Mobile IPv4/v6 translation gateway

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***Abstract*—IETF has specified Mobile IPv4 and Mobile IPv6 in RFC3344 and RFC3775 respectively, but not yet discussed Mobile IPv4/v6 in any published RFC. This paper proposes a scheme to solve one of Mobile IPv4/v6 problems which Home Agent (HA) is located in IPv4 network, Correspondent Node (CN) is located in IPv6 network, while MN moves within IPv6 network. In the solution, a gateway called Mobile IPv4/v6 translation gateway (MIPv4/v6-TG) is introduced to bridge between IPv4 network and IPv6 network, which is made up of a traditional NAT-PT gateway and a Mobile IP application level gateway (MIP-ALG) built upon the NAT-PT gateway. MIP-ALG maintains a MIP table, a data structure, which is formed by entries. And it can work compatibly with RFC3344 and RFC3775.**

Keywords—MobileIP(MIP), NAT-PT, Mobile IP application level gateway (MIP-ALG), Mobile IPv4/v6 translation gateway (MIPv4/v6-TG), MIP Table

I. INTRODUCTION

IETF specified the latest version of Mobile IPv4 [1] and Mobile IPv6[2] in RFC3344 and RFC3775 respectively. These two protocols work very well in pure IPv4 network and pure IPv6 network. However, both of them can not be directly applied to IPv4/v6 mixed networks. As the current network evolves gradually from IPv4 to IPv6, more and more mobile nodes need to roam in IPv4/v6 mixed networks. So we need to develop a transition scheme to support Mobile IP in IPv4/v6 mixed networks.

As a transition scheme, the solution should be developed based on the transition mechanisms for IP. Currently, three transition ways are recommended by IETF, namely, dual stacks (RFC4213) [3], tunneling (RFC3053) [4], and NAT-PT (RFC2766) [5][6]. There have been a lot of studies on Mobile IP in IPv4/v6 mixed networks, many of which are based on NAT-PT. An Internet Draft published by IETF [7] presents a solution to a situation of Mobile IPv4/v6, in which Home Agent (HA) and Mobile Node (MN) are in IPv6 network, Correspondent Node (CN) is in IPv4 network and NAT-PT gateway is located between IPv4 network and IPv6 network. It is proposed in this draft that NAT-PT do all of MIPv6 functionalilties on behalf of CN. This draft, however, deals with only part of the issues involved in Mobile IPv4/v6. In addition, this draft does not make clear how NAT-PT gateway does the functionalities on behalf of CN.

[8] studies the situation where both HA and CN are in IPv6 network and MN is in IPv4 network. A border router is placed between IPv4 network and IPv6 network to connect the two networks. After acquiring a new Care-of Address (CoA) in the IPv4 network, MN performs two registration processes, one is with the border router, and the other is with HAv6. Packets sent from CN to MN are encapsulated in new IPv6 packets which will be routed to the home network. In the home network, HAv6 intercepts these packets and again, encapsulates them in new IPv6 packets and then sends them to the border router. When these packets arrive at the border router, the border router encapsulates them in IPv4 packets and sends them to MN through a tunnel.

[9] studies the situation where HA is in IPv4 network, CN is in IPv6 network and MN moves within IPv4 network. A NAT-PT gateway is used to connect the two networks. In this scheme, MN has to register its new CoA with both HA and CN. Since CN knows exactly the location of MN, it can send packets directly to MN, without passing through the home network. In this way, the triangle routing in RFC3344 can be avoided.

In [10], if HA is in IPv6 network, MN always registers its new CoA with HA by BU messages. If MN moves to IPv4 network, the BU messages sent by MN will be tunneled to NAT-PT gateway which decapsulates the messages and sends them to HA. Similarly, if HA is in IPv4 network, MN always registers its new CoA with HA by register request messages. If MN moves to IPv6 network, the register request messages sent by MN will be tunneled to NAT-PT gateway which decapsulates the messages and sends them to HA.

Mobile IPv4/v6 should be compatible with Mobile IPv4 and Mobile IPv6 because it is a transition scheme from Mobile IPv4 to Mobile IPv6. RFC3344 and RFC3775 are the schemes to MIPv4 and MIPv6 recommended by IETF. However, the solutions proposed in [8][9][10] do not pay enough attention to the compatibility with RFC3344 and RFC3775. This would prevent them from being chosen as a feasible transition scheme. This paper proposes a scheme to solve Mobile IPv4/v6 problems. The solution is based on Mobile IPv4/v6 Translation Gateway (MIPv4/v6-TG) which is made up of NAT-PT and a Mobile IP-Application Level Gateway (MIP-ALG). In the following sections, we will first describe the fundamental principles of our solution. Then we will introduce the data structure, MIP table, which is maintained by MIP-ALG, and describe in details how to create, use and update MIP table entries.

II. TERMINOLOGY

The terms frequently used in this paper are listed in Table 1.

In addition, "v4" and "v6" are used to indicate IPv4 and IPv6, respectively. For example, HAv6 stands for HA that is located in IPv6 domain and CNAv6 the IPv6 address of CN.

By the way, if an IPv4 address is marked with a "#", it stands for an address from the address pool of NAT-PT gateway and is used to map an IPv6 address. If an IPv6 address is marked with a "*", it means that this address is made up of a 96-bit NAT-PT prefix and an IPv4 address.

TABLE I. TERMS THAT ARE FREQUENTLY USED

Terms	*Meaning*	*Terms*	*Meaning*
MIP	***Mobile IP***	***CNA***	***Correspondent Node Address***
HA	***Home Agent***	***BU***	***Binding Update***
MN	***Mobile Node***	***BA***	***Binding Acknowledge***
CN	***Correspondent Node***	***HoTI***	***Home Test Init***
HAA	***Home Agent Address***	***CoTI***	***Care-of Test Init***
HoA	***Home Address***	***HoT***	***Home Test***
CoA	***Care-of Address***	***CoT***	***Care-of Test***

III. MIPv4/v6-TG

MIPv4/v6-TG is made up of NAT-PT and MIP-ALG. On IPv6 network side, MIPv4/v6-TG acts as one of the Mobile IPv6 entities to combine with other MIPv6 entities inside the IPv6 network to form a complete MIPv6 model described in RFC3775. Inside the IPv6 network, the registration process and communication process can be performed as specified in RFC3775. Similarly, on IPv4 network side, MIPv4/v6-TG acts as one of the Mobile IPv4 entities to combine with other MIPv4 entities inside the IPv4 network to form a complete MIPv4 model described in RFC3344. Inside the IPv4 network, the registration process and communication process can be performed as specified in RFC3344.

As mentioned above, MIPv4/v6-TG will act as different MIP entities according to different combinations of the IP versions of HA, MN and CN. However, it can not decide which role it should act, if it does not know the IP versions of the three entities when MIPv4/v6-TG intercepts a MIP-related message or datagram. Therefore, MIPv4/v6-TG should keep the information of the IP versions of the three entities and the bindings that are used when it acts as a particular MIP entity. In our solution, we introduce a new data structure called MIP table to solve this problem. We use 3-bit binary numbers to indicate the location where MN, HA and CN sit. If the communication entity location in the IPv6 network we record it as 1, otherwise we record it as 0.

The three MIP entities have eight kinds of IP version combinations, from 000 to 111. At any time, there may be many MIP sessions, which correspond to the same scenario and thus use the same kind of MIP table entry. MIPv4/v6-TG should be able to distinguish them so that the messages and datagrams can be sent to the right place. Therefore, An MIP table entry should, typically, have the following fields.

Type: A three-bit field indicating the IP versions of HA, MN and CN respectively. For each bit, a value of 1 indicates the MIP entity is located in IPv6 network, while a value of 0 indicates the MIP entity is located in IPv4 network. Type value varies from 000 to 111.

MIPv6 Message Entrance: A 128-bit field through which a particular MIP table entry can be found and accessed when a MIPv6 message is intercepted by MIPv4/v6-TG. Usually, this field is set to the IPv6 home address.

MIPv6 Datagram Entrance: A 128-bit field through which a particular entry can be found and accessed when a MIPv6 datagram is intercepted by MIPv4/v6-TG. If an intercepted packet is not a MIPv6 message, MIPv4/v6-TG will take out its destination address and use the address as an index to search the MIP table.

MIPv4 Message Entrance: A 32-bit field through which a particular entry can be found and accessed when a MIPv4 message is intercepted by MIPv4/v6-TG. MIPv4 Datagram Entrance: A 32-bit field through which a particular entry can be found and accessed when a MIPv4 datagram is intercepted by MIPv4/v6-TG.

Cached Bindings: Bindings of home address and care-of address that are used by MIPv4/v6-TG when it acts as a particular MIP entity. Bindings may be of IPv4 form or of IPv6 form. Entries may have no binding, one binding, or two bindings. This depends on the types of the entries.

Source Port: A 16-bit field that records the source port value of Registration Request message, extended Registration Request message, or Agent Request message. All of these three messages are sent through UDP ports.

Destination Port: A 16-bit field that records the destination port value of Registration Request message, extended Registration Request message, or Agent Request message.

State: A 1-bit field indicating whether the entry is completed or not. There are two possible states for each entry: 1 (finished) and 0 (unfinished). An unfinished state indicates that the entry is now being created or updated. Entries with an unfinished state can not be used by MIPv4/v6-TG as a guide to process MIP datagrams.

Lifetime: A 16-bit field indicating entry lifetime. The meaning of this field depends on the value of the State field.

IV. APPLICATION EXAMPLE

We will solve one of Mobile IPv4/v6 problems which Home Agent (HA) is located in IPv4 network, Correspondent Node (CN) is located in IPv6 network, while MN moves within IPv6 network. And we will describe the creation, update and usage of type 011 MIP table entries as an example in the following.

A. *The create of Type 011 MIP Table Entries*

When MIPv4/v6-TG intercepts a BU message, it takes out HoAv6* from the message and uses it as an index to search the MIP table. If no matching entry is found, MIPv4/v6-TG will create a new entry, using the information carried in the BU message. If a matching entry is found, MIPv4/v6-TG will go further to see if the second bit of the Type is equal to 1 (i.e., MN is in IPv6 network). If so, MIP-ALG will just update the existing entry, without creating a new entry. Otherwise, MIP-ALG will create a new entry. The creation process of the 011 type MIP table entries is shown in Fig.1.

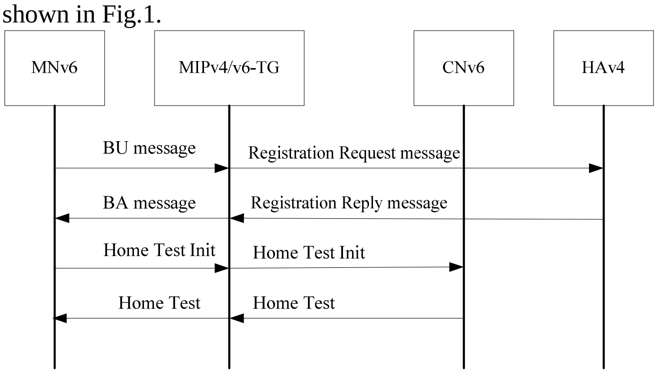

Figure 1. The creation process of the 011 type MIP table entries

The concrete steps as follows:

(1) On receiving the BU message, MIP-ALG can infer that HA is located in IPv4 network and MN is located in IPv6 network. However, MIP-ALG does not know the IP version of CN and needs other means to learn this information later.

MIP-ALG creates a new entry and sets the field of Cached Bindings to HoAv6* $\leftrightarrow$ CoAv6, MIPv6 Message Entrance to HoAv6*, MIPv4 Message Entrance to CoAv4#. CoAv4# is an IPv4 address taken from the NAT-PT address pool and mapped with CoAv6. The fields of HoTI/HoT, CoTI/CoT and State are all set to 0. Lifetime is set to a value in which the creation of the entry must be accomplished.

(2) MIP-ALG translates the BU message into a Registration Request message with CoAv4# and HAAv4 as its source address and destination address, respectively. HoAv4 is carried in the new message. HAAv4 and HoAv4 are acquired from HAAv6* and HoAv6*, respectively. This Registration Request message will be routed to HAv4.

(3) MIPv4/v6-TG intercepts the Registration Reply message replied from HAv4, takes out the destination address as an index to search the MIP table and finds this entry.

(4) MIP-ALG translates the intercepted Registration Reply message into a BA message with HAAv6* and CoAv6 as its source address and destination address, respectively. HoAv6* is carried in the message. HAAv6* and HoAv6* are acquired by adding a 96-bit NAT-PT prefix to HAAv4 and HoAv4. CoAv6 is acquired by searching the NAT table, using CoAv4# as the index. HAAv4, HoAv4, and CoAv6 can be all acquired from the intercepted Registration Reply message. This BA message will be routed to MNv6.

(5) MIPv4/v6-TG intercepts HoTI message, takes out HoAv6* from the intercepted message as an index to search the MIP table and finds this entry. Note that HoTI arrives through tunneling.

(6) MIP-ALG can judge the IP version of CN by the destination address of HoTI. MIP-ALG sets the field of Type to 011, and then sends HoTI to CNv6.

(7) MIPv4/v6-TG intercepts HoT message replied from CNv6, takes out HoAv6* from the intercepted message as an index to search the MIP table and finds this entry.

(8) MIP-ALG sets the HoTI/HoT field to 1, and then sends HoT to MNv6. Note that the HoT message is sent through tunneling.

(9) MIP-ALG sets the State to 1, and then sets the Lifetime to the lifetime of the binding.

B. The update of Type 011MIP Table Entries

When MN moves within network of the same IP version and acquires a new care-of address, it will update the binding caches on HA and CN (when CN is in IPv6 network) as well as the binding caches on the related MIP table entry under some circumstances. Like the creation of MIP table entries, the update of the entry is triggered by MIP messages, such as Registration Request messages, BU messages, HoTI/HoT messages and CoTI/CoT messages. In the creation process, MIPv4/MIPv6 Message Entrance of the entry have been set. MIPv4/v6-TG can access a corresponding entry through these entrances when it intercepts a MIP message, and then updates the entry.

Note that when MN moves to a network of a different IP version, the original entry (if any) becomes invalid and a new MIP table entry should be created.

A Type 011 entry corresponds to a scenario where HA is located in IPv4 network, while MN and CN are located in IPv6 network. The update process of a Type 011 MIP table entry is shown in Fig.2.

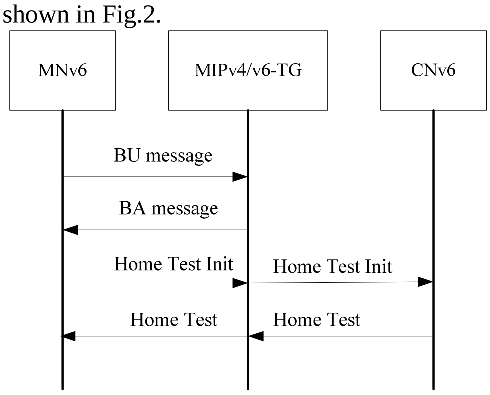

Figure 2. The update process of the 011 type MIP table entries

The concrete steps as follows:

(1) MIPv4/v6-TG intercepts a BU message, takes out HoAv6* and uses it as an index to search the MIP table, and finds a related Type 011 entry.

(2) MIP-ALG sets the fields of State to 0, and Lifetime to a value in which the update of this entry must be accomplished.

(3) MIP-ALG takes CoAv4# from MIPv4 Message Entrance and uses it as an index to search the NAT table. A mapping of CoAv4# $\leftrightarrow$ CoAv6 will be found. Then MIP-ALG updates the mapping with the new CoAv6 carried in the BU message.

(4)MIP-ALG updates Cached Bindings HoAv6*$\leftrightarrow$CoAv6 with the new CoAv6 carried in the BU message.

(5) MIP-ALG generates a BA message. The source address and destination address are copied from the destination address and source address of the BU message. HoAv6* is also carried in the BA message. This BA message will be routed to MNv6.

(6) MIPv4/v6-TG intercepts a HoTI message, takes out HoAv6* from the intercepted message as an index to search the MIP table and finds this entry. This HoTI message will be then delivered to CNv6.

(7) MIPv4/v6-TG intercepts a HoT message, takes out HoAv6* from the intercepted message as an index to search the MIP table and finds this entry. This HoT message will be routed to MNv6 through tunneling. The beginning point and endpoint of the tunnel are HAAv6* and CoAv6. CoAv6 can be acquired from the Cached Bindings field of the entry.

(8) MIP-ALG sets the field of State to 1, and the Lifetime to the lifetime of the binding.

C. The usage of Type 011MIP Table Entries

The introduction of MIP table aims to maintain MIP sessions in IPv4/v6 mixed networks. When a datagram sent by MN or CN passes through MIPv4/v6-TG, MIPv4/v6-TG will take out the destination address of the datagram and uses it as an index to search the MIP table. If a matching entry is found, MIPv4/v6-TG will process the datagram, based on the information recorded in the entry.

A Type 011 entry corresponds to a scenario where both MN and CN are located in IPv6 network. In this scenario, MN and CN can communicate with each other without the participation of MIPv4/v6-TG. Therefore, Type 011entries will not be used in the communication processes.

V. CONCLUSION

The key to our solution is Mobile IPv4/v6 translation gateway and a MIP table, a newly introduced data structure. With the help of this gateway and the MIP table, RFC3344 and RFC3775 can be reused in IPv4 network and IPv6 network respectively. In this way, the Mobile IP entities in IPv4 network and the Mobile IP entities in IPv6 network can be transparent to each other.

Compared with other solutions, our solution has three main advantages. Firstly, it can work compatibly with RFC3344 and RFC3775. This is very important in that it makes Mobile IP in IPv4/v6 mixed networks possible without any update to the existing networks. Secondly, our solution introduces MIP table. We can use the MIP table to realize the communication in IPv4/v6 mixed network easily. Thirdly, the creation, usage and update of the MIP table entries is easily too.

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