An IP-level Mobility Management Framework Based on Quasi-Registration in Wireless Technologies Convergence

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Abstract—**Mobility support in the Internet access has become a significant issue as wireless/mobile communications and networking are becoming widespread. More recently, there are efforts to equip a mobile node with multiple wireless/mobile communications interfaces, which is so-called *wireless technologies convergence*. Under this circumstance, mobility management of the mobile node that can select the appropriate interface depending on situations is of crucial importance. We propose a framework for mobility management consisting of Mobile IP with Route Optimization, Regional Registration, and Smooth Handoff. Considering the mobility pattern in wireless technologies convergence, we propose a *quasi-registration* concept that alleviate the disruption in the handoff signaling. Also, we illustrate the signaling message flows in this framework and analyze the delay/disruption in registration and handoff.**

I. Introduction

Recently, mobility support in the Internet access has gaining a significant interest as wireless/mobile communications and networking is becoming proliferated, especially boosted by the widespread use of laptops and handheld devices. An important trend to date is that there are ongoing works and trials on a mobile device with multiple wireless communications interfaces. The rational behind these efforts [1], [2], [3] is that, though there are diverse wireless/mobile communications technologies with their own characteristics (e.g., bandwidth, coverage), no single wireless/mobile communications standard is likely to be the norm in providing access to the Internet. Rather, these technologies have more or less complementary features. For example, the advantage of the cellular technology is the global coverage, while its weakness lies in the bandwidth capacity (currently tens of Kbps to the data traffic) and the operational cost. In contrast to this, IEEE 802.11 wireless LAN technology has the bandwidth capacity of Mbps order with little operational cost, but relatively short range of coverage.

With this perception, there have been approaches to equip a mobile node with multiple wireless communications interfaces. The most promising scenario so far is to equip the mobile node with a cellular network interface (e.g., GPRS, CDMA) and a wireless LAN interface (e.g., IEEE 802.11, HIPERLAN). With this configuration, the mobile node can connect to the Internet through the cellular network interface outdoors and also through the 802.11 interface indoors if there is an available 802.11 wireless LAN access point. In this era of *wireless technologies convergence*, we should note that diverse wireless coverage of technologies (e.g., cellular, wireless LAN, Bluetooth) are overlapping among each other and there would be frequent vertical handoffs between different kinds of wireless networks [12], [15].

To support seamless mobility to a mobile node with ongoing Internet connections, the most critical issue is handoff. There are mainly three kinds of handoff depending on situations: link-level handoff, intra-domain (subnet-level) handoff, inter-domain handoff. Here intra-domain handoff and inter-domain handoff are also called as micro-level mobility and macro-level mobility, respectively. The mobility management framework should deal with handoff in all of these cases, seeking to minimize disruption in handoff. Especially, the inter-domain handoff is likely to occur frequently in wireless technology convergence and it will accompany considerable signaling traffic load and delay with the current solutions to be detailed later on.

While there is a consensus that Mobile IP [4] will be used to provide *macro*-level mobility management in the wireless/mobile Internet access, there have been a number of proposal for the *micro*-level mobility issue. Here, micro-mobility is the case in which the mobile node (MN) is moving and thereby changing the point of attachment between subnets in the same wireless network (the same administrative domain). At large, the related work on the IP-level mobility management can be classified into three categories.

The works in the first category are focused on the micro-level mobility (shortly, micro-mobility) mostly in the cellular network domain. As it takes considerable time to exchange the registration message between the foreign agent (FA) and the home agent (HA), most proposals in the first category have considered a special agent node in each administrative domain, which accommodates the local handoff within the administrative domain without contacting the HA of the MN.

The works in the second category mainly seeks to reduce disruption and packet loss in handoff . The most proposed schemes suggest a cooperating scenario between the old FA and the new FA. For example, in [9], the current (old) FA is notified of a handoff of the MN through L2 layer event. Then a tunnel between the old FA and the new FA is established for data delivery to the MN during L2 handoff and L3 registration. In [5], the Binding Update message is proposed to exchange between the old FA and the new FA to notify and acknowledge the handoff.

The third category is concerned with the authentication, authorization, accounting (AAA) issue in regard to mobility in the Internet service. Currently AAA servers such as RADIUS and DIAMETER are in use within the Internet today to provide authentication services for dial-up computers. Mobile IP requires strong authentication services between the MN and its HA. Once the MN shares a security association (SA) with its home AAA server, it is also possible to use that SA to create derivative SA between the MN and its HA, and again between the MN and the FA currently offering connectivity to the MN. The establishment of this SA lengthens the registration time in Mobile IP because there has to be made security association among every entities involved in the registration in Mobile IP.

The AAA issue is especially important in *wireless technologies convergence* because different wireless networks (e.g., cellular networks and 802.11 networks) are likely be managed by different administrative domains. Accordingly, the handoff between different networks will requires the establishment of the SA among Mobile IP entities (MN, FA, and HA) by means of the AAA servers. Moreover, inter-domain handoff is likely to have larger delay since the MN should establish a new SA in the new foreign network by contacting its home network. To reduce this delay we propose a “quasi-registration” concept. With this quasi-registration, when a MN sends the Registration message to the HA of the MN, the AAAF (AAA server in the foreign network that the MN is visiting) attaches the adjacent AAAF server to which the MN might handoff.

In this paper, we seek to solve the IP-level mobility problem by proposing an overall framework. In designing the framework, we take into account all the above three categories in the context of wireless technology convergence. We adopt Mobile IP for macro-level mobility management. As for micro-mobility (the 1st category), we adopt *regional registration* [7]. Among the approaches to make FAs cooperate (the 2nd category), we consider *smooth handoff* proposed in Route Optimization in Mobile IP [5]. In the 3rd category, there are intensive works to combine Mobile IP messages and AAA protocol messages [13], [14], which are also employed in the framework.

The rest of this paper is organized as follows. The selected proposals consisting of the framework are briefly described in Section II. The quasi-registration for inter-domain handoff is proposed in Section III. The overall framework and how mobility is managed in the framework is illustrated in Section IV. The delay/disruption is analyzed in Section V. The concluding remarks are given in Section VI.

II. Selected Proposals

In this work, we basically employ the base Mobile IP [4] and Route Optimization [5], which alleviates the triangle-route problem in the base Mobile IP. Also we adopt *regional registration* [7] for *micro-mobility* between subnets within the same administrative domain and also leverage *smooth handoff* [6] to reduce packet loss and disruption. Let me overview these proposals respectively.

A. Regional Registration

Using Mobile IP, a MN registers with its HA each time it changes care-of address. If the distance between the visited network and the home network of the MN is large, the signaling delay for these registrations may be long. The authors propose a solution for performing registrations locally in the visited domain: *regional registration*.

When a MN first arrives at a visited domain, it performs a registration with its HA. At this registration, we assume that the home network generates a registration key (e.g., [5]) for the MN. This registration key is distributed to the MN and to the visited domain, and can be used for authentication of regional registrations.

If the visited domain supports regional tunnel management, the care-of-address that is registered at HA is the publicly routable address of a *gateway foreign agent* (GFA). This care-of-address will not change when the MN changes FA under the same GFA. When changing GFA, a MN must perform a home registration. On the other hand, when changing FA under the same GFA, the MN performs a regional registration within the visited domain. The authors introduce two new message types for regional registrations: *Regional Registration Request* and *Regional Registration Reply*.

B. Smooth Handoff (Route Optimization)

When a mobile node moves and registers with a new foreign agent, the base Mobile IP protocol does not notify the mobile node's previous foreign agent. IP datagrams intercepted by the home agent after the new registration are tunneled to the mobile node's new care-of address, but datagrams in flight that had already been intercepted by the home agent and tunneled to the old care-of address when the mobile node moved are likely to be lost and are assumed to be retransmitted by higher-level protocols if needed. (even though there is a work on buffering datagrams [6] in FA, we believe that will not be widely deployed.) The old foreign agent eventually deletes its visitor list entry for the mobile node after the expiration of the registration lifetime.

Route Optimization provides a means for the mobile node's previous foreign agent to be reliably notified of the mobile node's new mobility binding, allowing datagrams in flight to the mobile node's previous foreign agent to be forwarded to its new care-of address. This notification also allows any datagrams tunneled to the mobile node's previous foreign agent, from correspondent nodes with out-of-date binding cache entries for the mobile node, to be forwarded to its new care-of address. Finally, this notification allows any resources consumed by the mobile node at the previous foreign agent (such as radio channel reservations) to be released immediately, rather than waiting for its registration lifetime to expire.

As part of the registration procedure, the mobile node may request that its new foreign agent attempt to notify its previous foreign agent on its behalf, by including a Previous Foreign Agent Notification extension in its Registration Request message sent to the new foreign agent. The new foreign agent then builds a Binding Update message and transmits it to the mobile node's previous foreign agent as part of registration, requesting an acknowledgment from the previous foreign agent. This notification will typically include the mobile node's new care-of address, allowing the previous foreign agent to create a binding cache entry for the mobile node to serve as a forwarding pointer to its new location. Any tunneled datagrams for the mobile node that arrive at its previous foreign agent after the forwarding pointer has been created can then be re-tunneled to the mobile node's new care-of address.

III. QUASI-REGISTRATION

In the previous section, we have discussed the Mobile IP and related proposals consisting of the mobility management framework. The problem in wireless technology convergence is that there will be frequent inter-domain handoffs, where the message flow for the registration takes considerable time with the current proposals since it should exchange messages with the HA and also establish a SA by contacting relevant AAA servers. The rationale behind the quasi-registration is that we can maintain a status of quasi-registration of a MN in AAA servers in neighboring foreign networks when the MN registers in a given foreign network.

For seamless mobility, we believe it inevitable to make a *quasi-registration* of the MN. We propose that the mobility management framework should arrange the "quasi-registration" in the neighbor AAA servers, so that the neighbor foreign network can accommodate the MN if it handoffs to this foreign network. We will illustrate the signaling message flow in the mobility management framework with quasi-registration later.

Another possible realization of quasi-registration is that maintaining the quasi-registration status of a MN in adjacent FAs. However, in wireless technologies convergence, the number of the adjacent FAs of a given FA is likely to be very high and may result in overwhelming signaling traffic between FAs. In contrast, the number of AAA servers of a given AAA server is unlikely to be high since the number of overlapping administrative domains of wireless network would be low.

IV. SIGNALING FLOW IN THE FRAMEWORK

The entities in Mobile IP approach are depicted in Figure 1. As we choose Regional Registration, FAs are organized as a two-level hierarchy: RFA for each subnet and GFA for each foreign network. We assume that each radio access network (RAN) is an IP subnet, which consists of one or more base stations (or access points). Also, each foreign network is an administrative domain, and we assume there is only one GFA per administrative domain. Note that AAA servers in the home network and the foreign network are denoted by AAAH and AAAF, respectively. We employ DIAMETER for AAA protocol.

A. Without Quasi-registration

Figure 2 shows the message flow for initial registration at a foreign network. The MN sends Registration Request message to the RFA (1). Then the RFA sends the Regional Registration Request message to GFA (2). The GFA then sends the AA-Mobile-Node-Request (AMR) message

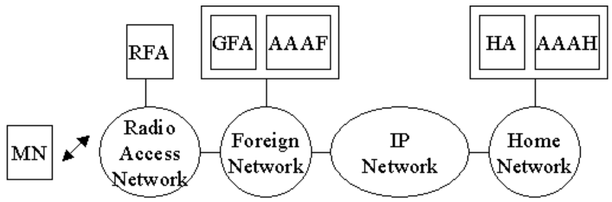

Fig. 1. Mobile IP Architecture

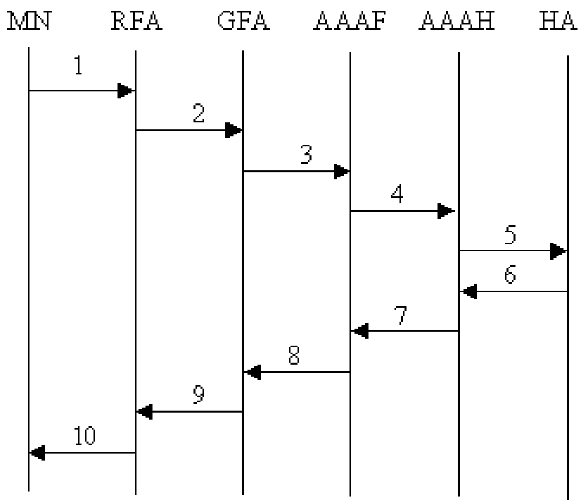

Fig. 2. Mobile IP Registration

to AAAF (3). (This message is detailed in [10], [11].) The AAAF possibly modifies and forwards this message to AAAH of the MN (4). The AAAH generates a Home Agent Request (HAR) message and sends it to the HA (5). The HA responds with a Home Agent Answer (HAA) message (6). After receiving HAA message, AAAH generates and sends a AA-Mobile-Node-Answer (AMA) message to AAAF (7). This AMA message is possibly modified and forwarded to GFA (8). Then the GFA sends Regional Registration Reply message to RFA (9). Finally, RFA returns Registration Reply message to the MN (10).

Figure 3 shows the message flow for the intra-domain handoff. Messages 1 and 4 are Registration Requset/Reply messages as defined in Mobile IP. Also, messages 2 and 3 are Regional Registration Request/Reply as described above. Note that message 5 is Binding Update message for the new RFA (NFA) to inform the old RFA (OFA) of the new CoA of the MN. Message 6 is Binding Acknowledgement message from OFA to NFA to confirm the update of binding cache entry on the MN. We assume that there is already an SA between the RFAs in the same administrative domain, so that Binding Updated message exchange is possible without signaling for other authentication in this scenario. Also, in this case, Binding Update message to the CN is not necessary because the address of GFA is

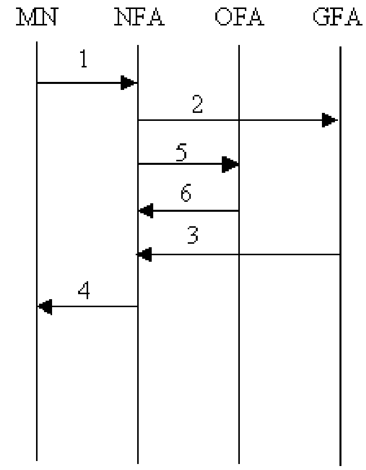

Fig. 3. Intra-handoff in Mobile IP

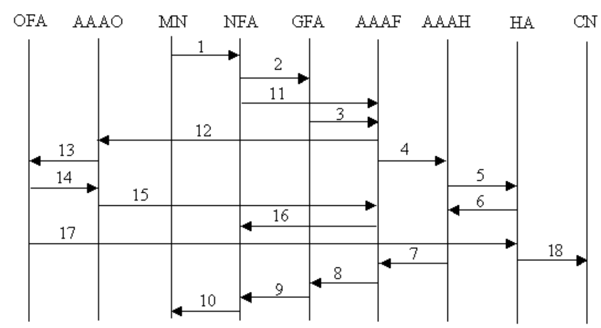

Fig. 4. Inter-handoff in Mobile IP

registered in the HA of the MN and in the binding cache of the CN.

Figure 4 shows the signaling message flow for inter-domain handoff. The messages from 1 to 10 are exactly the same as in Figure 2. However, in this case, Binding Update message and Binding Acknowledgement message should be authenticated since this message exchange is performed in different domains. Message 11-16 are Binding Update/Acknowledgement messages and its variant DIAMETER messages similar to Figure 2. Here, AAAO is the AAA server of the foreign network to which the OFA belongs. Similarly, AAAF is the AAA server of the foreign network to which the NFA belongs. Message 17 is Binding Warning message and message 18 is Binding Update message.

B. *With Quasi-registration*

Figure 5 shows the signaling message flow when a MN registers in a foreign network in the presence of quasi-registration. Message 1 - 10 are the same as in Figure 2. To make a quasi-registration state in neighboring FAs (neighboring RFAs with Regional Registration), messages

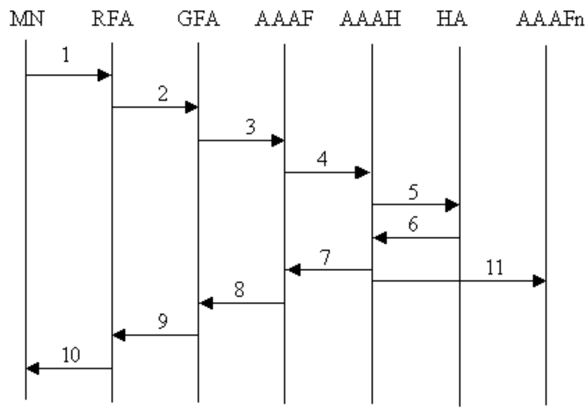

Fig. 5. Mobile IP Registration with Quasi-Registration

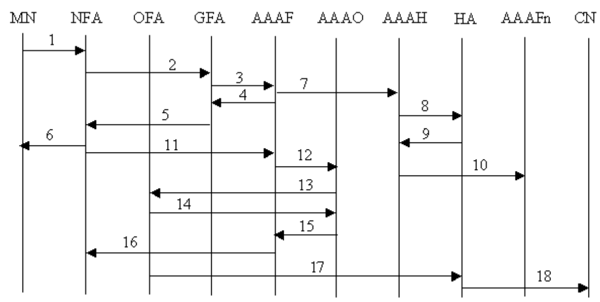

Fig. 6. Mobile IP Inter-handoff with Quasi-Registration

11 is sent. The AAA server in the neighboring foreign network are denoted by AAAFn. Here, we presume that an AAA server can learn information about the neighboring AAA servers due to handoff. Recall that in Figure 3, Binding Update message is forwarded via the relevant AAA servers.

The signaling message flows for intra-domain handoff in the presence of the quasi-registration is the same as the one in the absence of the quasi-registration.

Figure 6 shows the signaling message flows for the inter-domain handoff in the presence of the quasi-registration. Messages 7 - 10 are for quasi-registration. Message 11 - 16 are to inform/acknowledge Binding Update between OFA and NFA via the AAA servers. Messages 17 and 18 are Binding Warning message and Binding Update message, respectively.

V. Delay/Disruption Analysis

In this section, we analyze the signaling flow of the proposed framework in terms of delay at initial registration, and disruption in intra-domain handoff and inter-domain handoff, respectively. We do not take into account quasi-registration until last part. Furthermore, we disregard the quality-of-service (QoS) issue in signaling.

For simplicity, we assume the delay between the MN and the RFA is t_s, which is the time to send a message over a subnet. Also, the delay between the MN and AAAF server (or GFA) is assumed to be t_f, which is the time to send a message over the foreign network . The delay between the MN and the entities in its home network (e.g., AAAH, or HA) is assumed to be t_h, which is the time to send a message to the home network. We can assume that $t_s < t_f < t_h$ in general. Also, the delay between the MN and the CN is t_{mc}, and the delay between the the MN's home network and the CN is t_{hc}. We only consider the scenario where the CN is in its home network in this paper. The overall analytic model is depicted in Figure 7.

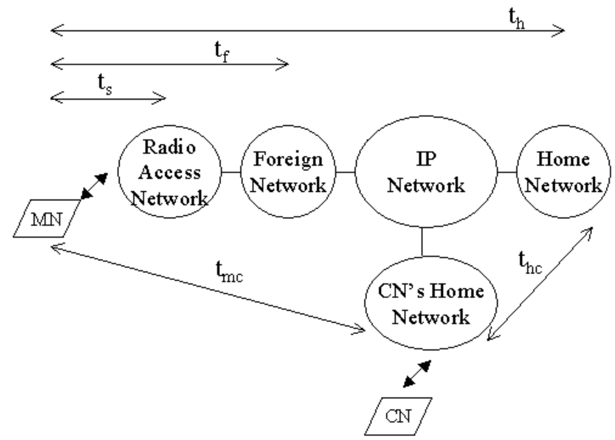

Fig. 7. Simple Model for Analysis

A. Initial Registration and Session Setup

We assume that the MN (caller) is located in a foreign network so that it must register to its home network via the foreign network and the CN (callee) is located in the CN's home network. Also, we assume that the MN will send Router Solicitation message immediately when the user initiates the Internet connection. Thus, the Router Solicitation message and the Router advertisement message will takes a round-trip time in the subnet ($2t_s$). Then, the registration message should round-trip the Internet to the home network. That will take $2t_h$ time. T_{mip_init}, is given by (1).

$$T_{mip\_init} = 2t_s + 2t_h \tag{1}$$

B. Intra-Domain Handoff

In Mobile IP, the MN first detects a new base station or a access point (and the IP subnet), it sends Router Solicitation message to the RFA, which then replies with Router Advertisement message. This will take $2t_s$ time. According to Figure 3, the whole registration takes $2t_f$ time since intra-domain handoff does not involve AAA resolution via the MN's home network .

During the Regional Registration, the new RFA (NFA in Figure 3) will also send Binding Update message to the old RFA (OFA in Figure 3). Therefore, packets destined for the MN will be forward from the old RFA to the new RFA. The total disruption time for intra-handoff in Mobile IP, T_{mip_intra}, is given by

$$T_{mip\_intra} = 2t_s + 2t_f \tag{2}$$

C. Inter-Domain Handoff

In Mobile IP, the inter-domain handoff will be handled as follows. First, the MN will detect the new wireless IP subnet of the different domain. The MN will select the new wireless network and then initiates the handoff. First of all, the MN and the RFA will exchange Router Solicitation and Router Advertisement messages, which will take $2t_s$ time. Then the MN will send the registration message to the HA and the HA will reply to the MN, which will take $2t_h$. The total disruption time for the inter-domain handoff in Mobile IP is given by

$$T_{mip\_inter} = 2t_s + 2t_h \tag{3}$$

Note that when the OFA receives the Binding Update message from the NFA, it will send Binding Warning message to the HA and then the HA will send Binding Update message to the CN. This signaling for binding update in the CN becomes effective (from the time the inter-domain handoff starts) after

$$T_{mip\_inter\_BU} = 2t_s + 2t_f + t_h + t_{hc} + t_{mc} \tag{4}$$

Therefore, during the interval between $2t_s + 2t_f$ and $T_{mip\_inter\_BU}$, there would be traffic for the MN forwarded from the OFA.

D. With Quasi-Registration

There is no difference in delay/disruption in initial registration and intra-domain handoff. However, there is notable reduction in inter-domain handoff.

$$T_{mip\_inter\_q} = 2t_s + 2t_f \tag{5}$$

VI. Conclusion

As the wireless/mobile communications technologies become widespread, providing the internet access to mobile devices is of crucial importance in networking. Furthermore, there are ongoing R&D efforts to equip mobile devices with multiple wireless communications interfaces, which announces the coming of wireless technology convergence. We have investigate the related works on the IP-level mobility management and classified into three categories: micro-mobility, handoff disruption, security issues. While the macro-mobility is managed by *Mobile IP*, we adopt *Regional Registration* for micro-mobility and *Smooth Handoff* for handoff. To reduce the disruption in inter-domain handoff, we propose the quasi-registration concept. This quasi-registration can be realized by augmenting Mobile IP messages and AAA protocol like DIAMETER. Finally, we illustrated the signaling flow for initial registration, intra-domain handoff, and inter-domain handoff and analyzed the delay/disruption. There is significant reduction in disruption in inter-domain handoff with quasi-registration; however, there are more signaling traffic.

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