Mobility Management with Distributed AAA Architecture

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Abstract

Mobile IP has been defined by Third Generation Partnership Project 2(3GPP2) to be the mobility solution for the next generation cellular networks. The Mobile IP related issues therefore become important and popular. Mobile IP provides the Mobile Node (MN) the ability of roaming around a foreign domain. An MN needs to register with its Home Agent (HA) through the attached Foreign Agent (FA) when it roams to a foreign domain. If the frequency of MN handoffs is high and the foreign domain is too far from the home domain, the delay of the registration will be significant. The hierarchical foreign agent management is proposed to solve this problem. However, the Gateway Foreign Agent (GFA) will become a bottleneck when it serves too many MNs. In this paper, we propose a mobility management with distributed architecture to solve the bottleneck problem. We also present some simulation results to support our scheme by using NS2.

Keywords: Hierarchical foreign agent, load distribution, mobile IP, mobility management

1 Introduction

Mobile IP [10, 15, 16] has been defined by the 3GPP2 to be the mobility solution for the next generation cellular networks [2, 4]. The Mobile IP working group in the Internet Engineering Task Force (IETF) has worked for several years to establish a general model of IP Mobility to provide the ability of roaming around a foreign domain. A Mobile node (MN) needs to register with its Home Agent (HA) through the attached Foreign Agent (FA) when it roams into a foreign domain. If the distance between the home domain and the foreign domain is long, the registration procedure will take more time. Besides, there will be too many registration messages between HA and FA when the MN micro-moves in the same visited domain frequently [5]. To solve the above problems, there are some proposes solutions, such as Hierarchical Foreign Agents [11], Region registration [7, 8] and HAWAII [17].

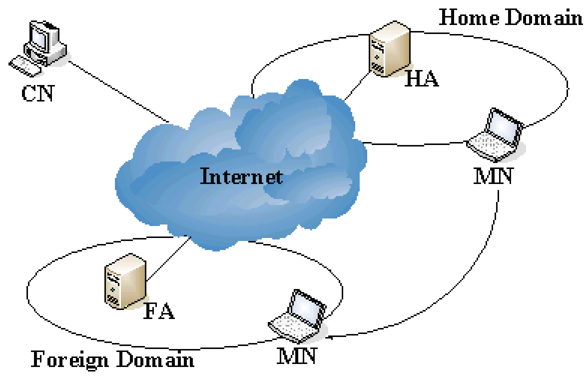

Figure 1: Mobile IP architecture

In the Hierarchical Foreign Agents scheme, the MN needs to find a Gateway Foreign Agent (GFA) when it enters a visited domain. The GFA will forward the registration message from the MN to the HA. The HA will record the care-of-address (CoA) to trace the location of the MN. After finishing home registration, the HA will tunnel all packets, sent from the Correspondent Node (CN) destined to the MN, to the GFA. If the MN changes its FA under the same GFA, it will send a regional registration within the same visited domain. This scheme reduces the numbers of registration message and the registration delay time when the MN moves between two FAs in the same visited domain.

However, the Hierarchical Foreign Agents scheme results a new problem, that is, the GFA becomes a bottleneck when it needs to serve many MNs. To keep the advantage of Hierarchical Foreign Agents and solve the

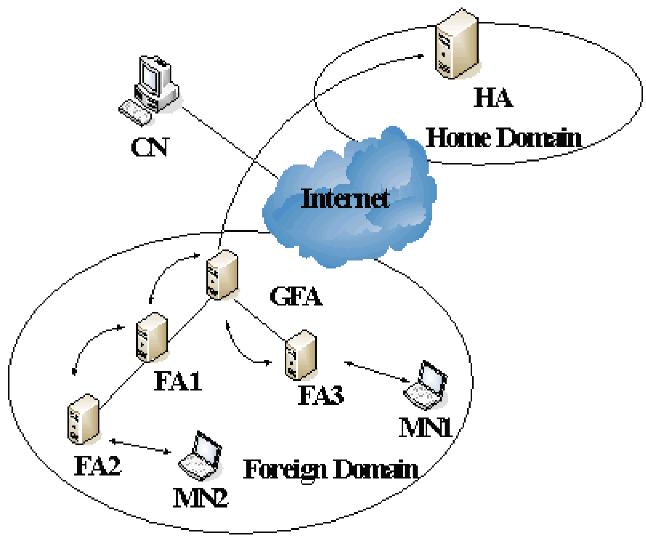

Figure 2: Hierarchical foreign agent architecture

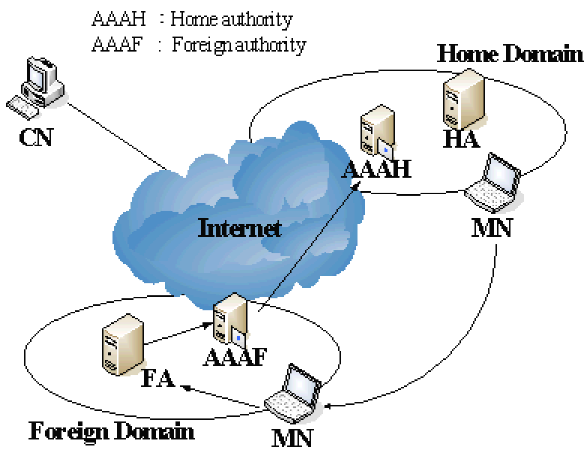

Figure 3: Mobile IP AAA architecture

bottleneck problem, we will propose a new mobility management with distributed architecture scheme to meet the above demand. The proposed scheme is based on some researches [7, 8, 11] which will be presented later.

This article is organized as follows. Next section presents a review of the Mobile IP. Besides, we will briefly discuss the Hierarchical Foreign Agents scheme and point out the bottleneck problem of it. In Section 3, details of the proposed scheme will be presented. In Section 4, we present some simulation results by Network Simulator - Version 2 (NS2). Finally, Section 5 shows our conclusion.

2 Related Work

2.1 Mobile IP

Mobile IP architecture is mainly composed of Mobile Node, Correspondent Node, Home Agent and Foreign Agent. The function of each component is described as follows:

- Mobile Node (MN): MN is capable of changing its location without changing IP address and using its IP address to communicate with other node at any location continually.

- Correspondent Node (CN): CN is a node that the MN communicates with.

- Home Agent (HA): HA is the agent on the home network of MN. When the MN is away from home, the HA will record the updated location information through the registration by the MN. The packets destined to the MN will be tunneled [12, 13] by the HA to the updated MN location.

- Foreign Agent (FA): The agent on the MN's visited network that detunnels packets destined to the MN. The FA also serves as a default router for the registered MNs.

- Care-of-Address (CoA): CoA is the address of MN while staying in the foreign network. It is also the address which the HA forwards packets to.

We graph the procedures of Mobile IP as in Figure 1. A MN has a fixed home IP address or a unique NAI [1, 3, 9]. When MN changes the location, the IP address or NAI can be used to identity MN. The MN also deals with the CoA that indicates its present location in the foreign network. Since the CoA shows the current location information of MNs, the HA is capable of routing the packets to the MN by tunneling datagram to the CoA. Each FA presents the similar function as a router for MN.

2.2 Hierarchical Mobile IP

In general, Mobile IP allows the MN to move unlimitedly between any FAs. If the MN handoffs frequently the overhead, process delay and packet loss will become high due to the repeated registrations for the micro-moves in the same visited domain. Therefore, the Hierarchical Foreign Agent scheme is proposed to solve such problems.

The architecture of the Hierarchical Foreign Agents scheme is shown in Figure 2. In the Hierarchical Foreign Agents scheme, the MN needs to find a Gateway Foreign Agent (GFA) when it first enters a visited domain. During the home registration procedure, the MN registers the CoA as the current address. This CoA will not be updated when the MN micro-moves under the same GFA. The GFA keeps a visitor list of all MNs but does not forward the MN's registration request to the HA. This scheme reduces the number of registration messages and the registration delay time when the MN micro-moves between two FAs under the same visited domain.

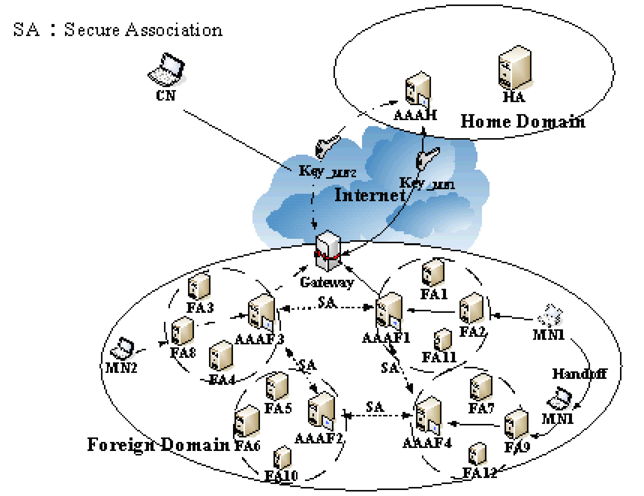

Figure 4: Mobility management with distributed security architecture

However, the Hierarchical Foreign Agents scheme results a new problem, that is, the GFA becomes a bottleneck in this kind of environment. As mentioned above, all registration messages passing to the HA and packets destined to the MN will be processed and routed through the GFA. Obviously, the GFA will become a bottleneck when it serves many MNs.

2.3 AAA Architecture

When an MN visits a foreign domain, it still needs service from FA. The Mobile IP and Authentication, Authorization, Accounting (AAA) working groups define RFC 2977 [6] to handle the detailed services when the MN is away from home network. The Mobile IP AAA architecture is shown in Figure 3. When the MN roams into the foreign domain, it sends its requirements and authentication information to an attendant (i.e. FA). Afterward, the FA forwards the information to the AAA server (called AAAF) located in foreign domain. Upon receiving the data, AAAF server carries out the authentication process if MN's authentication information is in its database. Otherwise, AAAF server sends MN's authentication information to the AAA server located in MN's home domain (called AAAH). AAAH server will confirm MN's identification by authentication information and send the authentication result to AAAF server. Upon receiving the result from AAAH server, AAAF server forwards it to the FA, which sequentially informs the result to the MN. The entire process is called AAA registration.

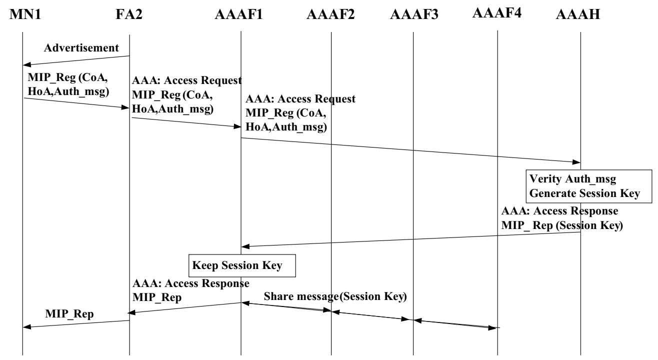

Figure 5: Authentication process flow for distributed AAA architecture

3 The Proposed Schemes

3.1 Distributed Mobile IP

In this paper, we propose a mobility management with distributed architecture to solve the bottleneck problem of the GFA. The mobility management with distributed architecture is shown in Figure 4. The major difference between the Hierarchical Foreign Agents scheme and the proposed scheme is the relationship among all FAs in the same domain and the MN registration flow. When an MN first enters the foreign domain, it will receive an advertisement sent by one FA. The MN will send a home registration message to the intercepted FA. This FA, designed as Boss FA, will deal with the current location information of the MN by maintaining a table. Note that this proposal is different from the Hierarchical Mobile IP in which the GFA is pre-selected by the administrator of the foreign network. However, the Boss FA in our design is defined to be the one that the MN first encounters when it enters a visited domain.

This designed method is based on probability. We assume the probability of the MN first meeting with one FA is the same as all the other FAs. In this case, the total FAs will serve the same amount of the MNs even each MN meets different FA when it enters this foreign domain at the first time. However, in our proposal the MN will select one FA as the Boss FA according to the probability that the MN first meets with the FA. For the worst case when all MNs select the same FA, the Mobility Management with Distributed Architecture will have the same result in efficiency as that of the Hierarchical Mobile IP. In this case, the Boss FA plays the same role as the GFA. On the contrary, if we meet the best or average case, every MN will pick up different or least selected Boss FA. In this case, the service load will be distributed to every FA evenly. Therefore, the proposed scheme on one hand will reduce the overhead of the home registration as that of the Hierarchical Mobile IP. On the other hand, this scheme keeps the balance of the Boss FAs' service loads when the MN micro-moves within the same visited

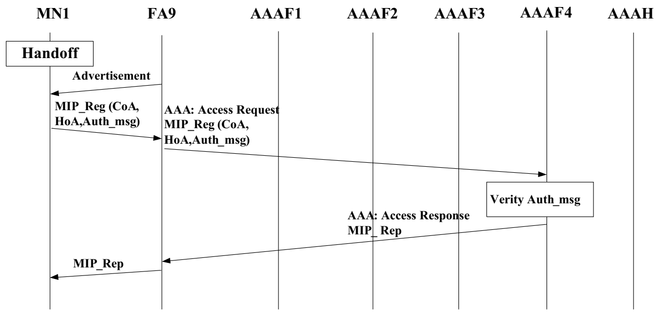

Figure 6: Re-authentication process flow for MN1 handoff

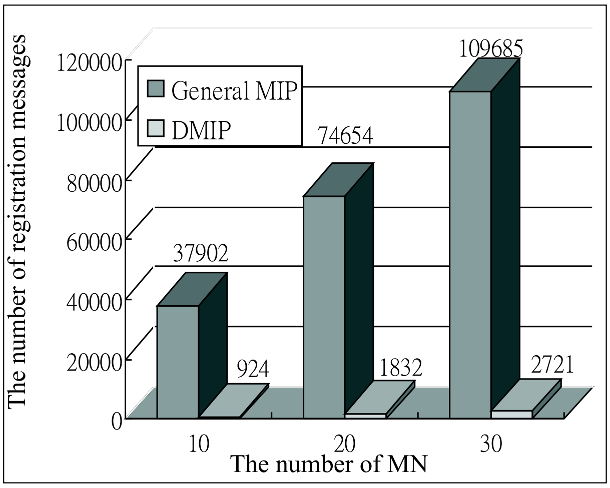

Figure 7: The number of home registration messages for different quantities of the MNs

domain frequently.

The registration steps are shown as follows:

Step1. The MN moves to the foreign domain from the home domain and receives the advertisement send by the FA.

Step2. If the MN do not have a Boss FA, it sends a home registration to the HA through this encountered FA, and this FA will serve as its Boss FA.

Step3. If the MN has a Boss FA, it sends a region registration to its Boss FA through this encountered FA. The Boss FA will update the current location information of the MN.

Step4. If the Boss FA has not received the region registration of the MN in a fixed time, it will send deregistration message to the HA to keep the location information in the HA correctly.

Step5. When the MN moves to the other foreign domain or backs to its home domain, the Boss FA needs to clear the registration information of this MN. The MN will send a new home registration message to the HA directly or through a new Boss FA.

As mentioned above, our scheme keeps the same result as the Hierarchical Foreign Agent scheme to reduce the number and time cost of home registration. Besides, the selected Boss FA in probability will maintain the load balance of the FA's service when the MN micro-moves in the same visited domain. On the other hand, the packet forwarding process will be similar to the two-level Hierarchical Foreign Agent Architecture. In the next section, we will present the simulation results.

3.2 Distributed AAA Mechanism

We apply AAA architecture in our proposed distributed mechanism. We assume that there is no intended attack in our proposed mechanism. In other words, MN and AAAF as well as AAAH servers trust to each other. The distributed security architecture is shown in Figure 4. As we can seen from Figure 4, we combine several AAAF servers to form a cluster where any one of the AAAF servers can authenticate with AAAH server. As long as one of AAAF servers acquires the authentication from AAAH server, the session key will be distributed and shared to other AAAF servers. When the MN moves within the same foreign domain but accesses via different AAAF server, the new AAAF server will process the authentication directly without sending the authentication message back to AAAH server again.

The major advantage of distributed security architecture is the reduction of authentication process and delay. For the original mobile IP AAA architecture, the authentication process between AAAF and AAAH is needed whenever an MN moves to different AAAF domain. On the other hand, for the hierarchical mobile IP architecture the AAAF gateway might become the bottleneck of the authentication process which will also increase the authentication delay. These problems, however, will be improved or reduced in our proposed distributed scheme where each AAAF server is capable of authenticate with AAAH server and authentication session key is shared to each AAAF server within the same foreign domain.

The proposed scheme will be further explained by the following example, and the authentication process flow will be shown in Figure 5. When MN1 just moves into the foreign domain accessed via FA2, it will be challenged by AAAF1 server. Upon receiving the authentication message, AAAF1 will send the message to its corresponding AAAH server since no matched database in AAAF1 server. If the authentication is passed, AAAH will respond with a message, including the authentication result and a generated session key, to AAAF1. Then, AAAF1 will forward the authentication result to MN1 and share the session key to other AAAF servers.

When MN1 moves to FA9, as shown in Figure 4, AAAF3, which got the shared session key from AAAF1, will process the authentication directly without sending

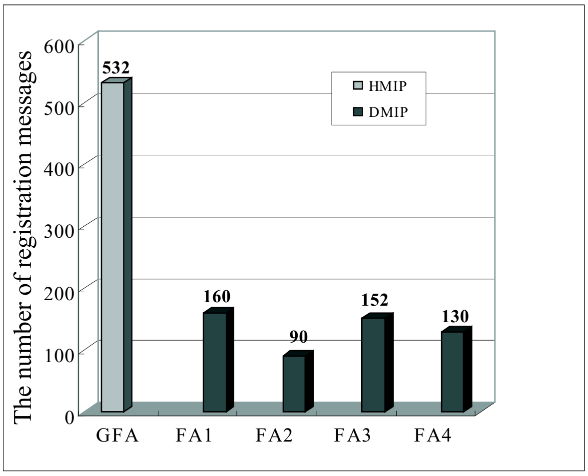

Figure 8: The number of regional registration messages with ten MNs

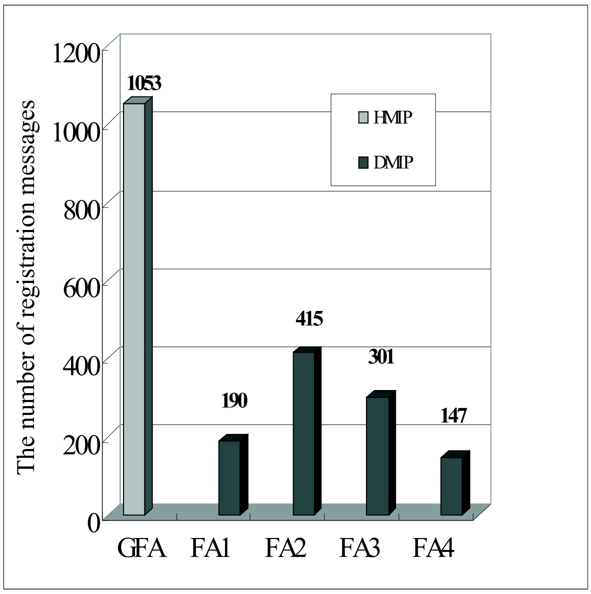

Figure 9: The number of regional registration messages with twenty MNs

message to AAAH server. The authentication procedure for such handoff is shown in Figure 6.

From the discussion and example above, only one authentication process between AAAF and AAAH servers is needed for our proposed distributed AAA architecture when the handoff for an MN happened within the same foreign domain. This will reduce the subsequent authentication delay of the handoffs. Also, since our proposed architecture provides AAAF servers the ability to communicate with AAAH directly, the bottleneck problem for the hierarchical mobile IP architecture will be solved. The key sharing and updating among AAAFs may cost some overhead, but the message is small and the transmission is only over the Local LAN. However, the long processing delay and transmission overhead due to the re-authentication between MN and AAAH over the internet is expected to be reduced significantly.

4 Simulation and Analysis

In this section, we present the simulation scenario and result by using NS2. First, we construct a 1600*1600 environment including one HA, four FAs, and some MNs. For the general situation; we could not forecast which FAs the MNs will move to. Therefore, the MNs will randomly move to one corresponding FA from its home domain when the simulation starts. Whenever an MN receives the advertisement sent by one FA, it will send a home registration message to the HA passing through such FA. This FA will forward its home registration message to the HA and serve as the MN's Boss FA. After the completion of the home registration procedure, the MN will move to the other FA and stay there for a short time until the MN visits all other FAs. During the experience, we will calculate all home registration messages sent from the MNs to the HA and those intercepted by each FA (include home and region registration).

Figure 7 shows the general Mobile IP as well as our scheme in the number of registration messages for different quantities of the MNs. The statistic result gives us the comparison between our scheme and the original Mobile IP structure. In general Mobile IP, when the MN moves to different FA, it must register to its HA again. But in our scheme, the MN will only send the region registration to the Boss FA to replace the whole process of the home registration. Therefore, our scheme can reduce the number of registration packets when the MH moves to different FA.

Figures 8, 9 and 10 show the relationship among the number of registration messages and different Foreign Agents with ten, twenty and thirty MNs, respectively. The GFA is associated with the Hierarchical Foreign Agents scheme and the possible selected Foreign Agents (Boss FAs) in our scheme are represented as FA1, FA2 and so on. As shown in figures, the total numbers of the home registration messages are the same for both the Hierarchical Foreign Agents and our proposed schemes. That means, our scheme keeps the feature of the Hierarchical Foreign Agents in reducing the unnecessary messages to the HA for region registration. In addition, the traffic loading and processing messages are distributed and shared by all Boss FAs for our designed scheme. This again is believed to solve the bottleneck problem for the Hierarchical Foreign Agents scheme.

5 Conclusions

In this paper, we have proposed a mobility management with distributed architecture scheme to solve the bottle-

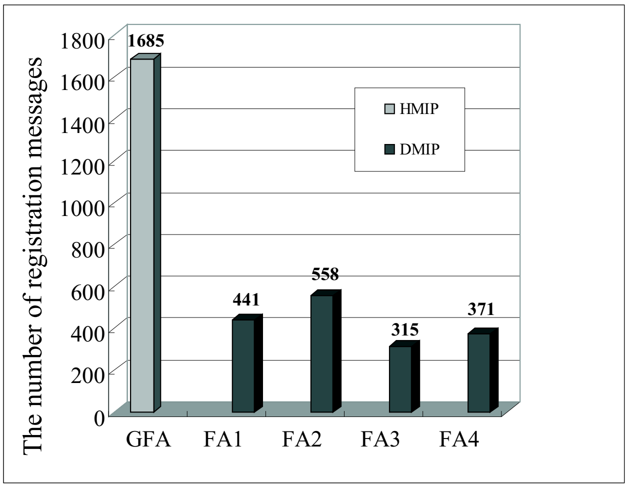

Figure 10: The number of regional registration messages with thirty MNs

neck problem in the Hierarchical Foreign Agents scheme. Our scheme maintains the same result as the Hierarchical Foreign Agents scheme in reducing the overhead of the home registration. In addition, our distributed architecture scheme keeps the balance of the Boss FAs' service loads when the MN micro-moves within the same visited domain frequently. Because our scheme only adds a field to the registration message and a table in the FA, it would be easy to implement and extend the distributed architecture scheme on the general Mobile IP environment.

The complete implementation of the proposed system as well as analysis with different parameters such as the delay due to handoff is under studied. Because the architecture of Mobile IP has been modified in our design, the handoff procedure will be changed. Also, the security issue with different Boss FAs will need further study. Therefore, the smooth handoff and security issues under the proposed distributed architecture will be conducted after this work.

Acknowledgements

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References

[1] B. Aboba, and M. Beadles, *The Network Access Identifier*, RFC 2486, Jan. 1999.

[2] I. F. Akyildiz, J. McNair, J. S. M. Ho, H. Uzunalioglu, and W. Wang, "Mobility management in next-generation wireless systems," *Proceedings of the IEEE*, vol. 87, pp. 1347-1384, Aug. 1999.

[3] P. Calhoun and C. Perkins, *Mobile IP Network Address Identifier Extension*, RFC 2794, Mar. 2000.

[4] F. M. Chiussi, D. A. Khotimsky, and S. Krishnan, "Mobility management in third-generation all-IP networks," *IEEE Communications*, vol. 40, no. 9, pp. 124-135, Sept. 2002.

[5] S. Das, A. Misra, P. Agrawal, and S. K. Das, "TeleMIP: telecommunications - enhanced mobile IP architecture for fast intradomain mobility," *IEEE Journal on Personal Communications*, vol. 7, pp. 50-58, Aug. 2000.

[6] S. Glass, Sun Microsystems, T. Hiller, Lucent Technologies, S. Jacobs, GTE Laboratories, C. Perkins, and Nokia Research Center, *Mobile IP Authentication, Authorization, and Accounting Requirements*, RFC 2977, Oct. 2000.

[7] E. Gustafsson, A. Jonsson, and C. Perkins, *Mobile IPv4 Regional Registration*, Internet Draft, draft-ietf-mip4-reg- tunnel-00, Nov. 2004.

[8] E. Gustafsson, A. Jonsson and C. Perkins, *Mobile IPv4 Regional Registration*, Internet Draft, draft-ietf-mobileip- reg-tunnel-09, Jun. 2004.

[9] F. Johansson, and T. Johansson, *Mobile IPv4 Extension for Carrying Network Access Identifiers*, RFC 3846, Jun. 2004.

[10] D. Johnson, C. Perkins and J. Arkko, *Mobility Support in IPv6*, RFC 3775, Jun. 2004.

[11] C. Perkins, *Mobile-IP Local Registration with Hierarchical Foreign Agents*, Internet Draft, draft-perkins-mobileip-hierfa-00, Feb. 1996.

[12] C. Perkins, *IP Encapsulation within IP*, RFC 2003, Oct. 1996.

[13] C. Perkins, *Minimal Encapsulation within IP*, RFC 2004, Oct. 1996.

[14] C. E. Perkins, *Application Statement for IP Mobility Support*, RFC 2005, Oct. 1996.

[15] C. E. Perkins, "Mobile IP," *IEEE Communications*, vol. 35, pp. 84-99, May 1997.

[16] C. Perkins, *IP Mobility Support for IPv4*, RFC 3344, Aug. 2002.

[17] R. Ramjee, K. Varadhan, L. Salgarelli, S. R. Thuel, S. Y. Wang, and T. La Porta, "HAWAII: a domain-based approach for supporting mobility in wide-area wireless networks," *IEEE/ACM Transaction on Networking*, vol. 10, pp. 396-410, June 2002.

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