Mobility Management Based on the Integration of Mobile IP and Session Initiation Protocol in Next Generation Mobile Data Networks

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Abstract—For a mobile node that uses both Mobile IP and Session Initiation Protocol (SIP), there is severe redundant registration overhead because the mobile node has to make location registration separately to the Home Agent for Mobile IP and to the Home Registrar for SIP. Therefore, we propose two new IP mobility management methods that integrate both Mobile IP and SIP. Performance comparisons are made among previous method, which makes separate registration for the Mobile IP and SIP without integration, and our two integrated methods. Numerical results show that proposed methods efficiently reduce the amount of signaling messages related to the location registration and handoff.

I. INTRODUCTION

Rapid adoption of the mobile and wireless communication technologies has led recently to significant attention being paid to mobile and wireless access to the internet. The development of next generation wireless systems, which are characterized by seamless worldwide communication and support of various multimedia services, has been accelerated along with the development of wireless internet. Standardization for fourth generation (4G) systems has already been discussed, and the future 4G systems are expected to be based on an all-IP solution. Moreover, strategies are now being taken to deliver wireless data applications and services to the mobile user over a packet-switched IP network and, ultimately, to reduce conventional circuit switching and cellular infrastructure. In such environments, it is critical to support seamless mobility of mobile terminals.

In this paper, we propose efficient IP mobility management methods integrating terminal mobility support functions of Mobile IP and SIP. The rest of this paper is organized as follows. We first review the previous works supporting IP mobility in Section 2. In Section 3, proposed efficient IP mobility management methods integrating Mobile IP and SIP are described. Performance evaluations are made in Section 4 and some numerical results are provided in Section 4. Finally, Section 5 presents conclusions.

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II. BACKGROUND AND RELATED WORKS

A. IP Mobility Support using Mobile IP

Currently, most solutions for wireless internet mobility are based on the Mobile IP standard in IETF [1]. When a mobile node (MN) is moving between IP subnets, Mobile IP is effective for providing transparent mobility, which hides changes in IP addresses for the application layer of the MN and the correspondent node (CN). Therefore, Mobile IP makes it possible to keep a TCP connection alive when the IP subnet of a MN changes. However, Mobile IP has a number of drawbacks, such as data encapsulation overhead and the usage of a unique IP address for each MN. In addition, Mobile IPv4 cannot avoid triangular routing, which increases routing delay for the traffic toward the MN. Further, although routing optimization is introduced, there still exist additional binding update and adjustment of the CN.

B. IP Mobility Support using SIP

Another IP mobility solution, which uses the SIP [2] has been studied by several researchers. Although SIP was developed initially for the signaling of multimedia sessions, it can be used for IP mobility support without much modification because it fundamentally supports personal mobility and service mobility. The adoption of SIP as an IP mobility solution has been proposed previously in [3] and [4]. When using SIP for mobility support, packet tunnelling and modification of protocol stack in the MN are no longer required. However, the SIP based mobility support method still has several problems to completely replace conventional Mobile IP, because SIP based IP mobility support requires some modification on the kernel level to trigger location registration in the application layer protocol from detection of L2 handoff [4]. In addition, SIP based mobility support method lacks the ability to maintain TCP connections for handoff case, because TCP connection should be re-established between CN and MN using newly allocated IP address or can be maintained by additional agent monitoring ongoing TCP connections [5].
C. Discussions

Although several wireless technical forums such as 3GPP, 3GPP2 and MWIF have chosen SIP as the signaling protocol of the mobile internet, SIP still has several problems to support terminal mobility as discussed in section II-B. Therefore, it is likely that most mobile nodes will adopt both Mobile IP for terminal mobility support and SIP for signaling protocol, respectively.

Fig. 1 describes the architecture of IP based mobile data network and Fig. 2 illustrates the signaling procedures for the location registration, SIP session setup and handoff when both Mobile IP and SIP protocols are adopted in the MN. If an MN using both Mobile IP and SIP changes its location, the MN performs twice location registration procedures to the Mobile IP Home Agent and SIP Home Registrar. However, the information included in the registration message is similar for both cases of Mobile IP registration and SIP registration, thus separate registrations for both Mobile IP and SIP are redundant and inefficient in view of utilizing radio resources and battery power of the mobile node. Also, this complex registration procedure raises severe packet loss and delay in handoff case. Therefore, it is very critical to devise an approach that integrates the functionalities related to the mobility support in Mobile IP and SIP. Such an approach ensures that IP mobility of a mobile node adopting both Mobile IP and SIP can be efficiently supported in the IP based mobile data networks.

III. PROPOSED MOBILITY MANAGEMENT METHOD INTEGRATING MOBILE IP AND SIP

In order to optimize redundant signaling traffics related to registration and handoff, we propose two mobility management methods integrating IP mobility support functionalities of Mobile IP and SIP. Mobile nodes having both Mobile IP and SIP are the concern of our integrated mobility management methods. Also, proposed methods should not modify conventional Mobile IP and SIP as much as possible to maintain compatibility with other mobile nodes not using our methods. Therefore, our proposed methods just make a little modification on the operating algorithm of mobile node and do not make any change in the protocol stacks of agent or server.

Each proposed method, which is differentiated according to the MN’s IP address used in the Contact field of SIP message header, is described in the following subsections.

A. Integrated Mobility Management Method using Mobile IP Home Address (INT-HA method)

INT-HA method integrates IP mobility support based on the Mobile IP. Mobile node using INT-HA performs only Mobile IP registration in case of terminal mobility and registers on the SIP Home Registrar only when the personality or service characteristics of the mobile node are changed. Therefore, mobile node does not make any registration on the SIP Home Registrar even in the subnet change. In INT-HA method, SIP Home Registrar maintains home address of mobile node.

Fig. 3 illustrates the signaling procedures when INT-HA method is applied in the network of Fig. 1. When a mobile node enters Foreign network A, the mobile node performs registration to the Home Agent with new care-of address (COA) allocated in the Foreign network A. Thus, Home Agent can keep track of the location of the mobile node.

Then, we consider SIP session setup procedures of INT-HA method. Because INT-HA method does not modify Mobile IP, we don’t need to consider normal IP packet transfer using Mobile IP. When correspondent node initiates SIP session setup toward the mobile node, it transmits SIP INVITE message to the home address of the mobile node stored in the SIP Home
Registrar. Therefore, **SIP INVITE** message is transferred to the current location of the mobile node through the Mobile IP protocol. When the mobile node receives **SIP INVITE** message, the mobile node sends **SIP Response 200 OK** message to the SIP Home Registrar directly. In INT-HA method, we intentionally set the **Contact** field of the **SIP Response** message header to the home address of the mobile node, even if the mobile node is not located in its home network. By doing so, INT-HA method can operate efficiently in case of handoff.

In case that the mobile node moves into another Foreign Network B from Foreign Network A with ongoing SIP session, the mobile node performs Mobile IP registration procedure. Shortly after completion of the Mobile IP registration, the mobile node can receive subsequent packets, because the correspondent node may transmit all packets to the home address of the mobile node without regard to the location change of the mobile node. Therefore, INT-HA method can effectively reduce handoff signaling and delay.

**INT-HA method** has a drawback that all packets from the correspondent node should be delivered via Mobile IP Home Agent using IP tunnelling. However, IP tunnelling is performed only in the wired link between Home Agent and Foreign Agent. Therefore, packet tunnelling overhead may not cause severe performance issue in large capacity wired link compared to the packet loss and delay that may be raised during handoff not using INT-HA method. Also, packet tunnelling is the inherent problem of Mobile IPv4 and can be solved when the network will evolve into the IPv6 based network.

**B. Integrated Mobility Management Method using Mobile IP Care-of Address (INT-COA method)**

INT-COA method integrates IP mobility support based on the Mobile IP, which is similar to the INT-HA method. Mobile node using INT-COA performs only Mobile IP registration in case of terminal mobility, and SIP registration is executed only in case of personal or service mobility. Therefore, SIP Home Registrar maintains home address of the mobile node and SIP session is established using home address. However, INT-COA method informs the correspondent node of the current location for the mobile node by setting the **Contact** field of the **SIP Response** message header to the care-of address. Thus, subsequent packets of SIP session can be delivered to the mobile node directly using new care-of address of the mobile node.

**Fig. 3. Signaling Procedure based on INT-HA method**

**Fig. 4. Signaling Procedure based on INT-COA method**
header. By doing so, it is possible for the correspondent node to transmit packets without IP tunnelling.

When the mobile node roams into another Foreign Network B with ongoing SIP session, the mobile node performs Mobile IP registration procedure. After Mobile IP registration is completed, the mobile node sends SIP Re-INVITE message to the correspondent node in order to inform the correspondent node of the changed care-of address. Then, subsequent packets can be transmitted by using new care-of address between the mobile node and the correspondent node.

INT-COA method does not raise IP tunnelling overhead in delivering SIP session traffics. However, INT-COA may cause additional delay and signaling message exchanges to inform the correspondent node of IP address change in case of handoff.

**IV. Performance Analysis**

In this section, we make analytic comparisons among the proposed INT-HA method, INT-COA method and conventional method supporting IP mobility by both Mobile IP and SIP without integration (NO-INT method). We investigate the overall performance in terms of signaling cost for the three events of initial registration, SIP session setup and handoff. Signaling cost is defined as the message traffics exchanged between network nodes during mobility management procedures. To analyze the performance of three comparative IP mobility support methods, we define signaling cost parameter between node A and node B as $C_{A-B}$. According to the signaling procedures in Fig. 2, 3 and 4, signaling costs of INT-HA, INT-COA and NO-INT methods can be evaluated.

Signaling cost for initial registration in each method, $C_{\text{regist}}$, is given as follows.

\[
C_{\text{regist}}(\text{NO-INT}) = 3c_{MN-FA} + 2c_{FA-HA} + 2c_{MN-HR} \tag{1}
\]

\[
C_{\text{regist}}(\text{INT-HA}) = 3c_{MN-FA} + 2c_{FA-HA} \tag{2}
\]

\[
C_{\text{regist}}(\text{INT-COA}) = 3c_{MN-FA} + 2c_{FA-HA} + 2c_{MN-CN} \tag{3}
\]

Also, signaling cost involved in the SIP session setup, $C_{\text{setup}}$, is given as follows.

\[
C_{\text{setup}}(\text{NO-INT}) = 2c_{HR-CN} + 2c_{MN-HR} \tag{4}
\]

\[
C_{\text{setup}}(\text{INT-HA}) = 2c_{HR-CN} + c_{HA-HR} + c_{FA-HA} + c_{MN-FA} + c_{MN-HR} \tag{5}
\]

\[
C_{\text{setup}}(\text{INT-COA}) = 2c_{HR-CN} + c_{HA-HR} + c_{FA-HA} + c_{MN-FA} + c_{MN-HR} \tag{6}
\]

Similarly, signaling cost for the active handoff in each method, $C_{\text{handoff}}$, can be obtained by

\[
C_{\text{handoff}}(\text{NO-INT}) = 3c_{MN-FA} + 2c_{FA-HA} + 2c_{MN-HR} \tag{7}
\]

\[
C_{\text{handoff}}(\text{INT-HA}) = 2c_{MN-FA} + 2c_{FA-HA} \tag{8}
\]

\[
C_{\text{handoff}}(\text{INT-COA}) = 3c_{MN-FA} + 2c_{FA-HA} + 2c_{MN-CN} \tag{9}
\]

Let $\lambda_s$ be session arrival rate for a mobile node and $\lambda_m$ be location update rate proportional to user mobility. Based on the signaling costs in equations (1) ~ (6), average signaling cost for the location registration and SIP session setup, $C_{\text{ave-CMR}}$, can be defined by

\[
C_{\text{ave-CMR}} = \lambda_m \cdot C_{\text{regist}} + \lambda_s \cdot C_{\text{setup}} \tag{10}
\]

where CMR (Call-to-Mobility Ratio) denotes the ratio of the session arrival rate $\lambda_s$ to the location update rate $\lambda_m$ [6].

Now, we define $\alpha$ as the active handoff probability that an MN will move into another network with active session. Then, average signaling cost for the active handoff and the idle handoff, $C_{\text{ave-activity}}$, can be obtained by the weighted sum of $C_{\text{regist}}$ and $C_{\text{handoff}}$ as follows.

\[
C_{\text{ave-activity}} = (1 - \alpha) \cdot C_{\text{regist}} + \alpha \cdot C_{\text{handoff}} \tag{11}
\]

**V. Numerical Results**

In this section, numerical results are provided to demonstrate the performance of proposed IP mobility management methods integrating Mobile IP and SIP. We consider two sets of signaling cost parameters given in Table I. In case of Set 1, signaling cost is the same as the summation of the number of exchanged signaling message during signaling procedure, because all signaling cost parameters are assumed to be one. Set 2 denotes the case when the signaling costs between foreign network and home network are assumed to be high considering the distance between two networks.

<table>
<thead>
<tr>
<th>TABLE I</th>
<th>SETS OF SIGNALLING COST PARAMETERS</th>
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<tbody>
<tr>
<td>Signalling cost parameters</td>
<td>Set 1</td>
</tr>
<tr>
<td>$c_{MN-FA}$</td>
<td>1</td>
</tr>
<tr>
<td>$c_{FA-HA}$</td>
<td>1</td>
</tr>
<tr>
<td>$c_{HA-HR}$</td>
<td>1</td>
</tr>
<tr>
<td>$c_{MN-HR}$</td>
<td>1</td>
</tr>
<tr>
<td>$c_{HR-CN}$</td>
<td>1</td>
</tr>
<tr>
<td>$c_{MN-CN}$</td>
<td>1</td>
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</tbody>
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Fig. 5 shows the effect of Call-to-Mobility Ratio on the average signaling cost related to the location registration and SIP session setup for the Set 1 in Table I. It can be seen that the average signaling costs of the INT-HA method and INT-COA method are lower than that of the NO-INT method, when the CMR is smaller than 1. Our proposed schemes can reduce signaling cost for the location registration, thus they are very effective when the mobility rate of mobile node dominates.
the session arrival rate. In contrast, NO-INT method has lower signaling cost for high CMR. Since NO-INT method performs location registration to both the Mobile IP Home Agent and SIP Home Registrar separately, signaling message related to SIP session setup can be routed to the mobile node without making access to the Home Agent of the MN.

Fig. 6 represents the average signaling cost when we assume the signaling cost between foreign network and home network to be high compared to that of intra network signaling. We can see that both INT-HA method and INT-COA method outperform NO-INT method, regardless of the value of CMR.

Fig. 7 represents the average signaling cost according as the active handoff probability of mobile node increases. Since INT-HA method performs only Mobile IP registration whether mobile node has ongoing session or not, the average signaling cost of INT-HA method is constant and the lowest among three methods, without regard to the value of $\alpha$. The signaling cost in case of idle handoff of INT-COA method is the same as that of INT-HA method, because both methods operate with the same manner when mobile node moves from one network to another network without continuing session. However, the signaling cost of INT-COA method increases according to the increase of $\alpha$ because mobile node adopting INT-COA method should execute additional SIP Re-INVITE procedure to maintain ongoing session. NO-INT method has the highest signaling cost for all range of active handoff probability because it performs complex registration procedures for both Mobile IP and SIP protocols. Also, NO-INT method should register to the SIP Home Registrar after completion of the handoff signaling between correspondent node and mobile node.

VI. CONCLUSIONS

In this paper, we introduced two mobility management methods integrating IP mobility support functions of Mobile IP and SIP. Both INT-HA method and INT-COA method can efficiently reduce signaling messages related to location registration. Also, our INT-HA method and INT-COA method can be easily implemented in the mobile node with simple algorithm that disables the registration function of SIP in case of location change. Especially, INT-HA method is expected to be promising candidate for the IP mobility support method in the IP based network adopting both Mobile IP and SIP. In fact, INT-HA method can be easily implemented in real networks with maintaining compatibility and significantly reduce the signaling traffics for the location registration and active handoff, even if it has a little traffic tunnelling overhead.

REFERENCES