Dynamic Tunnel Management Protocol for IPv4 Traversal of IPv6 Mobile Network

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***Abstract*— This paper specifies a mechanism for enabling IPv6 mobile network containing mobile network nodes to traverse through IPv4 networks that are comprised of wireless LAN, CDMA and GPRS. The traversal is possible by dynamic tunnel management protocol that dynamically updates the information of tunnel end point between mobile router and home agent, including a new IPv4 address of mobile router.**

I. Introduction

Recently, the demand and necessity of network mobility (NEMO) [1] is increasing along with those of host mobility based on Mobile IPv6 [2]. The purpose of network mobility is to guarantee the continuity of the sessions of fixed or mobile nodes within mobile networks, such as car, bus, subway train, airplane and submarine. IETF NEMO working group has been performing the standardization of network mobility support [3]. The current solution is based on bi-directional tunnel between home agent (HA) and mobile router (MR) [1]. The basic support protocol of NEMO enables mobile network node (MNN) and correspondent node (CN) to communicate through the bi-directional tunnel.

When we think over the applicability of NEMO in our daily life, we can forecast that network mobility service will be provided in vehicles, such as bus, subway train and airplane, because most passengers in such vehicles will have hand-held PC or PDA in near future. Now, it is transition period from IPv4 to IPv6. It is difficult to deploy IPv6 network mobility in the current Internet. Because most portions of the Internet is IPv4, IPv6 mobile network should use the infrastructure of the current Internet. Therefore, in the case where IPv6 access network based on wireless LAN is unavailable and we can use only either CDMA or GPRS networks that are connected to IPv4 Internet, IPv6 mobile network can traverse through IPv4 Internet via CDMA or GPRS networks. In this paper, it is suggested how to support the traversal in IPv4 Internet for IPv6 mobile networks.

The remainder of the paper is organized as follows. In Section II, related work is presented. In Section III and IV, respectively, we explains the overview of IPv4 traversal support scheme and Dynamic Tunnel Management Protocol (DTMP) that dynamically updates the information of tunnel end point between mobile router and home agent. In Section V, we explain our testbed for testing vertical handover between WLAN and CDMA networks. Finally, in Section VI, we conclude the paper with future research work.

II. Related Work

A. Vertical Handover based on L2 Triggers

We can use link-layer triggers in order to optimize movement detection process for Mobile IPv6 protocol [4]. The concept of L2 triggers is defined to optimize IP handovers between access points belonging to different subnets. In this context, five L2 triggers were proposed; two messages in reaction to an L2 handover/connection establishment (Link up and Link Down) and three messages that are issued before an L2 handover occurs (Source Trigger, Target Trigger or Mobile Trigger). These pre-handover messages have been designed to help L3 operations because they allow the anticipation of potential movements.

In the specification of L2-L3 interaction, a distinction is made between L2 Triggers and L2 Hints; L2 Trigger is an event that occurs at the Link Layer that is forwarded to the upper layer, i.e., Layer 3. This event can help the Layer 3 to instantaneously react by initiating an L3 operation (such as to trigger an L3 handover). An L2 Hint is the information that can be optionally transported with an L2 trigger and that can help the Layer 3 enhance triggered operations. Therefore, it is the supplementary information transported with the L2 Trigger that helps to make L3 link discovery faster. Especially, LINK-TYPE hint indicates the type of the technology from which the trigger was generated, e.g., CDMA, GPRS or WLAN.

III. Overview of IPv4 Traversal Support for IPv6 Mobile Network

We assume that every IPv6 network advertises Router Advertisement (RA) message for mobile node to make its Care-of Address (CoA) and every IPv4 network, including WLAN, CDMA or GPRS network, can provide mobile node with a global IPv4 address. Like in Fig. 1, when an IPv6 mobile network is placed in IPv6 foreign link of wireless LAN (WLAN), a bidirectional tunnel of IPv6-in-IPv6 is maintained for the communication between home agent (HA) and mobile router (MR) of the mobile network. When the mobile network moves out of WLAN signal range of access router 1 (AR1) and cannot reach any other WLAN, it starts

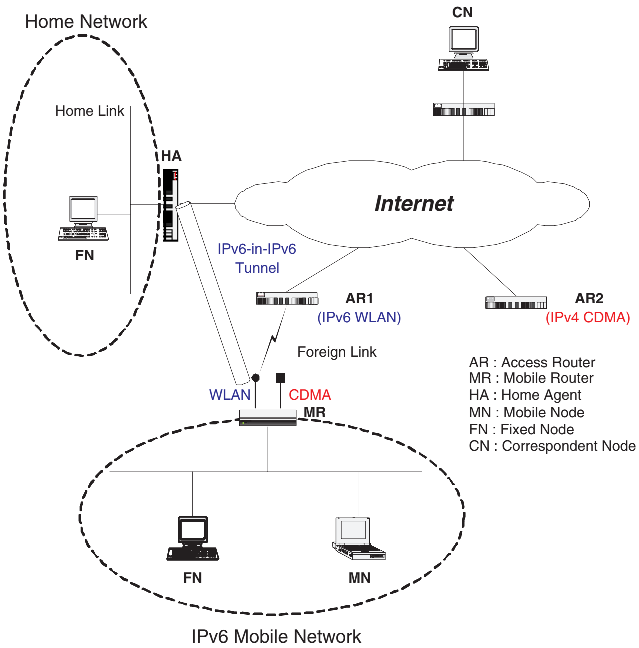

Fig. 1. IPv6 Mobile Network connected to IPv6 Access Network

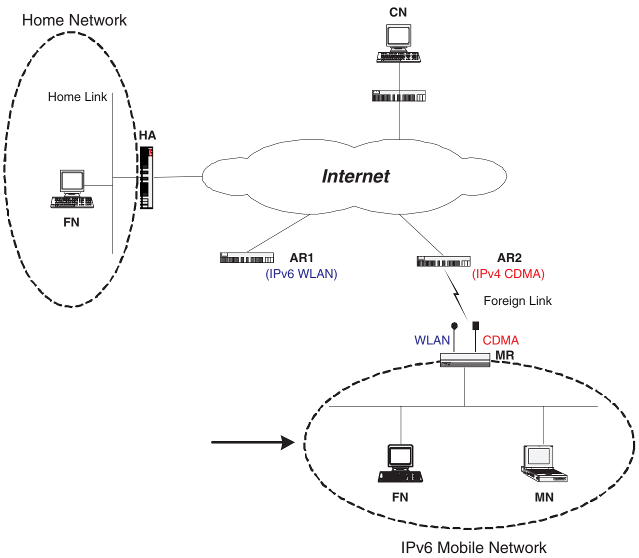

Fig. 2. IPv6 Mobile Network moving into IPv4 Access Network

to attach CDMA network like Fig. 2. We assume that CDMA network can provide a mobile node with a globally unique IPv4 address through IP Control Protocol (IPCP) of PPP. After configuring IPv4 address in its CDMA interface through AR2, the MR of the mobile network sets up an IPv6-in-IPv4 tunnel through DTMP of Section 4 for IPv6 connectivity like in Fig. 3. An access router AR2 consists of BTS/BSC, SDU and PDSN, which are CDMA network components [5]. The MIPv6 connectivity between MR and HA is maintained through the IPv6-in-IPv4 bidirectional tunnel. From the viewpoint of IPv6, MR is logically one-hop away from HA.

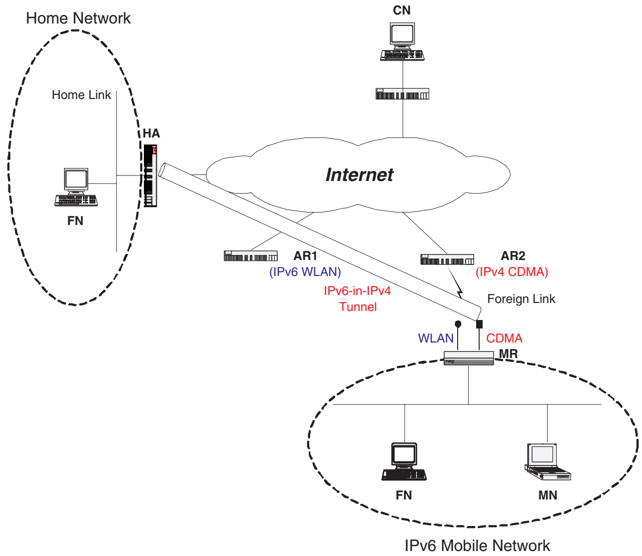

Fig. 3. Setup of IPv6-in-IPv4 Tunnel

IV. Dynamic Tunnel Management Protocol (DTMP)

DTMP plays a role of maintaining the connection between home agent and mobile router of a mobile network when the mobile router traverses IPv4 network. Whenever the IPv4 address of the mobile router changes according to either the change of PDSN in CDMA network or that of subnet link in WLAN, the update of IPv4 address is announced to home agent through DTMP and an IPv6-in-IPv4 bidirectional tunnel is set up between the mobile router and its home agent like in Fig. 3. However, when the mobile router moves into IPv6 subnet again, NEMO basic support protocol is used for setting up an IPv6-in-IPv6 bidirectional tunnel between the mobile rouer and its home agent. In this case, either implicit mode or explicit mode can be used for binding update of the mobile router's mobile network prefix [1]. Like this, DTMP manages an IPv6-in-IPv4 tunnel or IPv6-in-IPv6 tunnel between mobile router and home agent. For the binding update of IPv6-in-IPv4 tunnel, the IPv4 address of the mobile router is embedded in Alternate Care-of Address option of binding update message [2], which is represented as IPv4-mapped IPv6 address like Fig. 4 [6]. The binding update message is contained in MIPv6 mobility header [2]. The mobility header is contained as payload of DTMP message, which is the payload of IPv4 datagram that the mobile router sends to its home agent like in Fig. 5. Because DTMP message is a new ICMP message, the protocol field of IPv4 header has the code value of ICMP like in Fig. 5.

Home agent can distinguish the kind of these two binding updates with the kind of CoA contained in Alternate Care-of Address option of Fig. 5. For IPv6-in-IPv6 tunnel, home agent uses IPv6 header as outer IP header, and for IPv6-in-IPv4 tunnel, home agent uses IPv4 header as outer IP header. Also, binding acknowledgement message can be delivered

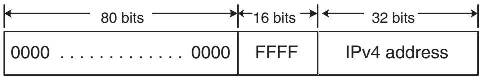

Fig. 4. IPv4-Mapped IPv6 Address Format

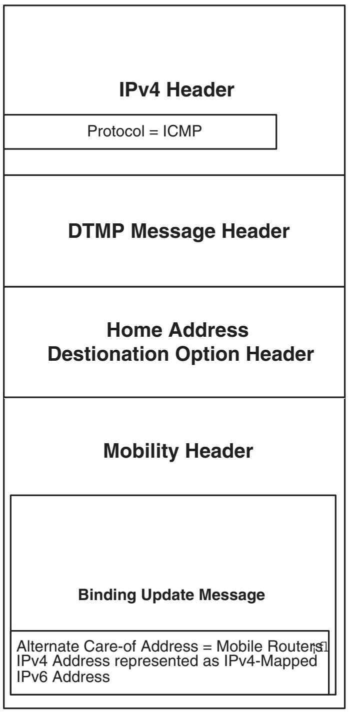

Fig. 5. IPv4 Datagram Layout for IPv6-in-IPv4 Tunnel Management

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 0                   1                   2                   3
 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 0 1
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|     Type      |     Code      |          Checksum             |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                        Identification                         |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
.                                                               .
.            Home Address Destination Option Header             .
.                                                               .
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
|                                                               |
.                                                               .
.                        Mobility Header                        .
.                                                               .
|                                                               |
+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+-+
```

Fig. 6. Dynamic Tunnel Management Protocol (DTMP) Message Format

from home agent to mobile router in the same way as binding update message.

A. *DTMP Message Format*

We define a new ICMP message for IPv6-in-IPv4 tunnel management through DTMP like Fig. 6. Table. I describes the fields of the message. DTMP messages consists of Tunnel Update (TU) message and Tunnel Update Acknowledgement (TU-Ack) according to code field. TU message is for binding updage message of MIPv6, and TU-Ack for binding acknowledgement message of MIPv6.

TABLE I

DTMP MESSAGE FIELDS

Field	Description
Type	As an ICMP type, this field indicates that this ICMP message is for DTMP.
Code	This field indicates two operations of DTMP: (a) Tunnel Update, and (b) Tunnel Update Acknowledgement
Checksum	As 16-bit unsigned integer, this field contains the checksum of DTMP message.
Identification	This field is used to identify DTMP message.
Home Address Destination Option Header	This header contains mobile router's home address for binding update.
Mobility Header	This header contains control messages related to binding update, e.g., binding update message and binding acknowledgement message.

B. *Movement Detection*

We assume that WLAN is IPv6 or IPv4 network and CDMA is always accessible for IPv4 networking when WLAN is not available; namely, when AP's Tx power of WLAN is below a predefined threshold. The movement detection is performed by MIPv6 movement detection algorithm between IPv6 networks based on WLAN, namely RA message and Neighbor Unreachability Detection (NUD) [2], [7]. The movement detection is performed by L2 trigger and L2 hint between heterogeneous networks consisting of WLAN and CDMA networks. Through LINK-TYPE hint, mobile router decides if it becomes to be attached to which network type among CDMA, GPRS and WLAN. When moving into the area managed by another PDSN in CDMA network or another subnet link in WLAN network, a mobile router gets another IPv4 address by IPCP or DHCP, respectively, and updates its IPv6-in-IPv4 tunnel information with its HA through DTMP.

V. EXPERIMENT IN TESTBED

We have implemented NEMO basic support protocol on the basis of MIPL Mobile IPv6 for Linux Kernel 2.4.22 [1], [2], [8] and DTMP for IPv4 connectivity in CDMA2000-1x network. We have developed IPv6 Wireless Mobile Router (WR) for NEMO testbed shown in Fig. 7, which is an embedded linux box with IEEE 802.11g interface and CDMA2000-1x interface. In order that we can set up vertical handover testbed consisting of IPv6 WLAN and IPv4 CDMA2000-1x networks, we have made the box regulate the signal range by controlling Rx and Tx power level of the wireless interface. In addition, we have implemented MAC filtering in wireless interface driver in order to filter adjacent node's packet in MAC level. With the Rx/Tx power control and MAC filtering, we can handle when vertical handover can occur at more liberty.

VI. CONCLUSION

In this paper, we suggest a mechanism of supporting IPv4 traversal for IPv6 mobile network based on NEMO basic support protocol, which is called Dynamic Tunnel Management Protocol. We assume that WLAN network is either IPv6

Fig. 7. IPv6 Wireless Mobile Router

or IPv4, and CDMA network is only IPv4. The movement detection is performed by AP's Tx power measurement of WLAN and L2 trigger/hint information between WLAN and CDMA networks. As future work, in order to minimize packet loss and delay of handover, we will enhance our movement detection mechanism.

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