Managing Private and Global IP Addresses in Mobile Networks

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Abstract

The Internet Protocol (IP) plays an important role of the mobile network. As the need of connecting to the Internet increases enormously, the address starvation problem for the IP version 4 (IPv4) is introduced. Many companies and institutes thus use private IP addresses to overcome the problem. However, the design of Mobile IP does not support private IP addresses. In order to deal with this problem, several approaches were proposed to support private IP addresses and NAT function in mobile IP. Nevertheless, the approaches may not have enough global IP addresses in home network and then lead to erroneous routing. In this paper, an approach to managing private and global IP addresses is described. When the home agent does not have any available global IP address for a mobile node, our approach will automatically obtain a global IP address from supported foreign agents.

1. Introduction

Currently wireless mobile networks toward the All-IP network architecture (i.e., fully IP protocols based networks) gradually [1–4]. The Internet Protocol (IP) thus plays an important role of mobile networks. The IP-based mobile network requires that every mobile node has its own IP address. However, the IP address space of IPv4 could be short in a few years. In order to struggle with this address starvation problem, the Internet Engineering Task Force (IETF) introduces the IP version 6 (IPv6) [5, 6]. The IPv6 offers many advantages over IPv4. The most obvious advantage is the increase in address size from 32 bits to 128 bits. However, the IPv6 is not totally supported recently due to the cost and efforts required to migrate from IPv4 to IPv6 [7]. Private IP addresses and the NAT function are usually adopted to solve the problem in normal IPv4. Instead of using global IP addresses, computers use private IP addresses in a closed network. When connecting to the global IP network, they utilizing global IP addresses assigned by the NAT function.

The IP starvation problem also appears in mobile IPv4. Some approaches using regional registration were proposed [8–10]. Mobile nodes within the home network and the foreign network can use their private IP addresses. Integration of DNS (Domain Name System) server and NAT function can manage global IP addresses for communication. Moreover, hierarchical structure of foreign agents could decrease latency of mobile nodes during handoff and also support AAA (Authentication, Authorization and Accounting) servers for security.

Nevertheless, the global IP address starvation problem still occurs in previous approaches. Our approach introduces a global IP address management scheme to solve the starvation problem. If global IP addresses of the home agent are not enough, the home agent could ask a gateway foreign agent to provide global IP addresses. The gateway foreign agent selects a foreign agent within the scope of itself. A foreign agent which has the highest percentage of available global IP addresses will be chosen. After obtaining the global IP addresses, mobile nodes can communicate with others or accept calls in the global IP network. Therefore, wireless mobile communication with correct routing can be assured.

2. Related Work

In order to enable mobile IP with private IP addresses, several approaches were proposed in recent years [8, 9]. They integrated mobile IP [11], the NAT function, and a DNS server to support mobile nodes with private IP addresses. When a mobile node moves form its home network to a foreign network, it still uses the same private IP address for communication. When

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a gateway foreign agent detects that a mobile node needs to communicate with others or accept calls, it will ask the HA to provide a global IP address from the global IP addresses pool of the HA for communication.

The approaches use private IP addresses and the NAT function support in mobile IPv4 to solve address starvation problem. The home network and the foreign network are all constructed by a closed network using private IP addresses. The home agents use the NAT function to assign global IP addresses to mobile nodes. The mobile nodes with private IP addresses than can communicate with others over the global IP network. However, there is an disadvantage that global IP addresses of the HA could be not enough when too many mobile nodes need to communicate with others. Our approach can deal with the problem using a global IP address management scheme. This is the most important functionality to mobile nodes in mobile IP networks.

3. Network System Overview

3.1. Requirements

The basic network system is based on the mobile IPv4 network with private IP addresses. Every mobile node has its own global IP address that is assigned by a home agent or a foreign agent. When a mobile node communicates with the correspondent node or accepts a call over the global IP network, it must use the global IP address for communication. Contrariously, it cannot communicate with others or accept a call using a private IP address because other nodes over the global IP network do not know where the private IP address locates.

Home agents and foreign agents support network address translator (NAT) [12] function to assign global IP addresses to mobile nodes that use private IP addresses for communication. When mobile nodes communicate with others, the NAT function will convert the private IP address to a global IP address.

The correspondent node cannot communicate with the mobile node that uses a private IP address. Therefore, it has to know Fully Qualified Domain Name (FQDN) of the mobile node. And then asks the DNS server within the home network for obtaining the global IP address of the mobile node.

The architecture of hierarchical foreign agents (i.e., Mobile IP Regional Registration [13]) is used with our mechanism. The gateway foreign agent controls several foreign agents and can request a foreign agent under itself to support the home agent for assigning a global IP address. An important advantage of this architecture is that handoff overhead for mobile nodes is reduced. The mobile nodes do not need to perform a home registration when changing foreign agents within the same gateway foreign agent. They simply perform a regional registration in the foreign network.

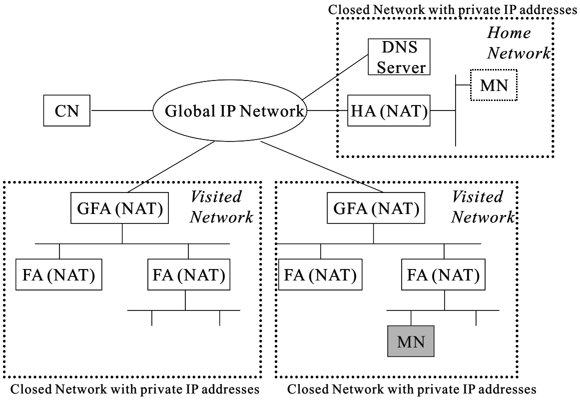

Figure 1. Network Architecture.

3.2. Network Architecture

As shown in Figure 1, the network architecture based on hierarchical mobile IPv4 consists of Home Agents (HA), Foreign Agents (FA) and Gateway Foreign Agents (GFA).

(1) Home networks and foreign networks are consisted of closed networks with private IP addresses. Every mobile node (MN) is assigned a private IP address by the HA and use this private IP address as its home address. The home address of MN is not changed when it moves from home network to a foreign network.

(2) HAs and FAs have their own the global IP addresses and provide the NAT function to manage assigning global IP addresses. The NAT function is usually used by companies and institutes. Most companies do not have enough global IP addresses. So they use the NAT function to support all PCs with private IP addresses in the closed network.

(3) The GFA that has its own global IP address and the NAT function works as gateway of several foreign networks. The MN uses FA's IP address as Local Care-Of Address (LCOA) registered at GFA and also uses GFA's IP address as Global Care-Of Address (GCOA) registered at the HA.

When mobile nodes need to communicate with others or accept calls, they use their private IP addresses assigned by HA for communication. It is not necessary for them to know their global IP addresses or the conversion between the private IP addresses and the global IP addresses.

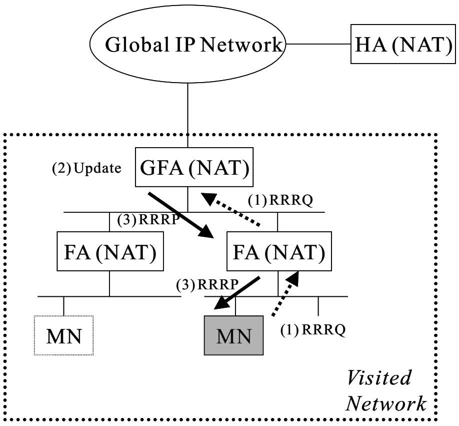

Figure 2. Regional Registration.

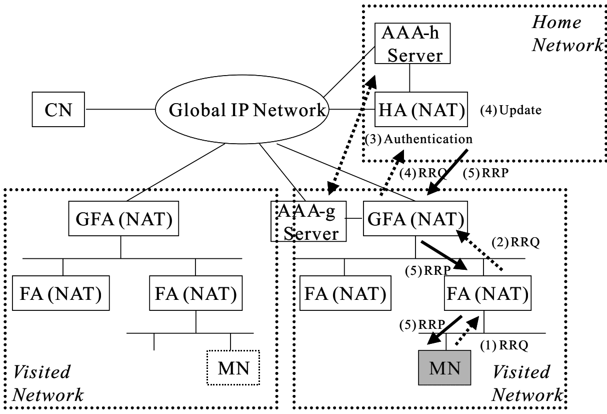

Figure 3. Home Registration.

4. Global IP Addresses Assignment Scheme

4.1. Registration

The process of registration for mobile nodes can be divided into two categories. The regional registration occurs when a mobile node moves from one foreign network to another foreign network within the same GFA. The home registration is activated when a mobile node moves to a foreign network belonging to a different GFA.

4.1.1 Regional registration

The detail of the regional registration is shown in Figure 2.

(1) When a mobile node moves from an old FA to a new FA within the same GFA, the MN will initiate a Regional Registration Request (RRRQ) message to the new FA. The new FA then relays this message to the GFA.

(2) After the GFA receives the message, it updates the mobility binding between MN's home address and its local care-of address. The new FA's IP address is set to the local care-of address of MN.

(3) The GFA replys a Regional Registration Reply (RRRP) message to the new FA, and the new FA relays the message to MN. With the mechanism, mobile nodes do not need to register to their home agent. So the performance for handoff can be improved.

4.1.2 Home registration

Figure 3 illustrates procedures for the home registration.

(1)When a mobile node moves from an old GFA to a new GFA, the MN will send a Registration Request (RRQ) message to its current FA. The MN uses the GFA's IP address as its global care-of address.

(2) The FA relays the RRQ message to its GFA. The FA also registers its IP address to its GFA using the local care-of address of MN.

(3) The GFA sends an Authentication Request message to the AAA server (AAA-g) for authentication of the MN. The AAA-g relays this message to the home AAA server (AAA-h). If the authentication succeeds, the AAA-h will send an Authentication Response message to the GFA via the AAA-g.

(4) After successful authentication, the GFA relays the message to the MN's HA in home network. If the HA receives a successful authentication, it will update the mobility binding between MN's home address and its global care-of address.

(5) The HA replys the Registration Reply (RRP) message to MN.

Global IP addresses do not participate in the process of registration (both regional registration and home registration). Therefore, the starvation problem for global IP addresses will not occur.

4.2. Mobile node communicates with correspondent node

A mobile node cannot directly uses its private IP address to communicate with others. The HA and FA with NAT function needs to support to assign a global IP address to the mobile node for delivering packets over the global IP network. The detail of the process is explained using Figure 4.

(1) A MN delivers data packets which destined to the correspondent node to FA first.

(2) The FA receives the packets sent by MN and tunnels them to the GFA.

(3) The GFA examines whether the MN's global IP address is assigned by HA or not. If the global IP address is not assigned by the HA, the GFA sends an Address Assign Request (AAQ) message to the HA.

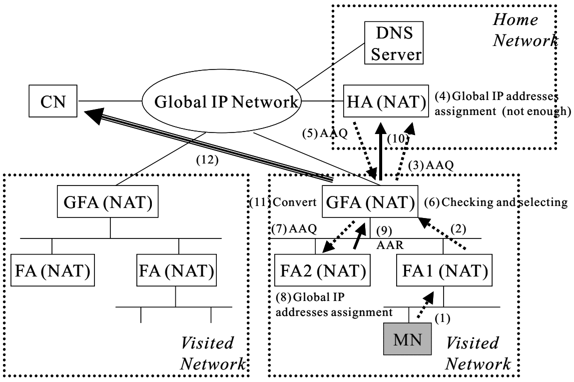

Figure 4. Mobile node communicates with correspondent node.

Table 1. Global IP addresses mapping table

FAID	Available global IP addresses	Total amount of global IP addresses	Percentage (%)
FA1	5	10	50%
FA2	4	5	80%

Otherwise, it uses this global IP address for communication.

(4) After the HA receives the message, it checks remaining available global IP address. If there exists an available global IP address for the MN, the HA will send an Address Assign Reply (AAR) message to the GFA. The GFA updates the mapping between the private IP address and the global IP address of the MN. The next step is (11).

(5) When the HA does not have enough global IP addresses, it will send an AAQ message to the GFA.

(6) The GFA checks its own usage of global IP addresses using a mapping table (see Table 1). The mapping table consists of four parts. The first part is the FAID that is a unique identification for a FA under its GFA. The second part represents available global IP addresses in all FAs. The third part is the total amount of global IP addresses in all FAs. The fourth part shows the percentage of available global IP addresses in all FAs. The GFA selects a global IP address from a FA that has the highest percentage of the available global IP addresses.

(7) After the GFA selects a FA using the selection policy, it relays the message to the FA chosen by the GFA.

(8) The FA with the NAT function assigns a global IP address to the MN. If it also does not have enough global IP addresses, the GFA will determine another FA to support assignment.

(9) After the FA assigns a global IP address to the MN, it sends an Address Assign Reply (AAR) message back to the GFA. The GFA then updates the mapping between the private IP address and the global IP address of the MN.

(10) The GFA relays the message to the HA. The HA also updates the mapping between the private IP address of the MN and the global IP address of the MN.

(11) After assigning the global IP address, the GFA converts the source address of the delivered packet sent by MN to the global IP address of MN.

(12) The GFA relays packets sent by the MN to CN using normal routing procedures.

4.3. Correspondent node communicates with mobile node

As shown in Figure 5, when a correspondent node communicates with a mobile node, it knows Fully Qualified Domain Name (FQDN) of the MN for communication. In order to obtain the IP address of the mobile node, the correspondent node asks for the related DNS server using the FQDN of MN. However, the private IP address of the mobile node cannot be used for accepting a call over the global IP network. Therefore, the DNS server should maintain a mapping between the private IP address and the FQDN of mobile node, and ask the HA to assign a global IP address to MN. The detailed procedures are described as follows.

(1) When a correspondent node needs to communicate with a mobile node, it asks the related DNS server for the global IP address of MN. The CN sends a DNS Query message to the DNS server.

(2) After the DNS server catches the message, it sends an Address Assign Request message to the HA with the NAT function if the MN does not have a global IP address. The AAQ message contains the private IP address of MN.

(3) The HA assigns a global IP address to the MN. If the HA has available global IP addresses, it will assign one to the MN and then sends an Address Assign Notification (AAN) message to the GFA. It updates the mapping between the private IP address of the MN and the global IP address of the MN. The next step goes to (10).

(4) If the HA does not have any available global IP address, it will send an AAQ message to the GFA.

(5) The GFA checks its global IP address mapping table (see Table 1) within itself.

(6) After the GFA selects a FA, it relays the message to the FA.

(7) The FA with the NAT function assigns a global IP address to MN. If it also does not have enough

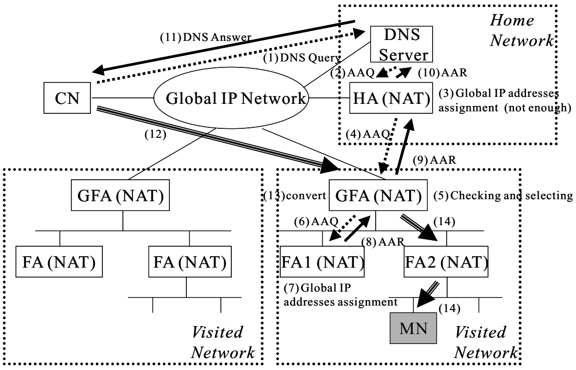

Figure 5. Correspondent node communicates with mobile node.

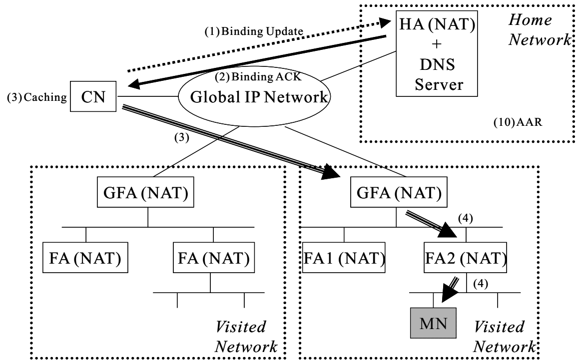

Figure 6. Supported route optimization.

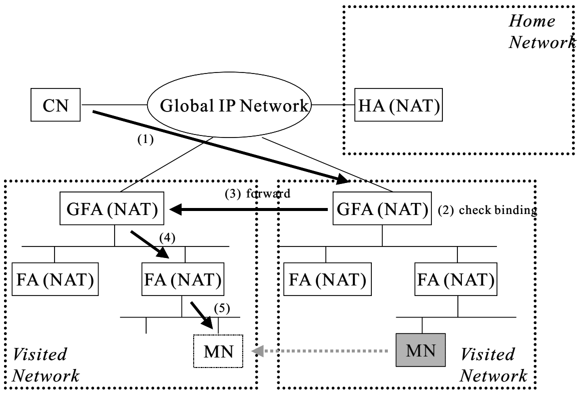

Figure 7. Handoff management.

global IP addresses, the GFA will determine another FA to support assignment.

(8) After the FA assigns a global IP address to the MN, it sends an AAR message back to the GFA. The GFA updates the mapping between the private IP address of MN and the global IP address of MN.

(9) The GFA relays the message to the HA. The HA then updates the mapping between the private IP address of the MN and the global IP address of the MN.

(10) The HA sends an AAR message to the DNS server.

(11) The DNS server sends a DNS Answer message to the CN. The CN knows thus the global IP address of the MN and is able to communicate with the MN at this time.

(12) The CN starts to deliver data packets to the MN. Since the global IP address is assigned by the FA, the packets will be delivered to the GFA. If the global IP address of MN assigned by HA, this packet will be delivered to the HA.

(13) When the GFA receives the packets, it will convert the destination address of the delivered packet sent by CN to the corresponding private IP address of MN. As result of the GFA also have the mapping between the global IP address of MN and the private IP address of MN that is updated by the AAR message.

(14) The GFA relays the packets to the MN.

As illustrated in Figure 6, if the route optimization [14] is supported by the HA and the CN, the CN can deliver packets to the MN directly via the GFA and the FA. The detailed procedures describe as follows.

(1) If the route optimization is supported by the HA and the CN, the HA will initiate a Binding Update message. The global IP address is certainly assigned to the MN by the HA or the FA.

(2) When the CN gets this message, it updates its binding and replies a Binding Acknowledgment message.

(3) The CN is able to cache the binding of the MN and tunnel packets to the GFA directly bypassing the HA of the MN.

(4) When the GFA receives the these packets, it relays the packets to the FA that the MN located. The FA then relays the packets to the MN.

4.4. Handoff management

In order to continue communication between the CN and the MN when the MN moves to adjacent GFA area, our scheme is based on mobile IP smooth handoff. As shown in Figure 7, the previous GFA will maintain a binding for its former visited mobile nodes. The binding contains the current global care-of Address of the former visited mobile node. When the packets are sent to the previous GFA, it can forward the packets to the current GCOA of the MN. Consequently, the MN is able to accept packets contiguously when MN moves off the original GFA.

(1) The CN delivers packets to the previous GCOA of the MN.

(2) The corresponding previous GFA checks the binding about the current GCOA of the MN.

(3) The corresponding previous GFA can forward

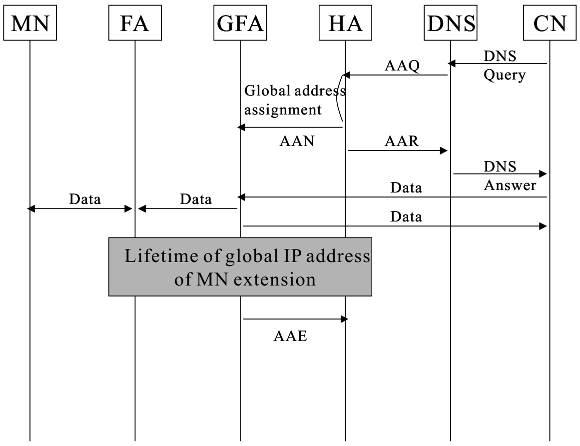

Figure 8. Management of global IP address (assigned by HA) lifetime.

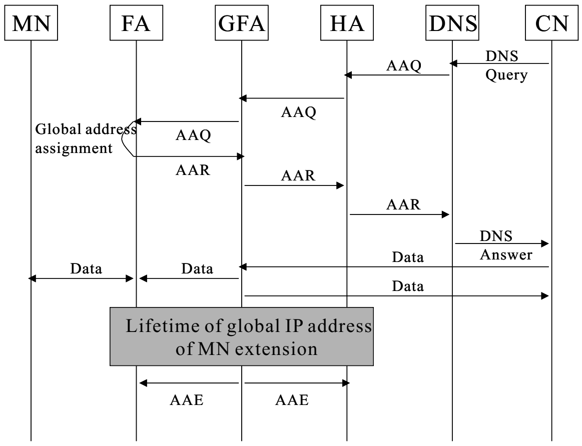

Figure 9. Management of global IP address (assigned by FA) lifetime.

the packets to the corresponding current GFA.

(4) The current GFA relays the packets to the FA which the MN located.

(5) The FA relays the packets to the MN.

4.5. Management of life time

There are four kinds of lifetime in our approach: the lifetime of the mobile node registration with HA (home registration lifetime), the lifetime of the mobile node registration with GFA (regional registration lifetime), the lifetime of the global IP address assignment, and the lifetime of DNS cache for the MN's FQDN and its global IP address.

The lifetime of the mobile node registration with the HA is maintained by MN, FA, GFA and HA. The lifetime of the mobile node registration with the GFA is maintained by MN, FA, and GFA. They are controlled by hierarchical mobile IP normal operations. When the value of the lifetime expires presently, the MN will update its registration with its HA or GFA. In the case of the lifetime of DNS cache for MN's FQDN and its global IP address, it is decided that its value equals to the value of the global IP address assignment managed by HA. The lifetime of the global IP address assignment, is maintained by HA and GFA. When the MN communicates with others or accepts calls, a global IP address will be assigned by HA or FA. The lifetime of the global IP address assignment is managed independently with the lifetime of the MN registration. However, when the lifetime of MN registration with HA (home registration lifetime) expires, the GFA will clear the value of the lifetime of global IP address.

The management of the lifetime of the global IP address assignment can be divided into two parts, as shown in Figure 8. One is the lifetime of the global IP address assigned by the HA. When the HA with the NAT function assigns a global IP address, it notifies the GFA of the address and its lifetime by an Address Assign Notification (AAN) message. The value of the lifetime will be extended by GFA when the MN starts communication. The GFA will notify the HA the latest lifetime by an Address Assign Extension (AAE) message. In Figure 9, another is the lifetime of the global IP address assigned by the FA. When a FA chosen by a GFA assigns a global IP address, it notifies the GFA of the address and its lifetime by an Address Assign Reply message. The GFA then relays this message to the HA. The same as above, the value of the lifetime will be extended by GFA when the MN starts communication. The GFA will notify the HA and FA the latest lifetime by an Address Assign Extension (AAE) message.

5 Summary and future work

In this paper, a mechanism was developed to support private IP addresses in mobile IP. With the mechanism, mobile nodes can obtain global IP addresses from its HA or FAs for mobile communication. The foreign agent selected by a gateway foreign agent can also provide global IP addresses if the home agent does not have available global IP addresses.

The future work is to implement the prototype of home agents, foreign agents and gateway foreign agents in the hierarchical mobile IP. More detailed measurements and evaluation will be included.

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