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TROUBLE-SHOOTING THE KEY PROBLEMS OF OVERHEAD AND PINBALL-ROUTING IN NESTED MOBILE NETWORK

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Abstract

As ubiquitous computing and pervasive computing are thriving, more electronic devices become capable of wireless communications and have continuous network connectivity to the Internet irrespective of the physical location of the node, often with their own Internet protocol (IP) address. Network Mobility (NEMO) Basic Support protocol is an extension of Mobile IPv6 to provide continuous, optimal and secure Internet access to all nodes and even recursively nested mobile sub-networks inside a moving network. However, this protocol suffers from pinball routing problem, which is caused by sub-optimal routing and resulting in substantial overhead and delays. In this paper, different methodologies include Routing Optimization using Tree Information Option (ROTIO), Port Address Translation (PAT), Optimized Link State Routing Protocol (OLSR), and Routing Information Protocol next generation Protocol (RIPng) have been evaluated to find a simple and easy way to implement nested mobile networks efficiently and effectively. It shows that the problems of “pinball routing” and “high overhead” in nested mobile networks can be alleviated by using ROTIO, PAT, OLSR, and RIPng. The most simple and easy way to reduce the overhead is using RIPng. And the most simply and easy way to solve the pinball problem is using ROTIO.

Keywords: Network Mobility, Mobile IPv6, Nested Mobile Network, and Route Optimization.

Introduction

Keeping in trend of ubiquitous computing and pervasive computing, many electronic devices are having the capability of communications through wireless technologies by using their own IP addresses. Nowadays, not only devices but also vehicles can be connected to the Internet. Mobile devices can get connected to the Internet even in vehicles. Moreover, they can move in groups, e.g. a radio, a Personal Digital Assistants (PDA), and a mobile phone of one person can organize together to form a Personal Area Network (PAN) that can move in a large vehicle. To route IP packets for such complex applications, nested mobile networks can be used. Network Mobility

(NEMO) Working Group in the Internet Engineering Task Force (IETF) has focused on this issue and been working to extend existing Mobile IP to support network mobility.

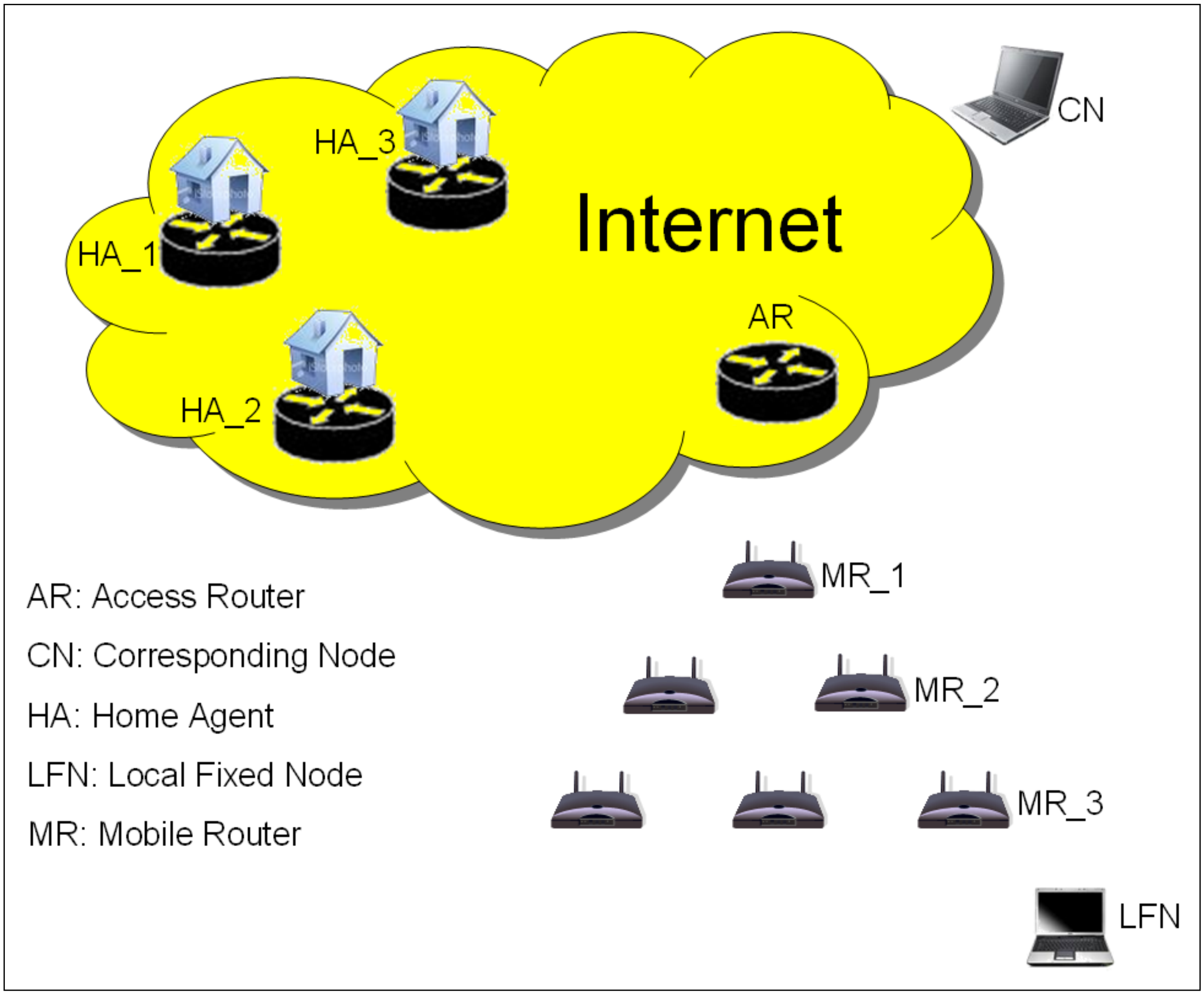

Figure 1: A Nested Mobile Network

NEMO Basic Support protocol is used to manage the mobility of an entire network, viewed as a single unit, which changes its point of attachment to the Internet [3]. This type of network will comprise one or more Mobile Routers (MRs) that connect it to the global Internet. A snapshot of a simple nested mobile network is shown in Figure 1. In the figure, the subnet of MR_1 is also the foreign link of MR_2. The same relation applies between MR_2 and MR_3. MR_1 is the Top-Level Mobile Router (TLMR) of the nested mobile network and is deemed to be the gateway to the whole nested mobile network. There are two types of Mobile Network Nodes (MNNs): Local Fixed Nodes (LFNs) and Visiting Mobile Nodes (VMNs). From the perspective of the LFN, MR_3 is the closest MR. When a Corresponding Node (CN) sends a packet to the LFN in the nested mobile network, the current NEMO protocol requires the packet to visit all the Home Agent (HAs) of all the MRs (from the closest MR of the LFN to the TLMR). Similarly, HA_n is the HA of MR_n. When the level of nesting increases, the packets destined for an LFN in a nested mobile network will suffer from more overhead and more inefficient routing. The overhead imposed by tunneling affects the performance of the overall system. The inefficient routing is called "pinball routing", which will be detailed in section 2.1. To route IP packets efficiently in such complicated networking environments, the current NEMO basic support protocol should be further comprehensively developed [2,11,16].

In this paper, a survey was conducted to solve the key problems of "high overhead" and "pinball routing" in nested mobile network. Pros and cons of different methodologies have been evaluated to solve the pinball routing problem in much simpler and easier ways. The methodologies include (i) Routing Optimization using Tree Information Option (ROTIO), (ii) Port Address Translation (PAT), (iii) Optimized Link State Routing Protocol (OLSR), and (iv) Routing Information Protocol next generation Protocol (RIPng) section.

Key Problems

NEMO allows "nested networks": a mobile network which attaches to another mobile network to arbitrary depth. However, for each level of nesting, traffic is encapsulated and tunneled to reach the destination. This leads to increased overhead (encapsulation) and to sub-optimal paths (tunneling without consideration for the actual network topology).

The Pinball Routing Problem

NEMO Basic Support protocol is the standard to provide continuous network connectivity and movement transparency to a group of nodes moving together, as in a vehicle. However, the protocol suffers from suboptimal routing and packet overhead caused by a bi-directional tunnel between the MR connecting the mobile network to the Internet and its HA. When nested mobile networks are formed, these issues are critical for real-time applications. In the worst case, when a CN sends a packet to the LFN which is located at the bottom level of the nested mobile network, the packet has to visit the HAs of all the MRs.

The problem of pinball routing with three levels of nesting was found in Figure 2. In the figure, data as IP packet was sent from CN to LFN would be routed to the HA of MR_3 (i.e. HA_3). The binding cache of HA_3 held the information that MR_3 was located below MR_2. Therefore, the data was encapsulated and rerouted to HA of MR_2 (i.e. HA_2). At this point, HA_2 had binding information indicating that MR_2 was located below MR_1. Thus, the data was encapsulated again and rerouted to the HA of MR_1 (i.e. HA_1). HA_1 encapsulated the data once again and delivered it to MR_1 through AR. In this scenario, the original data was encapsulated for three times. The MRs respectively de-capsulated the encapsulated data and respectively forward the data to the destination (i.e. LFN).

When the level of nesting increases and the routing distances between HA's become longer, the problem of pinball routing will be more complicated. Assuming there is a PAN in a vehicle, two levels of nested mobile networks will be found. If there is a PAN in a car on a ship, three levels of nested mobile networks will be found as well. Nevertheless, by including a multihop relay between mobile networks, a topology with four or more nested levels become conceivable. A multihop relay arises as a mobile network and attaches indirectly to the access network through neighbouring nested mobile networks. The high level of nesting will greatly aggravate the pinball routing problem.

We will know the effect of routing distances through this example. Supposing there is a PAN in an airplane on an international flight. The home network of the PAN is in China and the home network of the airplane is in Australia. If someone sends data to a PDA in the PAN, the data has first to go to the HA of the PAN in China, and then to the HA of the airplane network in Australia. After visiting the HA of the airplane, the data finally arrives at the MR of the airplane network, which may be located in yet another country. Due to the real-time characteristics of the data, we often cannot tolerate any resulting delay and jitter.

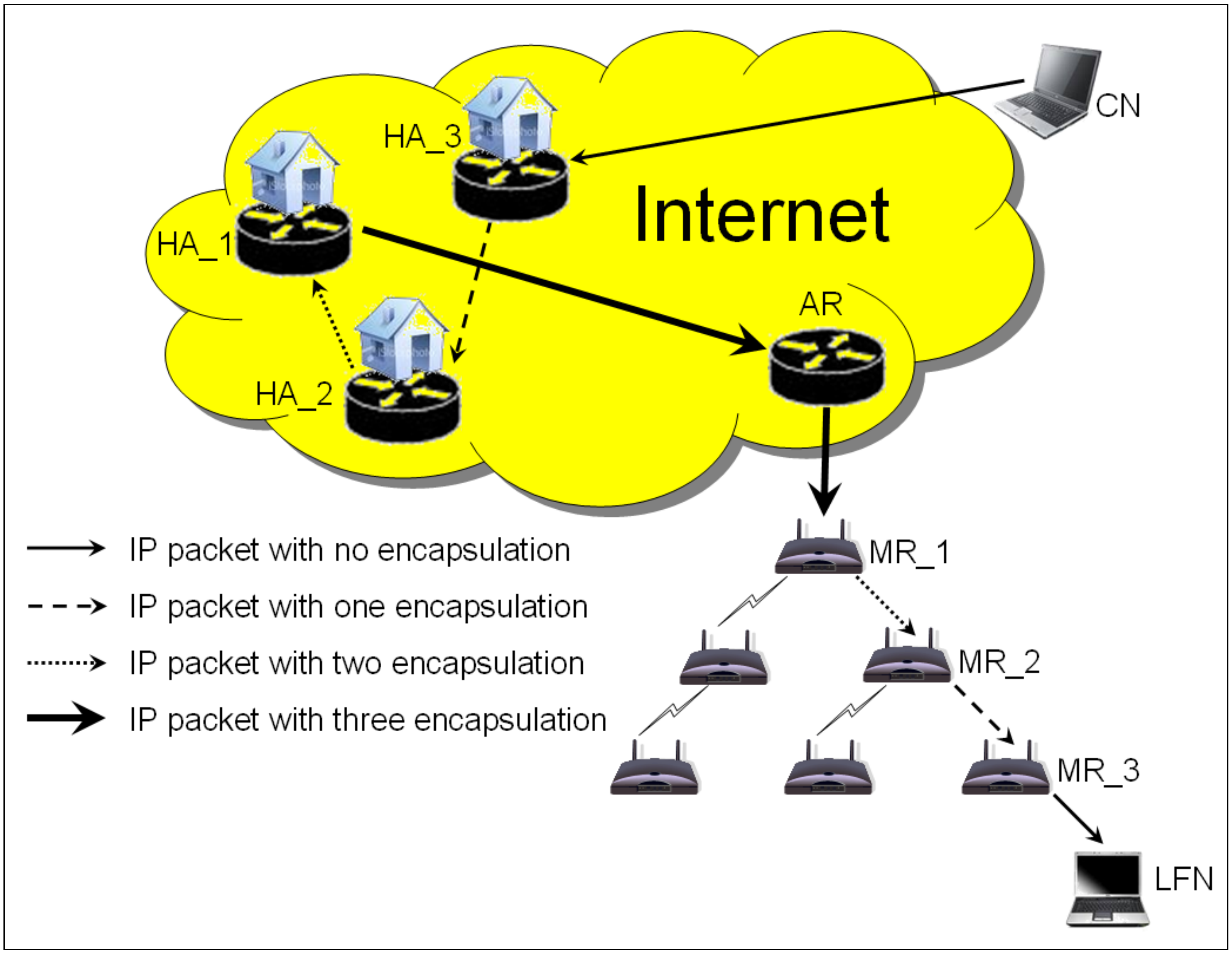

Figure 2: Pinball Routing Problem in a Nested Mobile Network

Proposed Solutions

For a nested mobile network, routing inefficiency is exacerbated as the level of nesting increases, which is called the pinball routing problem. Thus, the NEMO basic support protocol needs to be extended with an appropriate route optimization scheme.

Routing Optimization using Tree Information Option (ROTIO)

To solve the pinball routing problem, some authors propose a route optimization scheme called Routing Optimization using Tree Information Option (ROTIO). The ROTIO process contains two parts: basic ROTIO and extended ROTIO. The basic ROTIO scheme provides both forward and reverse route optimization while preserving the transparent mobility and location privacy of a NEMO. The basic ROTIO defines the route optimization mechanism between the CN and the LFN on both the forward and the reverse routing path. The extended ROTIO supports intra-NEMO routing optimization and seamless handoff. The extended ROTIO scheme localizes intra-NEMO communications and minimizes the handoff disruption.

As shown in Table 1, the simulation results show that the ROTIO scheme should be relatively more efficient when the levels of nesting increases or the average distance between HA's increases. Extended ROTIO also outperforms the other schemes in terms of intra-NEMO routing and NEMO handoff. The ROTIO scheme assumes that all MR's in a nested mobile network are ROTIO-capable. Since each MR understands the xTIO extension messages and decides an efficient routing, the ROTIO scheme can achieve the route optimization in the nested mobile network environment. Nevertheless, the ROTIO scheme may not work properly or shows declined performance when the ROTIO-capable and normal MRs are coexistent. Hence, it is recommended to further comprehensively develop the ROTIO scheme while considering the effect of heterogeneous composition of MRs and make the ROTIO scheme compatible with the existing NEMO basic support protocol [8,12,13].

Table 1: Summarized Characteristics of Route Optimization Schemes

RO criteria	NBS	ARO	RBU+	RRH	NPI	HMIP-RO	ROTIO
End-to-end route optimization	poor	good	moderate	good	good	moderate	good
Location privacy	strong	weak	weak	weak	weak	strong	strong
Mobility transparency	yes	yes	yes	no	no	no	yes
Intra-NEMO route optimization	poor	poor	moderate	poor	poor	moderate	good
Handoff disruption	moderate	poor	poor	poor	poor	moderate	good
Packet overhead	heavy	light	light	heavy	light	light	light
Processing overhead	light	moderate	moderate	moderate	moderate	heavy	moderate

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Port Address Translation (PAT)

To eliminate the pinball routing problem, Port Address Translation (PAT) was proposed. PAT uses the concepts of port redirection to route traffic to a node within the mobile network. This eliminates the need for tunneling between the nested mobile devices and their respective home network. It is shown that a significant improvement in overall performance for the participating nodes [10,14,15].

The proposed solution suggests building a communication tunnel between the HA of the mobile network and the TLMR. PAT makes use of three additional bits, one in the agent advertisement, one in the BU and one in the datagrams. The first additional bit termed as “N” bit, is used to notify all the MRs within the mobile network about the presence of nested mobility. The second additional bit termed “U” bit, which intimates the HA_n about the address of TLMR and also forces HA_n to update its binding cache with the new information. As the “U” bit is set in the BU packet, the intermediate MRs within the mobile network assign a port address to the source MR and update their respective database. The third additional bit termed as “O” bit (in the datagram's IP header), is used to indicate the intermediate MRs including the TLMR. This bit also indicates the datagram belongs to a nested mobile network and PAT needs to be performed.

The main advantage of PAT is that multiple internal hosts can share a single IP address for communication. The hosts on the private network do not have to expose their private IP addresses to the public network, making attacks from the public network less likely. Nevertheless, only a single public service (e.g. port 80 HTTP) can be exposed per public IP address. So, an organization using PAT and a single IP cannot easily run more than one of the same type of public service behind a PAT (e.g. two public web servers using the default port 20). For instance, if many hosts on the private network make many connections to the public network, the PAT device may not have sufficient room in its internal table to keep track of the connections or it may simply run out of unused ports.

Optimized Link State Routing Protocol (OLSR)

OLSR can be applied for route optimization within nested mobile networks. In order to solve the pinball routing problem, the concept of using periodic flooding of topological information to all OLSR routers in the network is applied in this suggested solution. By using the concept of Multi-point Relays (MPRs), the flooding is performed through a connected dominating set. Each OLSR router selects among its neighbour OLSR routers a subset, called MPRs. This set is chosen for any reachable OLSR router in the 2-hop neighbourhood through at least one MPR. An OLSR router periodically declares its MPRs to its neighbouring routers such that each OLSR router will learn about its “MPR selectors” for choosing a suitable route.

Even though in an arbitrary sized nested mobile network, the MRs naturally form an ad-hoc network for efficiently using OLSR to look for an optimal route. With OLSR, MRs can simply discover and maintain optimal routes to the AR, but also between MNNs themselves. This implies that communication between nodes within nested the mobile network can be routed through optimal paths, thereby avoiding layers of over-encapsulation and sub-optimal routing over the Internet, through the HAs, and back into the same nested mobile network. With reference to Figure 3, this implies that the nodes in Mobile Network No. 1 (i.e. MN_1) and Mobile Network No. 8 (i.e. MN_8) can communicate directly through the link between their MRs rather than via the long path through the Internet. By using the light-weight signaling features of OLSR, MR’s supporting OLSR exchange information in order to discover and maintain the network they form at the edge of the Internet through Topology Control (TC) and Host Network Address (HNA) messages. This includes periodically exchanging (i) the network prefix(es) of the MNNs they aggregate (using HNA messages) and (ii) summarize topology information (using TC messages), the MRs in a nested mobile network can provide fully optimized routing in the ad-hoc network they naturally form. Therefore, a MR running OLSR will include links to selected adjacent MR’s running OLSR in its TC-messages. Moreover, if MNNs are not MR’s, this will be advertised through HNA messages as well [4,5,7].

Having an OLSR network in a nested mobile network thereby provides an efficient way of reducing the route optimization problem to a simple application of the binding signaling mechanism found in basic NEMO. However, the original definition of OLSR does not include any provisions for sensing of link quality; it simply assumes that a link is up if a number of hello packets have been received recently. This assumes that links are bi-modal (either working or failed). Being a link-state protocol, OLSR sometimes requires a reasonably large amount of bandwidth and CPU power to compute optimal paths in the network.

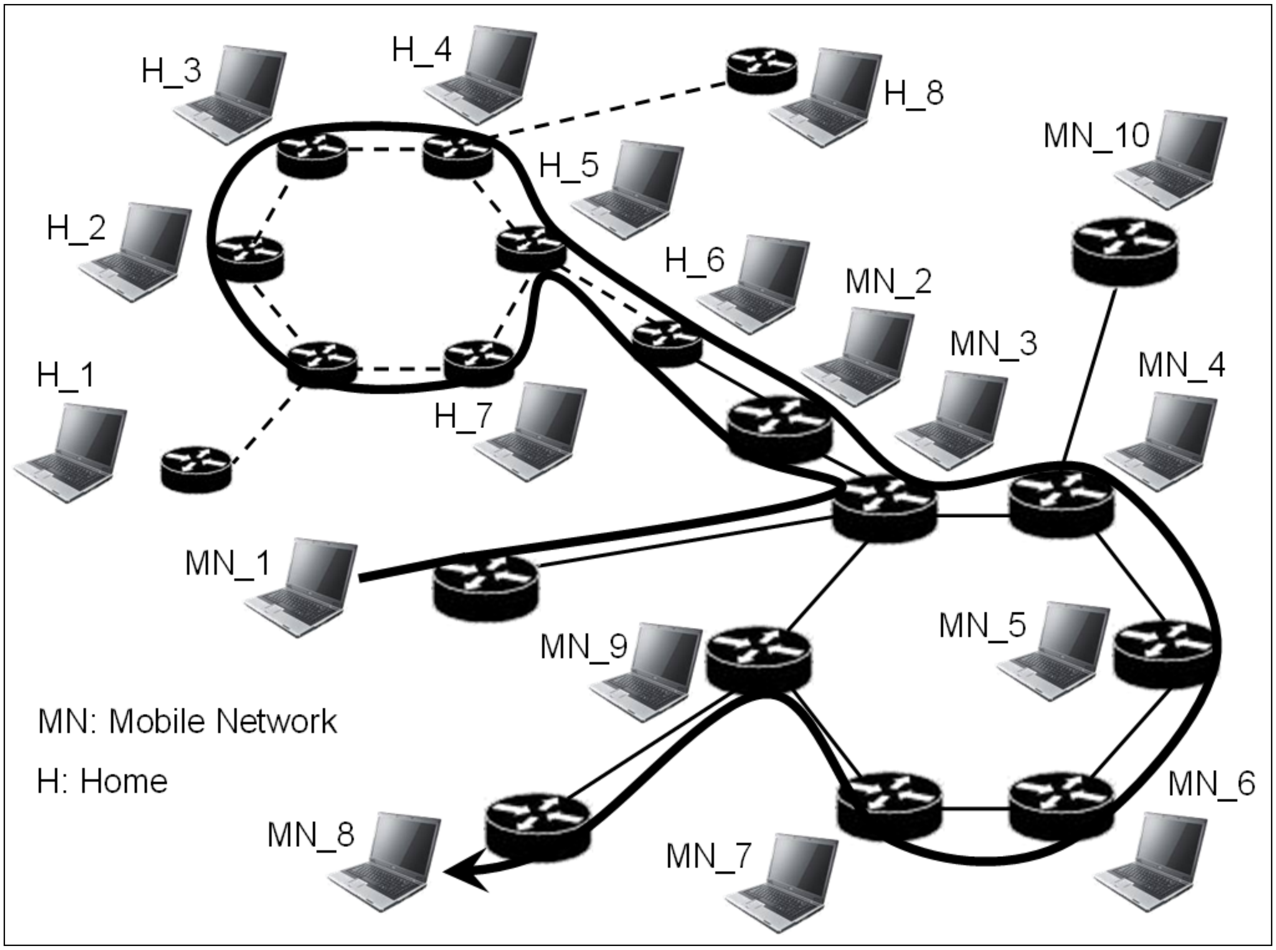

Figure 3: Nested Mobile Network

Routing Information Protocol next generation Protocol (RIPng)

RIPng (RIP next generation) is an information routing protocol for the IPv6. RIPng for IPv6 is based on protocols and algorithms used extensively in the IPv4 Internet such as RIP and RIP2. In a very large network, such as the Internet, there are many routing protocols used for the entire network. The network will be organized as a collection of Autonomous Systems (ASs). Each AS will have its own routing technology, which may differ among AS's. The routing protocol used within an AS is referred to as an Interior Gateway Protocol (IGP). A separate protocol, called an Exterior Gateway Protocol (EGP), is used to transfer routing information among the AS's. RIPng was designed to work as an IGP in moderate-size AS's. It is not intended for use in more complex environments. The pinball routing problem can be solved by providing route optimization in nested mobile network with a simple use of RIPng inside the nested network. The method provided in this section perceives two simple facts in providing efficient route optimization. First is that the MR is still a MR when it is being nested under another MR. Second is that a good protocol must be simple and easy to implement [1,6,9].

RIPng is the simplest routing protocol compared to other protocols, and the use of RIPng is recommended in smaller networks. As shown in Figure 4, the data as an IP packet was sent from CN to the node under MR_3. Originally, the CN not knowing the movement of the node sent the data to HA_3. The MR_3 had registered its CoA (i.e. MR_1CoA) of MR_1 to its HA (i.e. HA_3).

The data sent by CN would arrive at HA_3. The binding cache of HA_3 indicated the information that the TLMR of MR_3 was MR_1. Then, HA_3 would tunnel the packet to HA_1 (i.e. the HA of MR_1). The binding information of the MR_1 would be updated every time the MR_1 moved. So, the data was tunneled to MR_1 from HA_1. The newly formed routing table in the nested network was used from here. Since MR_1 was the TLMR, it checked the data header (i.e. IP packet header) to decide on the method of data de-capsulation. It was shown that the data was sent to lower-level MR (i.e. MR_3), it needed two de-capsulations. Thus, after the data was de-capsulated two times in TLMR, the data would be forwarded to the node (just below MR_3) in accordance with the routing table formed from routing protocol inside the nested mobile network; owing to it just having forwarded the data down the network. Thus, the entire packet-processing procedure had been simplified.

Nevertheless, RIPng does not solve every possible routing problem. Since it is primarily intended for use as an IGP in networks of moderate size, this protocol is limited to networks whose longest path (the network's diameter) is 15 hops. The designers believe that the basic protocol design is inappropriate for larger networks. Note that this statement of the limit assumes that a cost of 1 is used for each network. This is the way RIPng is normally configured. If the system administrator chooses to use larger costs, the upper bound of 15 can easily become a problem.

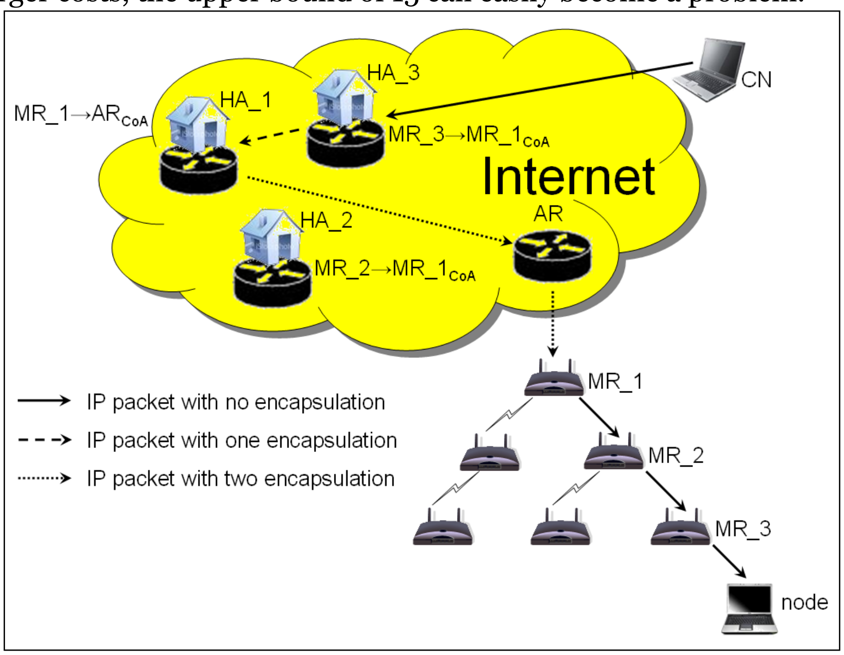

Figure 4: Route Optimization using RIPng Protocol

Conclusions

The algorithm of "Nested Mobile Network" has been described. It is found that the key problems of Nested Mobile Network are "Overhead" and "Pinball Routing". Four different methodologies have been evaluated so as to find the simple and easy way to implement "Nested Mobile Network" more efficiently and effectively. In the ROTIO scheme, each MR in the nested mobile network sends two BUs: one to its HA and the other to the TLMR. The former BU contains the TLMR's home address, while the latter contains routing information between the issuing MR and the TLMR. This alleviates the pinball routing problem significantly. PAT was designed to reduce the overhead involved in transmitting data between nodes within the nested mobile networks and the nodes within global internet. This can improved the throughput of the mobile network in addition to reducing the overhead and reducing the average delay involved in data transmission. OLSR employs an ad-hoc routing protocol between MRs to ensure shortest routes when both source and destination for traffic is within the nested mobile network. The mechanism also simplifies the requirements for route optimization when the source node is located outside of the nested mobile network. RIPng is the most simply and easy way to reduce the overhead, especially applying it in a smaller network.

References

[1] Bernardos, C., et.al., “MIRON: MIPv6 Router Optimization for NEMO”, Applications and Services in Wireless Networks, 2004(ASWN 2004), pp. 189-197, 9-11 August 2004.

[2] Clausen, T., Baccelli, E., and Wakikawa, R., “NEMO route optimization problem statement”, Internet draft, Oct. 2004. [Online]. Available: http://ietfreport.isoc.org/idref/draft-clausen-nemo-ro-problem-statement

[3] Devarapalli, V., Wakikawa, R., Petrescu, A., and Thubert, P., “Network mobility (NEMO) basic support protocol”, IETF, RFC 3963, Jan. 2005.Wireless Week, “Buying Numbers”, pp. 30, 2004.

[4] IETF Internet draft, “Network Mobility Route Optimization Problem Statement”, draft-ietf-nemo-ro-problem-statement-01, October 2005

[5] IETF Internet draft, “Network Mobility Support Goals and Requirements”, draft-ietf-nemo-requirements-05, October 2005

[6] IETF RFC 2080, “RIPng for IPv6”, January 1997

[7] IETF RFC 3775, “Mobility Support in IPv6”, June 2004

[8] Na, J., et al. “Route Optimization Scheme based on Path Control Header” (work in progress). Internet Draft (draft-na-nemo-path-control-header-00), Internet Engineering Task Force, April 2004.

[9] Na, J., et.al, “A Unified Route Optimization Scheme for Network Mobility”, Lecture Notes in Computer Science (LNCS), Number 3260, pp. 29-38, Springer-Verlag, September 2004

[10] Ng, C., et al. “Securing Nested Tunnels Optimization with Access Router Option” (work in progress). Internet Draft (draft-ng-nemo-access-router-option-01), Internet Engineering Task Force, July 2004.

[11] Ng, C., Thubert, P., Ohnishi, H., and Paik, E., “Taxonomy of route optimization models in the NEMO context”, Internet draft, February 2005. [Online]. Available: http://ietfreport.isoc.org/idref/draft-thubert-nemo-rotaxonomy

[12] Qayyum, A., et. al, “Multipoint relaying: An efficient technique for flooding in mobile wireless networks”, INRIA research report RR-3898.

[13] Thubert, P., and Montavont, N., Nested NEMO tree discovery Internet draft, July 2005. [Online]. Available: http://ietfreport.isoc.org/idref/draft-thubert-tree-discovery

[14] Thubert, P., et al. “IPv6 Reverse Routing Header and its application to Mobile Networks” (work in progress). Internet Draft (draft-thubert-nemo-reverserouting-header-05), Internet Engineering Task Force, June 2004.

[15] Wakikawa, R., and Watari, M., “Optimized Route Cache Protocol” (work in progress). Internet Draft (draftwakikawa-nemo-orc-00.txt), Internet Engineering Task Force, July 2004.

[16] Zhao, F., Wu, S.F., and Jung, S., “NEMO route optimization problem statement and analysis”, Internet draft, February 2005. [Online]. Available: http://ietfreport.isoc.org/idref/draft-zhao-nemo-ro-ps