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Routing optimization over network mobility with distributed home agents as the cross layer consideration

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Abstract Routing optimization (RO) is an important support for Mobile IPv6 while performing handover. It can reduce the overhead of a home agent and make the traffic more fluent between MN and CN; however, Network Mobility (NEMO) in Mobile IPv6 lacks the capability of RO. In this paper, we propose an enhanced architecture by deploying Home Agents Location Registration Agents (HALRA) on cellular data switch (3G/B3G) network incorporating with Distributed Home Agents (NEMO-DHA) on NEMO for a Mobility Critical Area. Under this architecture, it can provide less handoff latency on the Mobility Critical Area and make a detour to avoid the perplexed NEMO routing optimization problem. Moreover, NEMO-DHA can also solve a sort of Nested-NEMO problems by setting authorized Mobile Routers to serve as a set of Distributed Home Agent, and we provides a Cross-Layer suggestion by utilizing R-bit to schedule fairly for NEMO connections. The wireless network can also benefit from Distributed Home Agents by cooperating cellular data switch network with sharing HALR resource. Most models in the paper are described through UML modeling language evaluated by a mathematical model and simulated by NS2-Mobiwan2 (http://www.ti-wmc.nl/, 2009).

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1 Introduction

The recent advances in portable devices and wireless networks have resulted in a new paradigm of computing to access Internet while users changing their positions frequently. Mobility support for IPv6 (Mobile IPv6, MIPv6) [1] is one of the most important technologies when the continuous connectivity of mobility environment is taken into consideration.

There are some strong demand scenarios of IP mobility in the real world, such as passengers in MRT or city buses, etc. If a mount of mobile devices request to change their attachment at the same period of time, a handoff bottleneck will be encountered. Obviously, MIPv6 is not good enough for group mobility, because the original design of MIPv6 is only for a single device.

Network Mobility (NEMO) proposed in RFC 3963 [2] is expected to scale for a potentially large number of devices in mobile networks. It provides the basis support of group mobility and is adopted by several important vendors, such as Cisco. There are also some open or commercial sources available for Linux [3], FreeBSD [4], and Cross Platform [5]. In the NEMO Basic Support protocol compliant mobile network, Home Agent (HA) is the only anchor point for Correspondent Node (CN) and Mobile Node Network (MNN) [6]. It lacks support of RO and makes a longer latency in HA. In our experience of setting up a MIPv6 testbed with MIPL [3] and Futuresoft [7], the configuration of Home Agent is not harder than ones of other network services. We believe this reason causes Multiple Home Agents architecture with potential to be prevailing for the coming network environment.

In this paper, we extend NEMO basic support with Distributed Home Agents (DHA). A Home Agent Location Register (HALR) is used to maintain the Home Agents location information and HALRAs play the role to redirect ICMPv6 DHAAD request on demand. To deploy HALRAs will reduce the handoff latency for a busy core network. The mechanism also makes the support of authorization, dynamic Home Agent assignment, and inter-network mobility support possible.

After analysis of our setup scenarios, the NEMO-DHA architecture also has the potential to decrease handoff latency between cellular data switch (3G/B3G) network and Internet, no matter it is in a tightly coupled or loosely coupled inter-working hybrid network.

The rest of the paper is organized as follows. Section 2.1 gives the introduction of Network Mobility, Sect. 2.2 shows what are the problems of the NEMO Routing Optimization (NEMO RO) problems; Sect. 2.3 gives the introduction of the distributed home agents (DHA). Our NEMO-DHA architecture and MR-DHAD mechanism are present in Sect. 3. Internetworking models of the hybrid network are present in Sect. 4. Simulation results, mathematical analysis and discussions are presented in Sect. 5. Finally, the conclusion is remarked in Sect. 6.

2 Related works

2.1 Network mobility

NEMO Basic Support is a solution to preserve session continuity by means of bi-directional tunneling between MRs and their HAs much like what is done with Mobile IPv6 [17] for mobile nodes when Routing Optimization is not used. In the case of normal fixed network, data packets are sent to the destination directly. But in the case of Mobile IP and NEMO Basic Support protocol, all of the packets forwarded by Mobile Node (MN)/Mobile Router (MR) in the outbound direction have to go through HA first. NEMO Basic Support has become IETF proposed standard in Jan. 2005. This protocol allows session continuity for every node in the mobile network as the network moves. Every node in the mobile network is reachable while this network is changing its position.

NEMO Basic Support protocol is backward compatible with MIPv6, so HA can operate as a MIPv6 HA as well. In addition, NEMO Basic Support protocol defines required operations and messages for basic group IP mobility support, and let terminal devices access multiple networks transparently through the MR. A MR is located at the edge of the MNN and connects the MNN to the backbone of Internet. Consequently, a MR can be assigned as a default gateway for the MNN, which can include both fixed and MNs behind the MR; then, the Internal network topology of MR keeps relatively stable when the MNN is migrating. In NEMO Basic Support, only the MR and the HA are NEMO-enabled. The following will describe them briefly.

2.1.1 Mobile router (MR)

A MR is capable of changing its point of attachment to the network, forwarding packets between two or more interfaces, and possibly running a dynamic routing protocol. As shown in Fig. 1, a MR acts as a gateway between an entire MNN and the rest of Internet, and has one or more egress interfaces and one or more ingress interfaces. Packets forwarded upstream to the rest of the Internet are transmitted through one of the MR's egress interface; packets forwarded downstream to the MNN are transmitted through one of the MR's ingress interface.

NEMO-enabled home agent (NEMO-HA)

In Fig. 2, it shows the NEMO-enhanced ICMPv6 Dynamic Home Agent Address Discovery (DHAAD) Request message, which adds one more Mobile Router Support Flag (R).

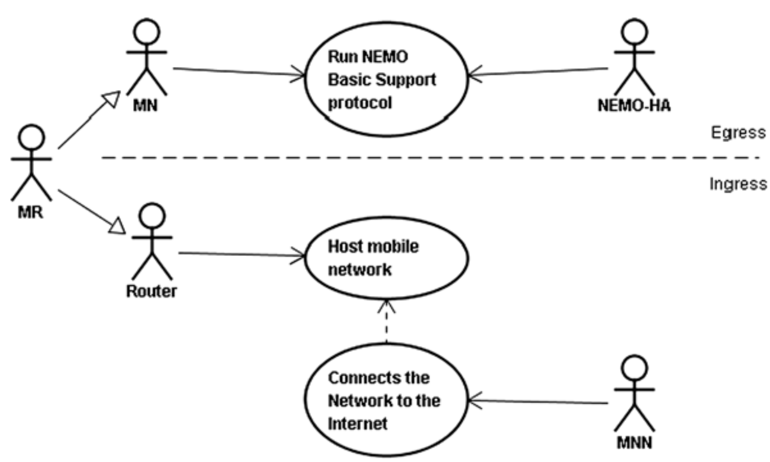

Fig. 1 Illustration of mobile router

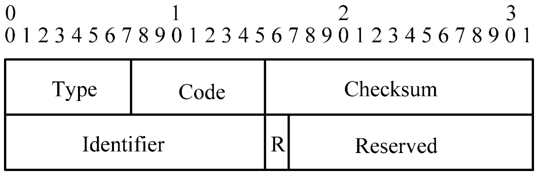

Fig. 2 Dynamic home agent address discovery request message with NEMO support

Table 1 Modified fields of dynamic home agent address discovery request message for NEMO basic support

Packet field ID	Field size	Default value	Note
Type	8 bits	144	
Code	8 bits	0	
Checksum	16 bits		The ICMP checksum
Identifier	16 bits		Aid in matching Reply messages to this Request message
R	1 bit	0	1 if NEMO support
Reserved	15 bits	0	Unused

If a NEMO-HA receives a DHAAD request message with the Flag set, it MUST reply with a list of NEMO-HAs supporting MRs. If none of the NEMO-HAs support MRs, the NEMO-HA MAY reply with a list of HAs that only support Mobile IPv6 MNs. The modified message format and field details (Table 1) are as follows.

As described above, most of the NEMO operations are inherited from MIPv6, so a HA may respond for multiple MNs on the home link. Nevertheless, the failure of a single HA can result in the loss of connectivity for many MRs located throughout the Internet, which would cause more serious problems than MIPv6.

2.2 NEMO routing optimization problems

As IPv6 provides the world of global IP addresses, P2P connection between MNs and CNs in MIPv6 introduces the mobility Routing Optimization (RO) features and problems. In addition, NEMO, which the network itself is moving entirely, extended the MIPv6 protocol and intensified the RO problems.

The protocol hides the MR mobility by making as if the MR was always connected to a Home Link. With current NEMO Basic Support, all communications to and from MNNs must go through the MR-HA tunnel when the mobile network is away. Therefore, all the packets MR-CN flow should be via the single HA without route optimization. This approach insures the packet will be delivered to proper MNN but also results in longer packet route and larger packet delay. In short, the longer route leads to the increased delay, packets overhead, and chances of packet fragmentation. Because of nested NEMO network where multiple levels of mobility are formed, NEMO RO problems have more challenges and more difficulties than MIPv6 RO problems. Compared to MIPv6 which provides 'Return Routability (RR) mechanism as a standard solution for routing optimization, the NEMO RFC seems to describe less about RO problems. Although MR can use RO just like any Mobile Host and the NEMO home agent allow route optimization to mobile network nodes known to be attached to a mobile router, the Local Fixed Node which is hosted by Mobile Router does not implement RO because it's not a MIPv6 node. There are a couple of drafts such as draft-Thubert [8], draft-Zhao [9], draft-Watarti [10], and draft-Clausen [11], etc. and a lot of discussions on the NEMO working group mailing list, which address and analyze those NEMO Route Optimization Problems.

Thubert [8] coined three user cases to illustrate the reasons why any sort of RO in NEMO is desirable:

1. You have a high quantity of traffic and transmitting all these packets via the home agent would consume too many network resources if the CN is relatively closer to the MNN on the direct path.
2. You have a small quantity of traffic, but it is very sensitive to delay, so you need the shortest path if the CN is relatively closer to the MNN on the direct path.
3. Each radio hop adds a probability of loss. If the traffic becomes useless at a given degree of loss, RO might be highly desirable.

Nevertheless, in order to achieve the optimal route in NEMO, MR and Corespondent Agent (CA, which denotes either CN or Correspondent Router (CR)) should become anchor points too.

Instead of basic MR-HA bi-directional tunnel, there are two kinds of RO problems remaining to be solved. The first one is MR-CR tunnel; in specific, MR will search the nearest CR to CN, and make a binding with it. CR is binding some kind of anycast address to ensure the discovery process possible. The binding process between MR and CR are activated to acquire some required information such as MR, CR prefixes. One example of that is MNN to MNN RO, which might save a number of radio hops in a (fixed or mobile) mesh network.

Another scenario is named as "pinball" or "dog-leg" routing [8], which figuratively illustrates a tortuous path for the case that multiple mobile networks are nested. It incurs very inefficient routing depending on the relative location of HAs however, extra IP header for IP tunneling is added per level of nesting to all the packets.

2.3 Distributed home agent with distributed home agent discovery mechanism

In the current specification of MIPv6, a MN can have one single HA on the home link during the connection, so the