The 23rd International Technical Conference on Circuits/Systems,
Computers and Communications (ITC-CSCC 2008)

Route Optimization Using Collective Binding Update and Mobile Network Prefix for Nested Mobile Networks

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Abstract: Network Mobility (NEMO) supports the movement of some part of network that a group of Mobile Nodes (MNs) or Mobile Routers (MRs) moves together. To support NEMO, the NEMO basic support protocol (NBSP) was proposed [1]. In the nested mobile network, however, the NBSP exhibits pinball routing problem. The More nesting level, the problem becomes more serious. In this paper, we propose a new NEMO management scheme using Collective Binding Update (CBU) and Mobile Network Prefix (MNP). It can achieve route optimization and easy to implement. Performance analysis indicates that proposed scheme can reduce packet delay with low processing and signalling overheads.

1. Introduction

As the proliferation of ubiquitous mobile devices and services, users can access the Internet from anywhere at anytime with their Internet Protocol (IP) addresses. Mobile IP [1] can support host mobility that a node moves and changes its point of attachment. Mobile IP needs two kinds of addresses. One is a Home address (HoA) and the other is a care-of address (CoA). A node can maintain global reachability by registering its location (CoA) to its Home Agent (HA). Every packet destined to the Mobile Node first visit the HA and by the binding information, the packet is rerouted to the current location of the Mobile Node.

However, the Network Mobility (NEMO) manages the mobility of entire network. NEMO supports the movement of some part of network that a group of Mobile Nodes (MNs) or Mobile Routers (MRs) moves together. To support NEMO, The Internet Engineering Task Force (IETF) proposed the NEMO basic support protocol (NBSP) [2]. In the architecture for the NBSP a MR provides collective Internet connectivity to a group of MNs. The operations of the MR and HA is defined in the NBSP and the operations of CNs and MNs are the same as MIPv6. NEMO has some advantages. First, since the radio transmission distance from a device to the MR is much shorter than to an Access Router (AR) on the Internet, many mobile devices can save their transmission power by communicate with MR rather than AR. Second, mobile node does not need to update its location when the mobile network moves. Only the MR need to update its location. This significantly reduces the number of handoffs. Third, mobile network node (MNN) does not need to configure its CoA since this is performed by the MR. This reduces the hardware and software complexity.

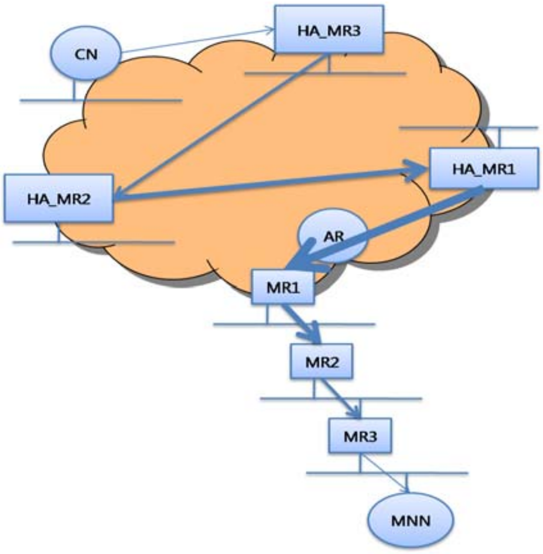

Figure 1. Pinball routing problem in nestd mobile network

Several mobile networks can be nested hierarchically. For example, a personal area network (PAN) access Internet via MR in an airplane or a PAN in a car on a ship [4]. And other complex NEMO scenarios can exist [3]. In the nested mobile network, the NBSP exhibits the so-called pinball routing problem that the packet has to visit the HA of every MR. Figure 1 shows the pinball routing problem in nested mobile network. The width of each arrow represents that the number of encapsulation of the packet. Each MR has its own Home Agent (HA). When a Corresponding Node (CN) communicates with the MNN which is at the bottom of the nested mobile network, first, the packet is sent to the HA_MR3. Since the binding cache of HA_MR3 has the information that MR3 is located below MR2, the packet is encapsulated and sent to the HA_MR2. HA_MR2 has binding information that MR2 is located below MR1. Then, the packet is encapsulated again and sent to the HA_MR1. The HA_MR1 tunnels the packet to MR1. Finally, the packet can be sent to MNN via MR2 and MR3. Also, whenever each packet is encapsulated, a new MIPv6 header, which is 40 bytes, is added. In the case of figure 1, at first the IP packet overhead was 40 bytes when the CN send the packet to HA_MR3. It is increased to 80, 120 bytes and finally 160 bytes between the HA_MR1 and the MR1.

The more nesting level, the problem becomes more serious. Some algorithms was proposed to solve this

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"This research was supported by the MKE(Ministry of Knowledge Economy, Korea, under the ITRC(Information Technology Research Center) support program supervised by the IITA(Institute of Information Technology Assessment)" (IITA-2008-C1090-0801-0038)

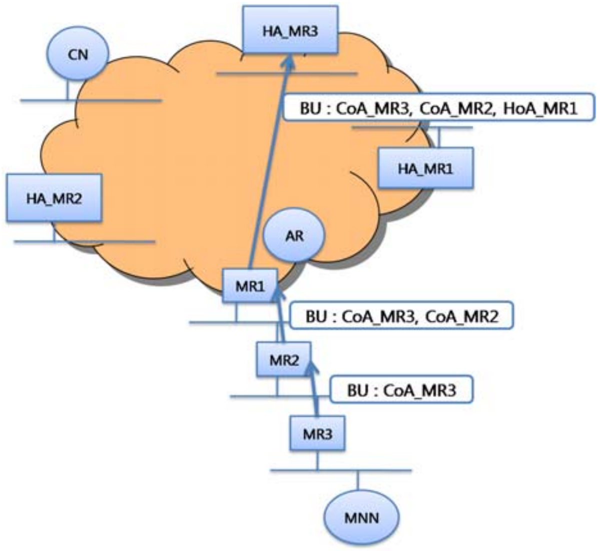

Figure 2. Binding update procedure

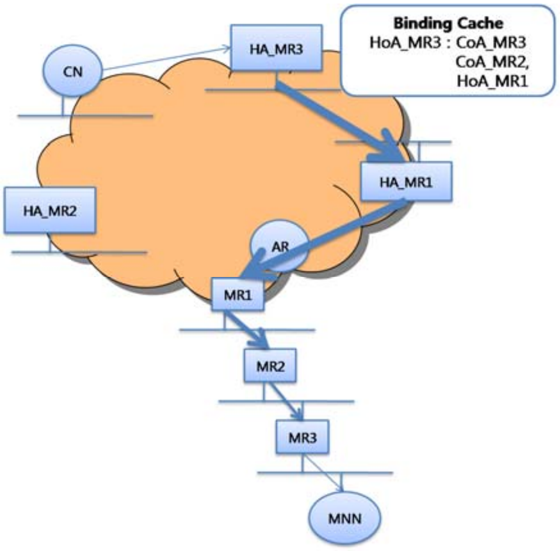

Figure 3. Forward route optimization

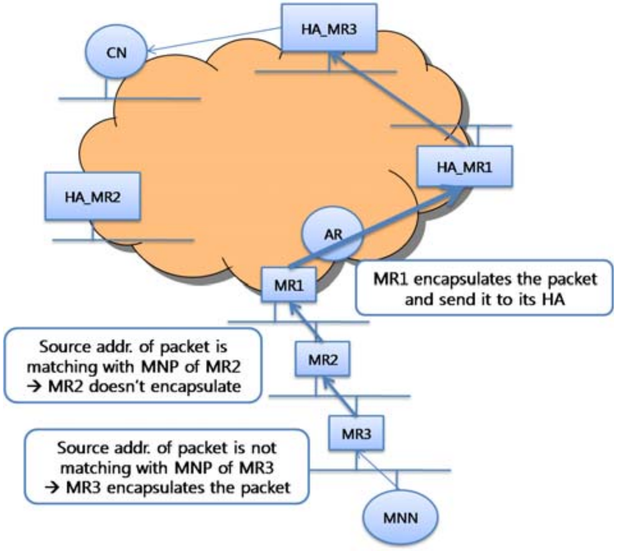

Figure 4 Reverse route optimization

problem [4][5][6]. In [4] and [5], a new method to achieve route optimization was proposed, however, suffers heavy processing overhead and needs many modifications to implement. In [6], SIP based NEMO was proposed. It uses SIP protocol to support NEMO rather than Mobile IP. However, to implement that, all routers must have SIP capacity and it can be useful only for multimedia applications. In addition, the message size of the SIP-based NEMO is much larger than the NBSP.

In this paper, we propose a new NEMO management scheme using Collective Binding Update (CBU) and Mobile Network Prefix (MNP). It achieves forward and reverse route optimization by little changes in existing NBSP. Also, It is easy to implement.

The remaining of this paper is organized as follows. Proposed scheme is presented and its operation is described in section 2. In section 3, the performance analysis is given. Finally, Section 4 concludes this paper

2. Proposed scheme

We propose a new NEMO management scheme that each MR to send a BU message which contains the addresses of its parent MRs. Figure 2 shows the BU procedure. When the MR3 sends BU to its HA, this packet is sent to the HA_MR3 via the MR2 and the MR1. During the BU message go through the MRs, it collects the CoA_MR3, CoA_MR2, HoA_MR1. Then, the HA_MR3 knows that the address of the Root-MR and the route from Root-MR to the MR3. In our scheme, all the packets are tunneled at most twice.

2. 1 Forward Route Optimization

Figure 3 shows the forward route optimization. When performing forward route optimization, CN sends a packet to the MNN. Then, the packet is routed to the HA of the closest MR of the MNN (HA_MR3). HA_MR3 has the binding information that the addresses of HoA_MR1, CoA_MR2 and CoA_MR3. Then, HA_MR3 encapsulate the packet three times: The first to the CoA _MR3, the second to the CoA_MR2 and the third to the HoA_MR1. Then, the packet is sent to the HA_MR1. When the packet arrives to the HA of the Root-MR, it is decapsulated and sent to the CoA_MR1. After that, the MR1 decapsulate the packet and checks the destination of the packet. Because the packet is already encapsulated at the HA_MR3, The MR1 can send the packet to the MR2. Similarly, the MR2 decapsulate the packet and send the packet to the MR3. Finally, the packet can be delivered to the MNN.

2. 2 Reverse Route Optimization

In the case of reverse path, the operation of the MR needs some modifications. As the forward route optimization, there is two tunneling. Figure 4 shows the reverse route optimization. The MNN sends the packet to the CN. The MR3 receives the packet and checks whether the source address of the packet is matching with its MNP or not. If the source address is matching with its MNP, the packet is from its sub router. However, the source address is not matching with its MNP, the packet is from the node. Since the MNN is a node, the source address of the sent packet is HoA_MNN. Therefore, it is not matching with the MNP of the MR3. Then the MR3 knows that the packet is from the node. The packet is encapsulated and sent to the MR2. Now, the source address of the encapsulated packet is the CoA_MR3. Since the source address of the packet (CoA_MR3) is matching with its MNP, the MR2 knows that it is from the router. Therefore, the MR2 does not encapsulate the packet and simply relays. The packet is encapsulated again at the MR1 which is Root-MR and routed to the CN via the HA_MR1 and the HA_MR3.

2. 3 Handoff

When the Root-MR and all the subtrees are moving together, only the Root-MR sends a BU. Then, all the packets come to the HA of the Root-MR are delivered to the CoA of the Root-MR and delivered as before.

There is two cases of subtree handoff: One is that the Root-MR of the departing subtree attaches to another MR and becomes a new subtree. The other is that the Root-MR of the departing subtree attaches a new Access Router (AR) and becomes a new Root-MR. In the former case, each MR sends a BU message that contains the addresses of the parent MRs. In the latter case, the Root-MR sends a BU that only contains its CoA. And the other subtree MRs don't sends a BU message. Since the HA of itself knows the HoA of root MR, the packet can be routed to the CoA_MR. Then the packet can be routed.

3. Performance Evaluation

3. 1 End-to-end packet delay

We compared proposed scheme and the NBSP. We assume the MNN is located in an n-level nested mobile network. First, the end-to-end packet delay of NBSP and proposed scheme can be represented as follows.

$$T_{NBSP} = \sum_{i=1}^{n}(T_{HA}^{i} + T_{MR}^{i}) + \sum_{i=1}^{n-1}(T_{HA-HA}^{i} + T_{MR-MR}^{i}) + T_{MR-MNN} + T_{AR-MR} + T_{AR-HA} + T_{AR-HA} + T_{CN-HA} \qquad (1)$$

$$T_{proposed} = \sum_{i=1}^{n}(T_{MR}^{i}) + \sum_{i=1}^{n-1}(T_{MR-MR}^{i}) + 2\times T_{HA} + T_{HA-HA} + T_{MR-MNN} + T_{AR-MR} + T_{AR-HA} + T_{CN-HA} \qquad (2)$$

Where n is the level of nesting, T^{i}_{HA} and T^{i}_{MR} denotes the processing delay of HAs and MRs, $T^{i}_{HA\text{-}HA}$ and $T^{i}_{MR\text{-}MR}$ denotes the link delay between HAs and between MRs, $T_{MR\text{-}MNN}$ denotes the link delay between MR and MNN, $T_{AR\text{-}MR}$ denotes the link between AR and MR, $T_{AR\text{-}HA}$ denotes delay between AR and HA, $T_{CN\text{-}HA}$ is the delay between CN and HA.

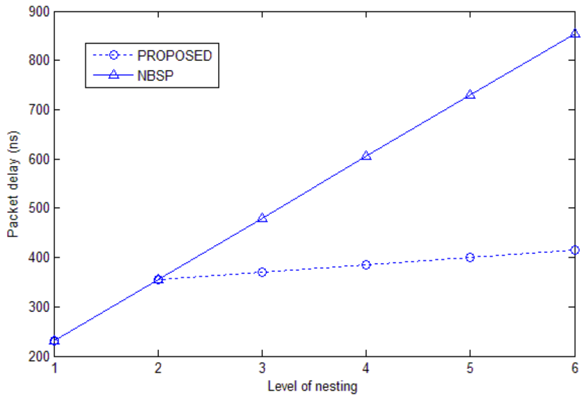

Figure 5. End-to-end packet delay

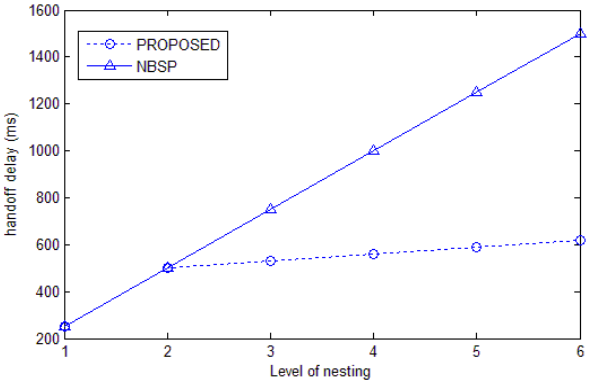

Figure 6. Handoff delay

We assume that the HA and the MR processing delays are 10ms, the link delays between HA and CN, HA and HA, HA and AR are 100ms. Link delay between two MRs, and between MR and MNN are assumed to be 5ms [5]. We varied the level of nesting. Figure 5 shows the packet delay according to the level of nesting. If the level of nesting is 1 or 2, the packet delay of proposed scheme is almost the same as the NBSP. But, if the level of nesting is more than 3, the delay of proposed scheme is reduced significantly, because the packet is tunneled at most twice.

3. 2 Handoff delay

Since packet loss rate and throughput are affected by handoff delay, it is important to reduce handoff delay. We can think a scenario that a Root-MR and its subtree moves together. In this case, both in the NBSP and proposed scheme, only the Root-MR needs to register its new CoA with its HA. The CoAs of the subree MRs below the Root-MR is not changed while the MR resides under the coverage of the Root-MR. The handoff delay caused when Root-MR and its subtree moves together can be derived as follows

$$T_{NBSP}^{HO} = RTT_{Root-MR <-> HA\,of\,Root-MR} \qquad (3)$$

$$T_{proposed}^{HO} = RTT_{Root-MR <-> HA\,of\,Root-MR} \qquad (4)$$

Where $\mathrm{RTT}_{\mathrm{Root\text{-}MR <-> HA\ of\ Root\text{-}MR}}$ denotes the round-trip-time between Root-MR and HA of Root-MR.

Figure 6 shows the handoff delay according to the level of nesting. Since in proposed scheme, packets are doesn't visit all the HAs of MRs, the handoff delay is relatively low especially when the level of nesting is increased.

4. Conclusion

The pinball routing problem becomes serious as the level of nesting increases for a nested NEMO. Therefore, it is necessary for NBSP to be extended with route optimization scheme. In this paper, we proposed a new NEMO management scheme using collective binding update and mobile network prefix. Proposed scheme provides forward and reverse route optimization. Results of the performance analysis shows that proposed scheme can reduce not only end-to-end packet delay but also handoff delay. It is also very easy to implement.

We were not considered handoff case where the Root-MR changes and evaluated the performance of proposed scheme only analytically. In the future work, we will evaluate the performance of other handoff cases and examine the analytical results by simulation in wireless and mobile environment. In addition, it is needed to compare proposed scheme with other methods.

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