

Region-based Shadow Registration Scheme for Efficient Mobility Management in the SIP

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In the session-initiated protocol (SIP) for wireless networks, delays and disruptions that occur during the handoff of nodes are related to authentication, authorization, and accounting (AAA). Various schemes have been proposed to reduce these handoff delays, and one such proposal, shadow registration in adjacent cells, has been adopted. Shadow registration reduces handoff delays by preregistering a cell with all of its neighboring cells. However, preregistering with multiple adjacent cells significantly increases both the amount of network traffic and the corresponding waste of network resources. This paper introduces region-based shadow registration (RSR) for efficient mobility management in mobile SIP environments. The proposed scheme performs shadow registration with neighboring cells selectively, only when it is necessary at the FAAA level. In an experiment implementing the system, we show that it reduces handoff latency while decreasing excessive signaling traffic during shadow registration.

Keywords: delay, handoff, mobility management, shadow registration, SIP

1. INTRODUCTION

Most studies examining the support of efficient mobility in a mobile session-initiated protocol (SIP) environment have focused on the handoff of radio links between cells. In a commercial SIP session, most handoff delays are related to authentication, authorization, and accounting (AAA). Shadow registration was proposed to reduce handoff delay [1]. The basic concept of shadow registration is to complete the AAA-related registration of a cell with all of its neighboring cells before a handoff occurs. This can speed up message exchange. However, the technique fails to consider SIP environments that provide mobility in the application layer, and the added costs of delivering the information to all neighboring cells and in managing the information make the system impractical.

We propose a region-based shadow registration (RSR) method, which divides a cell into a number of regions and executes a shadow registration only when the mobile node (MN) is in a region that has a high probability of receiving a handoff. The technique uses an algorithm to divide a cell into regions and determine the location of the MN. First, a cell is split into two zones, using two concentric circles based on the strength of the radio signal from the base station (BS) at the center of the cell. Then the outer zone is divided into three sectors based on the beam section of the antenna. The four resulting cell regions are then used for shadow registration. The results of a simulated network with multiple mobile nodes show that the system can achieve the same reduction in handoff delay as simple shadow registration, but also significantly reduce network registration traffic.

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The rest of this paper is organized as follows: In section 2, we review related systems and discuss their advantages and disadvantages. Section 3 describes the proposed RSR technique. Section 4 presents the results of an experiment designed to compare the technique with existing approaches. Finally, section 5 discusses our conclusions.

2. RELATED WORK

2.1 Mobility Management

The Internet Engineering Task Force (IETF) has standardized IP mobility support, which provides transparent mobility by hiding the change of IP address when the MN is moving between IP subnets. Mobility management protocols used in IP-based communication networks include Mobile IP, SIP, and H.323. Mobile IP is designed to solve mobility issues in the network layer, while SIP and H.323 address mobility in the application layer [2]. In the mobile/wireless environment, mobility must be seamless, and to provide high-quality multimedia services it is important to minimize any delay or disruption time. If users experience frequent delays or disruptions during voice conversations, for example, they will have a lower opinion of that mobile/wireless system.

2.2 Delay Analysis in Handoff

Mobile SIP has been extended to provide presence, event notification, and instant messaging services [2]. As depicted in Fig. 1, to support a mobile environment for SIP users, a structure that combines SIP, dynamic host configuration protocol (DHCP) [3], and AAA protocol is used. The MN, which is a user agent client whose address is provided by the foreign network, uses DHCP. The visited registrar (VR) and home registrar (HR) are assumed to be a combination of the outgoing/incoming SIP proxy server, the location server, and the user agent server [4-6]. CN is the corresponding node that communicates with the MN.

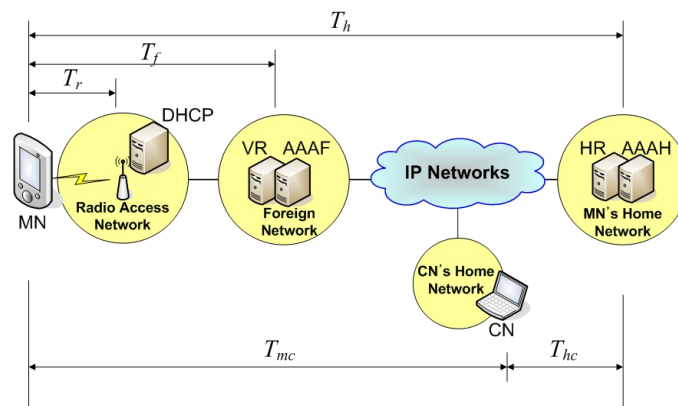


Fig. 1. A simple model for delay analysis in mobile SIP.

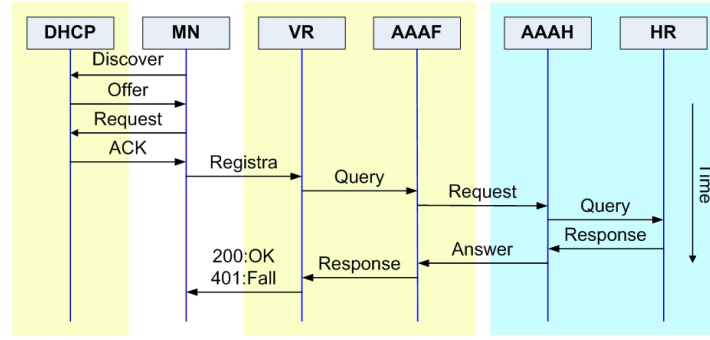


Fig. 2. SIP registration for handoff.

In addition, we assume that T represents the delay in transmitting a message among nodes (Fig. 1), and that the effect of QoS and other factors on the system are negligible. Therefore, we focus only on periods related to signaling delay.

T_r : delay between MN and the DHCP server

T_f : delay between MN and the AAAF server

T_h : delay between MN and the home network

T_{mc} : delay between MN and CN

T_{hc} : delay between MN Home Network and CN

Fig. 2 shows the flow of signals for a SIP registration. The MN broadcasts a DHCP_DISCOVER message to the DHCP servers, several of which may offer a new address to the MN via a DHCP_OFFER. Then, the MN sends a DHCP_REQUEST to the selected server [4]. Finally, the DHCP server sends a DHCP_ACK to the MN. This takes $4T_r$. The assignment of an IP address to the MN by the DHCP server initiates the signal flow for a general SIP registration in the foreign network. The MN sends a registration message to its HR, which takes $2T_h$. Then, the MN re-invites the CN by sending an INVITE message, which takes $2T_{mc}$. Therefore, in a SIP intercell handoff, the total delay time (T_{sip_reg}) can be expressed as follows:

$$T_{sip_reg} = 4T_r + 2T_h + 2T_{mc}. \quad (1)$$

2.3 Advantages and Limitations of Shadow Registration

Shadow registration was proposed to reduce disruption time during macro-mobility (inter-domain) handoff, which occurs whenever a user moves from one administrative domain to another. Therefore, a user of a MN must be identified and authenticated, and interact with the AAA server of the home network. Shadow registration is a security association between the MN and the AAA server of neighboring cells, established a priori before the actual handoff. Therefore, when a MN's handoff to a neighboring cell occurs, the registration request is processed locally within that cell without having to contact the AAA of the home network (AAAH). The basic signaling mechanism of shadow registration is shown in Fig. 3. When a MN triggers its registration on a given foreign network,

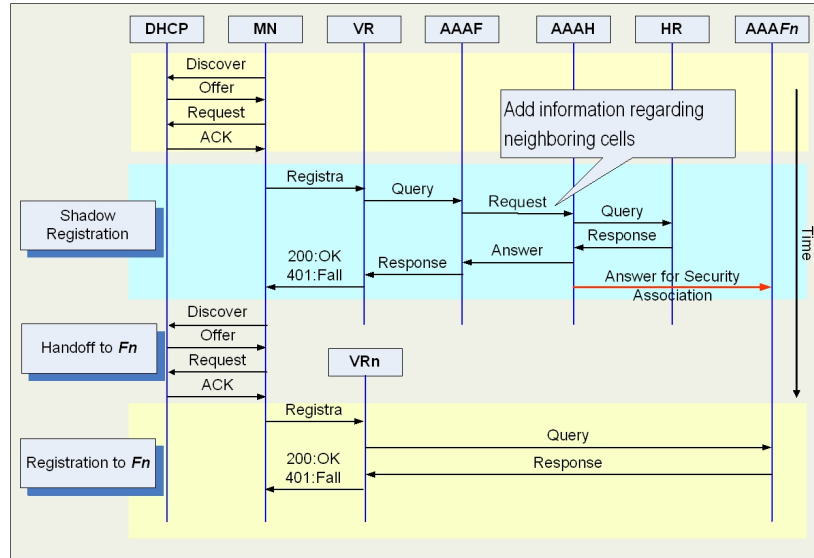


Fig. 3. SIP handoff with shadow registration.

the AAA of the foreign network (AAAF) sends the REQUEST message, including information about all of its neighboring AAA servers or neighboring cells, to the AAAH. The AAAH stores this information and, after receiving a reply from the HR, identifies which neighboring AAA servers are available to the MN. Then, it sends the ANSWER message to those AAA servers for shadow registration; these messages are in addition to those required for normal registration (Fig. 2). As with standard SIP shadow registration, the DHCP requires $4T_r$. However, in the proposed system, the AAAF can respond to the MN's registration message without having to contact the AAAH server. The REGISTER message is processed in the local AAAF and VR, which takes $2T_f$. Finally, the MN re-invites the CN by sending a SIP INVITE message that takes $2T_{mc}$. Therefore, the total disruption time, $T_{SIP_Shadow_reg}$, can be formulated as follows:

$$T_{SIP_Shadow_reg} = 4T_r + 2T_f + 2T_{mc}. \quad (2)$$

Eq. (2) expresses the handoff delay after shadow registration. Because AAAF requests pre-handoff registration at AAAH, which has a security association with AAAF_n, the actual handoff does not contribute to the delay. The difference between Eqs. (1) and (2) is that the destination of the message exchanged with the AAA server is switched from the home network to the foreign network. It takes T_h at T_{sip_reg} , but only T_f at $T_{SIP_Shadow_reg}$. The delay in a general SIP registration, T_h , reflects the time necessary to exchange a message between the MN and the home network. In shadow registration, it is the delay in message exchange between the MN and the foreign network, T_f , which does not consider the characteristics of the MN's movement. All MN movement, even when it is not related to a handoff, has to be registered in advance, at n neighboring cells. Consequently, the existing shadow registration technique causes an excessive amount of network traffic. If multiple MNs attempt to complete a shadow registration at a given cell

simultaneously, the corresponding FA will become congested with traffic. Hence, the existing shadow registration technique is not practical [7].

3. REGION-BASED SHADOW REGISTRATION (RSR)

3.1 System Model

Fig. 4 shows the general mobile computing architecture, which consists of the fixed/wireless network, fixed node (FN), MN, and BS [8, 9]. The BS with radio interface is linked to the IP network, which is a fixed network. One cell is a logical or geographical area managed by a BS. The MN can move while connecting to the network, and should have radio communication with the BS of the cell in which it stays to exchange information with fixed nodes or other MNs.

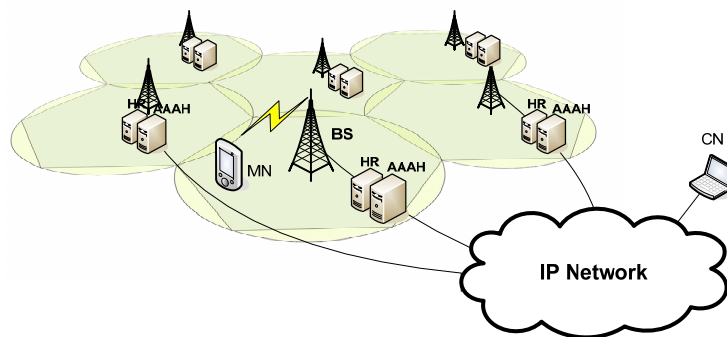


Fig. 4. Mobile computing architecture.

In addition, the system must be designed considering user mobility. Our system uses a hexagonal cell model divided into a geographical unit managed by one BS.

3.2 Regional Cell Sectoring

The RSR method overcomes the network congestion problem associated with simple shadow registration. In the real world, MN users usually spend a long time at a specific location, moving only within a narrow space without leaving the boundary of the service area. The basic concept of the RSR technique is to divide a cell into a number of regions. Then, based on the current cell region of the MN, further shadow registration is temporarily suspended for MNs whose cell center is unlikely to change imminently. The outer zone of a cell is divided into three regions based on the beam section of the antenna. Shadow registration is activated only for the two adjacent cells with the highest probability of a handoff in the near future.

In Fig. 5, if the MN is in sector *a*, it can move only to sector *b*, sector *c*, cell 1, or cell 2. If the MN moves to sector *b* or sector *c*, it is an intra-cell handoff that does not require AAA-related registration. Therefore, shadow registration is performed only with cells 1 and 2. When a MN is positioned inside a cell core, the probability of a handoff

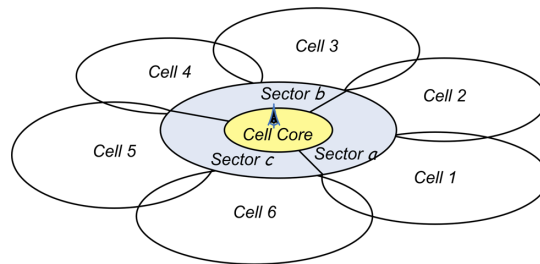


Fig. 5. Division of a cell using antenna sector and signal strength.

between cells is low. A handoff is necessary only when the MN moves toward the outer area of the cell. Therefore, as long as the MN stays within the cell core, no shadow registrations are made.

3.3 MN Location and Speed Measurement

To decide whether to execute shadow registration, it is important to know the location of the MN within the cell. Many technologies for locating MNs have been developed. Of them, angle of arrival (AOA) and time of arrival (TOA) are network-based position-sensing technologies that consider that the MN signal is received not only by the BS of the current cell but also by the BS of neighboring cells, the global positioning-assisted system (A-GPS) uses GPS, and enhanced observed time difference (E-OTD) combines network-based technology and MN-based positioning technology. However, these technologies represent the position of a MN in 2-dimensional or 3-dimensional coordinates, and are costly to implement. In the proposed system, it is only necessary to discern whether a MN is in the cell core or on its periphery, *i.e.*, a much simpler 1-dimensional distance.

In cellular systems, the simplest method of measuring the distance between a BS and a MN is estimating the distance using the received signal strength indication (RSSI) received by the MN [10]. However, RSSI is unstable in most cellular systems because the MN receives not only direct waves but also countless reflected waves via multiple paths. Moreover, diffraction and attenuation caused by fading and changing geographical features (*e.g.*, moving from an urban to suburban environment) may also deteriorate estimation accuracy. To address these problems, we measured the distance between the BS and the MN using the empirical propagation path loss model. This requires information on transmission power and the geographical environment (*e.g.*, urban, suburban, rural) of the cell and cell size. We assumed that these data were provided by the BS when the MN was registered at the first cell.

Propagation models are used extensively in network modeling, particularly for conducting feasibility studies and during cell design. These models can be broadly categorized into three types: empirical, deterministic, and stochastic. Empirical models are those based on observations and measurements alone. They can be split into two sub-categories, namely, time dispersive and non-time dispersive. The former are designed to provide information relating to the time dispersive characteristics of the channel, *i.e.*, the multipath delay spread of the channel. An example of this type is the Stanford University

Interim (SUI) channel model developed under the Institute of Electrical and Electronic Engineers (IEEE) 802.16 working group [11]. Examples of non-time dispersive empirical models are ITU-R, Hata, and the COST-231 Hata model [12-14]. All of these models predict mean path loss as a function of various parameters (*e.g.*, distance, antenna height) [15]. We chose the COST-231 Hata Model for our system because it is widely used for predicting path loss in mobile wireless systems. This model is an extension of the Hata-Okumura model, and is designed to be used within the 500-2000 MHz frequency band [12, 14]. It also contains corrections for urban, suburban, and rural (flat) environments. Although its frequency range is outside that of the measurements, its simplicity and the availability of correction factors has made it widely used for path loss prediction in this frequency band [14]. The basic equation for path loss in dB is as follows:

$$PL = 46.3 + 33.9 \log_{10}(f) - 13.82 \log_{10}(h_b) - ah_m + (44.9 - 6.55 \log_{10}(h_b)) \log_{10} d + C_m, \quad (7)$$

where f is the frequency in MHz, d is the distance between the BS and the MN antennae in kilometers, and h_b is the BS antenna height above ground level in meters. The parameter c_m is defined as 0 dB for suburban or open environments, and 3 dB for urban environments. The parameter ah_m is defined for urban environments as [14, 16]

$$ah_m = 3.20(\log_{10}(11.75h_r))^2 - 4.97, \text{ for } f > 400 \text{ MHz} \quad (8)$$

and for suburban or rural (flat) environments as

$$ah_m = (1.1 \log_{10} f - 0.7)h_r - (1.56 \log_{10} f - 0.8), \quad (9)$$

where, h_r is the MN antenna height above ground level.

Considering Eqs. (7) through (9), the path loss exponent of the predictions made by the COST-231 Hata model can be calculated as

$${}^n\text{COST} = (44.9 - 6.55 \log_{10}(h_b))/10. \quad (10)$$

In wireless networks, information about the cell is contained in the beacon and sent together with registration information. Distance d can be calculated, based on Eq. (7), as follows:

$$d = 10^{\frac{(PL - 46.3 - 33.9 \log f + 13.82 \log h_b + ah_m) - C_m}{44.9 - 6.55 \log h_b}} \quad (11)$$

where f is the frequency from 150 to 1500 MHz, h_b is the effective transmitter antenna height from 30 to 200 m, and ah_m is a correction factor for effective mobile antenna height, which is a function of the coverage area.

In addition, the MN must receive an appropriate standard signal from the BS and measure the strength of the signal. In IP wireless networks such as IEEE 802.x, for which output power is constant, beacon or currently received signals can be measured. However, in networks for which output power is not constant, such as CDMA, a different method

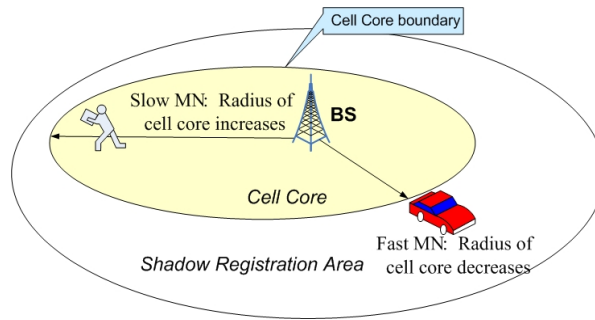


Fig. 6. The cell core is sized by the speed of the MN's movement.

has to be used. Therefore, pilot channels are used instead of beacons in CDMA networks. When a MN is connected to a BS through a pilot channel, it can choose the highest signal received, synchronize itself with it, and locate the nearest base station. In addition, because a mobile station considers a connection without any information on the BS, it sends only the short code of the BS spread to Walsh code 0 without any data at constant output power [17]. Therefore, in CDMA, a MN can calculate the distance between itself and a BS stably as it receives and measures the pilot channel periodically.

For RSR, the current position of a MN is classified into four categories: inside the cell core, Sector a outside the cell core, Sector b outside the cell core, and Sector c outside the cell core. It is necessary to discern which of the four positions a MN belongs to at present. When $R_{cell-core}$ is the radius of the cell core and d is the distance between the MN and the BS, if $d < R_{cell-core}$ or $d = R_{cell-core}$, the MN is considered inside the cell core. If $d > R_{cell-core}$, it is considered in a registration zone outside the cell core. The MN's region can be identified by determining which sector antenna is active. Cellular systems use a different frequency channel between sectors and require an inter-sector handoff [18, 19].

The size of the cell core does not have to be equal for all MNs. If a MN is moving quickly to the outer region of a cell, the shadow registration area outside the cell core should be increased to allow time for registration, thereby concurrently reducing the size of the core. In contrast, if a MN is moving slowly toward the outer region, the cell core can be large. Here, the speed of the MN (V_m) includes both the moving speed and the rate at which it is moving from the center of the cell (BS) to the periphery. If the MN is making concentric circles around the cell core, its moving speed toward the outer region will be 0. Because a MN measures its distance from the BS periodically, the speed of a MN moving to the outer side V_m is expressed as follows:

$$V_m = \frac{d_t - d_{(t-1)}}{t_{init}}, \quad (12)$$

where d_t is the most recently measured distance between the BS and the MN, $d_{(t-1)}$ is the distance between the BS and the MN measured just before measuring d_t , and t_{init} is the time interval between the two measurements of the distance between the BS and the MN. Thus, $R_{cell-core}$, the radius of the cell core considering shadow registration time and the speed at which the MN is moving outward, can be expressed as follows:

$$R_{cell-core} = R_{cell} - (V_m * (T_{sh} + T_{margin})), \quad (13)$$

where R_{cell} is the radius of the cell, V_m is the speed at which the MN is moving toward the outer region, T_{sh} is the time for the shadow registration of the MN (see Eq. (2)), and T_{margin} is the extra time for stable shadow registration in case the MN suddenly changes direction or speed.

3.4 Algorithm for RSR

The basic concepts of the proposed RSR algorithm are as follows.

1. When a MN enters a new cell, it registers itself and receives information about the environment of the cell (*e.g.*, its size, RF power of the beacon, antenna height).
2. The MN regularly measures d (distance between the BS and the MN) by executing Eq. (11), and compares the results to the radius of the cell core. If it is still inside the cell core, the MN does not take any other action except for its regular check on location.
3. If the MN continues to move, it can judge when it has left the cell core by determining whether the measured d is larger than the radius of the cell core. If it is, then a shadow registration is required for the handoff.
4. The MN checks whether a shadow registration has been made with the adjacent cells. If not, it performs a shadow registration with the appropriate cells.
5. As the MN continues to move, and eventually performs a handoff to another cell, a RSR is completed for the new cell.
6. If the MN moves to a new outer region in its current cell, it must also complete a RSR. The process is then repeated for the new cell.

The following data structures are used in the algorithm.

- **Loc_Cell**: Current cell ID of the MN and cell environment parameters
- **Loc_Sector**: Current sector of the MN
- **Neigh_FA**: Neighboring cell ID of the current sector
- **Prev_Reg**: Already registered cell ID
- **Rad_cell-core**: Cell core size (its radius)

The pseudocode of the proposed algorithm is as follows:

RsrMain()

Begin

Whenever a new cell ID is acquired **do**

Loc_Cell = Get current cell ID

Loc_Sector = Get current sector ID

Call MN_Location()

// Judge whether the MN is inside cell core

If (the MN is outside cell core)

Query (Neigh_FAs)

 // Query information for neighboring cells

If (Prev_Reg ≠ Neigh_FA)

```

    Call ShadowReg( )
    Prev_Reg = Neigh_FA
  End If
End If
Repeat RsrMain
End RsrMain
MN_Location( )
Begin
  P = RSSI( )
  // Measure for RSSI
  D = distance(PL)
  // Compute distance between the MN and the BS
  If (Rad_cell-core > D)
    Location of the MN = inside cell core
  Else
    Location of the MN = outside cell core
  Endif
End MN_Location

```

3.5 Expected Performance and Cost

The delay time of the RSR is identical to that of simple shadow registration. Both techniques perform security association (SA) with the neighboring cells in the AAAF and AAAH before the actual handoff. Therefore, this delay time does not change during handoff. However, the RSR method minimizes the handoff latency and backbone signaling.

Simple shadow registration assumes an equal probability of moving to all neighboring cells, as shown in Fig. 7 (a). For each cell through which the MN passes, shadow registration must be performed in six adjacent cells. Thus, if the MN passes through a series of eight cells, including the starting and destination cells, 48 shadow registrations

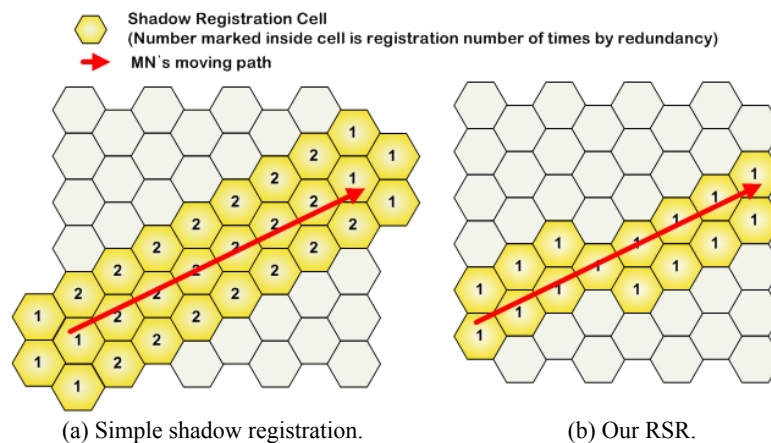


Fig. 7. Shadow registration results using a MN's path.

are performed en route. In contrast, the RSR methodology requires shadow registration in only two neighboring cells of each current cell. Moreover, cells are not reregistered, *i.e.*, a registered cell does not need to be registered again. Thus, if a destination cell has no probability handoff, the journey through eight cells requires a total of only 15 registrations. In addition, if a MN is not moving and remains near the cell core, no shadow registrations are performed, further reducing network traffic. We considered the following network traffic categories:

- D_r : Number of messages that MN exchanges with the DHCP server of the visited network to obtain a new address.
 - The MN broadcasts DHCP_DISCOVER to the DHCP servers.
 - The DHCP server may offer a new address to the MN via DHCP_OFFER.
 - The MN sends a DHCP_REQUEST to the DHCP server.
 - The DHCP server sends DHCP_ACK.
- D_f : Number of messages that MN exchanges with VR of the visited network for registration and authentication.
 - The MN sends a SIP REGISTER message to the VR.
 - The VR sends a Diameter-compliant message.
- D_{fh} : Number of messages that AAAF exchanges with HR of the home network for authentication.
 - The AAA entity (AAAF) of the visited network sends a request (Diameter-compliant message) to the AAA entity (AAAH) of the home network.
 - The AAAH queries the HR and gets a reply from the HR, and then sends the appropriate answer to the AAAF.
 - The AAAF sends an appropriate response to the VR.
- D_{mc} : Number of messages that MN exchanges with CN to initiate the SIP session.
 - The MN can initiate the SIP session by sending the INVITE message to the CN.
 - Then the CN responds with a SIP OK message.
- D_i : Number of messages that the AAAF exchanges with the HA for the information of neighboring cells.
- D_{SA} : Number of messages that the HA exchanges with AAAF_n to acquire a security association.

Table 1. Comparison of traffic in each method.

Method	Traffic
SIP registration	$D_r + D_h + D_{mc}$
Simple shadow registration	$D_r + D_f + D_{mc} + 6(D_i + D_{SA})$
Our RSR	$D_r + D_f + D_{mc} + 2(D_i + D_{SA})$

Table 1 compares the traffic for a handoff using each method.

Given that D_{SA} is the size of the data set interchanged between the AAAH and AAAF_n for a SA with neighboring cells, and n is the number of neighboring cells, the RSR method reduces network traffic by a factor of $(n - 2)D_{SA}$ compared to simple shadow registration.

However, the methodology incurs some inevitable costs. To measure the position

and speed of a MN, upon registration the MN has to receive information such as the transmission power of the beacon, the geographical environment of the cell (*e.g.*, urban, suburban), and the cell radius. In typical mobile cellular networks, information such as channel information is exchanged when a MN is registered at a cell, so data such as that listed above could be received as additional information. Each BS should maintain not only information about its own cell environment but also information about neighboring cells. Since these are fixed data that are defined when the BS is built, this requirement would not burden the network.

4. PERFORMANCE EVALUATION

We conducted two experiments to evaluate the performance of the proposed RSR. The first focused on delay time, comparing the RSR method to general SIP registration and simple shadow registration. The second experiment addressed network traffic, comparing the RSR technique to simple shadow registration. A simulation environment, consisting of 100 cells divided as described above, was created that assumed the SIP structure shown in Fig. 1. We chose a honeycomb-like cell organization, *i.e.*, abutting hexagons filling a 2D plane. Radio transmission ranges were modeled as (minimal) circles enclosing the cells.

We used walking models, a random waypoint model, and a random direction model [20] to consider mobility regions of various sizes, *i.e.*, squares ranging from cell dimensions to infinity. MNs moved (piecewise) in straight lines within the preset boundaries, possibly coming to rest at their final destination, even if their current call was ongoing. One hundred MNs were produced, following an input rate with a Poisson distribution. Velocities were governed by a uniform distribution.

Each parameter to apply in an experiment must reflect real-life. But, actuality parameters show much difference according to performance of end systems and processing capability of networks [21]. So, we try to refer result that come in testbed that is consisted of standard system and decide parameter. A. Dutta, J. C. Chen, *et al.* proposed different techniques associated with building a wireless Internet testbed [22]. It touches upon the realization steps for real-life Internet roaming, by providing the implementation details of several components associated with the testbed.

However, improved performance of server and increased speed of network are not appropriately reflected to the result values. Only 40msec is required for the SIP Call setup if using the latest server technology [23]. We regard the processing delay of each entity as 20msec, each user's bandwidth as 9.6kbps and round trip time (RTT) between routers used for the internet as 140msec respectively in consideration of improved speed of server and network and result values [22]. We also assume that the processing delay of entities such as MN, HR, VR and CN is same [24]. Also, traffic means the volume of data used when sending the message via a textual encoding method. Table 2 shows the parameter values.

The simulation was implemented using Linux, and data were analyzed using a statistical analysis program.

The total of all handoff delay times created as each MN traveled its given path is shown in Fig. 8. As path length and intercell handoffs increased, so did the delay time across all methods. However, the delay times of general SIP registration were larger than

Table 2. Parameter values.

Parameters	Symbol	Value
T_r	delay between MN and the DHCP server	160msec
T_f	delay between MN and the AAAF server	200msec
T_h	delay between MN and the home network	$200 + (180 * \text{number of hops})$ msec
T_{mc}	delay between MN and CN	$380 + (180 * \text{number of hops})$
T_{hc}	delay between MN Home Network and CN	180 msec
D_r	Number of messages that MN exchanges with the DHCP server of the visited network	620 byte
D_f	Number of messages that MN exchanges with VR of the visited network	860 byte
D_{fh}	Number of messages that AAAF exchanges with HR of the home network for authentication	860 byte
D_{mc}	Number of messages that MN exchanges with CN to initiate the SIP session	620 byte
D_i	Number of messages that the AAAF exchanges with the HA for the information of neighboring cells	550 byte
D_{SA}	Number of messages that the HA exchanges with AAAF n to acquire a security association	860 byte

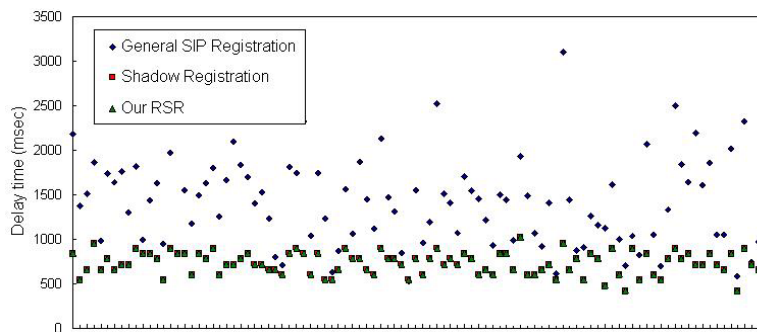


Fig. 8. Delay times for MN handoffs.

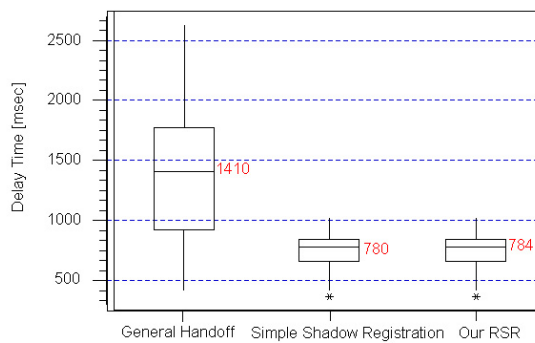


Fig. 9. Box plot of delay times.

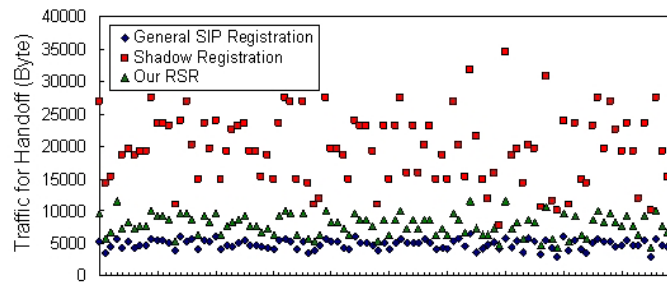


Fig. 10. Network traffic for each MN handoff.

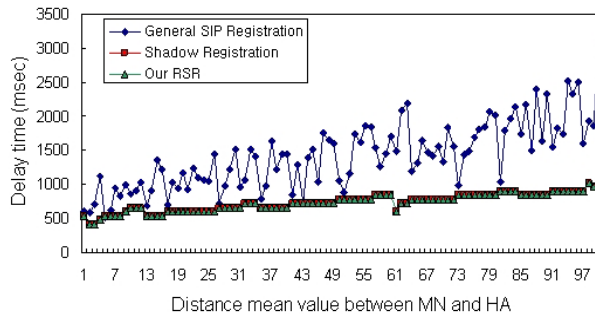


Fig. 11. Changes in delay time according to distance between the MN and HR.

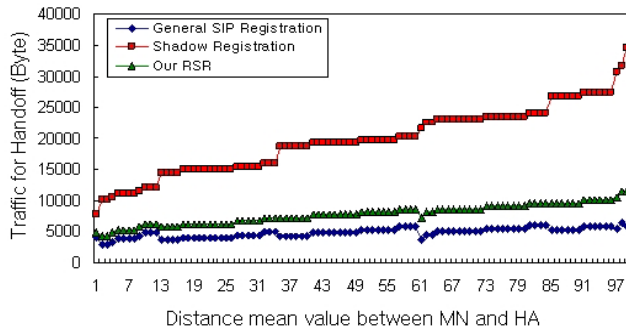


Fig. 12. Changes in network traffic according to distance between the MN and HR.

those of simple shadow registration, while simple shadow registration and the RSR method had identical delay times for all simulations. Fig. 9 shows the delay time of each MN in a box plot. The delay characteristics of RSR are almost identical to those of simple shadow registration.

Fig. 10 shows the sum of all network traffic during the handoff of a MN. When the number of intercell handoffs is high, so is network traffic. However, when the MN travels only between the sectors of a single cell, network traffic is low. When only the amount of network traffic is considered, the RSR method produces less traffic than simple shadow registration. Obviously, general SIP registration creates the least amount of network traffic.

Figs. 11 and 12 show changes in the delay time and network traffic corresponding to the distance between the MN and the HR. As the distance increases, there is a corresponding reduction in delay time for simple shadow registration, and in both delay time and network traffic for the RSR technique.

General SIP registration has a delay time of T_h , which is the time for a message exchange to occur between the MN and its home network. However, this does not cause any additional network traffic or data management costs. By contrast, simple shadow registration has a time delay of only T_f , which is the time for a message exchange to occur between the MN and its foreign network. This does cause additional network traffic and data management costs in direct proportion to the number of neighboring cells involved in each handoff. The proposed RSR method shortens the delay time to T_f . Furthermore, it reduces network traffic and data management costs by a factor of at least $n - 2$. In addition, when the MN remains in a cell core, no handoffs occur, thereby further reducing network traffic.

5. CONCLUSION

We presented a scheme that divides cells into three sectors and two zones. The four regions thus created are used to overcome excessive network traffic associated with simple shadow registration. The modified shadow registration technique, called region-based shadow registration (RSR), considers the minimum number of neighboring cells in each region. Moreover, if the MN stays within a cell core, the RSR method reduces additional network traffic to zero because no shadow registrations are required. The experimental results of a simulated SIP environment show that RSR can significantly reduce delay time, in comparison with general SIP registration, and make the use of shadow registration practical, as it produces dramatically less network traffic by reducing the number of registrations required. RSR also effectively reduces time delays and network traffic caused by an increased distance between the HR and the MN, which is particularly pertinent to commercially viable networks.

REFERENCES

1. T. T. Kwon, M. Gerla, S. Das, and S. Das, "Mobility management for VoIP service: mobile IP vs. SIP," *IEEE Wireless Communication*, Vol. 9, 2002, pp. 66-75.
2. F. Vakil, *et al.*, "Mobility management in SIP environment," Internet Draft, Internet Engineering Task Force, 2000.
3. H. Schulzrinne, "DHCP option for SIP servers," Internet Draft, draft-ietf-sip-dhcp-05.txt, 2001, work in progress.
4. H. Schulzrinne and J. Rosenberg, "The session initiation protocol: internet-centric signaling," *IEEE Communications Magazine*, Vol. 38, 2000, pp. 134-141.
5. J. Rosenberg, *et al.*, "SIP extensions for presence," Internet Draft, Internet Engineering Task Force, 2000.
6. H. Schulzrinne, "SIP registration," Internet Draft, Internet Engineering Task Force, 2000.
7. H. S. Suh, "DSRR organizing and its algorithm for efficient mobility management in

- the SIP,” *IEICE Transactions on Communications*, Vol. E87-B, 2004, pp. 1866.
8. S. Dixit and R. Prasad, *Wireless IP and Building the Mobile Internet*, Artech House Publishers, 2003.
 9. W. W. Lu, *Broadband Wireless Mobile: 3G and Beyond*, John Wiley & Sons, 2002.
 10. H. H. Xia, “An analytical model for predicting path loss in urban and suburban environments,” in *Proceedings of IEEE International Symposium on Personal, Indoor and Mobile Radio Communications*, 1996, pp. 19-23.
 11. V. Erceg, K. Hari, *et al.*, “Channel models for fixed wireless applications,” Technical Report, IEEE 802.16 Broadband Wireless Access Working Group, 2001.
 12. Recommendation ITU-R P.1546, “Method for point-to-area predictions for terrestrial services in the frequency range 30 MHz to 3000 MHz,” Technical Report, International Telecommunication Union, 2001.
 13. M. Hata, “Empirical formula for propagation loss in land mobile radio services,” *IEEE Transactions on Vehicular Technology*, Vol. VT-29, 1981, pp. 317-325.
 14. COST Action 231, “Digital mobile radio towards future generation systems – Final report,” Technical Report, European Communities, EUR 18957, 1999.
 15. V. S. Abhayawardhana, *et al.*, “Comparison of empirical propagation path loss models for fixed wireless access systems,” in *Proceedings of IEEE Vehicular Technology Conference*, Vol. 1, 2005, pp. 73-77.
 16. H. R. Anderson, *Fixed Broadband Wireless System Design*, John Wiley & Sons, 2003.
 17. S. Moshavi, D. Yellin, J. S. Sadowsky, Y. Perets, and K. Pick, “Pilot interference cancellation technology for CDMA cellular networks,” *IEEE Transactions on Vehicular Technology*, Vol. 54, 2005, pp. 1781-1792.
 18. S. Y. Park and K. D. Chung, “A resource reservation scheme using dynamic mobility class on the mobile computing environment,” *KISS Transaction*, Vol. I-31, 2004, pp. 112-122.
 19. W. L. Stutzman and G. A. Thiele, *Antenna Theory and Design*, 2nd ed., John Wiley & Sons, 1998.
 20. C. Bettstetter, G. Resta, and P. Santi, “The node distribution of the random waypoint mobility model for wireless ad hoc networks,” *IEEE Transactions on Mobile Computing*, Vol. 2, 2003, pp. 257-269.
 21. Unis, CEFRIEL and FhG Focus, “EVOLUTE Architecture Simulation,” Delivery date to the CEC: 08/11/2002.
 22. A. Dutta, J. C. Chen, S. Das, M. Elaud, D. Famolari, S. Madhani, A. McAuley, M. Taail, S. Baba, T. Maeda, N. Nakajima, Y. Ohba, and H. Schulzrinne, “Implementing a testbed for mobile multimedia,” in *Proceedings of IEEE GLOBECOM*, Vol. 3, 2001, pp. 1944-1949.
 23. White Paper “Set up procedure for performance characterization results: benchmark to demonstrate improvement in SIP performance for IMS, Powered by Dual-Core Intel® Xeon® Processors,” by Intel.
 24. <http://download.intel.com/design/telecom/papers/SIPwp.pdf>.
 25. N. Banerjee, K. Basu, and S. K. Das, “Hand-off delay analysis in SIP-based mobility management in wireless networks,” in *Proceedings of the International Parallel and Distributed Processing Symposium*, 2003, pp. 224b.



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