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프리픽스 할당에 기반한 중첩된 NEMO 환경에서의 경로최적화 기법

Route Optimization Scheme in Nested NEMO Environment based on Prefix Delegation

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요 약 망이동성지원 프로토콜 (NEMO basic support protocol)은 이동망의 통신노드들에 대해 인터넷 연결을 제공하기 위한 확장된 MIPv6이다. 그러나, 망이동성지원 프로토콜은 중첩된 이동망의 경우에 다중 캡슐화와 함께 최적화되지 않은 경로 선택으로 인하여 데이터 전송 지연과 많은 비용을 요구한다. 본 논문에서는 계층적 MIPv6 (HMIPv6)와 계층적 프리픽스 할당 (HPD) 프로토콜을 결합한 제안 기법을 통해 핸드오프 발생시 효율적인 경로최적화와 더불어 패킷헤더비용과 위치등록부하를 감소시켰다. 제안 기법은 계층적 프리픽스할당과 트리기반 경로방법을 통하여 이동망 노드들에 대한 주소를 할당하고, 마이크로 이동성을 지원함과 동시에 도메인 내에서의 상호통신을 가능케 한다. 제안된 기법의 성능평가를 위해 NS-2로 모의실험을 하였다.

Abstract The Network Mobility (NEMO) basic support protocol extends the operation of Mobile IPv6 to provide uninterrupted Internet connectivity to the communicating nodes of mobile networks. The protocol is not efficient to offer delays in data delivery and higher overheads in the case of nested mobile networks because it uses fairly sub-optimal routing and multiple encapsulation of data packets. In this paper, our scheme combining Hierarchical Mobile IPv6 (HMIPv6) functionality and Hierarchical Prefix Delegation (HPD) protocol for IPv6, which provide more effective route optimization and reduce packet header overhead and the burden of location registration for handoff. The scheme also uses hierarchical mobile network prefix (HMNP) assignment and tree-based routing mechanism to allocate the location address of mobile network nodes (MNNs) and support micro-mobility and intra-domain data communication. The performance is evaluated using NS-2.

Key Words : *NEMO, route optimization, MIPv6, HMIPv6, MAP*

1. INTRODUCTION

Mobile IPv6 (MIPv6) provides a moving node with transparent communication while it moves in Internet but it does not support network mobility(NEMO). In the near future, demands of network mobility are required from real situation such as PAN (Personal Area Network) and network inside vehicles. The network and all nodes inside them also move in the Internet when the human or the vehicle moves. Such network is called mobile network. A mobile network is the network that dynamically changes its attachment point to the Internet as a single unit. A mobile network has one or more Mobile Routers (MR) through which the mobile network is connected to the Internet. The interfaces connecting to the Internet are called egress

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interfaces [1]. The interfaces connecting to own mobile network are called ingress interfaces. A mobile network may attach inside another mobile network. The aggregated hierarchy of mobile networks is called a Nested Mobile Network. The nodes inside the mobile network are called a Mobile Network Node (MNN) which can be a MR or a MN (Mobile Node) or a LFN (Local Fixed Node). Since a LFN does not support MIPv6 functionality, the MR connected to the LFN can execute the MIPv6 route optimization function as a proxy MN for the LFN. We will not deal with LFN operations in this paper.

Network Mobility (NEMO) Basic Support Protocol (hereafter referred to as NEMO Basic) [2] was proposed to support network mobility as a whole, such as PAN. NEMO Basic extended from mobile IPv6 [3] enables mobile networks to preserve communication with other nodes, while changing their point of attachment to the Internet. Nevertheless, it has some important limitations inherited from mobile IPv6. These problems increase path length and introduce much packet overhead, especially in nested network, due to sub-optimized routing, which is so-called pinball routing.

In [4], the Reverse Routing Header (RRH) Protocol avoids the multiple encapsulation of the traffic but maintains the home tunnel of the first MR on the egress path. The HA of the MR (MR-HA) learns the ingress path towards this MR inside the nested mobile network and performs source routing using a routing header when sending packets through the corresponding tunnel. However, RRH protocol increases the packet header caused by adding CoA (Care-of Address) for each MR on the egress path in RRH although it doesnot suffer from the tunnel in tunnel problem of NEMO Basic. In this way, the HA receiving this packet can construct the chain of access routers the first MR on the egress path is attached to. Whenever mobile network moves, it is necessary for the MNNs in the mobile network to inform all CNs of the changes of routing path. The more CNs are present, the more handoff signals must be sent. The optimal route can sometimes be suboptimal when the CN is also nested. For example, if both end nodes are located behind two distinct nests, the path includes two HA which can still cause crucial delay in packets.

As a solution to resolve these problems, Hierarchical Prefix Delegation (HPD) protocol [5] is an extended prefix delegation protocol based on Automatic Prefix Delegation Protocol (APD) [6]. HPD is not limited to a leaf router. It also provides efficient network mobility in a nested mobile network. It allows routers to request any prefix from upper routers. Once a requesting router receives a prefix from its upper router, it can play the role of the delegating router. It provides its lower routers with parts of its address space by delegating longer level prefixes, enabling multiple-level hierarchical prefix delegation. HPD enables that every node in the mobile network will have a topologically meaningful address. In this way, nodes outside the mobile network can send packets to a MNN inside the mobile network without adding a source routing header or using additional tunnels inside the MR. Thus, HPD provides optimal routing between correspondent nodes. However, significant handoff latency is caused when MNNs move frequently within a nested mobile network because they take some time to configure and update new CoA.

Other approach to minimize the number of tunnels required outside the nested mobile network is that the Top Level Mobile Router (TLMR), the sole MR with a topologically meaningful address, acts for mobility administration (i.e., virtual home agent (VHA)) in the nested mobile network [7]. In essence each MR sends the CoA of this TLMR (TLMR-CoA) to its HA, so the HA maintain a tunnel with the TLMR. In addition the MR registers to TLMR and has to provide some information that allows the TLMR to find out the ingress path towards this MR inside the mobile network. For instance, the TLMR maintains a tunnel to each MR, a tunnel to the HA of each MR, and switches packets between the two, which capacitates micro-mobility support efficiently and solves the dog-leg routing problem. However, an extended RA (Router Advertisement) message that includes an address of the TLMR egress interface is required to discover and notify the TLMR address to the nested MRs.

Our proposalmakes it possible to support routing for intra-domain communication via crossover MR. As MNNs in the mobile network creates their on link care-of address (LCoA) using the delegated MNP (hereafter refered to HMNP) advertised from MR in their mobile network and sets the TLMR-CoA as their RCoA (Regional CoA) and nested MRs maintain routing information about the HMNP, our scheme enables packets to be routed optimally whether CN is located within same nested mobile network or not. Our main objectives are to reduce the overhead, the delays and packet losses and allow efficient communications within the nested mobile network.

The rest of this paper is organized as follows. Section II describes our proposed architecture and provides the detailed routing and handoff procedures. A performance evaluation of the proposedarchitecture and mechanisms is described in section III. We present some conclusions and future works in section IV.

2. PROPOSED HANDOFF SCHEME

Our proposed scheme applies HMIPv6 concepts to the routing method that uses HPD protocol [5].The scheme aims at localizing handoff signals and optimizing the routing. TLMR with the role of VHA introduces the function of MAP agent in HMIPv6 in nested mobile network. We cite this scheme as RO-NEMO.

2.1 Network Architecture for RO-NEMO

Let us consider the nested mobile network of Fig. 4. It consists of an IP network with a TLMR and Mobile IP components such as MRs, MNs, HAs, CN, and AR. We assume that a mobile network consists of an MR, working as a gateway and several MNNs. The MR which is a parent node of the MNNs in the mobile network will be described as upper MR in this paper. If MRs are placed in multiple levels, the mobile network has a hierarchical architecture. mobile networks are composed of a tree topology from the TLMR to the MRs of each mobile network, where TLMR is the root node of the tree and, the nested MRs, and MNs are tree nodes. All other mobile routers except for TLMR in nested mobile network are denoted as nested MR.

2.2 HMNP Assignment

Our scheme makes the MNP hierarchical to AR, resulting in CoAs which are hierarchical to the nested mobile network. MR acquires a delegated MNP (hereafter referred to as HMNP) from its access router by running HPD method when the MR changes its point of attachment. The HMNP is topologically consistent with the hierarchical structure of the mobile network. Suppose that the net mask of the AR, which is an edge router of the nested mobile network, is 32 bits long [8]. The mobile network is allocated a HMNP with a 32 + 8 * (n + 1) bits mask as the nesting level n increases where n = 0 to 3, to form a hierarchical structure with the AR. Then, each MNN creates a CoA using this HMNP. Thus, CoAs hierarchical to the nested mobile network are achieved, which makes it possible to meet route optimization requirements.

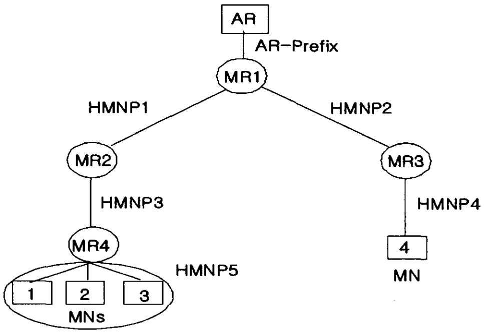


Fig.1 Nested Mobile Network Architecture for proposed routing method

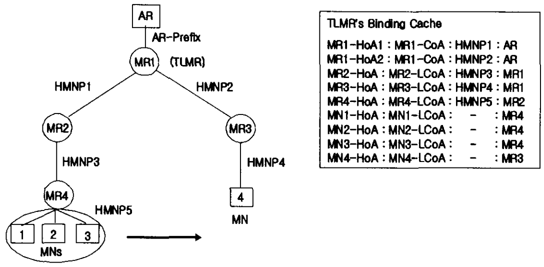
2.3 Hierarchical Address Configuration

The CoA for each MNN, which is created using the HMNP assignment in the pro-posed scheme, is divided into a node locator and a node identifier. The node locator is a 64-bit network prefix made from HMNP advertised in a RA, which indicates the location of the mobile network in the nested mobile network. In the case of handoff, it is changed. On the other hand, the node identifier is a globally unique IPv6 64-bit interface ID [9] which remains unchanged even when handoff occurs.

2.4 Tree-based routing mechanism

Even when a MNN moves within nested mobile network, a major drawback of HPD protocol and conventional solution such as NEMO Basic and RRH protocolis that BU messages should be sent to HA or CNs, which results in high delays. Thus, our proposal provides micro-mobility management to overcome the handoff latency by allowing TLMR to have the MAP function, in addition to supporting route optimization.

CN maintains the RCoA of MNN (MNN-RCoA) which is the TLMR address regardless of the location of MNNs in nested mobile network. In this mobility management, CN sends packets only to the TLMR based on MNN-RCoA in this scheme. The TLMR receives the packets and encapsulates those packets with MNN-LCoA after searching it in its binding cache. Therefore, when MNN moves locally within TLMR domain, TLMR supports the hierarchical rerouting to reduce handoff latency and packet losses, and optimize routing as the MNN just sends BU message to TLMR (i.e., neither HA nor CNs). When TLMR receives a BU message from a nested MR, the proposed solution supports that TLMR updates the binding information for the MR and also MNNs connected to the MR. Therefore, Each MNN does not have to send a BU message to TLMR because all MNN-LCoAs are changed by using HMNP in BU message sent only by MR. Thus, the proposed scheme can reduce the handoff signal overhead as it localizes the handoff signals. The new functionality performed by TLMR and nested MRs to reduce handoff signal overhead are described below.



TLMR's Binding Cache
MR1-HoA1 : MR1-CoA : HMNP1 : AR
MR1-HoA2 : MR1-CoA : HMNP2 : AR
MR2-HoA : MR2-LCoA : HMNP3 : MR1
MR3-HoA : MR3-LCoA : HMNP4 : MR1
MR4-HoA : MR4-LCoA : HMNP5 : MR2
MN1-HoA : MN1-LCoA : - : MR4
MN2-HoA : MN2-LCoA : - : MR4
MN3-HoA : MN3-LCoA : - : MR4
MN4-HoA : MN4-LCoA : - : MR3

Fig. 2 TLMR' s Binding Cache for Nested Mobile Network Architecture shown in Fig. 1

2.4.1 TLMR functionality

TLMR which has a MAP function keeps the binding information of MNNs belonging to its nested mobile network using information in the BU messages from MNNs. Fig. 2 shows TLMR's binding cache that is composed of HoA, CoA, upper-MR, and HMNP fields. CoA field contains LCoAs of MNNs which are divided into a node locator and an individual node identifier. The node locator indicates the location of a mobile network, where all MNNs have the common MNP in the mobile network. The individual node identifier, which indicates the location of each MNN within the mobile network and is unique in the mobile network, is not changed. The upper-MR field contains the home address of the MR associated with MNNs in its mobile network, which indicates that the MR is a parent node of MNNs. HMNP field contains a Hierarchical MNP (HMNP) which represents the location of the subnets of a MR.

2.4.2 nested MR functionality

When a MR detects its movement after receiving a RA message, the MR updates its routing table using a delegated MNP (HMNP) obtained by running HPD protocol. It is possible because each MR in nested mobile network has information about the delegated MNP.

2.5 Protocol Operation

An intra-domain handoff that explains the movement of a mobile network itself occurs when the mobile network moves within TLMR domain. In case that MR4's mobile network moves and connects to MR3 as shown in Fig. 2, the MR (MR4) receives a RA message containing HMNP (HMNP6), the HoA of upper MR (MR3-HoA) and the CoA of TLMR (MR1-CoA). MR4notices that it is connected to a new upper MR (MR3) in another network. In other word, when it is found that the RA message sent from an upper MR has a different HoA, the MR notices that moves into another network. Then, the MR (MR4) creates its local CoA (MR4-LCoA) based on the HMNP (HMNP6). The MR4, then, sends a BU message, containing MR4-HoA, MR4-LCoA, the HoA of upper MR (MR3-HoA) and HMNP (HMNP6) received from its upper MR, to TLMR (MR1). TLMR receives the BU message, and updates the binding information of the MR (MR4) in its binding cache.Then, TLMR finds MNNs (MN1, MN2, MN3) within the mobile network associated with the MR4, using the upper-MR field which contains MR4-HoA in TLMR's binding cache table and finally, it updates binding information for them by changing their LCoAs from the HMNP6. Thus, the handoff signals to TLMR from the MNNs are not needed and therefore it results in reducing handoff signal overhead from MNNs to TLMR. On the other hand, in the case of the handoff of a mobile network due to the movement of the parent mobile network within TLMR domain, the MR in the mobile network repeats above-mentioned handoff procedure for MNNs within its mobile network. Thus, in case that a mobile network moves locally within TLMR domain, MR in the mobile network and all nested MRs on lower levels connected to the MR send BU messages on behalf of MNNs within their mobile network.

An intra-domain handoff which explains the movement of a MN occurs when the MN moves locally between mobile networks within TLMR domain. MN gets a HMNP, MR-HoA and TLMR-CoA from a RA message by MR in visited mobile network. The MN detects its movement within the nested mobile network since the HoA of the MR, which is currently connected to it, differs from the HoA of the old MR and its RCoA (TLMR-CoA) is not changed. The MN acquires only new LCoA (MN-LCoA) based on the new HMNP. Then, the MN sends a BU message which contains MN-HoA, MN-LCoA and MR-HoA (its new upper MR's HoA) to TLMR.

An inter-domain handoff of a MNN occurs when the MNN receives a RA message, which contains a new TLMR-CoA, from MR in the mobile network associated with the MNN due to the movement of the MNN, or when the MNN directly connects to a AR. When the MNN is a MN, The MN should send a BU message to TLMR, containing MN-HoA, MN-LCoA and the HoA of the MR when the MN connects to thatnested MR, that is, the upper node of the MN. After this, the MN should send a BU message to its HA/CNs. When the MNN is a nested MR, the MR should send a BU message to TLMR, containing MR-HoA, MR-LCoA, upper MR's HoA and a received HMNP from its upper MR. Next, the MR sends a RA message to MNNs in its mobile network, containing its HoA (MR-HoA), the HMNP, and TLMR-CoA. Then, Each MNN in its mobile network creates its LCoA (MNN-LCoA) based on the HMNP and sets the TLMR-CoA as its RCoA. It then sends a BU message containing its LCoA and its upper node's HoA (MR-HoA) to TLMR. After this, the MNNs should send a BU message to their HA/CNs.

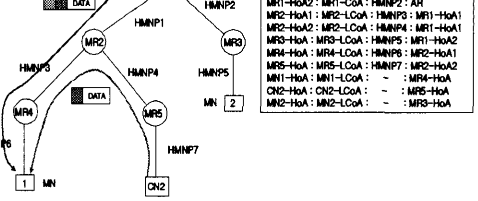


Fig. 3. Communication Processes

Fig. 3 illustrates the communication of RO-NEMO in the environment where there areMNNs in nested mobile network and CNs in or outside nested mobile network. MR1 which directly attaches to the AR is called TLMR. Assume that MR1 has all binding information of all MNNs within the nested mobile network according to the procedure mentioned above. When assuming that CN1 has the binding information of MN1, where the RCoA of MN1 is TLMR-CoA (MR1-CoA), CN1 sends packets destined to MN1 via MR1 (TLMR) using RHO(Routing Header Option) which contains MN1-HoA. MR1 intercepts and encapsulates the packets with MN1-LCoA after searching for MN1's entry in its binding cache and transmits the packets to MN1. In the case that MN1 sends packets to CN1, the packets can be transmitted without the ingress filtering problems since the source address of the packets is created based on HMNP (HMNP6) included in the RA message from the upper MR (MR4).

On the other hand, assume that the communication between MN (MN1) and CN (CN2) occurs within same TLMR domain. CN2 is supposed to be a visiting mobile node (VMN) as well. The proposed scheme supports the intra-domain data communication between CN2 and MN1 directly rather than the communication via HAs of CN2 and/or MN1. When MN1 from the external network, moves into MR4's mobile network, MN1 receives a RA message which includes HMNP6 and MR1-CoA in root-MR option, sent by MR4. MN1 creates MN1-LCoA using HMNP6 and sets MR1-CoA as its RCoA, and then MN1 determines whether CN2 is in the same region or not by comparing MN1-RCoA and CN2-RCoA. If MN1 is in the same region as CN2, MN1 sends a BU message whose source address is MN1-LCoA and destination address is CN-RCoA to CN2. After MR1 receives the BU message, MR1 encapsulates the BU message and tunnels it to CN2. After CN2 receives the BU message, CN2 makes packets whose source address is CN2-LCoA and destination address is MN1-LCoA. Then CN2 can directly deliver this packet to the MN1 over the crossover MR (MR2) without any tunneling at the HA and TLMR. Thus, the proposed scheme makes a route efficiently optimized between CNs and MNs.

3. PERFORMANCE ANALYSIS

We have evaluated RO-NEMO, NEMO Basic and RRH protocol, using network simulator (NS-2), in nested mobile network environment. Fig. 4 shows network models for simulation where there may be at least one MR per level below TLMR in nested mobile network. We defined that TLMR under a AR is zero-level (i.e., AR-TLMR). Therefore, AR-TLMR-MR means one nested-level. In the hierarchical approach, we assume that TLMR has the role of VHA with MAP function. TLMR-MR means one nested-level within TLMR domain and a MN means to be L+1 level when the MN moves to L level's mobile network in nested mobile network.

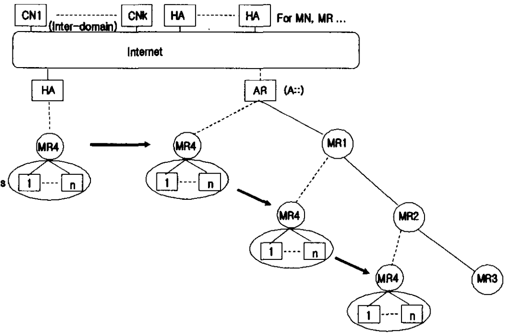


Fig. 4. Network Model for Simulation

Table. I. Parameters for simulation

dHA-HA: 10 hops between HA and HA
dCN-HA: 5 hops between CN and HA
dHA-TLMR: 5 hops between HA and TLMR
Lp: packet size (1500 bytes)
Lhd: packet header size (40 bytes)
Lbu: BU size (112 bytes)
Lback: BACK size (96 bytes)
BW: wired link bandwidth (100 Mbps)

BWw: wireless link bandwidth (11 Mbps)
tW: latency of the wired link (0.5 ms)
tWw: latency of the wireless link (2 ms)
Hoff: handoff interval (2 s)
pTLMR: processing time in the TLMR (0.003 ms)
pHA: processing time in HA (0.005 ms)
DR: data transmission rate (1.2 Mbps)

In this network topology, an MR's mobile network can detect its movement due to the RA from different upper MR. The simulation time was 10 seconds, and the date in the first 2 seconds was discarded because the network initializing procedure was executed during the time. We evaluated each scheme assuming 5, 10, and 100 MNNs in the mobile network. The performance of our proposal is evaluated in terms of end-to-end packet delay and the number of handoff signals. All the parameters that are needed by the model can be seen in Table 1.

3.1 End-to-End packet delay

End-to-end packet transmission delay measurements from a CN on external domain to a MN in the mobile network are depicted in Fig. 5. RO-NEMO significantly reduces the end-to-end packet delay as nesting level increases in comparison with NEMO Basic because in NEMO Basic, the packets must pass through multiple tunnels from the MN to MN-HA and it also requires tunneling processing time for the packets. Furthermore, RO-NEMO is superior to NEMO Basic as the number of level increases when the MR is far from the MR-HA. RRH method requires the processing time for RRH at each IMR and has to pass through a HA. The packet transmission delay saving time between RO-NEMO and RRH method is 3.19 ms at level 0 and 3.49 ms at level 4. Thus RRH method is superior to NEMO Basic but is inferior to RO-NEMO.

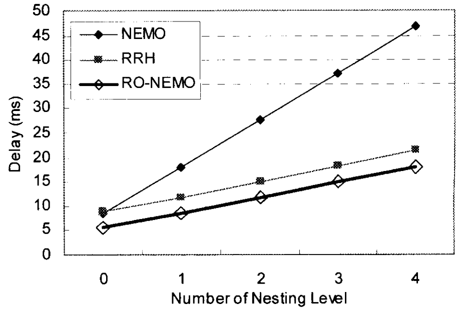


Fig. 5. Inter-domain Data Transmission

3.2 Handoff signals number

Whenever a handoff occurs, each scheme requires the handoff signals such as RS message, RA message, BU message and BACK message [3,8]. Fig. 6 shows the number of handoff signals per handoff when each MNN in mobile network is assumed to have 2 CNs. We also assume that RO-NEMO-1 means that mobile network moves within the same TLMR, whereas RO-NEMO-2 means that mobile network moves to a different TLMR. In RO-NEMO-2, the number of handoff signals increases as the number of MNNs in the mobile network increases because each MNN in mobile network sends a BU to TLMR, CNs and its HA. RRH method has similar characteristics of RO-NEMO-2 in which each MNN sends a BU message to its HA and CNs. On the other hand, RO-NEMO-1 offers low and constant handoff signals as MR sends a BU message only to TLMR regardless of the number of MNNs in the mobile network when handoff occurs within TLMR domain. NEMO Basic alsorequires that whenever handoff occurs, MR sends a BU message to its HA and CNs instead of MNNs in its mobile network. Thus, NEMO Basic offers low and constant handoff signals regardless of the number of MNNs in the mobile network but requires long handoff latency. When the number of MNNs in mobile network is 100, RO-NEMO-1 has about the same level of performance of NEMO Basic, while it requires about 1200 fewer handoff signals than RRH method. Therefore, when assuming that the most handoffs correspond to intra-domain handoff, as mentioned in

[14], RO-NEMO provides better performance compared to the other schemes.

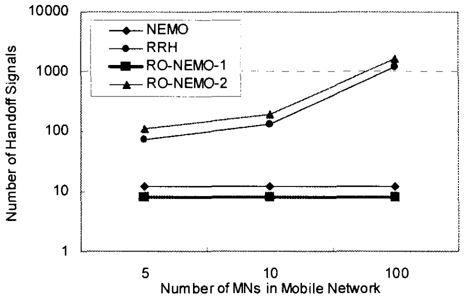


Fig. 6. Num. of Handoff signal

4. CONCLUSIONS

In this paper, we have proposed a new routing scheme for improving the problems of the existing solutions in nested mobile network such as non-optimal routing, multiple IPv6 encapsulation and handoff signal overhead. By combining HMIPv6 concept and HPD solution, the proposed scheme minimizes the packet header size with HMNP assignment, and as TLMR is provided with the MAP function, it provides hierarchical re-routing and localizes handoff signals. It also reduces the number of handoff signals and packet losses, and supports intra-domain data transmission over crossover MR within TLMR domain. Our schemeadded functionality to the TLMR so that TLMR updates the binding information for all MNNs within the mobile network associated with a MR when it receives a BU message from the MR. We simulated the performance using ns-2 and verified the effectiveness of HROS compared to the conventional techniques, NEMO Basic and RRH method.We are currently exploring to extend the current proposal for a solution to reduce the load of TLMR while retaining most of predicted advantages.

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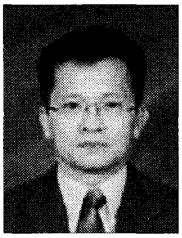

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