

Experimental Analysis of Multi Interface Mobility Management with SIP and MIP

Ashutosh Dutta, Byungsook Kim, Tao Zhang
Telcordia Technologies
Shinichi Baba, Kenichi Taniuchi, Yoshihiro Ohba
Toshiba America Research Inc.
Henning Schulzrinne, Columbia University

Abstract: We provide an experimental analysis of MIMM (Multi-Interface Mobility Management) demonstrated in a heterogeneous network involving 802.11b and CDMA access technologies. We have experimented WAN-LAN handoff for real-time service (voice and video) in the test-bed. The subnet handoff managed by MIMM was done seamlessly in this environment and is proved to support real-time application effectively. Both application layer and network layer mobility management were used in the experiment and their results were analyzed for real-time traffic.

1 Introduction

Wireless LAN (WLAN), or Wi-Fi is becoming prevalent means of access to the wireless Internet. Especially the advent of the hotspot service brings the roaming user the benefit of receiving broadband internet access while outside one's enterprise network. But the coverage of the hotspot in public area is still limited and may not be available everywhere. On the other hand 2.5G/3G cellular system provides a wide area connectivity to the roaming users. Therefore, the scenario for seamless communication involving movement between cellular and hotspot is becoming realistic these days. Because of lack of available solutions to take care of such mobility scenarios, switching among multi-interface causes several problems as it involves interaction between physical layer, network layer and the application layer. MIMM (Multi-Interface mobility management) is a module that helps realize the seamless interface switching involving 802.11 and CDMA networks. It provides the interaction between cross layers while providing the mobility management solution.

In this paper, we demonstrate the capability of MIMM for supporting the seamless interface switch between WLAN and WAN (i.e. cellular data system). The situation 'make before break' was realized and examined, since those two interfaces can work independently and MIMM or the switching module can have enough time to prepare the handoff before it happens. Through the experiment we demonstrate that seamless handoff for voice and video service is achieved when the interface-switch occurs. The discussion below describes how the handoff takes place and we confirm the effectiveness by experimenting with

RTP/UDP traffic under multi-interface mobility management scenario.

The paper is organized in the following manner. Section 2 describes the related work. Section 3 provides MIMM overview and experimental system configuration where both the mobility protocols SIP [1] and MIP [2] are experimented. Section 4 provides a discussion of the experimental analysis and results of heterogeneous mobility and explains the benefits of MIMM. We conclude the paper in Section 5.

2 Related Work

As movement across heterogeneous networks becomes widely prevalent, it becomes essential to provide seamless mobility support to the roaming users. There have been recent research efforts that carefully study the performance issues to support both voice and data traffic and design different handoff mechanism to enable smooth handoff. Buddhikot et al [4] explains a mechanism of smooth handoff involving multiple interfaces, but it has shown the experimental results using Mobile IP only. Chakravarty et al [3] study the delay factors and describe some of the performance issues associated with handoff between heterogeneous access networks such as GPRS and 802.11. This study is focused on effect of Mobile IP assisted vertical handover on TCP traffic however. Zhang et al [5] introduce connection manager and virtual connectivity manager that provide intelligent detection mechanism and methodology to provide continuous connectivity to the mobile. Sharma et al [7] describe a Mobile IP-based vertical handoff system for wireless LANs and GPRS links. It provides several ways to extend Mobile IP and use of Network Address Translation (NAT) to intercept the traffic in the GPRS network. While most of the above cited work deal with providing handoff mechanism involving Mobile IP, these have not reported any experimental results using application layer mobility such as SIP. This paper focuses on experimental results where MIMM technology has been used to enhance both network layer and application layer mobility management scheme using MIP and SIP respectively for handoff involving heterogeneous access. Our results here have focused on real-time traffic however.

3 MIMM Architecture

This section provides an architectural overview of how MIMM module can be utilized to take care of layer 2 and layer 3 handoff in a heterogeneous networks involving Bluetooth, 802.11b and CDMA access technologies. In a practical scenario the mobile may move between two access points belonging to the same subnet or between subnets belonging to two different domains.

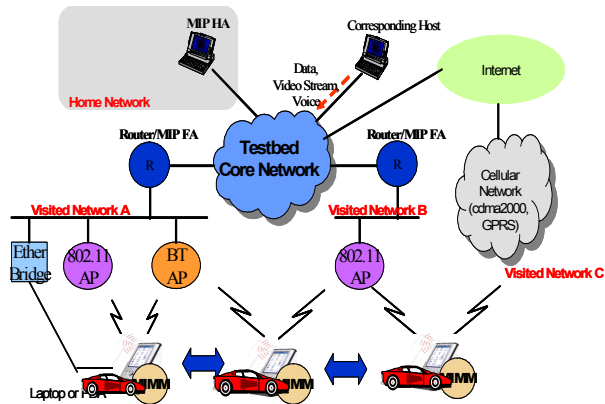


Figure 1 System configuration

Figure 1 depicts the system configuration of WAN-WLAN handoff that we have experimented with. The mobile node (MN) is equipped 802.11b PCMCIA card, and 1X-RTT PCMCIA card, so that it can use both 3G cellular system and the wireless LAN to provide IP communication. Besides the 3G cellular network, there are two LANs, one is for the home network and the other one is used as a visiting network for MN. The mobile node moves between one visiting network B (802.11b) to another visiting network C (Cellular) and comes back to the home network. The correspondent host (CH) can be located in the home network or in any other network. CH sends video or audio stream to the MN. We used vic and rat as the real-time application for video or audio source respectively. MIMM module on the mobile node MN checks the signal-to-noise ratio on 802.11b connection and if it goes below the threshold, MIMM decides to use 1xRTT connection and otherwise it selects to use 802.11b connection. 802.11b card used on MN has the external antenna with attenuator. By changing the attenuation level, signal-to-noise ratio of 802.11b connection is changed, so that MN does handoff between 802.11b and 1xRTT without physical movement. In order to avoid the hysteresis the handoff transition takes place in two phases. At a certain Signal-to-Noise ratio S_1 , the mobile begins the preparation to connect to CDMA

network in the background and as the Signal-Noise-Ration goes below another threshold S_2 , the mobile makes the CDMA interface as the primary one and communicates using that interface.

3.1 MIMM Module

MIMM module manages the mobility involving more than one physical interface and/or communication media. In this experiment, MIMM behaves as an intelligent network interface switch in L3 layer. Policy decision that helps trigger the network handover is implemented in MIMM. Once MIMM decides to change the active interface, it takes care of the routing table and invokes the registration or another mobility management process of Mobile IP or SIP mobility. In this particular experiment, IP address of 802.11b connection on MN was static and assigned from the beginning, thus time due to IP address acquisition is not included, but in reality it will include the time associated with the IP address acquisition such as DHCP. 1xRTT connection is carried by PPP from MN's PCMCIA interface to the PDSN (Packet Data Service Node). IP address on MN is assigned through PPP, since we used so-called "simple IP" service and used mobile IP in Collocated-Address mode. Because of timeout, PPP connection may get dropped sometimes and in that case MIMM needs to start setting up PPP connection so as to enable the switching of the interface. During the new PPP setup, assigned IP address may or may not change at that time, since it depends upon the NAS it connects to and the policy set up within a NAS.

A mobile that is not equipped with MIMM module prepares the secondary interface after the connection to the primary interface is lost completely. In these scenario, when the mobility module decides to switch interface, it cannot use the former interface anymore and suddenly it needs to setup another interface including new SSID, IP address and other networking parameters. These standard handoff mechanisms take excess time during handoff. This type of handoff model is called "break before make" model. When the mobile is equipped with MIMM module, it can always setup the secondary interface when the mobile is still communicating with the first interface. So the setup procedure for each interface was done before switching the interface. Therefore, excess time for configuring the interface doesn't need to be taken into consideration. This specific type of model is called "make before break" model. MIMM module helps the mobile to this type of model. It does so by communicating with a policy engine that helps to switch the active interface. In most cases the MIMM module resides within a mobile, however MIMM module can always be part of a network entity such as a server at the edge of the network. Based on

certain condition of the network such as load in the network it can trigger the switch.

4 Experimental Analysis

In this section we analyze the results of the experiment conducted when MIMM module was used for both SIP-based mobility and MIP-based mobility.

Handoff between WAN-WLAN (CDMA – 802.11) was demonstrated using both SIP-based mobility management and Mobile IP. These sets of experiments involve the following: voice with Mobile IP, video with Mobile IP and voice with SIP mobility. In each case, all packets transmitted were analyzed by tcpdump (www.tcpdump.org) both on MN and CH. For mobile IP, HUT implementation is used as a base. For SIP mobility, SIP user agent developed by Columbia University is modified to support mid-session mobility. Table 1 shows details about configuration, OS, protocols, and networking tools.

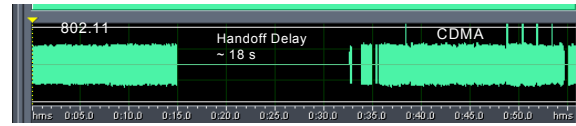
Table 1 Software details

OS	Linux version 2.4.12
Rat	Version 3.0 (http://www-mice.cs.ucl.ac.uk/multimedia/software/)
Vic	Version 2.8ucl-1.1.3 (http://www-mice.cs.ucl.ac.uk/multimedia/software/)
Mobile IP	Dynamics by Helsinki University of Technology http://www.cs.hut.fi/Research/Dynamics/
SIP	SIP version 1.51 by Columbia University (http://www.cs.columbia.edu/sip/)

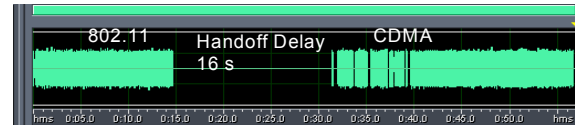
In order to measure the effectiveness of make-before algorithm supplied by MIMM we provide here a sample of results without make-before algorithm being used. Figure 2 clearly indicates that a mobile is subjected to packet loss and handoff delay in a normal handover scenario without the use of MIMM algorithm. This delay is attributed to the fact that a mobile spends some time in getting attached to the new access network, configuring the IP address and sending the binding update to the correspondent host after it loses contact with the old interface. Figure 3 shows SIP and MIP-based signaling as the mobile makes a transition between the heterogeneous networks. These signaling are actually part of the binding updates from the mobile node to the correspondent node, after the mobile's active interface has been changed. This attributes to the part of delay showed in Figure 2 however.

Figures 4, 5 show the increment of RTP sequence numbers at MN. Both voice and video are carried by RTP over UDP over IP. Especially the voice packet flows every 20 ms (millisecond). Then sequence number shall increase

periodically and the graph becomes a single smooth and monotonous incremental line in the event of no packet loss.



a) SIP handoff-delay without MIMM



b) MIP handoff-delay without MIMM

Figure 2. Effect of handoff delay and loss without MIMM

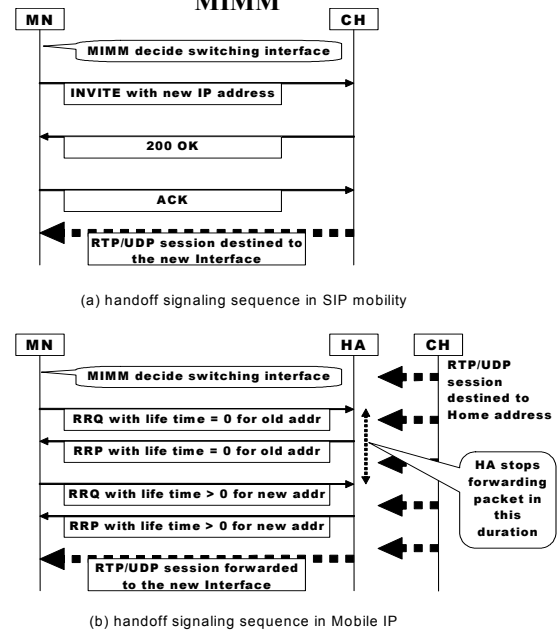


Figure 3 Signaling sequence during handoff

In case of both Mobile-IP and SIP mobility experiments, G.711(μ-law) codec generated 160 bytes data every 20ms and that includes 12 bytes RTP header, 8 bytes UDP header, and 20 bytes IP header. Furthermore, over PPP link or 802.11b link, 14 bytes Ethernet header was added also. Thus the total number becomes 214 bytes per packet in MAC layer, or 1712bits. And 1712 bits every 20ms converts to 85.6kbps line speed. The size of Mobile IP message control packet was around 100 bytes/message, while SIP INVITE was nearly 500 bytes large per message,

Table 2. Handoff Timing with MIP mobility

Movement Type	Cellular-802.11b		802.11b-Cellular	
	#1	#2	#1	#2
RRQ for deregistration -> RRP for new registration	0.56	0.55	0.91	5.22
RRQ for deregistration -> 1st packet on new I/F	0.57	0.58	1.21	5.24
Retransmission				Yes

Table 3. Handoff Timing with SIP mobility

Movement type	Cellular-802.11b		802.11b – Cellular	
	#1	#2	#1	#2
Handoff Trials				
INVITE -> OK	0.12 s	0.12 s	1.32 s	6.64 s
INVITE -> 1 st Packet	0.39 s	0.41 s	2.54 s	7.18 s
Re-transmission	None	None	Yes	Yes

this takes 40 ms to be carried over 100kbps link. These figures show that the packet loss at MN during the handoff is fairly small number or no packet loss most of the times, thus providing almost smooth handoff experience. The packet behavior during handoff is slightly different between the case of handoff from 3G to 802.11b and that from 802.11b to 3G. During the demonstration using MIMM algorithm we experienced smooth and seamless handoff as the mobile made either interface as the active interface during the transition. Figures 3 (a) and 3 (b) depict normal protocol sequences during the handoff for SIP mobility and Mobile IP respectively. In case of SIP mobility, MN sends out an INVITE message keeping the same Call-ID but including new IP address of the interface to which MIMM decides to switch. Then, CH replies with 200 OK and waits the other message, ACK, from the MH. After receiving ACK from MH, CH changes the destination IP address of media session. Then MN begins to receive it on the new interface switched by MIMM. Therefore, we analyze the timing closely in Table 3, those are the time between sending INVITE and receiving 200 OK on MN and the time between sending INVITE and receiving the first media packet on the new interface switched by MIMM. The first one can be considered as a time for protocol to exchange the information properly. The second one can be seen as more practical switching time, in which MN waits a packet on the new interface.

In case of Mobile IP, MN sends out Registration request (RRQ) with zero life time in order to remove the current binding from HA registration, when MIMM decides to switch interface. Then, MN sends out another RRQ with a certain life time period to register the new IP address which the switched interface has. By receiving this new RRQ, HA replies Registration Reply (RRP) to confirm new registration and begins to forward the media packet to the new destination address simultaneously. Between the first RRQ and the second RRQ, MN is considered to be in the de-registration state, HA doesn't forward packet for MN and the media packet destined to the MN's home address is just dismissed in the home network. Table 2 shows, again, two numbers, the time waiting RRP message for the second RRQ after sending first RRQ with zero life time for de-registration and the time waiting a media packet on the new interface after sending the same RRQ as the first one. Comparing the values of Table 2 and Table 3 doesn't make sense so much. Because it depends on implementation and in this experiment transmission delay is so unbalanced in CDMA network. But one interesting result is that 802.11→Cellular handoff using SIP mobility seems to be bit unstable because of associated re-transmission. In the similar situation, MIP succeeds to send the registration almost all the time. It may depend on the length of the registration message.

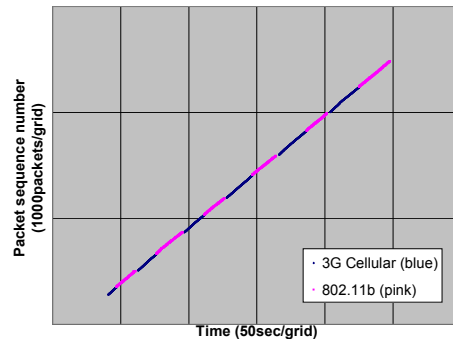


Figure 4: Video with Mobile IP using MIMM

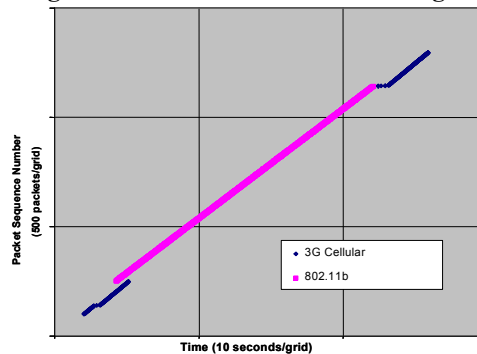


Figure 5: Audio with SIP Mobility using MIMM

MIP registration could be short enough message to be carried by the dedicated control channel over the

cdma2000 access, whereas SIP Re_INVITE gets delayed because of re-transmission.

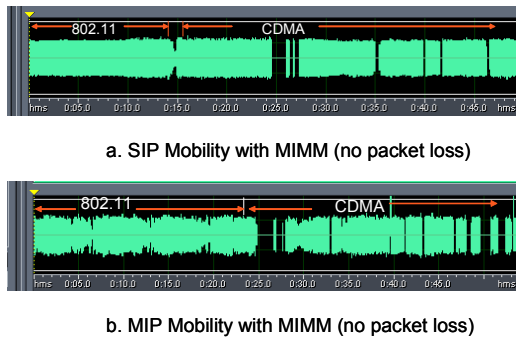


Figure 6: Audio Sample with MIMM

Figure 6 shows the audio sample recorded at the MN using MIMM algorithm. As is observed there is no packet loss during movement between 802.11b network to cellular network. Gaps shown while within CDMA network is due to the intermittent connection. However there are some out-of-order packets received when the mobile moves from cellular network to 802.11 network. Figure 7 shows audio snapshot of a scenario when the mobile traverses its path back to 802.11 network after switching to CDMA network. Out-of-order packet during its movement back to 802.11 network is basically caused by the difference in transportation delay between CH-MN through 802.11b and through 3G. It seems that rat (Robust Audio Tool) or vic (Video Conferencing) can work fairly properly under the situation in which the sequence number of the received packet is not in order. By investigating this data with RTP and codec implementation of rat or vic, we may be able to estimate the user experience because of the gap or overlap of packet reception. For example, RTP [8] recommends that the RTP packets can be considered valid if the range of out of order packets is within certain range. Therefore, the overlap and gap shown in figure 5 are in the range of expected case and don't break anything of the RTP session. And codec can mitigate this kind of fluctuation usually by using play-out buffer at the receiving end.

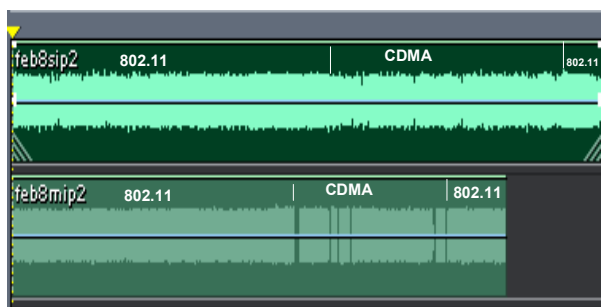


Figure 7. MIMM - SIP/MIP (802.11 - CDMA - 802.11)
 Procedure for switching from Cellular to 802.11b finishes quicker than that from 802.11b to Cellular. Since the

transmission delay between MN and CH or HA is much smaller in case of using 802.11b connection from MN.

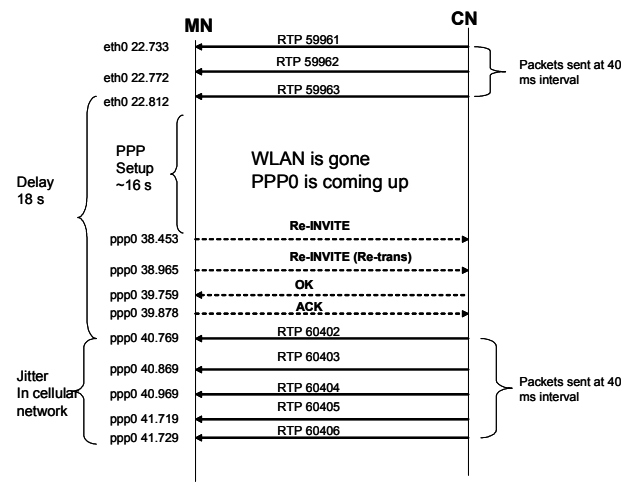


Figure 8. SIP mobility without MIMM

And the protocol handshake is mostly carried out on the new connection interface to be switched by MIMM. But it may not be necessary in case of “make before break” situation such as carried out in this experiment. 802.11b connection can be used for signaling even for switching from 802.11b to Cellular. Especially in case of SIP, it doesn't matter which route is chosen for signaling. But it is necessary to have another way to check the availability of media route.

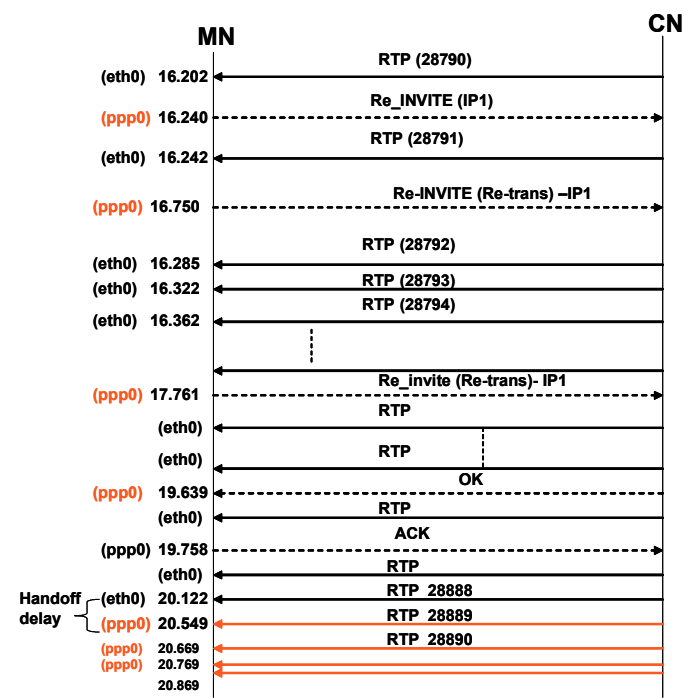


Figure 9. SIP with MIMM (802.11b - Cellular)

In case of SIP, time for processing consecutive processes on CH or MN seems large. This is the main portion of 120 millisecond of time duration for “INVITE → 200OK”. This could be attributed to the processing power of the end host and SIP implementation. Although message processing in case of MIP is quick, MN waits around five hundred millisecond to send out the second RRQ after sending first RRQ or receiving RRP for the first RRQ. It could be the issue of implementation. Another point of investigation for MIP is to see if MN can change the order of sending out RRQ or not. If HA can accept the duplicate binding, MN can send out the RRQ for new registration first so that HA can forward the packet to the new place without dropping any packet. Simultaneous binding or registration at the home agent can take care of this problem. But we did not use simultaneous binding case here. Figures 8 and 9 show some detailed timing analysis of SIP-based mobility without and with MIMM. Packet loss and delay is quite evident in figure 8 when MIMM module is not implemented. In these pictures, eth0 is the interface associated with 802.11b network and ppp0 is the interface associated with the CDMA 2000 interface.

Following observation were made for SIP Mobility with Make-before-break mechanism:

- Make-before-break allows PPP connection-setup to continue when the mobile still communicates using 802.11 interface
- Jitter was observed in Cellular, packets are buffered in the beginning, inter-packet gap decreases gradually
- Several Re-INVITE retransmission were observed in the CDMA network
- Packets are received in eth0 until SIP Re-INVITE sequence is complete, after that packets are received using ppp0 (cellular interface)
- No packets are lost during the actual handoff from 802.11 to CDMA
- There were few out-of-order packets during the transition from CDMA network to 802.11

MIP mobility with Make-before-break has the following observation:

- Jitter is found on the cellular side
- There is no retransmission for MIP signaling observed
- No packets seem to have lost during actual handoff from 802.11 to CDMA

SIP and MIP mobility without make-before-break have the following observation:

- PPP connection takes place after the WLAN SNR goes below certain level
- Handoff delay is composite of time taken to setup PPP connection and binding update
- Jitter was observed in cellular network right after the mobile moved into CDMA network

Adjusting the threshold value as to when to make the cellular/802.11 interface active is very important, as beyond a certain SNR threshold value 802.11 interface may start losing packets. Current MIMM module polls 802.11b interface every second. In case of “make before break” the effect of this period is not apparent. But it may be important to optimize this time for “Break-Before-Make” situation. This can be done easily if the 802.11 driver sends a trigger to the MIMM module only when its SNR goes below certain threshold.

5 Conclusions

We have investigated heterogeneous mobility involving wireless LAN and cellular network. We have shown how real-time communication is affected without any make-before-break mechanism because of excessive delay and packet loss during the handover. Some obvious and interesting results relating to WAN-WLAN handoff were shown. We used MIMM module within the mobile and demonstrated that the packet loss and delay is reduced drastically so that it can support the real-time communication. MIMM module within a mobile incorporates make-before-break mechanism and enhances both SIP and MIP-based mobility management. We also observed that SIP’s large signaling message size contributed to re-transmission in the narrow-band link. However SIP-based mobility seems to offer better flexibility when used in conjunction with MIMM, compared to Mobile IP and MIMM combination because of direct binding update between the CH and MN.

6 References

- [1] J. Rosenberg, H. Schulzrinne, et al, “SIP, RFC 3261
- [2] C. Perkins et al. “Mobility Support for IPv4 », RFC 3344
- [3] R. Chakravorty et al, “Performance Issues with General Packet Radio Service”, IEEE PERCOM 2004
- [4] M. Buddhikot et al, “Integration of 802.11 and Third-Generation Wireless Data Networks” IEEE INFOCOM 2003
- [5] Q. Zhang et al, “Efficient Mobility Management for Vertical Handoff between WWAN and WLAN, IEEE Communication Magazine, November 2003
- [6] A. Rajkumar et al, “Seamless SIP-based VoIP in disparate wireless systems and networks, Bell Labs Technical Journal, May 2004
- [7] S. Sharma et al, “OmniCon: A Mobile IP-based Vertical Handoff System for Wireless LAN and GPRS Links”, International Workshop on Network Design and Architecture, August 2004
- [8] H. Schulzrinne et al, Transport Protocol for Real-time application, RFC 3550.