Route Optimization for Intra Communication of a Nested Mobile Network

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ABSTRACT

Network mobility, i.e. Internet access services for a moving network as a single unit brings about new challenging issues. A nested mobile network is a hierarchical form of multiple mobile networks. Nested mobile networks suffer from a pinball routing problem. This problem becomes more serious in the case of a communication between any two nodes in the same nested mobile network. To solve this sub-optimality, we propose a nested NEMO route optimization (NNRO) protocol to retain the mobility transparency as the NEMO basic support protocol and to reduce the communication cost of any two nodes in a nested mobile network. The results of simulation reveal that the proposed NNRO protocol efficiently supports communication within a nested mobile network.

Categories and Subject Descriptors

C.0 [**Computer-Communication Networks**]: Data communications; C.2.2 [**Network Protocols**]: Routing protocols

General Terms

Design, Performance

Keywords

Network Mobility, Nested Mobile Network, Routing Optimization

1. INTRODUCTION

With the advances of wireless access technologies (e.g., 3G, IEEE 802.11/16) and mobile communication services, the demand for Internet access in mobile vehicles such as trains, buses, and ships is constantly increasing [1]. In these vehicles, there are multiple devices constituting a vehicular area network (VAN) or a personal area network (PAN) that may need to access to Internet. The mobility support problem for these services is referred to as *network mobility (NEMO) support*. To address the NEMO support problem, Internet Engineering Task Force (IETF) has established a working group called *NEMO* [2] and the NEMO working group has extended the Mobile IPv6 protocol [3], i.e. the NEMO basic support protocol [4].

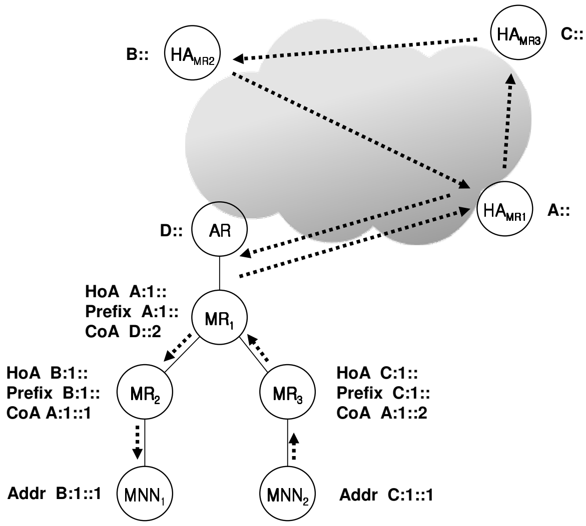

Figure 1: Pinball Routing Problem.

According to NEMO terminologies [5], a mobile network is defined as a network whose point of attachment to the Internet varies as it moves about. A mobile network consists of mobile routers (MRs) and mobile network nodes (MNNs). Each mobile network has a home network to which its home address belongs. When the mobile network is in the home network, the mobile network is identified by its home address (HoA). On the other hand, the mobile network configures a care-of-address (CoA) on the egress link when the mobile network is away from the home network. At the same time, on the ingress link, the MNNs of the mobile network configure CoAs, which are derived from the subnet prefix (i.e. NEMO prefix). This NEMO prefix remains fixed after being assigned to the mobile network while it is away from the home network. The assigned NEMO prefix and the current CoA of the egress link are registered with the home agent (HA) according to the NEMO basic support protocol [4].

A mobile network that consists of multiple MRs with a hierarchical topology is called as a nested mobile network. When

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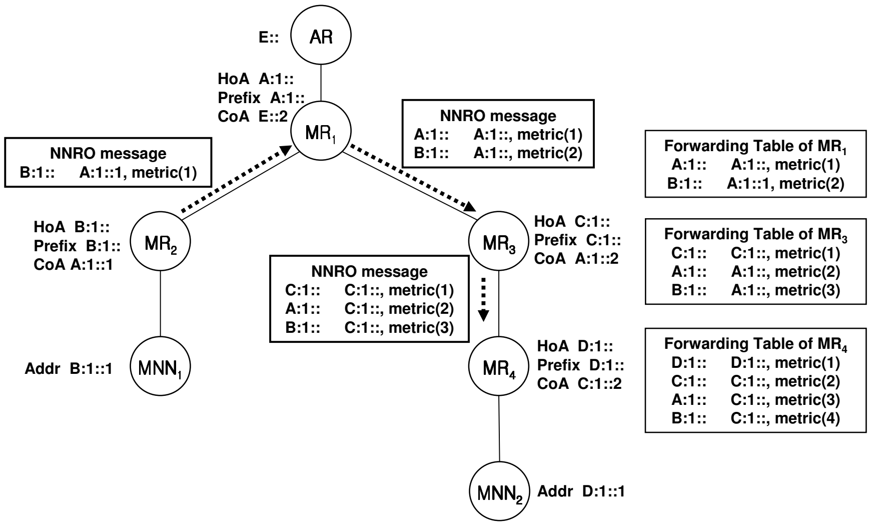


Figure 2: The Propagation of the NNRO message.

a PAN that consist of a MR and MMNs enters a vehicle that serves a NEMO service, the whole network has a two level hierarchy. Likewise, when a group of users, each of which has a PAN already, are connected in an ad hoc fashion and one user has an Internet connectivity, a more complicated nested mobile network can be constructed.

The concept of a nested mobile network saves signaling overhead (binding update traffic) when the whole mobile network moves. However, it causes a pinball routing problem. Especially, when the two nodes are located within the same nested mobile network, the sub-optimality between the two nodes becomes significant although the two nodes are located within the same nested mobile network. Figure 1 shows an example of the pinball routing problem when the two MMNs in the same nested mobile network communicate. When MNN_2 sends a packet to MNN_1, the packet has to travel via all HAs that correspond to the MRs of the nested mobile network. In addition to the inefficient routing, the original data is encapsulated twice for MR_3 and MR_1. This encapsulated packet is decapsulated in HA_{MR1} and HA_{MR3}, respectively. Likewise, HA_{MR2} and HA_{MR1} encapsulate the packet twice and MR_1 and MR_2 decapsulate it. Finally, MR_2 forwards the packet to MMN_1. Therefore, communication within a nested mobile network incurs inefficient routing and subsptantial packet tunnelling overhead. To solve the pinball routing problem, [6], [7] propose the recursive binding update scheme. However, it's not proper when nodes in same intra NEMO communicate each other. In this paper, we propose a route optimization protocol that provides an optimal route between any two nodes in the same nested mobile network.

The remainder of this paper is organized as follows. Section 2 describes the proposed route optimization protocol. In Section 3, simulation results are presented. Section **??** finally concludes this paper.

2. NESTED NEMO ROUTE OPTIMIZATION (NNRO) PROTOCOL

2.1 Overview of NNRO Operation

We proposed that an MR should multicast nested NEMO route optimization (NNRO) messages that contain reachable destinations and their path metrics to the MR's one hop neighbor MRs. The route optimization messages are transmitted by an IPv6 link local multicast to the MR's child MRs in ingress interface and by an unicast to the MR's parent MR in egress interface. After the neighbor (child and parent) MRs receive these route optimization messages, they transmit not only their own information of reachable destinations but also the received information from their neighbors. Consquently, the information of NEMO prefixes is delivered to all of the MRs in the nested mobile network. Based on this information, each MR in the nested mobile network constructs a forwarding table for the mobile network prefixes in the nested mobile network. Each forwarding table has entries, each of which contains the NEMO prefix, the path metric of the destination, the next hop, and the lifetime of the entry. Before the MR forwards packets through the bi-directional tunnel, it searches the forwarding table. If the MR finds out an entry that matches the destination of the packet, it forwards the packet to the next hop MR, not performing the bi-directional tunnelling with its HA. Otherwise, the MR acts as specified in NEMO basic support protocol [4].

Figure 2 shows the propagation of the NEMO prefix information through NNRO messages. At first, MR_2 sends the NNRO message that contains its own NEMO prefix information. When MR_1 receives the NNRO message from MR_2, MR_1 updates its forwarding table and it sends the NNRO message that contains not only its own NEMO prefix entry but also updated forwarding table entries. In the same way, MR_3 updates its forwarding table and sends an NNRO message to its neighbor MRs. After this procedure, all of the MRs in the nested mobile network learn the routing information for the NEMO prefix of MR_2 in their forwarding tables. Like MR_2, all other MRs also send NNRO message with the forwarding table entry about their own NEMO prefixes. Consquently, all MRs learn NEMO prefix of other MRs in the nested mobile network.

1	8	16	24
		D R P	# of entries
Forwarding Table Entry 1 (20 byte)			
...			
Forwarding Table Entry N (20 byte)			

Figure 3: NNRO message format

2.2 Operation of Mobile Router

An MR maintains a forwarding table. The forwarding table is a data structure that records the reachability to the MNNs in the same nested mobile network. There is one entry per each NEMO prefix.
Each forwarding table entry conceptually contains the following fields.

- The NEMO prefix of the MRs in the same nested mobile network. This field is used as the key for searching the forwarding table for the destination address of a packet being forwarded.
- The metric field is the cost at which the next hop MR can deliver packets to the destination.
- The next hop field is the address of the MR to which packets are forwarded.
- A lifetime value, indicating the remaining lifetime for this forwarding table entry. The lifetime value is updated whenever NNRO messages are received.

The MR sends the NNRO messages to its ingress interface and its egress interface periodically. When the MR sends NNRO messages to its ingress interface and its egress interface, the source IP address field of that packet is set to the HoA and the CoA of the MR, respectively. When an MR starts its operation, there is only one entry in the forwarding table, which contains its own NEMO prefix. As the NNRO messages from other MRs propagate, the number of entries in the forwarding table will be incremented. Initially, an MR has an entry about its NEMO prefix in the forwarding table. This entry has the minimum metric value. When an MR receives the NNRO messages from its neighbor MRs, it updates its forwarding table based on the following criterion. When an MR receives the forwarding table entry that is not in its forwarding table, it inserts a new entry for that destination. In the case of an entry with a better metric, it modifies the metric and the next hop values of existing entry. Otherwise, an MR ignores the forwarding table entry. When the forwarding table is updated, the MR sends the NNRO message containing the updated forwarding table entry immediately.
When the MR receives a data packet, it searches the forwarding table to find out entry that matches the destination IPv6 address of the packet before the MR forwards the packet through the bi-directional tunnel. If the MR finds out the matched entry, it forwards the packet to the next hop MR in the forwarding table without tunnelling. Otherwise, the MR forwards the packet through the bi-directional tunnel based on the NEMO basic support Protocol [4].

1	8	16	24
Mobile Network Prefix (16 byte)			
Prefix Length	Metric	Reserved	

Figure 4: Forwarding Table entry in NNRO message

2.3 NNRO Message Format

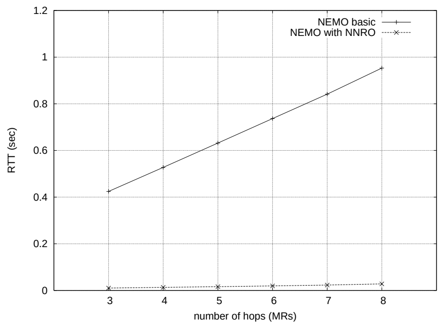
In the proposed protocol, we define the NNRO message that is similar to the RIPng packet [8]. The NNRO message is used by an MR to notify other MRs in the same nested NEMO of a reachability for the entries. Each MR that supports nested NEMO route optimization sends and receives this NNRO message. Figure 3 describes the format of an NNRO message which is the data field in the mobility header of mobile IPv6 [3]. The NNRO message will use a new mobility header (MH)type value (that is 11). The D (default) bit is set when an MR sends NNRO messages periodically. The R (request) bit is set by the sending MR to request that one hop neighbor MRs should send its whole forwarding table. When the MR that receives the NNRO message with the R bit set, the P (response) bit in the response NNRO message is set. Each forwarding table entry has the format in Figure 4.

2.4 Design Considerations

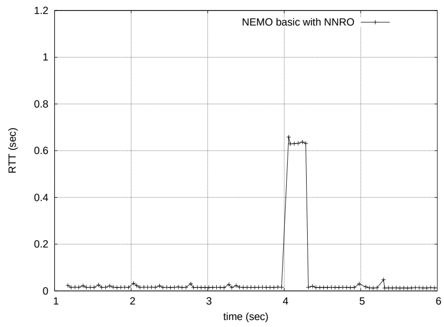
Besides communication between an local fixed node (LFN) and another LFN in the same nested mobile network, the proposed NNRO protocol supports route optimization between an LFN and a visiting mobile node (VMN) for between a VMN and another VMN. VMNs conform to Mobile IPv6 protocol [3]. According to Mobile IPv6 protocol, a mobile node can establish optimal route through binding update directly to the correspondent node. After the procedure of binding update to the correspondent node, the destination address of the packet is the CoA of the VMN using type 2 routing header when the LFN sends packets to the VMN in the same nested mobile network. Therefore, the MR used by the VMN can forward the packet to the VMN by searching the forwarding table.// If the entire nested mobile network moves together and changes its point of attachment, the additional operations in the nested mobile network are not needed. The MRs in the nested mobile network are transparent to this movement. However, if an MR in the nested mobile network goes away, the topology of the nested mobile network is changed, and the forwarding table entry of the MR in the other MRs will be deleted.

3. PERFORMANCE EVALUATION

In this section, we evaluate the effect of mobility and the number of hops between two MMNs. We simulated NNRO using Network Simulator 2 (NS2) [9]. The link delays between the HAs and and foreign network (AR) are fixed at 50ms. Each MR uses IEEE 802.11b on its wireless link interface and sends NNRO messages with the interval of 500ms. Figure 5(a) shows the end-to-end packet delay between two MMNs in a nested mobile network. The number of hops (MRs) between two MNNs varies from 3 to 8. When NNRO is not used, the RTT is increased greatly as the hop count between two nodes increase due to the pinball routing problem. However, with the proposed NNRO protocol, the effect of the degree of nesting is not notable.



(a) The effect of the number of hop



(b) The effect of mobility

Figure 5: Packet delay

Figure 5(b) plots the end-to-end packet delay variation due to handoffs as time goes by. There are two handoffs in this experiment. At 2 seconds, the whole nested mobile network hands off (the top level MR performs handoff) and changes its point of attachment to Internet. At 4 seconds, the topology of the nested mobile network is changed as one of the MRs in the nested mobile network goes away. After 2 seconds, the packet delay between two MNNs in a nested mobile network is not changed because the movement of the whole nested mobile network doesn't affect forwarding tables of the MRs. However, the packet delay soars for 0.3 second after the second handoff. This time, the MR sends the packets through a bi-directional tunnel before the forwarding table is refreshed.

4. CONCLUSIONS

In this paper, we propose a route optimization protocol for any two nodes in the same nested mobile network. The proposed protocol is consistent with the NEMO basic support protocol in that the mobility transparency is supported. The central idea behind the proposed protocol is to introduce a NNRO message, so that the MRs learn the NEMO prefixes of other MRs in the nested mobile network.
Performance evaluation reveals that the NNRO protocol reduces delay between any two nodes significantly in the same nested mobile network. Furthermore, the proposed protocol removes the packet overhead due to the bi-directional tunnelling in the NEMO basic support protocol. When the nested NEMO moves as a single unit, it does not cause additional NNRO messages and binding update messages among MRs inside in the same nested NEMO.

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