BACK to MRi+1.

11. MRi+1 will update its routing table per the new MNP, meaning MRi becomes the designated default router for MRi+1 (::/0->MRi). 12. With regards to its attached MNNs, MRi+1 will update its routing table per the new MNP, meaning MRi becomes the designated default router for MRi+1 (::/0->MRi).

12. With regards to its attached MNNs, MRi+1 will broadcast on its local link the unsolicited RA(old MNP, new MNP, on-link prefix, MAP option) which contains old MNP with a valid lifetime of 0 in order to expire the addresses derived from the old MNP and the new MNP that has a new lifetime.

3.2 Mobile Router Operation

(Figure 3) in case referring to (Figure 1), illustrates the following topology: The three MRs move from home link to the foreign link then, VNN moves from MR2's mobile network to MR3's mobile network. Each MRs performs its prefix delegation.

First, after receiving RA that includes MAP prefix(a::) and on-link prefix(a::) from AR(MAP), MR1 detects the location change. Because MAP prefix(a::) and on-link prefix(a::) are same in AR(MAP)'s case, RCoA and CoA which are identical are created based on each's prefix. Using the HPD protocol, MR1 is allocated by AR(MAP) a number of delegated MNPs (a:1::, a:2::) equal to its number of subnet links, then, broadcasts RA that includes MNPs, the MAP prefix and the on-link prefix. MR1 sends BU message containing RCoA and CoA to MAP and BU message containing RCoA, HoA, and on-link prefix to HA/CNs. AR(MAP) and HA/CNs saves to their binding caches each BU information received from MR1.

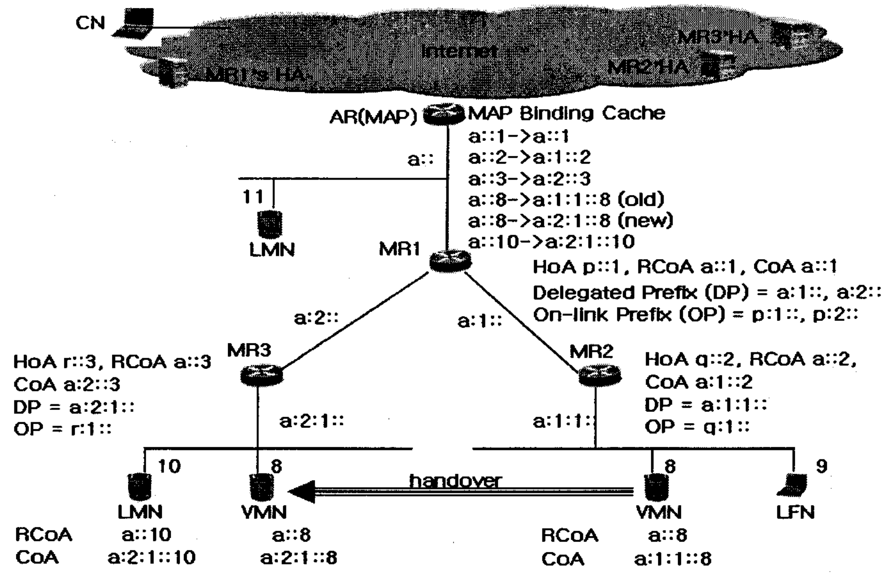


Figure 3. Network Mobility using proposed protocol

Second, MR2 relocates to MR1's network then creates RCoA(a::2) using MAP prefix and CoA (a:1::2) using MNP(a:1::) from the MR1. Afterwards, BU containing RCoA and CoA is sent to MAP and also BU message containing RCoA, HoA, and on-link prefix is sent to HA/CNs. MR2 receives from MR1 MNP(a:1:1::) derived from prefix delegation and broadcasts to its local link.

Third, MR3, in same sequence as MR2, relocates to MR1's network, then, sends BU containing RCoA and CoA to MAP and also BU message containing RCoA, HoA, and on-link prefix is sent to HA/CNs. MR3 receives from MR1 MNP(a:2:1::) derived from prefix delegation and broadcasts to its local link.

Finally, when VMN, which is visiting MR2's mobile network, detects location change in MR3's mobile network, because micro-mobility within AR(MAP) is evident, it sends BU containing RCoA(a::8) and CoA(a:2:1::8) to MAP.

After receiving BU(new RCoA, HoA) from MMN, CNs outside of the nested NEMO changes their binding caches from old RCoA to new RCoA, then, sends the packets with the RCoA as a destination address to MNN.

AR(MAP) receives the packets with the RCoA as a destination address, changes the RCoA to a local CoA, then transmits the packets to MNN via intermediate MRs. When MNN within NEMO sends the packet to CN outside NEMO, it sends a packet with home address option that has source address as its CoA. AR(MAP), using binding cache, changes CoA to RCoA, then transmits to CN.

In case where LFN cannot perform MIPv6, MR designates as the source address on the outer header of the packets it received from LFN its own CoA, then, tunnels through the encapsulated packets designated for MR's HA

MR's HA decapsulates the packets and forwards them to CN destination.

MR, which serves the proxy function to LFN, sends to CN BU that contains LFN home address and care-of address RCoAMR. Using the received binding information, CN sends to AR(MAP) packets containing type 2 routing header. Subsequently, AR(MAP) changes RCoAMR to CoAMR and sends to MR. MR, then, transfers the packets to the LFN destination.

The proposed protocol will solve micro-mobility problems encountered during packet transmission by MNN to CN as well as problems in regard to ingress filtering or route suboptimization.

IV. Evaluation through Numerical Calculation

Because the proposed protocol enables the sending of BU to MAP instead of HA/CNs outside the nested NEMO during location changes in the MAP domain, it can lessen the handover latency markedly over existing protocol [9]. Thus packets losses and signaling loads, too, will be reduced.

Referring to (figure 3), wireless delay between upstream MR and downstream MR in the MAP domain is assumed to be c ms and wired delay between AR(MAP) and HA/CNs is assumed to be b ms. Time required to receive delegated network prefix between MRs using ICMP prefix delegation operation and processing time required of MRs, AR(MAP) and HA/CNs will be ignored. Assuming MNN's current position is at level i, the handover latency period, HOold, referred to [9], defined as the sum of time, indicated by $c*i$ ms required to send BU between MNN and AR(MAP), b ms required to send BU between AR(MAP) and HA/CNs, b ms required for the first packet to travel between HA/CNs and AR(MAP), and $c*i$ ms required for the same packet to travel between AR(MAP) and MNN, is similar to the time requirement of MIPv6. The handover latency period, HOnew, in the proposed protocol, on the other hand, is the sum of time, indicated by $c*i$ ms required for BU to travel in the wireless medium between MNN and AR(MAP) plus $c*i$ ms required from AR(MAP) to MNN. The efficiency of the new protocol, HOeff, explains the relationship between HOold and HOnew. They are defined as follows:

$$HOold = 2*c*i + 2*b$$

$$HOnew = 2*c*i$$

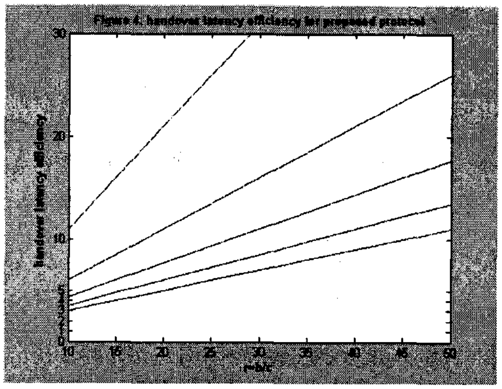
$$HOeff = HOold / HOnew = 1 + b/(c*i)$$

$$HOsave = HOold - HOnew = 2b$$

Using MATLAB, performance evaluation was done. (Figure 4) illustrates handover latency efficiency, HOeff, in micro-mobility which is effected by level i and $r=b/c$ value fluctuations. Even if level i increases, if the wired delay time caused by the route length between AR(MAP) and HA/CNs is longer than the wireless delay time between MRs and AR(MAP), then there will be a noticeable increase in handover latency efficiency.

The packet loss rate, during the registration period, is directly proportional to the accumulated link transmission time over the wired and wireless portions because the MNN is unreachable during this period. If any CN sends packets to MNN, the packet will be lost.

Within the micro-mobility, the latency period of HPD is indicated by HOold and the latency period of the proposed protocol is indicated by HOnew. The measured time difference in the latency period in the micro-mobility between the HOold and HOnew is HOsave.



Thus compared to HPD, the number of packet loss is lessened by the same number of packets in the HOsave period. Because 69% of user mobility is contained within a local site, an attribute of micro-mobility [10], packet losses can be lessened by the packets that occur during the period of at least 0.69*HOsave.

V. Conclusion

The route optimization method based on hierarchical prefix delegation provides route optimization between correspondent nodes and a mobile network node. However, it requires sending BU messages to the home agents and correspondent nodes which may be located at long distance from itself when the micro-mobility of the mobile network node within the domain under access router. Its problems are lots of packet losses and is much more deteriorated in fast moving.

This study, by applying HMIPv6 to Hierarchical Prefix Delegation (HPD) protocol, solved the problems inherent in NEMO basic solution such as non-optimal routing, multiple IPv6 encapsulation and micro-mobility.

The proposed protocol allows for the MR to create RCoA based on MAP prefix sent from AR(MAP) and CoA based on the delegated MNP. When the MR moves within the MAP domain, because MR sends its signal only to AR(MAP) instead of to HA/CNs, handover latency, packet losses and signalling load are significantly reduced. Also, as mobile networks move frequently within AR(MAP), the above advantages will further be realized. For further study, we are going to consider the smooth handover support of MNN in mobile network which is situated below the MR during the changing the location of MR.

참고문헌

[1] C. Perkins, D. Johnson, and J. Arkko, "Mobility Support in IPv6", internet draft, draft-ietf-mobileip-ipv6-24 (work in progress), June 2003

[2] H. Soliman, C. Castelluccia et al, "Hierarchical Mobile IPv6 management (HMIPv6)," IETF draft, draft-ietf-mobileip-hmipv6-07.txt

[3] Vijay Devarapalli et al. "Network Mobility (NEMO) Basic Support Protocol", draft-ietf -nemo-basic-support-02, work-in-progre ss, December 2003

[4] H.Soliman, C. Castellucia, K. Elmalki, L. Bellier, "Hierarchical MIPv6 Mobility Management (HMIPv6), internet draft, July 2001, draft-ietf-mobileip-hmipv6-05.txt, work in progress

[5] Byung-Yeob Kim, Kyeong-Jin Lee, Jung-Soo Park, Hyoung-Jun Kim, "Hierarchical Prefix Delegation Protocol for Internet Protocol Version 6 (IPv6), internet draft, October 2003," draft-bykim-ipv6-hpd -00.txt

[6] B. Haberman and J. Martin, "Automatic Prefix Delegation Protocol for Internet Protocol for

Internet Protocol Version 6 (IPv6)", draft -haberman-ipngwg-auto-prefix-02.txt,Feb 2002
[7] N. Lutchansky "IPv6 Router Advertisement Prefix Delegation Option" IETF draft, work in progress, URLhttp://www.join.uni-muenster.de/drafts/draft-lutchann-ipv6-delegate-option- 00.txt.
[8] O. Troan, R. Troms "IPv6 Prefix Options for DHCPv6" IETF draft, work in progress, URL: http://www.ietf.org/internet-drafts/draft-troan-dhcpv6-optprefix-delegation-01.txt.
[9] KyeongJin Lee, Jungsoo Park, Hyoungjun Kim, "Route Optimization for Mobile Nodes in Mobile Network based on Prefix Delegation", 2003 IEEE
[10] G. Kirby. Locating the User. Communication International, 1995
[11] 노경택 "NEMO와 결합된 Hierarchical Mobile IPv6에서 멀티캐스팅을 이용한 핸드오프 지원기법" 한국컴퓨터정보학회논문지 VOL. 9. NO. 3. Sept. 2004
[12] 노경택, 김혜영 "이동성이 잦은 Mobile IP를 위한 효율적인 연결 설정 기법" 한국컴퓨터정보학회논문지 VOL. 9. NO. 4. Dec. 2004

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