The Use of SCTP Failover Mechanism for Efficient Network Handover on Mobile IPv6

Ryuji Wakikawa
Keio University
5322 Endo Fujisawa Kanagawa, Japan
ryuji@sfc.wide.ad.jp

Yoshifumi Nishida
Sony CSL Inc.
3-14-13 Higashigotanda Shinagawa-ku Tokyo, Japan
nishida@csl.sony.co.jp

Jun Murai
Keio University
5322 Endo Fujisawa Kanagawa, Japan
jun@wide.ad.jp

***Abstract*— In the near future, mobile communication will become majority on the Internet according to quick progress of wireless technology and mobility protocols. Mobile IPv6 has been standardized at IETF and almost ready to deploy on the Internet. However, handover technology of Mobile IPv6 is still under development. Since Mobile IPv6 does not specify optimized handover mechanism, it takes certain period to complete handover. In this paper, we investigate a mechanism to minimize handover latency without any modification to Mobile IPv6. We take position that a mobile node will utilize multiple interfaces to achieve smooth handover. With multiple interfaces, the Internet access can be continued even while Mobile IPv6's movement is proceeded. SCTP is a transport protocol capable of handling multiple addresses for each session. A mobile node uses a home address as a primary address and another available address as a secondary address. The SCTP fails over to the secondary address while the primary address (i.e. home address) is inactive during handover. The advantage of this proposal is that it required modification to neither Mobile IPv6 and SCTP.**

I. Introduction

Mobility support is the key feature to realize all IP mobile networks. Many mobility technologies have already been introduced and standardized at the Internet Engineering Task Force (IETF). Mobile IPv6 [1] is a mobility protocols which enables a mobile node to roam between sub-networks without any session break. However, during handover, the small disconnection can be observed because the mobile node must update its binding to newly acquired care-of address. To do so, the mobile node sends a binding update to its home agent and may also transmits binding updates to correspondent nodes. Before completion of binding updates, the mobile node cannot communicate with any nodes. The latency depends on round trip time between a mobile node and either a home agent or a correspondent node. This handover latency must be minimized to absorb awareness of roaming period from users and application. It is expected that several new services will be built on all IP mobile networks, such as 4G cell phones, vehicle communications (Intelligent Transport System) and Personal Area Network. Real-time applications such as VoIP and streaming are sensitive to even small session break. Although it is required that the handover latency must be minimized, Mobile IPv6 does not provide optimized scheme for smooth handover.

In this paper, we propose to separate session management from Mobile IPv6 and handle it by SCTP. We investigate the use of Stream Control Transmission Protocol (SCTP) [2] to achieve low handover latency of regular Mobile IPv6. SCTP is capable of handling multiple addresses for session and has feature of failover mechanism when one of address is failed. Mobile IPv6 only keeps IP reachability with a unique address (i.e. Home Address) for incoming connection and SCTP manages session end associations according to IP reachability after connection is established. Our scheme is designed not to modify existing protocols at all. Only operations of a mobile node are newly defined between SCTP and Mobile IPv6.

The remainder of this paper is organized as follows. We first introduce SCTP and Mobile IPv6 protocols and issues which we investigate, in Section II. Then, we introduce the concept of the SCTP and Mobile IPv6 convergence in Section III. In Section IV, we report performance study on handover latency. Finally, we provide concluding observations in Section V.

II. Mobile IPv6 and SCTP

In this section, we briefly describe Mobile IPv6 and SCTP and explain the problem of each protocol which we deal with in this paper.

A. Mobile IPv6

Mobile IPv6 allows a mobile node to be addressed by a home address all the time even though the mobile node changes its point of attachment to the Internet. When the mobile node is attached to a new network, the mobile node sends a binding update to its home agent (called home registration), a router on the mobile node's home link as shown in Figure 1. A binding update describes the relation between the home address and an IP address associated with the mobile node while it is on the visiting link, called care-of address. When a correspondent node sends a packet to the home address of the mobile node, the home agent receives the packet by normal routing in the Internet. Since the home agent has the binding for mobile node, the home agent can forward the packet to the current mobile node's care-of address over the bi-directional tunnel. After the mobile node receives the tunneled packet, the mobile node may send a binding update, causing the correspondent node to cache the mobile node's binding into its binding cache database. Though all the Mobile IPv6 related signals must be basically protected by IPsec, Mobile IPv6 employs the different security mechanism, called return routability, to exchange a key to encrypt the binding update. The mobile node sends two messages such as HoTI and CoTI to a correspondent node. The HoTI must be tunneled through its home agent. The corresponded node

1-4244-0398-7/06/$20.00 ©2006 IEEE

will reply HoT and CoT carrying keys. After these messages exchange, the mobile node finally sends a binding update to the correspondent node. The binding acknowledgment is not mandatory for binding registration to correspondent nodes. After this binding registration, the correspondent node routes packets directly to the mobile node's care-of address according to the registered binding cache.

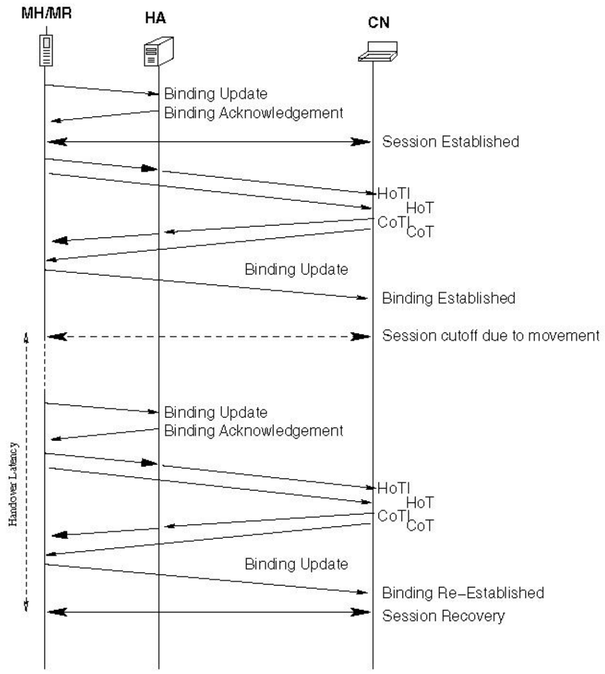

Fig. 1. Handover Latency

The one of major problem of Mobile IPv6 is handover latency. When a mobile node changes its care-of address, it must send a binding update to update all the binding cache entry stored in a home agent and correspondent nodes. While this binding update exchange, the mobile node cannot receive or send packets to the correspondent nodes as shown in the left arrow of Figure 1. Note that it can send packets to correspondent nodes which it does not notify binding, as soon as home registration is completed. This loss is not negligible when a mobile node run a real-time application. In addition to that, connection oriented communication such as TCP session will start congestion control for this loss of connectivity caused by this binding update. Therefore, as often as mobile node moves, the performance of communication surely decrease.

There are several research to minimize this handover latency of mobility protocols. Fast Mobile IPv6 [3], and Hierarchy Mobile IPv6 (HMIP) [4] are already standardized at IETF. However, these technology require extension to a mobile node. Modification to end node is not fitted to our motivation in this paper. Our scheme is designed not to modify Mobile IPv6 and SCTP.

B. SCTP

Stream Control Transmission Protocol (SCTP) [2] is a newly defined transport protocol. One of the features of SCTP is message oriented reliable transmission while TCP is byte-oriented. The message oriented transmission is suitable for telephony applications which often required rigid timing. TCP provides reliable transmission, but the rigid timing is hard to make because of strict packet sequence management. In addition, a SCTP endpoint can support multiple IP addresses per association, while a TCP endpoint can only support a single IP address per connection.

SCTP picks one destination IP address as the primary address from the set of destination IP addresses available for the SCTP association. A packet transmitted over an SCTP association from the source host to the destination host will be sent uses this primary address. If a packet fails to reach its destination, SCTP can retransmit the packet using a different destination IP address. This feature enables data communication over SCTP to be more robust and efficient under multi-home environments. Hence, when an IP address becomes invalid, a TCP endpoint has to terminate a connection. On the contrary, a SCTP endpoint can continue communication by using the rest of the available IP addresses.

Furthermore, to support seamless mobility, Mobile SCTP has been introduced [5]. Mobile SCTP use an optional function of SCTP called ADD-IP extension [6]. If a mobile node supports the ADD-IP extension, it can notify a newly obtained IP address to the peer by sending an ADDIP ASCONF chunk. The mobile node can also notify a deleted IP address to the peer by sending DELETEIP ASCONF chunk. In this way, a SCTP node can achieve seamless handover. The advantage of mobile SCTP technology is that no modification is needed in networks, while Mobile IPv6 requires a home agent to provide mobility support. However, mobile SCTP does not provide a location management function that can identify the current location of mobile nodes. On the contrary, Mobile IP can use a binding update messages to notify the current location of a mobile node to a home agent. To support correspondent node initiated communication, other mechanisms such as Dynamic DNS or SIP are needed to reach the mobile node.

III. Coordination of SCTP and MIP6

A. Why SCTP and MIP6?

Nowadays, a mobile node often has multiple wireless interfaces such as 802.11b, mobile phones, and WiMAX for Internet connectivity. At the same time, more than one interfaces are available. This assumption is reasonable because several mobile phone terminal equip with multiple interfaces and acquire multiple connectivity simultaneously. If a mobile node wants permanent IP reachability, it should maintain multiple wireless access to the Internet because each wireless coverage is limited. Therefore, when an interface becomes active and communication is stopped, the mobile node can redirect all the communication to another active interface. This strategy also has capability to reduce the latency of the network handover, if we can efficiently switch the interface.

In Section II-A, we show the binding registration causes certain overhead to network handover. During the binding registration, the home address becomes in active. On the other hand, the regular IPv6 addresses, known as care-of address in Mobile IPv6, is still IP reachable although the mobile node cannot use these addresses as a permanent address (i.e. home address). After session establishment, permanent IP reachability is not key issue unless the session can be maintained. TCP which is most deployed transport protocol cannot keep session if end-points addresses are changed, because it can manage only single end-point addresses per session. In this paper, SCTP is selected to continue session regardless of end IP address change. As we explained in Section II-B, SCTP can handle multiple SCTP endpoints per session. SCTP is also capable of session management in terms of connection failure recovery. When the mobile node moves, SCTP can detects the home address failure during the binding registration and will start failure recovery by itself.

B. System Overview

We propose to separate session management from Mobile IPv6 and handle it by SCTP. Mobile IPv6 only keeps IP reachability with a unique address (i.e. Home Address) for incoming connection and SCTP manages session end associations according to IP reachability after a connection is established.

Figure 2 shows our system overview. Return Routability procedure is omitted from this Figure for simplicity. A mobile node has two interfaces such as *IF-a* and *IF-b* in order to access the Internet permanently. The mobile node obtains an IP addresses at the visiting network at each interface, *addr-a* and *CoA* in Figure 2. The mobile node selects one of IP address as a care-of address of Mobile IPv6 in order to register its binding. Once the mobile node completes binding registration, it can start SCTP session with the home address. The home address becomes a primary address in the SCTP association. During this communication, the mobile node notifies the IP addresses other than the care-of address as secondary IP addresses to correspondent nodes.

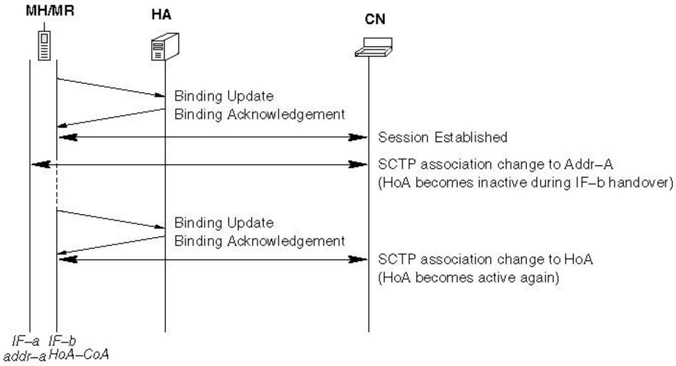

Fig. 2. System Overview

After *IF-b* becomes invalid, the mobile node cannot communicate from the home address. It must re-register another available care-of address such as *addr-a* to its home agent in Mobile IPv6. Imagine that *IF-b* is 802.11, the real handover is not smooth. After ping-pong between active and inactive state, *IF-b* becomes completely inactive. Therefore, this movement detection must be sophisticated to conceal this ping-pong situation. In our system, the secondary IP address, *addr-a* will be used when the primary IP address (i.e. *HoA-CoA*) becomes invalid due to handover. This failover is conducted by SCTP. Therefore, each session will not be interfered by ping-pong situation, since SCTP changes its association to *addr-a*. To recover home address reachability, Mobile IPv6 waits for a new care-of address on the same interface *IF-b*.

After the binding updates are completed and home address is active again, the mobile node notifies correspondent node to let the home address be a primary address again. Then, the communication is now back to the primary address which is home address. Note that our scheme assumes that the mobile node always uses only one of interface for communication. This limitation is from SCTP specification, because SCTP uses multiple addresses management feature only for redundancy purpose.

The possible issue for SCTP failover is that the SCTP failover process is triggered only consecutive retransmission timeouts. Since SCTP is a transport protocol, it is difficult for SCTP to notice the change of network configuration. Thus, the only way for SCTP to recognize a network connectivity lost is consecutive packet losses. Due to this limitation, the failover process for SCTP takes certain time. The SCTP specification [2] stated that the failover process will be initiated after *Path.MAX.Retrans* times consecutive retransmission timeout. Since the retransmission timeout is doubled each time a retransmission timeout occurs, it takes over 30 seconds from first retransmission to the time that failover process is initiated. Because only several packets have been transmitted during failover, 30 seconds failover time is critical for communication performance.

C. Advantages

Our scheme has several advantages compared to other scheme such as:

- End nodes do not need to extend Mobile IPv6 and SCTP, while most of related work extend Mobile IPv6.
- When the fail over is occurred, the trigger of flow redirection is done by SCTP. Since IP does not have such capability in original, it is more natural to handle it in transport layer.
- During the movement procedures, a mobile node can send and receive packets at one of active interface. Once it finishes binding registrations, the traffic is redirected to the home address.

Our scheme do not target zero packet loss during handover. The goal of this research is to decrease the handover latency and packet loss. There are several on-going researches to target zero packet loss such as FMIP. These researches require extension to mobile nodes and correspondent nodes. Modification to end nodes is not so easy with the current Internet because the Internet is already deployed and in service. Therefore, our scheme can be fitted until these extensions will be supported (i.e. transition period).

IV. Evaluation

We implement Mobile IPv6 stack on BSD operating system, called SHISA. SHISA has been tested with different vendor implementations of Mobile IPv6 and is confirmed to have full compliance to RFC3775 [1]. It supports all the correspondent node, mobile node, and home agent. It also supports Network Mobility [7]. We use SCTP implementation on FreeBSD5.4 from KAME project [8]. The SCTP code originally from the SCTP Kernel Implementation for FreeBSD [9] and it supports core specifications of SCTP and ADD-IP extension with other functions. SHISA is used for evaluation with SCTP implementation which is available on BSD. We conduct experiment running Mobile IPv6 and SCTP at the same time and investigate how this scheme is effective for smooth handover. The handover latency is compared between our scheme and original Mobile IPv6.

The experiment network and equipments information are illustrated in Figure 3. Two visiting networks are prepared for the mobile node. The home agent serving 2001:200:0:8c2a/64 home network is located in the three hops away from the mobile node, while the correspondent node is located in 2001:200:120:1/64 network which is reachable over the Internet from the IGP network which the mobile node and the home agent belong to.

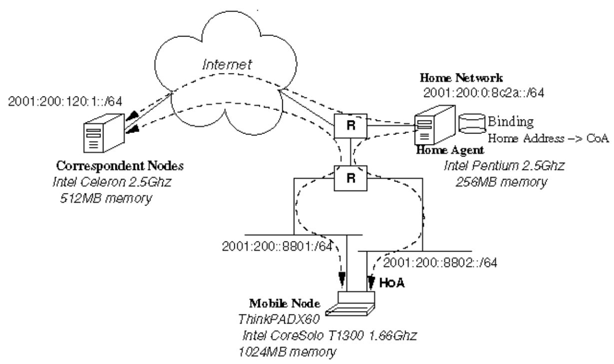

Fig. 3. Experimental Network

We tried three scenarios on this experimentation such as: 1) SCTP and MIP6 co-operation with two interfaces, 2) MIP6 with single interface, 3) MIP6 with two interfaces. In the scenario 1), a mobile node connects to the network by two Ethernet interfaces. One of interface (IF-b) is used for Mobile IPv6 operation and the other (IF-a) is backup interface. We observe the traffic behavior when IF-b is plugged in and out. When IF-b is inactive and home address becomes unreachable, SCTP uses IF-a for communication. After IF-b is connected again and the home address is ready to use, SCTP switches all traffic back to IF-b. In the scenario 2), a mobile node connects to the network by single interface (IF-b). During SCTP session, the mobile node moves from 2001:200::8801/64 network to 2001:200::8802/64 network with IF-b. Since this is manual movement, there is certain time loss while IF-b is being plugged out and in. Scenario 3) is similar to the scenario 2) except for the number of interface. The mobile node has two interfaces and changes its interface depending on reachability. When IF-a becomes unreachable by disconnecting the cable from IF-a, the mobile node detects this and dynamically switches to 2001:200::8802/64 network (IF-b). The results are shown in Figure 4 5 6 7. Each figure shows the relationship between SCTP's packet sequence number and time. The blank gap of the data indicates the packet loss due to the movement.

Figure 4 plots data of all the scenarios, 1), 2) and 3). It is obvious that the SCTP performance of our scheme is less effected by handover than the performance of other scenarios.

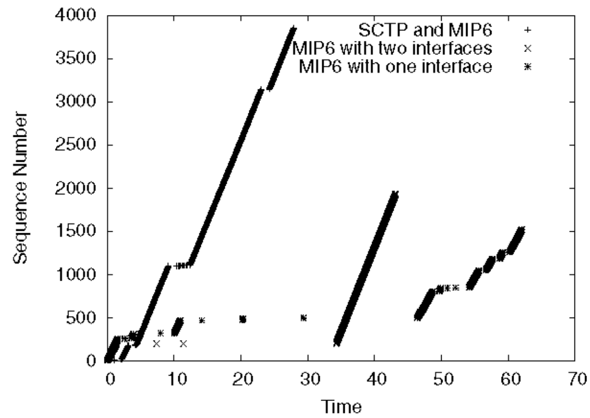

Fig. 4. Result of Experimentation

Figure 5 shows only the data plot of the scenario 1). Three handovers are happened in this experimentation. While the mobile node conducts binding registration, SCTP switches the primary address to the available address and continue to transmit packets. Therefore, the packets loss occurs only while SCTP changes its primary address. Congestion control is slightly started, but SCTP does not meet the timeout and transmission is soon recovered.

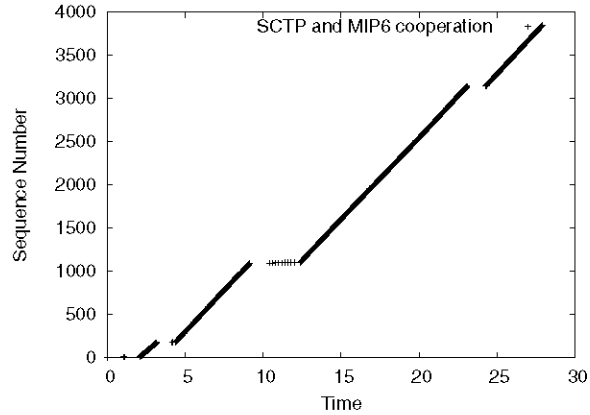

Fig. 5. Result of Experimentation

Figure 6 is the plot data of the scenario 2). In this case, only one time handover is taken. The mobile node needs amount of time for movement operation, movement detection and binding registration. SCTP performance is decreased. Since movement is manually operated by changing network cable, the data is not accurate. However, it can see that SCTP did timeout and transmission is not restarted for about 30 seconds. The small packet loss in the figure is caused by binding registration process. We use short binding lifetime for the experimentation of this scenario 2) in order for the mobile node to update binding quickly when movement is happened. SHISA implementation stop transmission while exchanging binding update and binding acknowledgment. We should ignore this loss because this is implementation limitation.

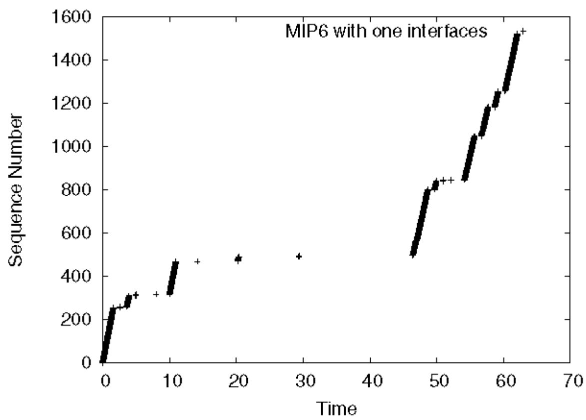

Fig. 6. Result of Experimentation

Figure 7 shows the plot data of the scenario 3). In this case, only one time handover is taken, too. The mobile node has multiple network interfaces and multiple reachability to the Internet, the movement operation of the scenario 2) can be eliminated from the loss time. When the mobile node detects the loss of connectivity, it switches its interface and sends a binding update to its home agent. The possible factor which affect to SCTP performance are movement detection and binding registration. Movement is detected by watching states of router advertisement and router on-link reachability states of NDP in SHISA implementation. The algorithm can be found in the paper [10]. For this experimentation, we prepare another program to watch the link status of each interface. The program let SHISA stack initiate the movement detection procedure as soon as the link status becomes inactive. As a result, Figure 7 shows the same result of Figure 6. SCTP session is timed out and transmission is stopped due to congestion control. The performance of SCTP session is effected by movement event.

V. CONCLUSION

This paper presents a smooth handover scheme for Mobile IPv6 by using SCTP failover mechanism. The scheme does not require any modification to existing protocols, though it

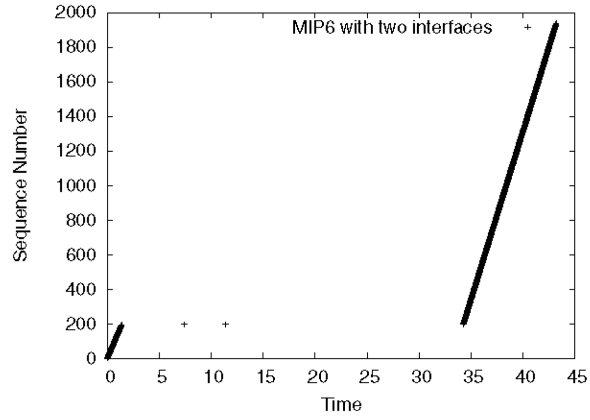

Fig. 7. Result of Experimentation

may need some parameter tuning to enhance smooth handover. Both SCTP and MIP6 provide their own handover schemes. However, if we use these technologies alone, there are some possibilities for severe performance degradation during handover process. By combining the advantage of two technologies, we can reduce the possibilities for performance degradation drastically and realizes smooth failover.

Several mechanisms that can minimize handover latency have been proposed. However, most of these proposals need certain amount of modification to end nodes and home agents. From the view of short period, modification to protocols on a number of nodes are not realistic work on the Internet. Therefore, our scheme can be useful to achieve low handover latency to non-modified end nodes.

REFERENCES

[1] D. Johnson, C. Perkins, and J. Arkko, "Mobility support in IPv6," Internet Engineering Task Force, Request for Comments (Proposed Standard) 3775, June 2004.
[2] R. Stewart and et al., "Stream Control Transmission Protocol," RFC 2960, Oct. 2000.
[3] E. R. Koodli, "Fast Handovers for Mobile IPv6," Internet Engineering Task Force, Request for Comments (Experimental) 4068, July 2005.
[4] C. Castelluccia, "HMIPv6: A Hierarchical Mobile IPv6 Proposal," in *ACM Mobile Computing and Communication Review (MC2R)*, Apr. 2000.
[5] M. Riegel and M. Tuexen, "Mobile SCTP," Internet Engineering Task Force," Internet Draft (draft-riegel-tuexen-mobile-sctp-06) , Mar. 2006.
[6] R. Stewart, M. Ramalho, Q. Xie, M. Tuexen, and P. Conrad, "Stream Control Transmission Protocol (SCTP) Dynamic Address Reconfiguration,"
draft-ietf-tsvwg-addip-sctp-15.txt, May 2006.
[7] V. Devaraplli, R. Wakikawa, A. Petrescu, and P. Thubert, "Network Mobility (NEMO) Basic Support Protocol (proposed standard)," Internet Engineering Task Force, Request for Comments 3963, Jan. 2005.
[8] "Kame projects http://www.kame.net," work in progress, Jul. 2006.
[9] "Sctp kernel implementation http://www.sctp.org," work in progress, Jul. 2006.
[10] K. Shima, R. Wakikawa, K. Mitsuya, and T. Momose, "SHISA: The IPv6 Mobility Framework for BSD operating systems," in *International Conference on Wireless and Mobile Communications ICWMC*, July 2006.