Dynamic Home Agent Reassignment in Mobile IP

Yu Chen
yrchen@agere.com
Agere Systems
1247 South Cedar Crest Blvd.
Allentown, PA, 18103

Terrance Boult
tboult@eecs.lehigh.edu
Lehigh University
19 Memorial Drive West
Bethlehem, PA. 18015

***Abstract*- Under conventional Mobile IP, all traffic to a MN is tunneled to the current Foreign Agent (FA) from the remote HA, which can result in poor efficiency. Dynamic Home Agent (HA) reassignment model is proposed in this paper to reduce both the signaling traffic and the data traffic to the home network. Simultaneous bindings with two or more HAs are supported in our model to provide seamless HA handover. Furthermore, the whole dynamic Home Agent/home address reassignment procedure is completed in a single registration signaling cycle. Hence it minimizes the delay of the (regional) Foreign Agent (FA) handoff. Finally, the Network Access Identifier (NAI) or Full Qualified Domain Name (FQDN) is used instead of the home address to uniquely identify a MN since the home address is no longer permanent.**

***Keywords*- Mobility Agent (MA); Home Agent (HA) handover; Authentication, Authorization, Accounting (AAA) server; Network Access Identifier (NAI); Full Qualified Domain Name (FQDN); Care-Of Address (COA)**

I. INTRODUCTION

Mobile IP (RFC2002 [1]) requires that a Mobile Node (MN) have a static Home Agent (HA) and a permanent home IP address, which is not always desirable for MNs, especially MNs in a commercial ISP domain. Most ISPs provide users automatically allocated temporary IP address via DHCP or PPP/SLIP. Furthermore, for some big network domains such as national wireless network service providers, the MN's current network attach point could be far away from the static HA and hence could cause severe triangle routing problems. Finally, when a MN keeps migrating to a nearby Foreign Agent (FA) if the MN is fast moving, which is typical for wireless network subscribers, the signaling with the remote HA will cause an unacceptable long delay.

Route optimization [8] alleviates the triangle routing problem. However, it still requires substantial remote HA signaling and does not help much when the MN is fast moving. Moreover, it poses high requirement on the Correspondent Node (CN) such as the ability of processing binding update messages and data encapsulation.

With a new HA, as those FAs are within this HA's local network, the handoff process must be expedited. Another advantage is that new data connections could be started directly at the new home address via the new HA. Therefore, most data traffic goes to the new HA directly while a small part is forwarded to the new HA by the old HA. Furthermore, the MN need not send any registration request to its old HA when it is roaming within the new HA later. Our model will automatically route the datagrams destined to the old home address to the current location of the MN.

Mobile IPv6 [3] enables any IPv6 host to learn and cache the care-of address associated with a MN's home address, and then to send datagrams destined to the MN directly to it at the care-of address using an IPv6 routing header. However, such routing efficiency could not be achieved until universal Mobile IPv6 deployment. It is most likely that in the mid-term future only the more-or-less standalone 3G network will be implemented as the first mobile IPv6 inter-network while most networks will be mainly based on IPv4. Therefore, the model presented in this paper focuses on mobile IPv4. However, with certain modifications, it could be adapted to Mobile IPv6.

We assume in this paper that only in the same administrative domain is the MN able to request dynamic HA reassignment. However, if the two different administrative domains could agree on Authentication, Authorization, Accounting (AAA) transactions, the dynamic HA/home address assignment may be extended to a foreign domain.

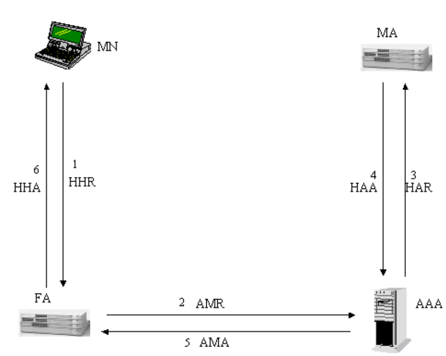
II. DYNAMIC HOME AGENT REASSIGNMENT

A. Agent Advertisement

A FA in the domain which supports dynamic HA reassignment must include the 'D' flag in its agent advertisement message. The 'D' bit occupies the first reserved bit after the other flag bits specified in RFC2002. The FA must also include its Network Access Identifier (NAI) in the agent advertisement message. By comparing the domain part of the FA NAI with the domain part of its own NAI, the MN can determine whether it is in its home domain (the same administrative domain).

B. Signaling

Figure 1: HA reassignment signaling procedure



The dynamic HA/home address reassignment signaling procedure is summarized as follows: when the MN arrives on the foreign network, it sends a dynamic HA handover request (HHR) message to the advertising FA. As the FA receives such a request message, it constructs an AA-Mobile-Node-request (AMR) message, which is defined in [6], sends to the closest AAA server. The AAA server authenticates the MN and assigns the MN a Mobility Agent (MA), which will be described in detail in later section. It then sends a Home-Agent-MIP-Request (HAR) message

[6] to the assigned MA. The MA will then assign a new home address to the MN and return it in a Home-Agent-MIP-Answer (HAA) message to the AAA server. The MN will receive a dynamic HA handover answer (HHA) message from the FA after the FA receives an AA-Mobile-Node-Answer (AMA) message from the AAA server.

Figure 1 gives an illustration of the entire HA reassignment signaling procedure. Note a successful dynamic HA/home address reassignment procedure should present the following complete signaling cycle:

HHR---AMR---HAR---HAA---AMA---HHA

The HHR message is defined as the Registration Request message in RFC2002, but with the following changes:

Type 4 (Dynamic HA handover request)

Home address the current home address if the MN request simultaneous HA bindings, null address (0.0.0.0) otherwise.

HA address null address (0.0.0.0)

COA Care-Of Address of the advertising FA

Extensions MN NAI Extension, which is defined in GNAIE draft [4]

The MN must include its NAI or Full Qualified Domain Name (FQDN) in the extension for authentication purpose. Since the home address is no longer permanent in our model, the NAI (FQDN) is the unique ID to identify the MN. The MN must set the 'S' bit in its HHR message if it requires simultaneous HA bindings.

Upon receiving the AMA message, the FA must create an entry in its visitors-list for the new assigned home address. If simultaneous HA bindings are requested, it should create an entry for the old home address too.

The HHA message is defined as the Registration Reply message in RFC2002, but with the following changes:

Type 5 (Dynamic HA handover answer)

Home address the new home address

HA address the new HA address

C. *Key Distribution*

The MN and the relative mobility agents use registration keys to compute authentication extensions. The AAA server must create them and distribute them to the corresponding entities after the MN is successfully authenticated and authorized. Once the registration keys have been distributed, subsequent MIP registrations need not invoke the AAA infrastructure until the keys expire.

The detail of key distribution procedure could be found in [6].

III. Seamless Home Agent Handover

Under most situations, MN requests continuous mobility support. Hence, our model proposes seamless HA handover to support simultaneous HA bindings.

A. *Registration with the old HA*

According to RFC2002, the MN must send a registration request message to the old HA to start the FA-handoff procedure. It is also required that the MN to perform a registration with the old HA if simultaneous HA bindings are requested. Hence, our model employs a single registration for both FA-handoff and HA-handover. The registration complies with the RFC2002, but it is sent to the MA or the old HA directly instead of the advertising FA.

The home address, HA and COA fields in the registration request message are specified as follows:

Home address the old home address

HA address the old HA address

COA the new home address

Since the COA of the old home address is set to the new home address, after the home registration with the old HA, all the datagrams destined to the old home address will be redirected to the new home address of the MN by the old HA. The MA will then collect these datagrams and forward them to the current location of the MN. Therefore, such registration completes both the FA-handoff for the old home address of the MN and the seamless HA handover.

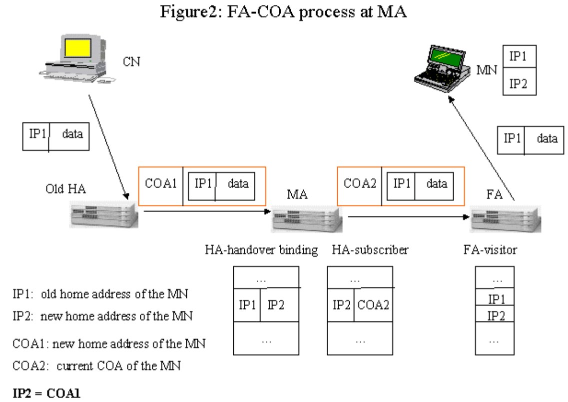
B. *Mobility Agent (MA)*

A MA is a special HA which does some extra work as a FA. But it must not function as a normal FA concurrently. More specifically, the MA should accept the home registration request with the old HA of the MN and relay it to the old HA like a normal FA does. However, the MA does not broadcast normal FA advertisement message and does not provide any COA addresses to the MNs. Furthermore, the MA does not maintain a FA-visitor list.

The MA should maintain two user lists, one is for normal HA function, another is for seamless HA handover purpose. We refer them as HA-subscriber list and HA-handover binding list correspondingly. If the MN requests simultaneous HA bindings, the MA must create a new entry in its HA-Handover binding list after it receives a HAR message with the following format:

<MN_OLD_HOME_ADDR, MN_NEW_HOME_ADDR>

Figure2: FA-COA process at MA



The MA could receive two kinds of the datagrams both destined to the new home address of the MN, one is encapsulated and received from some CNs via the old HA of the MN, the other is not encapsulated and received from most CNs directly. The MA must process them separately. First, the MA must check the outer protocol field of each IP datagram that it intercepts. If a value of 4 is set to indicate the presence of the encapsulated IP datagram, the MA must search its HA-handover binding list and compare with the destination address. If it finds a match with the entry of MN_NEW_HOME_ADDR, it determines that it has received an encapsulated datagram whose inner destination address is the old home address. Then the MA should decapsulate the datagram and tunnel it to the MN's current location by re-encapsulating the datagarm with the current COA of the MN. The MA should find the current COA of the MN under the entry of new home address in its HA-subscriber list. Figure 2 illustrates the procedure.

On the other hand, if the MA receives an un-encapsulated datagram destined to the new home address, it functions as the normal HA of the MN.

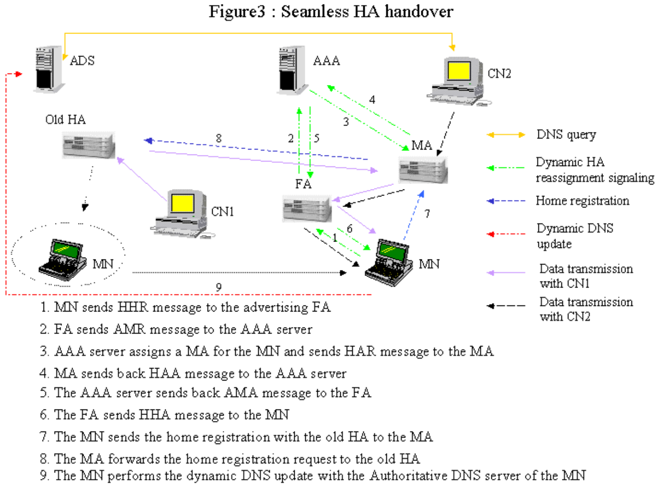
Note the MA needs to maintain two security associations simultaneously: one is the MN-MA security association employing the Mobile-Home registration key, another is the MA-OHA (Old HA of the MN) security association employing the Foreign-Home registration key. For the latter security association, the MA acts as a special FA role for the old HA of the MN.

C. Dynamic DNS Update

The MN should perform a secure dynamic DNS update [5] with its Authoritative Domain Name Server (ADS) to update its name bindings after it gets a new home address.

Dynamic DNS update makes it possible to take advantage of local HA/home address. Most CNs (e.g. CN2 in Figure 3) can open new data connections with the new home address via the new HA.

Figure3 : Seamless HA handover



As illustrated in Figure 3, the MN is able to continue the communication with CN1 at the old home address and to start a new communication session with the CN2 directly at the new home address simultaneously after the seamless HA handover.

Although dynamic DNS update is efficient and simple to track the location of MNs, it has the following two limitations:

1) Stale cache problem. Since caching schemes are widely used in DNS systems, it is possible that Some CNs may use the old home address of the MN before the corresponding DNS cache expires. A direct solution is to employ 0 TTL to prevent any name caches. [11] argues that it does not cause a significant scaling problem since the following name queries can benefit from the cached "NS-Record" (name server record) and starts directly from the authoritative name server of the MN's administrative domain. However, even 0 TTL could not prevent a possible race condition that the MN performs a DNS update just after the CN makes a DNS query. Under this situation, the CN gets a stale location of the MN and the connection attempt will fail. Simultaneous HA bindings are supported in our model to solve the problem. As long as the old home address is bound with the old HA, the datagrams destined to the old home address will be routed automatically to the current location of the MN. Therefore, we can set the DNS record's TTL less than the valid period of the old home address to avoid any stale cache problems. On the other hand, if the old HA/home address becomes invalid immediately after the dynamic HA handover, seamless HA handover could not be achieved.

2) Weak support for fast roaming MNs. Due to the limitation of DNS update speed and the importance of DNS in Internet applications, the DNS updates should not be performed too frequently. Fortunately, our model does not have strict requirement on the speed of DNS updates based on two reasons. First, the HA handover would not be performed frequently. Once the new HA is assigned, later roaming will employ FA-handoff instead of HA-handover until the MN is far away from the new HA again. Hence, the frequency of the dynamic DNS update will be fairly low. Second, simultaneous HA bindings provide fail-safe support for the old home address during the DNS update period.

D. Dynamically Allocated Address

The MN could get a temporary IP address via DHCP or PPP/SLIP independently before the HA reassignment procedure. If the MN uses the dynamically allocated address as its new home address, it must set the home address filed in the HHR message to the dynamically allocated address. When the FA sends the AMR message to the AAA server, the Mobile-Node-Home-Address-Requested flag in the MIP-Feature-Vector AVP [6] must be set to zero to indicate that no further home address need to be assigned to the MN. Note if the home address is DHCP-allocated, the MN has the choice to delegate the responsibility for performing the DNS update to the DHCP server by setting the 'S' bit (the rightmost bit) in the Flags field in the option of its DHCPREQUEST message [7].

E. Home Address

The home address specified in this paper is not a common sense home address. It is only significant during a specific period --- as long as the HA remains same. Whenever the MN changes the HA, its home address is changed too. Hence, the ISP (administrative domain) should assign each MN a unique NAI (FQDN) instead of a permanent home IP address. The MN's home address (including the original one) is only meaningful with its corresponding HA and by no means permanent. A MN could have multiple home addresses bound with multiple HAs. The home address could be reassigned to other MNs if the MN no longer uses it and deregisters with it. However, to support seamless HA handover, it should not be recollected until its DNS cache expires.

A local home address can have another advantage over a permanent home address. When a local network employs ingress filters [9] to defeat Denial of Service attacks, a MN may not send out datagrams whose source address is the permanent home address since the router refuses to forward any packets with a source address foreign to the local network. Although reverse tunneling [10] could solve the problem, a local home address is certainly a more efficient and simpler solution.

It is the responsibility of the MN to decide whether renews an expiring home address or not. If there is any open data connections associated with the old home address, the MN could extend the home address lease or simply terminates the connection. Such decision may depend on the expense and other factors.

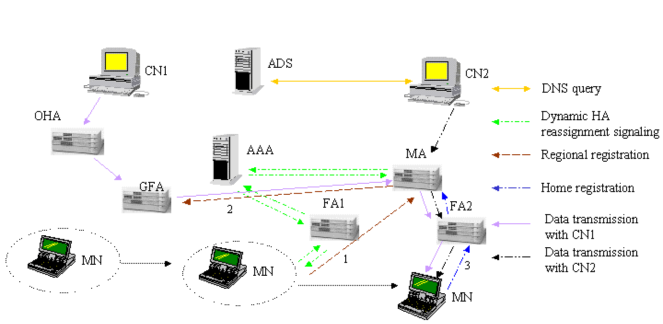
F. Regional Registration

If the regional registration is supported in the visited network, the home registration with the old HA is similar with the home registration described in [2].

We assume the MN has registered the GFA address as the COA of the MN with the old HA. Then the MN could perform the regional registration with the GFA instead of the home registration with the old HA. The MN must set the new home address as the COA address and send the registration request to the GFA directly. The GFA address should be learned from the FA advertisement message and specified in the GFA IP address field. The remaining procedure complies with the specification of [2]. If the MN later roams again, the MN need not perform the regional handoff again with the GFA. Instead, it only needs to update its location with the MA. The regional handoff is only performed once as a part of seamless HA handover like the home registration with the old HA. Note the regional registration is performed for the old home address of the MN only. Figure 4 gives an example of regional registration.

The MN can always start the regional FA-handoff registration procedure independently to get even faster (regional) FA-handoff. That is, before it learns about its MA and new home address, the MN could start a separate temporary regional FA-handoff to obtain fast handoff and resume any open data connection immediately. Later the MN completes the seamless HA handover in a separate registration request after it receives the HHA message. Note this registration request should update any existing bindings of the MN in the GFA and invalidate the previous temporary regional handoff.

Figure 4: Further migration of the MN after dynamic HA handover



1. MN sends regional registration request to the MA

2. MA relays the registration request to the GFA

3. MN migrates again and registers the new COA with the MA for the new home address and all the previous home addresses by specifying the Previous Home Address Extension in the registration request.

G. Further Migration Within The New Home Agent

As illustrated in Figure 4, if the MN roams again but does not change the HA, it should send registration request to the MA including its new COA. Furthermore, if the MN intends to maintain the open data connection for any previous home addresses, it must include Previous Home Address extensions for these previous home addresses in the registration request. When the MA receives the registration request, it should verify these previous home addresses in its HA handover binding list, respond with the registration reply. The registration reply must include all the verified previous home addresses in the Previous Home Address Extensions. When the new FA receives the registration reply, it must create the entries for the new home address and all the previous home addressess of the MN specified in the Previous Home Address Extensions.

The Previous Home Address Extension is defined as follows:

Type 27 (Previous Home Address (TBD))

Length 4

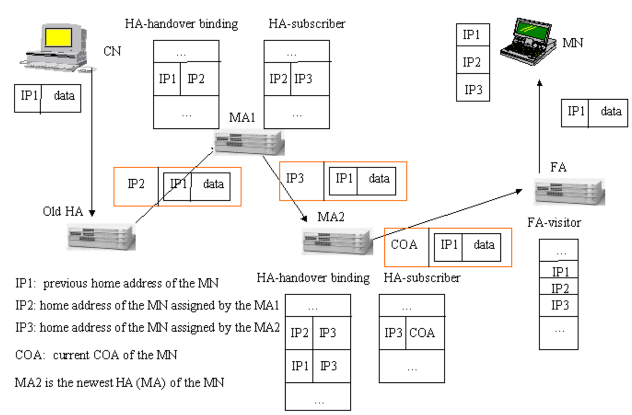
Previous Home Address the IP Address of the previous home address

H. Multiple Home Agent Reassignments

If the MN requests further dynamic HA/home address reassignment in later migration, the MN may have more than two HAs. By specifying the previous home address in the Previous Home Address Extension in the HHR message, the MN requests the FA to create additional entries for the MN in its visitor list for any previous home addresses of the MN. Note there could be multiple Previous Home Address Extensions in the HHR message. Figure 5 gives an example of multiple HAs (MAs).

Frequent HA/home address reassignments will cause multiple bindings and relatively complicated situations as shown in Figure 5. It is recommended that the previous HA bindings be invalidated before the MN changes its HA again. The multiple HA bindings support in our model is only provided to make the model complete.

Figure5: Multiple HAs (MAs)



IV. Conclusion

The decrease of the signaling traffic to the old home network is obtained by slightly increasing the signaling traffic to the new home network. Since reasonably the new home network signaling is faster, such tradeoff is desirable. At the mean time, data traffic from the old HA is greatly reduced too.

Our model employs dynamic DNS update to reflect home address changes. Clearly, other schemes like binding cache [8] could be used as alternatives. However, we argue that dynamic DNS update is fast enough due to the relatively low frequency of updates. Furthermore, it is more convenient and easier to implement since it does not have any additional requirements on CNs.

Seamless HA handover is proposed in our model to support simultaneous HA/home address bindings. It also solves the problem of possible stale naming caches.

The dynamic HA reassignment model presents an important point: a MN should get an IP when necessary. The home address is no longer static, but dynamically assigned to the MNs. Instead, the MN uses the NAI (FQDN) as its unique ID. Therefore the function of the IP is relieved to routing only.

The implementation of our model would be based on existing DIAMETER mobile IP extension [6]. Thus only MA and MN need be implemented from scratch. The FA needs slight modification to support dynamic HA handover signaling while the old HA and CNs are not affected at all. Although there is an implementation underway in VAST lab of Lehigh University, currently this paper remains a theoretical proposal. However, we believe the gains of dynamic HA reassignment is clear enough.

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