Link Layer Assisted Mobility Support Using SIP for Real-time Multimedia Communications

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Abstract
Session Initiation Protocol (SIP) was standardized for real-time applications and extended to support terminal mobility by Internet Expert Task Force (IETF). However, SIP terminal mobility suffers from the considerable handoff latency which is unsuitable for the real-time communications. In this paper, we propose Predictive Address Reservation with SIP (PAR-SIP) which decreases handoff delay by proactively processing the address allocation and session update using link layer information of wireless networks.

Categories and Subject Descriptors
C.2.2 [**Computer-Communication Networks**]: Network Protocols – *applications.*

General Terms
Design, Performance, Measurement, Experimentation.

Keywords
SIP mobility support, real-time multimedia communications, and predictive address reservation.

1. INTRODUCTION
Wireless networks such as IMT-2000 and wireless LAN with powerful wireless devices introduce real-time multimedia services in wired Internet to mobile users. Mobility support in those wireless networks can be achieved without infrastructure such as mobile agents in Mobile IP [1]. Mobility support using SIP uses an address dynamically allocated in the visited network. However, a mobile node (MN) using SIP terminal mobility should get a new IP address and inform it to both a home registrar and a peer node during handoff. This process incurs handoff latency that is not suitable to real-time communications [5, 6].

In order to reduce the handoff delay from mobility support using SIP, the link layer information can be used in the application layer as some approaches [7] for the purpose of reducing network layer handoff latency. With this idea, we propose a new mechanism, Predictive Address Reservation with SIP (PAR-SIP), which reduces handoff latency in the application layer mobility using SIP. In order to prove the practicability and feasibility of the proposed mechanism, the PAR-SIP mobility is implemented on the testbed. We analyze and compare handoff delays of the conventional SIP mobility and PAR-SIP mobility. The experimental results show that PAR-SIP mobility requires handoff latency of about 60 milliseconds while conventional SIP mobility takes about 1.5 seconds.

2. PROBLEM DEFINITION
The handoff procedure in SIP mid-call mobility consists of 6 sub-procedures. Delay for each sub-procedure can be represented with T0~T5 as following: *Link layer handoff delay (T0*) is from several tens milliseconds to about two hundreds milliseconds depending on wireless technology. *Movement detection delay (T1)* is a time taken in detecting movements in the network layer using Router Advertisement (RA), which a router periodically broadcasts. *Address allocation delay (T2) using Dynamic Host Configuration Protocol (DHCP)* is a time taken in acquiring a new IP address using DHCP in a newly connected network [2]. *Configuration delay (T3)* is a time taken for re-configuring its own network interface and some network parameters to communicate again. *SIP re-INVITE Delay (T4)* consists of the Round Trip Time (RTT) between participants and the processing time of a SIP re-INVITE message. *RTP packet transmission delay (T5)* is a time taken for receiving the first RTP packet from a CN after an OK message arrives at a MN.

The major drawback of SIP mid-call mobility support is considerable handoff delay which makes it unsuitable for the real-time communications. Among the above delay components, T2 and T4 take the most part of the handoff delay in SIP mid-call mobility. When DHCP is used for IP address allocation, T2 appears for more than a second. Even though DRCP [8] reduces the address allocation time, a handoff still requires a few hundred milliseconds. It becomes the main cause of delay in degrading the service quality in real-time applications. T4 can also add a hundred milliseconds to the total handoff delay depending on the distance between participants. Thus, T2 and T4 delays need to be shortened to support real-time communication.

3. THE PROPOSED MECHANISM
The proposed mechanism, Predictive Address Reservation with SIP (PAR-SIP), performs the address allocation and SIP re-INVITE procedures before a link layer handoff to reduce handoff delay. It can be achieved by employing the movement detection scheme using link layer information.

Figure 1 shows a handoff procedure with PAR-SIP in order. Note that before link layer handoff starts, the jobs for T2 and T4 are executed in parallel to an existing SIP session as illustrated. T2

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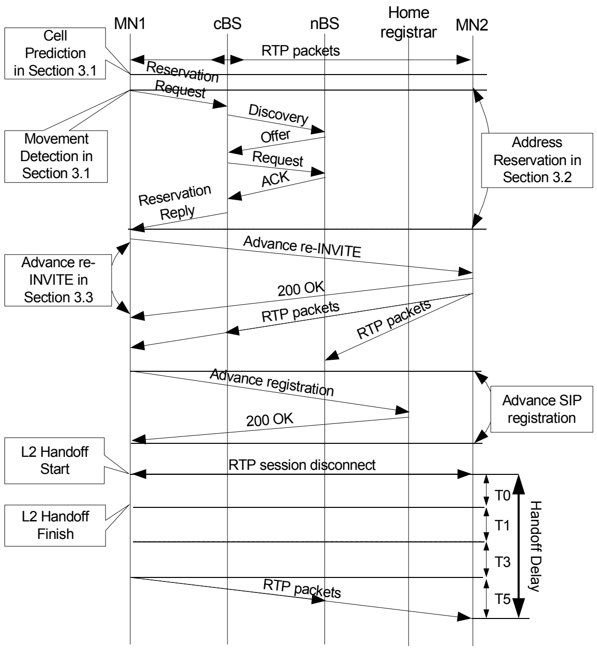

Figure 1. PAR-SIP handoff flow

required for address allocation is canceled by performing address reservation in Sections 3.1 and 3.2. Delay of session update, T4, with a re-INVITE message is also abbreviated from total handoff latency by an advance re-INVITE procedure in Section 3.3. Therefore, the required delay for a PAR-SIP handoff becomes T0 + T1 +T3 + T5.

3.1 Movement Detection in PAR-SIP

A MN starts to search another reachable access point (AP) using active scan [3, 4] as the Signal to Noise Ratio (SNR) value of the current AP falls below the Cell Search Threshold. The MN selects a predictive AP which sends signals of similar or higher SNR than the current AP. Then, if necessary, the MN performs the proactive handoff procedure using a MAC address of the predictive AP.

A MN forecasts its movement in the network layer using internal information before receiving a Router Advertisement (RA) from a router. The MN uses an AP list to verify whether network layer handoff is needed or not after predicting link layer handoff. Each BS manages a neighbor BS information table to perform IP address reservation and to make an AP list for a MN. It consists of AP MAC addresses and network identifiers as shown in Table 1.

Table 1. Neighbor BS information table

Base station number	Access Point MAC address	Network ID
BS1	00:39:99:82:23:54	203.101.23.0/24
	00:34:94:12:23:52	
BS2	00:30:28:85:21:51	203.101.22.0/24

3.2 Address Reservation

After a MN detects handoff in the network layer, the MN sends a reservation request message to the current BS, BS1, as shown in

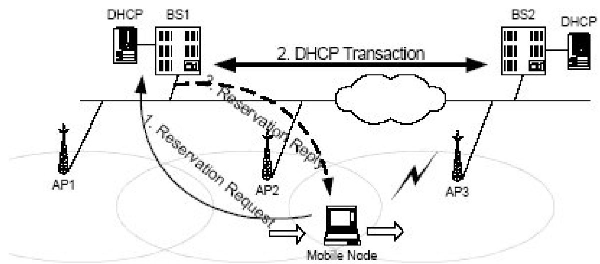

Figure 2. Address reservation procedure

Figure 2. BS1 confirms whether the predictive AP belongs to the same network or not. If the MAC address of the predictive AP is one of the APs in the same network, BS1 will send a layer 2 handoff (L2HO) message. Otherwise, BS1 performs the DHCP transaction with BS2 and then sends a reservation reply message of reservation acknowledgement that includes a reserved address to be used by the MN after the handoff.

3.3 Advance re-INVITE Procedure

When a MN gets a reserved address as described above, it sends a re-INVITE message to a CN with the reserved address before link layer handoff occurs as shown in Figure 1. The MN receives an OK message from the CN as a reply to the re-INVITE message. Subsequently, the CN creates another session with the reserved address and bi-casts packets for the MN through the new session and the existing one. This advance re-INVITE can reduce delay caused by session update procedure and the bi-casting can also lessen packet loss during handoff.

4. PERFORMANCE EVALUATION

We implemented the proposed mechanism on an experimental testbed. Following our measurements, the average inter-arrival time and the frame size appear about 20 milliseconds and 33 bytes, respectively, when GSM codec is used. When SIP mobility support is applied, the MN Rx transmission rate (at a receiver-side) falls into zero at about 1.8 seconds and rises up at 3.2 seconds in Figure 3. This represents a period that the MN could not receive packets from the CN. Thus, the handoff delay was estimated as about 1.4 seconds. Each delay described in Section 2 was measured. T1 took about 5 milliseconds. This delay is needed to detect link layer handoff, to send a Router Solicitation (RS) and to receive a Router Advertisement (RA). T2 took about 1.35 seconds, including the Duplication Address Detection (DAD) procedure. T3 including network interface and routing table

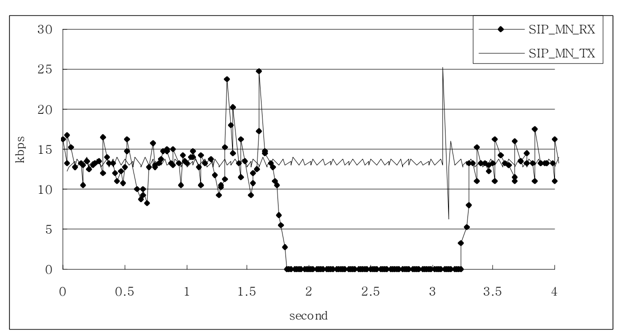

Figure 3. Transmission rate during a handoff (SIP)

configuration usually took 11 milliseconds. T4 varies with the distance between the participants. It took around 10 milliseconds in our testbed. With the measured results, SIP_Handoff_Delay = $\sum$ Tn (n=0 to 4) + RTT/2 = 50 ms + 5 ms + 1.35 sec + 10 ms + 10 ms + RTT/2 ≅ 1.4 sec.

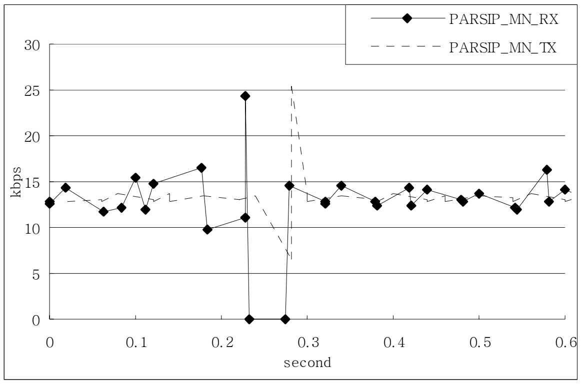

Figure 4. Transmission rate during a handoff (PAR-SIP)

Figures 4 show the transmission rate during handoff when PAR-SIP mid-call mobility is applied. The environment and methodology for this experiment are equivalent to those of the experiment with conventional SIP mid-call mobility. Therefore, the transmission rate variance appeared quite similar with that of the conventional SIP mobility. In PAR-SIP mid-call mobility, the handoff delay of receiving traffic was measured as about 60 milliseconds as shown in Figure 4.

With PAR-SIP mid-call mobility, the delay required for DHCP transaction and the re-INVITE procedure is not necessary since a MN proactively performs the address allocation and re-INVITE procedure before handoff. Thus, T2 and T4 values appeared zero. The total handoff delay can be estimated with the following: PAR-SIP_Handoff_Delay = SIP_Handoff_Delay - T2 –T4 = T0 + T1 + T3 + T5 = 50 ms + 1 ms + 7 ms + RTT/2 ≅ 60ms. This value illustrates that the PAR-SIP mobility guarantees reasonable handoff latency to communicate real-time data in wireless networks. As presented in our experimental results, PAR-SIP mobility significantly reduced handoff latency in both session ends below a hundred milliseconds.

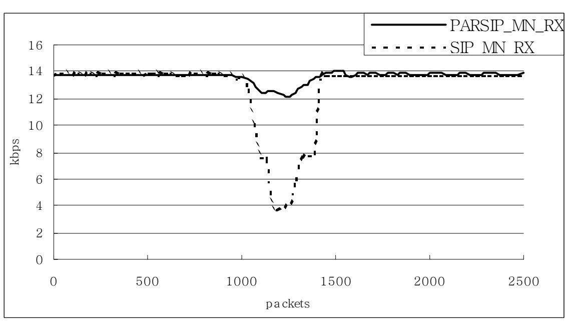

Figure 5. Comparison of the Average Transmission Rates

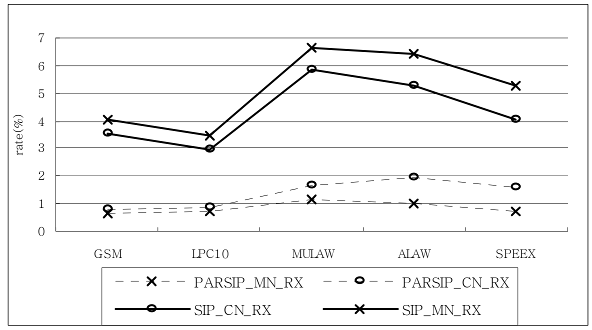

Figure 6. Comparison of the Average Packet Loss Rates

The average transmission rate was measured while a CN sent 2500 packets to a MN using conventional SIP and PAR-SIP mobility, respectively, in Figure 5. The average transmission rate of the SIP mobility dropped to 4 Kbps due to the handoff latency while the MN received 2500 packets. However, the average transmission rate of PARSIP mobility was only reduced by 2 Kbps during the handoff. Figure 6 shows the packet loss rates of SIP and PAR-SIP mid-call mobility where both nodes receive packets. We could observe that the packet loss rate of the proposed scheme was 1% on average while the packet loss rate of the SIP mobility appeared 5% on average.

5. CONCLUSION

In this paper, we have proposed a new mechanism, Predictive Address Reservation with SIP (PAR-SIP), which significantly reduces the handoff latency in SIP terminal mobility. PAR-SIP lessens the SIP handoff delay by performing the address allocation and session update processes proactively using link layer information of wireless networks.

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