A Terminal Mobility Management Architecture for IPv4 and IPv6 Environments

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Abstract. An interworking translator for IPv6 and IPv4 services can be defined as an intermediate component between a native IPv4 host and a native IPv6 host to enable direct communication between them without requiring any modifications to the hosts. But if the host is a mobile node, triangle routing problem occurs, since Mobile IPv4 allows mobile node to roam transparently in any network. In this situation, mobile node must notify transfer information to its own home agent and correspondent node in IPv6 network. But current NAT-PT does not permit mobility header translation. Therefore, NAT-PT does not support efficient communication between Mobile IPv4 and Mobile IPv6. In this paper, we propose a mobility service interworking mechanism for heterogeneous mobile network environments.

1 Introduction

A great number of mobile nodes will be connected to the Internet in the near future. The current IPv4 can not provide a sufficient number of unique IP addresses for all elements(e.g., Router, Switch, Mobile Node, Terminal) connected to the Internet. The limited size and structure of the Internet address space of IPv4 has caused difficulties in coping with the explosive increase in the number of Internet users. So, IPv6[1] has been standardized by the Internet Engineering Task Force(IETF) to cope with vastly increased demand from a wide range of users and mobile networks among users. IPv4 networks and services will continue to exist for quite a long time, making efficient inter working between IPv4 and IPv6 which is very important. The transition period will be lengthy and network/terminal equipment supporting both IP versions will be needed during the transition period. Thus, IPv4 to IPv6 transition issues are very important. The three main transition mechanisms[10] are dual stacks[7][8][10] in network elements, tunneling[10], and translators[4][5][6] in the network.

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We can use NAT-PT for communication between host of IPv4 network and host of IPv6 network. But if host is a mobile node, triangle routing problem[2] occurs.
In this paper, we propose a new scheme to resolve the triangle routing problem[2] between Mobile IPv4 and Mobile IPv6[3]. The remainder of this paper is organized as follows. In section 2, we describe works related to IPv4 to IPv6 translation mechanism. In section 3, we show the problem of current translator. In section 4, we explain our proposed scheme. In section 5 and section 6, we show the performance measures and simulation results. We conclude in section 7.

2 Related Works

In this section, we describes of a dual stack, a automatic tunneling and configured tunneling and translator.

2.1 Dual Stack for IPv6/IPv4

Dual Stack means that host and network elements(e.g., Router, Switch..) have the IPv4 stack and IPv6 stack. So they can access both IPv4 and IPv6 services without additional translators in the network[4][7][8][10].

2.2 Tunneling Mechanism

Tunneling means encapsulating IPv6 packets within IPv4 packets and decapsulating in the other end of the tunnel. Tunneling requires dual IPv4/IPv6 stack functionality in the encapsulating/decapsulating nodes. In configured tunneling, the endpoint of the tunnel is manually configured to a certain IPv4 address. In automatic tunneling, the encapsulation is done automatically in the encapsulating router/host, and the tunnel endpoint IPv4 address is included in the IPv6 destination address of the packet. An example of such a tunneling mechanism is so called 6to4 tunneling[4][10].

2.3 Translation Mechanism

A translator can be defined as an intermediate component between a native IPv4 host and a native IPv6 host to enable direct communication between them without requiring any modifications to the hosts.
Header conversion is an important translation mechanism. In this method, IPv6 packet headers are converted to IPv4 packet headers, or vice versa, and checksums are adjusted or recalculated if necessary. Network Address Translator/Protocol Translator (NAT-PT) is an example of such a mechanism. There are also other translation mechanisms, but only NAT-PT is considered here[4][5][10].

3 Problem of NAT-PT

NAT-PT does header conversion using SIIT[5] algorithm. So, hosts in IPv4 network could send packets to host in IPv6 network. Of course, it is possible in opposite case. But in this case host is a fixed node. If host is a mobile node, some problem may occur. Mobile IPv4 enables mobile node to roam transparently in any network. In this situation, mobile node must notify transfer information to its home agent and correspondent node in IPv6 network. Mobile IPv4 enables mobile node to send transfer information using registration request message. But correspondent node in an IPv6 network that receives a registration request message can not understand the meaning of this message. The reason is the message for transmitting the transfer information in a Mobile IPv6 is different from the registration request message. This message is called the binding update message[3] in Mobile IPv6. These are shown in Figure 1 and Figure 2.

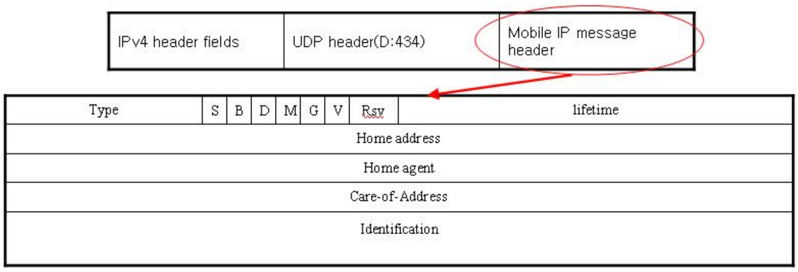

Fig. 1. Message format of registration request/reply in Mobile IPv4

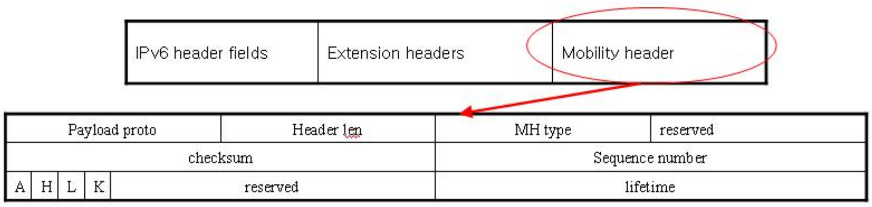

Fig. 2. Message format of binding update/acknowledge in Mobile IPv6

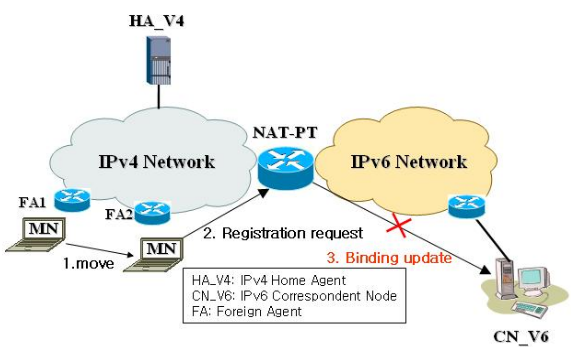

Fig. 3. Problem of NAT-PT

Figure 3 shows the problem of NAT-PT. If a mobile node moves from FA1(Foreign Agent) to FA2, the mobile node sends registration request message to correspondent node which contains the new care-of-address. Then NAT-PT changes IPv4 packet to IPv6 packet and delvers it to a correspondent node in IPv6 network. Here, NAT-PT only changes IPv4 header to IPv6 header without mobility header conversion. So, correspondent node can not know of a mobile node's care-of-address. Finally, this situation creates triangle routing problem. Figure 4 shows the triangle routing problem.

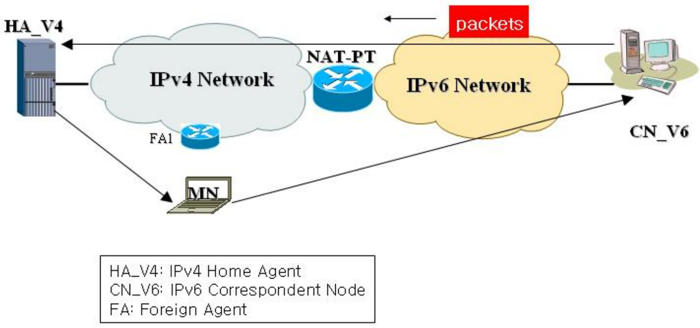

Fig. 4. Triangle routing problem

4 Mobility header conversion algorithm

In this section, we will introduce the two rules to provide a suitable conversion mechanism for mobile nodes in IPv4 network.

4.1 Translation of registration request message to binding update message

When an NAT-PT receives an IPv4 datagram, it translates the IPv4 header of that packet into an IPv6 header. It then translates the registration request message to the binding update message. And it forwards the packet based on the IPv6 destination address. The binding update header fields are set as follows:

▪ *Payload proto* field: according to the current specification, this field is always set to the decimal value 59, which indicates mobility header that is the last header.

▪ *Header len* field: this field is the length of this extension header in 8 octet units, excluding the first 8 octets.

▪ *MH Type* field: the mobility header type field is used as a switch to indicate which message is included in the mobility header. When a binding update message is included in the mobility header, this field is set to 5.

▪ *reserved* field: all zero

▪ *Checksum* field: this is computed when the binding update header has been created.

▪ *Sequence number* field: it is allocated by NAT-PT.

▪ *flags* : only A flag is set to one. The A flag indicates whether an acknowledgment is expected for this binding update.
▪ lifetime: lifetime field is copied from Mobile IPv4 header.

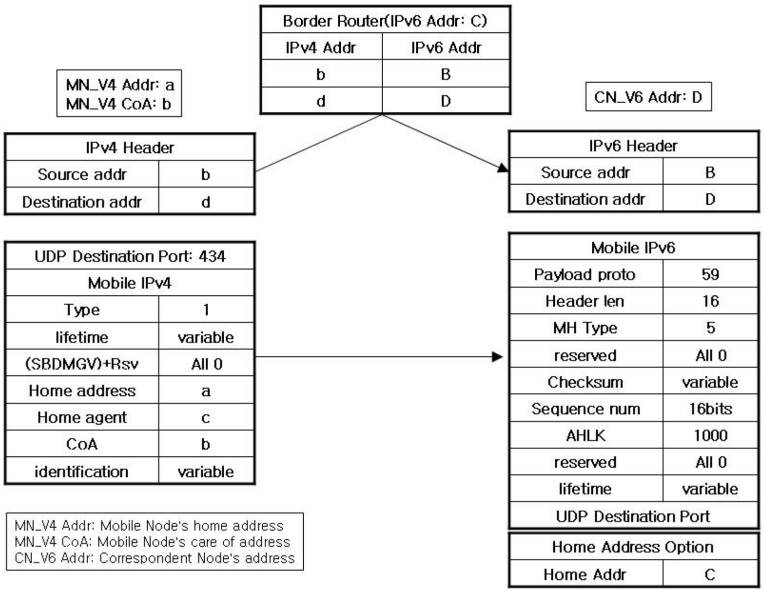

Fig. 5. Translation of registration request to binding update message

4.2 Translation of binding acknowledgment message to registration reply message

When an NAT-PT receives a binding acknowledgment message from a correspondent node in IPv6 network node in IPv6 network, it translates the IPv6 header of that packet into an IPv4 header. It then translates the binding acknowledgment[3] to a registration reply[2]. And it forwards the packet based on the IPv4 destination address. The registration reply fields are set as follows:
▪ Type field: set to decimal value 3 which means that this message is registration reply.
▪ code field: set to decimal value 0 which means registration accepted.
▪ lifetime field: lifetime field copied from Mobile IPv6 header.
▪ Home address field: set to IPv4 address of the mobile node.
▪ Home agent field: set to IPv4 address of the NAT-PT.
▪ Identification field: allocated by NAT-PT(when NAT-PT receives registration request, it saves identification value).

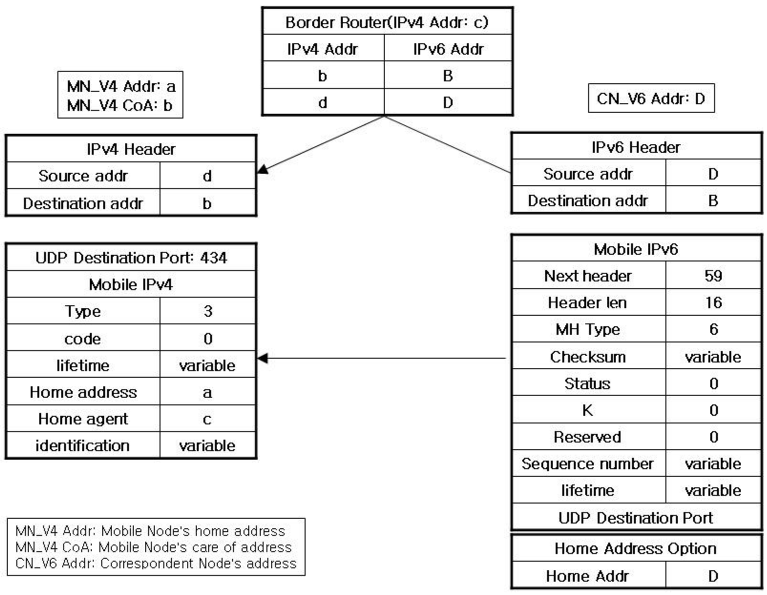

Fig. 6. Translation of binding acknowledgment message to registration reply message

4.3 Operation of our proposed scheme

Operation of our proposed scheme is shown in Figure 7

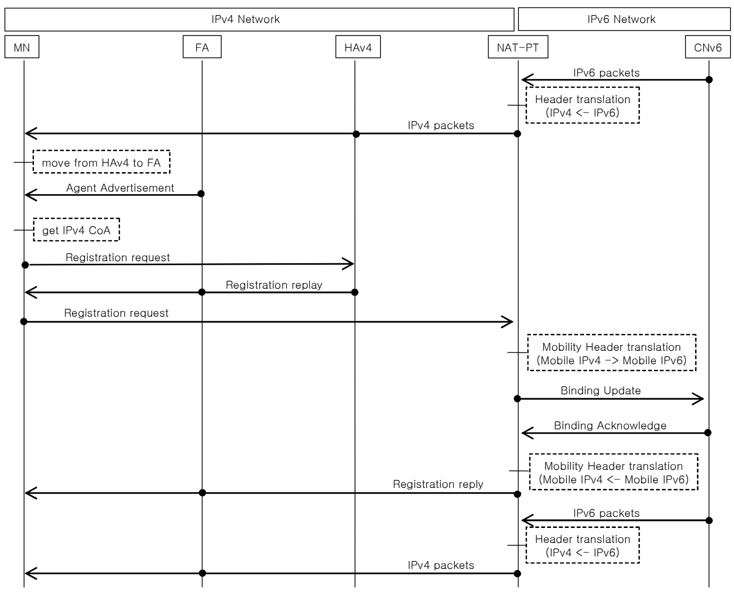

Fig. 7. Protocol operation schenario for Mobile IPv6/IPv4

1. Mobile node moves from home network to foreign Network.
2. Mobile node sends registration request to correspondent node in IPv6 network.
3. NAT-PT intercepts registration request and it translates the registration request message to a binding update message. Finally it forwards the binding update based on the IPv6 destination address.
4. In response, the correspondent node sends the binding acknowledgement message to mobile node in IPv4 network.
5. NAT-PT intercepts a binding acknowledgement and it translates the binding acknowledgement to a registration reply. Finally it forwards the registration reply based on the IPv4 destination address.

5 Performance measures

The performance measures used in this study are the M/M/1[9] queuing model. The total end-to-end delay is the sum of the propagation delay, queuing delay and transmission delay. The queuing delay, transmission delay and propagation delay are calculated by the following formulas:

- service time(Ts): $Ts = \frac{packet\_length(bits)}{Line\_speed(bits/\sec)}$
- node utilization(ρ): $\rho = \lambda \times Ts$ (λ : arrival packet rate)
- transmission time(Tr): $Tr = \frac{Ts}{1-\rho}$
- Propagation delay(Pd): $Pd = distance(m) \times (3 \times 10^8 m/s)$

We can calculate end-to-end delay of packet transmission using above formulas. In current NAT-PT scheme, it can not notify mobile node's transfer information. So, triangle routing problem occurrs. Therefore, we can calculate end-to-end delay by following formula:
End-to-End delay of packet transmission from correspondent node in IPv6 network to mobile node in IPv4 network.(TD: Total Delay, D_{A_B}: propagation delay from A to B, PD_A: processing delay of A, n: number of routers in network)

$$\begin{aligned} TD &= D_{CN\_NAT-PT} + PD_{NAT-PT} + D_{NAT-PT\_HA} + PD_{HA} + D_{HA\_MN} \\ &= (2+n)PD + D_{CN\_MN} \end{aligned} \quad (1)$$

In our proposed scheme triangle routing problem does not occur. So, in our case we can calculate end-to-end delay of packet transmission by following formula:

$$\begin{aligned} TD &= D_{CN\_NAT-PT} + PD_{NAT-PT} + D_{NAT-PT\_MN} \\ &= (1+n)PD + D_{CN\_MN} \end{aligned} \quad (2)$$

Formula 1 and formula 2 show that our proposed scheme experiences less end-to-end delay of packet transmission.

6 Simulation Results

In order to evaluate the benefits of our proposed scheme, we compared the end-to-end delay of packets with and without applying mobility header conversion algorithm in NAT-PT. Simulation parameters with increasing hop count are shown in the Table 1.

Table 1. Simulation parameters with increasing hop count

Parameter	IPv6 network	IPv4 network
Hop count	3	Increase value
Packet length	1000 bits	1000 bits
Service time(each router)	0.12 sec	0.12 sec
Packet arrived rate(each router)	0.5 packet/sec	0.5 packet/sec
Transmission time(each router)	0.3 sec	0.3 sec
Propagation delay	$100{,}000m/3*10^8$	

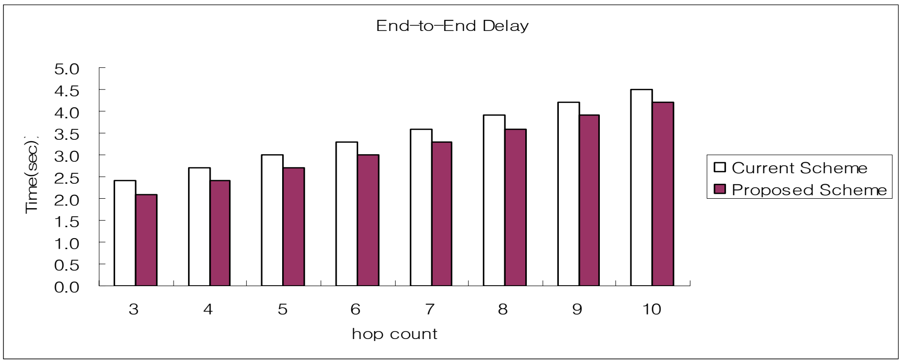

Fig. 8. End-to-End delay with increasing hop count

Table 2. Simulation parameters with increasing congestion in IPv4 network

Parameter	IPv6 network	IPv4 network
Hop count	3	3
Packet length	1000 bits	1000 bits
Service time(each router)	0.12 sec	Increase value
Packet arrived rate(each router)	0.5 packet/sec	Increase value
Transmission time(each router)	0.3 sec	Increase value
Propagation delay	$100{,}000m/3*10^8$	

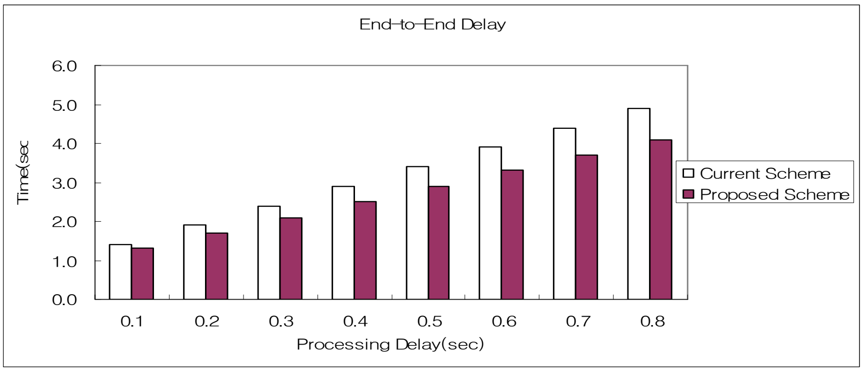

Fig. 9. End-to-End delay with increasing congestion in IPv4 network

Table 3. Simulation parameters with increasing congestion in Ipv6 network

Parameter	IPv6 network	IPv4 network
Hop count	3	3
Packet length	1000 bits	1000 bits
Service time(each router)	Increase value	0.12 sec
Packet arrived rate(each router)	Increase value	0.5 packet/sec
Transmission time(each router)	Increase value	0.3 sec
Propagation delay	$100{,}000m/3*10^8$	

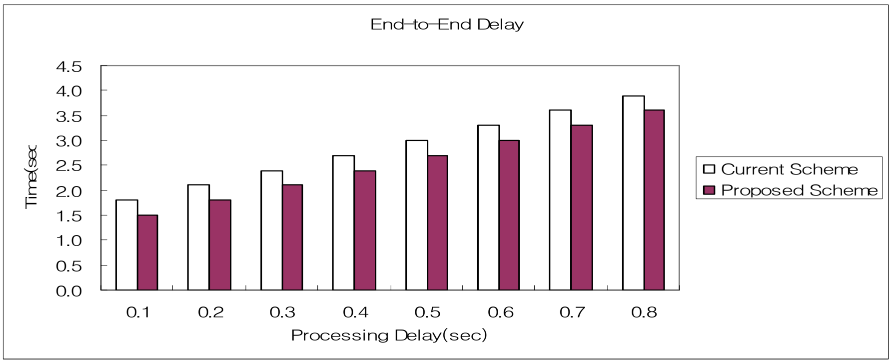

Fig. 10. End-to-End delay with increasing congestion in IPv6 network

In our first simulation as shown in Fig. 8, we assume that mobile node moves far from home agent. And other parameters have the same values. In second simulation in shown in Fig. 9, we assume that congestion increases in IPv4 network. And in final simulation as shown in Fig. 10, we assume that congestion increases in IPv6 network. According to simulation results, we could find that our proposed scheme with applying mobility conversion algorithm has less end-to-end delay than current scheme without applying mobility conversion algorithm. The reason is current NAT-PT only changes an IPv4 header to an IPv6 header without mobility header conversion. As a result, a mobile node can not send a binding update message to a correspondent node. Finally a correspondent node is unable to know the mobile node's a new care-of-address. In this case triangle routing problem can be created. But our proposed scheme changes IPv4 header to IPv6 header with mobility header conversion. So it removes triangle routing problem.

7 Conclusion

In this paper, we proposed a new scheme to resolve the triangle routing problem between Mobile IPv4 and Mobile IPv6. The proposed scheme also can be easily implemented and applied in current NAT-PT system. First, we proposed that translates a registration request message to a binding update message. Second, we proposed that translates a binding acknowledgment message to a registration reply message. Through our proposed scheme, a mobile node in an IPv4 network can notify transfer information to a correspondent node in IPv6 network. By measuring end-to-end delay of packets with and without applying mobility conversion algorithm in NAT-PT, we could find that proposed mobility conversion algorithm has less end-to-end delay than current NAT-PT scheme. In the future work, we will implement and verify the scheme that is proposed in this paper by making a test-bed.

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