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Integrating GSM and Internet for Mobile Computing*

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Abstract

Recent advances in wireless communication technology have made a world-wide cellular telephone network practical. On the other hand, the current TCP/IP Internet has a richer data computing resource and is an extensively used data network. In the near future, a mobile user can be expected to carry a portable computer with a wireless interface to access information from anywhere and at anytime. Such a communication environment is called a Mobile Computing System. In this paper, we propose an infrastructure capable of integrating Internet with the existing GSM system to provide wide-area mobility for mobile computing applications. An efficient routing mechanism is also developed for the proposed infrastructure. The routing mechanism is not only compatible with the current TCP/IP protocol, but can also interwork effectively with the existing mobile IP proposals.

Keywords: *Mobile Internet Protocol, TCP/IP, GSM, mobile computing, PCS.*

1 Introduction

Recent advances in wireless communication technology have made a world-wide cellular telephone network practical. On the other hand, the TCP/IP Internet has a richer data computing resource and is an extensively used data network. In the near future, a mobile user can be capable carry a portable computer with a wireless interface to access information from anywhere and at anytime. Such a environment is called *Mobile Computing System* [2].

The current mobile communication systems can be classified into two major types: the cellular phone systems, e.g., *Advanced Mobile Phone System (AMPS)* and *Global System for Mobile Communication (GSM)*, and wireless Local Area Networks (LANs). To construct a mobile computing system, the cellular phone providers add data services to their existing cellular phone systems. On the other hand, the Internet researchers use wireless LAN to provide mobile services on the Internet. Moreover, the most significant feature in mobile environment is obviously mobility. Mobility can provide users many new services; however, doing so incurs a mobility management problem. Therefore, constructing a mobile computing system requires an effective mobility management system.

The current cellular phone systems have installed richer wireless resources (mobile radio equipment) and have a wide service area. Moreover, the cellular systems already have their mobility management mechanisms, but these schemes are originally designed for circuit-switched voice transmission. Hence it will be inefficient for data packet routing. Therefore, both AMPS and GSM have attempted to provide packet transmission for data services. The *Cellular Digital Packet Data (CDPD)* system [8] uses idle transmission capacity in AMPS to transmit IP (Internet Protocol) datagrams. However, its routing mechanism is inefficient. In GSM, the original design already includes some raw specifications for data services [13, 10]. However, these data services only offer a connection link to the data network; it has not truly provided a packet routing mechanism to support the mobility for mobile computing. Therefore, Mademann [12] proposed a new data service of GSM – *General Packet Radio Service (GPRS)*. The GPRS system aimed to improve the efficiency of the radio transmission and the routing mechanism in it own network. However, it has not developed adequate protocols for effectively interworking with the TCP/IP Internet to share the rich computing resources and provide an ideal mobile computing environment.

On the other hand, the mobility makes the Internet Protocol (IP) unable to route datagrams correctly. On the Internet, a host's IP address depends on the network it is connected to, and packets are routed based on the IP address [1]. However, such a scheme is inadequate for mobile hosts since a mobile host may move into another network and use other temporary IP addresses [6]. To support mobility and then provide a mobile computing system, various proposals have been made for supporting mobility on a datagram-based internetwork [6, 14, 4]. Moreover, in recent years, the Mobile-IP group of the *IETF (Internet Engineering Task Force)* has also devoted itself to adding wireless interface to the Internet and de-

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velop the mobile IP (Internet Protocols) on the current TCP/IP Internet. These proposals have been designed to be compatible with today's TCP/IP-based Internet, and they are generally referred to as *Mobile-IP* proposals. However, the mobile-IP developers have addressed IP layer routing but they do not have an ideal mobile infrastructure to support wide area mobility. Moreover, they have also not pondered the practical layout cost and detail implementation considerations for wide area roaming application. Therefore, they may become impractical and are limited to scale to world-wide area.

Since both the mobile-IP developers and the cellular provider lack an ideal total solution to the mobile computing system, in this paper, we design a more effective mobile computing system. To achieve this goal, the TCP/IP Internet is integrated with the GSM system to construct a mobile computing system. An infrastructure and a set of effective mobile IP protocols are also proposed for mobile computing applications.

In the following section, we shall propose the mobile computing infrastructure and the mobile IP datagram format for mobile computing system. Section 3 describes the mobile Internet protocols for our proposed system. Section 4 provides an evaluation. Concluding remarks and several directions for future research are finally offered.

2 Infrastructure

To provide an ideal mobile computing system, simply adding the packet routing capability to the current cellular phone system or adding the wireless interface to Internet is inadequate. A preferable approach to constructing an ideal mobile computing system is to integrate the GSM system with Internet since each system has its own domination; the cellular systems have installed wide area resources and the backbone for wireless communication. On the other hand, the Internet has richer computing resources and a more effective data transmission mechanism. However, the current proposals for the mobile computing system do not take the advantage of both the GSM system and Internet. Taking advantage of their merits will result in a better design for a mobile computing system. Owing to this reason, we propose an integrated approach to constructing a mobile computing system.

Our proposed system will share radio and mobility management resources in the GSM system and the data network resources on the Internet. In addition, no change shall be required in non-mobile hosts and gateways on the Internet and the switching system in GSM. Our proposed protocol should also operate within TCP/IP protocol suite and effectively interwork with the existing mobile-IP mechanisms. Of course, wide area services shall be supported in our proposed system.

When a mobile host migrates from one coverage area of a gateway to another, our proposed system uses the *Dynamic Host Configuration Protocol (DHCP)* [3] on the Internet to dynamically assign a temporary IP address to the mobile host. In addition, our system can also support an additional service that a mobile host can use the *personal identification number (PIN)* of another mobile host to initiate communications. This service is implemented by the GSM *Short Message Service protocol (SMS)* [13, 10] as described in Section 3.2.3.

2.1 A Mobile Computing Infrastructure

This subsection presents a mobile computing infrastructure for packet data transmission. As Figure 1 indicates, the infrastructure proposed herein consists of two subnetworks, *GSM* and *Internet*, and *mobile support gateways, MSGs*. The GSM system is selected as the wireless backbone of our system because the current service coverage area of GSM is wider than the wireless LAN. On the other hand, Internet is chosen because it is the most extensively used data internetwork. In our proposed system, the subsystems of GSM and the gateways of Internet do not require any changes. However, to integrate these subnetworks, an additional mobile support gateway is required in our proposed system. As Figure 1 reveals, a *mobile host (MH)* is a portable equipment (e.g., possibly a notebook computer) with wireless hardware and additional software, thereby allowing it to roam the network (both in GSM and in Internet) in a manner transparent to the software above the network layer within the host. In GSM, each subscriber has a PIN number within his SIM card. In our proposed system, besides the PIN, each MH is assigned an additional unique identifier, called a permanent IP address which is used by the Internet Protocol for routing. A *base station (BS)* provides MHs a wireless link to the wired network through the air interface.

Our proposed system uses the same cellular phone network and switching subsystem as the GSM architecture. It consists of many entities, including *Mobile services Switching Center (MSC)*, *Inter-working Function (IWF)*, *Home Location Register (HLR)*, and *Visitor Location Register (VLR)*. MSC is a switch which coordinates a call setup to and from GSM subscribers. An MSC controls several BSCs and is responsible for the inter-BS hand-off management in GSM. Similar to the GSM system, in our system, an IWF is placed between a BSS and a mobile support gateway to interface the GSM radio resources with the TCP/IP Internet; therefore, an MH can directly access to Internet through the base station. An HLR contains subscriber's information such as the service profiles and the current locations of the subscribers. Each HLR also has an authentication center (AuC). An VLR in GSM links to one or more MSCs. It temporarily stores the information of those subscribers currently served by its local MSC. The control signals among MSCs, VLRs, and HLRs are supported by the Signaling System 7 (SS7) signaling [11].

The Internet subsystem in our infrastructure is only the Internet. The Internet can provide packet (connectionless) transport for data transmission. The packet transport mechanism is supported by the IP datagram forwarders which are referred to as gateways. However, traditional gateways can not adequately support mobile computing requirements. Hence, we propose a new gateway, mobile support gateway (MSG), for mobile computing.

An MSG functions as an *Internet gateway*, a *mobil-*

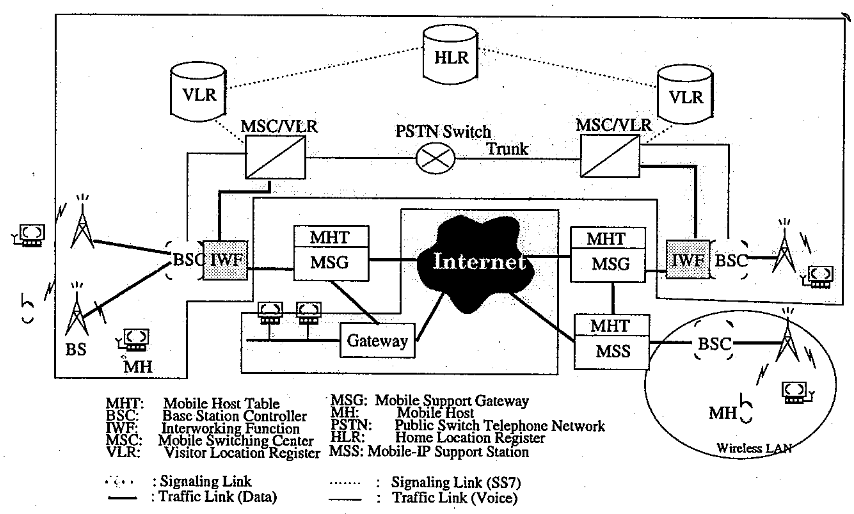

Figure 1: Infrastructure

ity gateway, and an *interworking gateway*. An Internet gateway performs the basic TCP/IP routing functions and the other existing control protocols on the Internet. An mobility gateway maintains location information databases for mobile hosts. An interworking gateway interfaces with the MSC/VLR and the IWF of the existing GSM system, and translates the datagrams between GSM and Internet. Consequently, an MSG is responsible not only for performing the basic routing functions on the Internet, but also handling the interface between GSM and Internet. Furthermore, an MSG supports the mobility management as well. To interwork with the other existing mobile-IP systems, each MSG maintains two additional tables: *Agent Table (AT)* and *Mobile Host Table (MHT)* (Figure 2) as well as an elementary routing table. The gateway looks up the AT to serve as an agent for fixed hosts to effectively communicate with mobile hosts, while maintains the MHT for location tracking of mobile hosts. The home MSG of an MH is the gateway

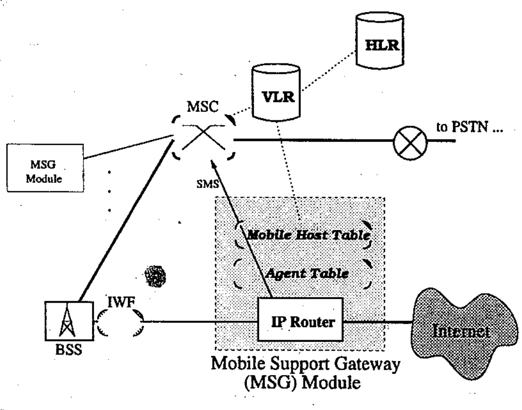

Figure 2: Mobile Support Gateway Module

which has been assigned a permanent IP address to the MH. Each MH with a permanent IP address has an entry in the MHT of its home MSG, and the home MSG maintains the location information of its home mobile hosts up-to-date.

2.2 Mobile Internet Protocol Message

As Figure 3 indicates, a mobile IP datagram is divided into three parts: the upper part is the normal IP datagram header, the middle part is the modified fields as an option of IP datagram, and the lower part is the user's data with its transport and higher layer header. The option fields in our mobile IP datagram

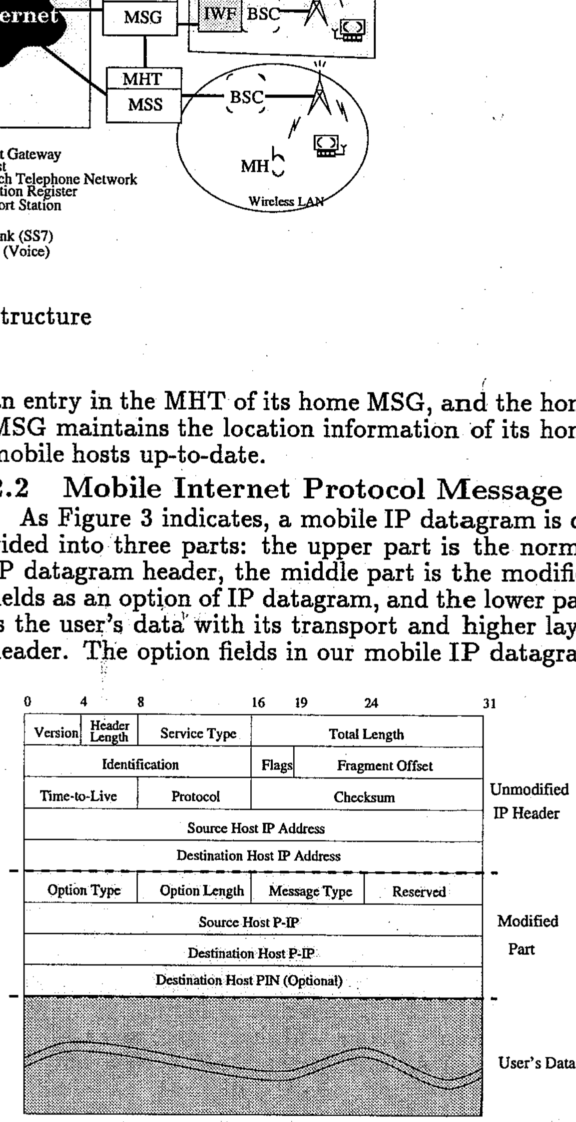

Figure 3: Modified IP Datagram Structure for Mobility Requirement

consists of Option Type, Option Length, Message Type, the permanent IP addresses of the sender and the receiver, and one optional auxiliary PIN fields.

3 The Mobile Internet Protocol

This section describes the mobile Internet protocols for our proposed infrastructure. These protocols includes registration, data transmission, and hand-off processes.

3.1 Registration Process

In cellular phone systems, when a mobile host first joins the network or moves out from the coverage area of an MSC/VLR (i.e., the registration area) to the coverage area of a new MSC/VLR, it must register with the new MSC/VLR via a registration process. The registration process of the voice services in our system is the same as that in GSM. On the other hand, to provide the data service in mobile environment and make it compatible with the TCP/IP Internet, our system makes some changes to the registration process of data packet services in GSM. The major changes include the request and assignment of dynamic IP addresses. The registration process for our proposed system is as follows (Figure 4).

- When an MH initially joins the network or moves into a coverage area of a new MSG, it first sends a REQUEST_IP message to its local MSG to request a temporary IP address.

  This operation is different from the registration process in the current GSM system that the mobile host first sends the registration request to the MSC/VLR.

- After receiving the IP request, the local MSG performs a DHCP protocol to the DHCP server to request a temporary IP (T-IP) address for the MH.

- The MH is assumed to be a GSM subscriber. Therefore, the MSG must also notify the local MSC/VLR of the MH's registration.

- After the MSG obtains the T-IP from the server, it adds an entry in its MHT if the MH's is valid. This entry contains the mapping between the permanent IP and the temporary IP addresses of the MH. Moreover, the MH's home MSG is also notified of the MH's T-IP.

- Then the temporary IP address is also conveyed to the MH via an IP_ASSIGN message.

3.2 Data Transmission Process

This subsection proposes a set of procedures for the data transmission process in a mobile computing environment. The data transmission procedure describes how a host sends data to another host.

The data transmission process can be classified into four cases: fixed host (FH) to FH, MH to FH, MH to MH, and FH to MH. Since the case in which an FH communicates with another FH does not concern mobility, we will focus on the later three cases: MH to FH, MH to MH, and FH to MH.

3.2.1 MH to FH using IP

On the current TCP/IP Internet, each fixed host (FH) has its own IP address that is permanent and indicates the location of the FH. Therefore, a host (either an MH or an FH) can use IP address to send datagrams to an FH.

When an MH (source MH) attempts to communicate with an FH, it first executes the registration process as mentioned in Section 3.1. After the registration process, the source MH is assigned a temporary IP (T-IP), and it can then emulate as a new plug-in host on the TCP/IP Internet and thus can use the applications provided by the existing Internet.

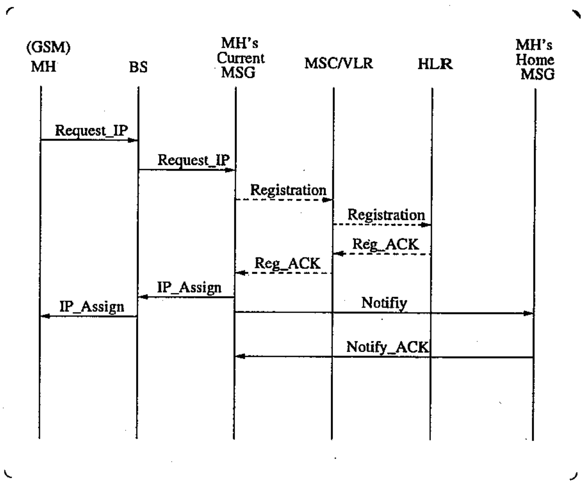

Figure 4: Registration Process

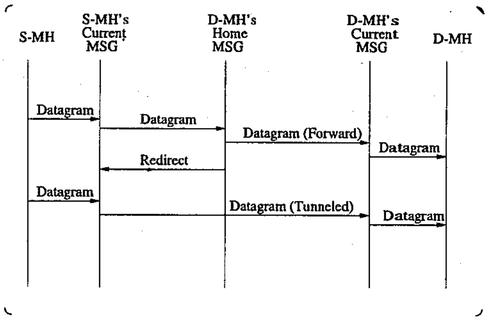

Figure 5: Data Transmission Process from MH to MH using Mobile IP

3.2.2 MH to MH using IP

When an MH attempts to communicate with another MH, if both of them are GSM subscribers, then the source MH can use either the IP address or the PIN of the corresponding MH to initiate the communication. Which identification is chosen depends on the preference of mobile users. However, if at least one of them are not GSM subscribers, it can only use IP to initiate data transmission.

In the following, we first discuss the case that the source MH (S-MH) uses the IP address of the destination MH (D-MH) to send datagrams (see Figure 5). The data transmission process using the PIN of the D-MH is described later.

- When an S-MH wants to initiate a communication to another MH, it first executes the registration process as mentioned in Section 3.1. After the registration process, the S-MH is assigned a temporary IP (T-IP), and then it can use this T-IP as its current IP address reflecting its current location.

- Because the S-MH uses the D-MH's IP address to initiate a communication in this case, the S-MH first sends datagrams to its local MSG. The local MSG then routes the datagrams to the D-MH's home MSG via the TCP/IP protocol.

- When the datagrams arrive to the D-MH's home MSG, the home MSG examines its MHT entry to distinguish whether the D-MH is at home or not. If the D-MH is within its home area, the datagrams are then directly delivered to the D-MH by looking up the entry. Otherwise, the datagrams are encapsulated and then forwarded to the D-MH's current location. The datagrams will then be eventually routed to the D-MH.

  Because we use a compatible IP format with other mobile IP protocol (e.g., IP-within-IP, VIP, IMHP), our system has the advantage that the home MSG (or mobile support station, MSS) can also use the existing mobile IP to forward datagrams to the D-MH if the other mobile-IP protocol has been implemented.

- If the D-MH is not at home, then its home MSG is required not only to forward datagrams but also to notify the S-MH's local MSG of the D-MH's current T-IP via a REDIRECT datagram. Next, the S-MH's local MSG receives the REDIRECT datagram and then updates the corresponding host IP address field in its MHT.

- After the S-MH's local MSG becomes aware of the D-MH's current T-IP address, it can use the D-MH's current T-IP to tunnel the datagrams direct to the D-MH's current location.

3.2.3 MH to MH using PIN

In addition to using IP address to send out a datagram, if two MHs are both GSM subscribers and attempt to communicate with each other, they can also use the additional service provided by our proposed system, i.e., an MH uses the PIN of a destination mobile host (D-MH) to initiate a communication. Under this condition, the mobile system first finds out the D-MH's current T-IP via the D-MH's PIN. Then, the MHs establishes the communication between them.

3.2.4 FH to MH using IP

The data transmission process that an FH communicates with another MH is similar to that an MH communicates with another MH via the IP of the destination MH (D-MH). However, two differences arise between these two data transmission processes. One difference is that the FH in the existing Internet does not implement any mobile-IP protocols, such that it needs a mobile support gateway (MSG) as its mobile routing agent. Another difference is that the FH is not required to perform the registration process to request a temporary IP before sending data because its IP address will never change.

When a source FH attempts to send data to a mobile host, it merely sends datagrams into the Internet; the datagrams will then be first routed to the receiver's home. If there is an MSG in local area, it will intercept the REDIRECT notification and add an entry in its agent table for the FH. By looking up the AT, the MSG can use the D-MH's current T-IP to tunnel the datagrams sent from the FH to the D-MH's current location directly. That is, the FH's agent MSG functions as a routing agent between the FH and the D-MH. Notably, if there are not any agent MSGs for the FH, the communication can operate normally. However, under this condition, all datagrams sent from the FH must be first delivered to the D-MH's home MSG, and then be forwarded to the D-MH's current location by the D-MH's home MSG. Without agent MSGs, the system will result in a triangular routing between the FH and the D-MH. Therefore, the FH's agent MSG resolves the non-optimal routing path and thus provides a better routing performance.

3.3 Hand-off Process

In a mobile system, if an MH moves from one cell to another during communication, the mobile system must perform a hand-off process. The hand-off procedure includes channel assignment in the new cell, passing the control to the new agent and in particular taking the communication link transfer process. However, in the packet service mode (e.g., in a mobile-IP system), the link transfer is not required, but the system still requires a hand-off procedure to redirect datagrams to the correct location and release the occupied resource in the obsolete cell.

According to the switching point's location in the infrastructure, the hand-off process can be classified into four levels: *intra-BS* (base station), *inter-BS*, *inter-MSG*, and *inter-MSC*. The intra-BS hand-off is a hand-off between two cells that are both under the same base station controller (BSC). This type of hand-off is already supported by the current GSM system. Because our proposed system is based on the GSM system, this type of the hand-off can be handled by the BSC itself without any change. Similarly, the inter-BS is also already supported by the current GSM system and does not need any change. In our proposed system, the T-IP of an MH will be changed only when the inter-MSG or the inter-MSC hand-off occurs. Since the inter-MSC hand-off process is similar to the inter-MSG hand-off process, we will focus on the inter-MSG hand-off process.

The inter-MSG hand-off occurs when an MH moves into the coverage area of a new MSG. The MH must first execute the registration process and request its local MSG a new temporary IP address to reflect its current location. The local MSG then informs its local MSC/VLR of the MH's movement. Next, the MH notifies the home MSG of its current T-IP and informs its previous MSG to forward the later coming datagrams to its current location. Moreover, since we assumed the mobile hosts in our proposed system are GSM subscribers, the movement information must

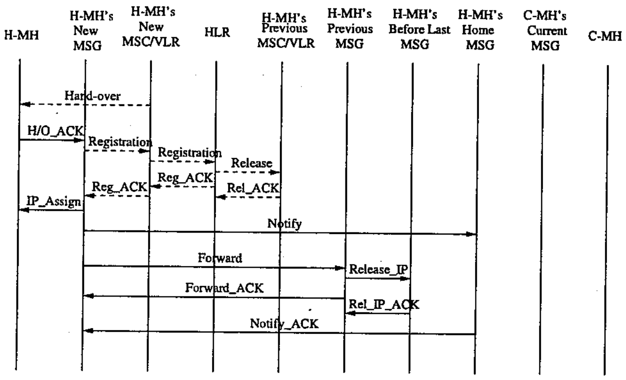

Figure 6: Inter-MSG Hand-off Process

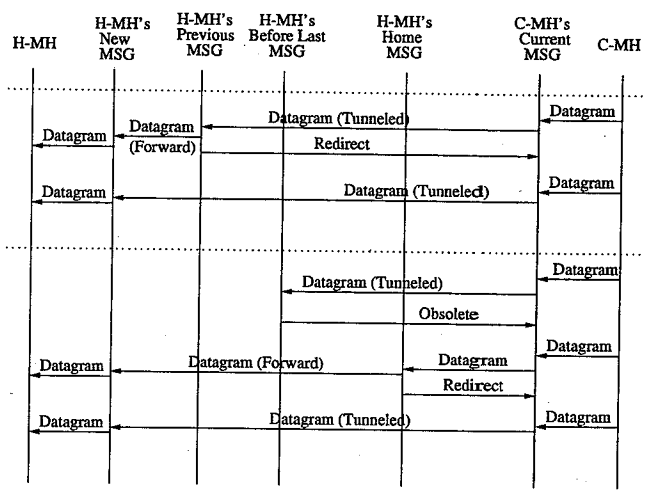

Figure 7: Data Transmission Process After Inter-MSG Hand-off

also be conveyed to HLR and the previous MSC/VLR. The detailed process is described below (Figure 6).

- Our system is based on GSM. When a hand-off MH, H-MH, moves from one coverage area of an MSG to another, it will be notified of a GSM hand-off command (Handover) by the local MSC/VLR. On receiving the hand-off command, the H-MH sends a hand-off acknowledgment (H/O_ACK datagram) to its local MSG.
- When the local MSG receives the H/O_ACK datagram, it requests the DHCP server a temporary IP and performs a registration process with the MSC/VLR for the H-MH. After the registration process, if the H-MH is valid, it will be assigned a temporary IP (T-IP). Then, the H-MH can use this T-IP as its current IP address.
- After the T-IP is assigned, the H-MH's new MSG notifies the H-MH's home MSG of its current T-IP.
- After passing the T-IP to the H-MH, the new MSG sends a FORWARD datagram to inform the previous MSG to forward the later coming datagrams to the H-MH's current location.
- When the previous MSG receives the FORWARD datagram, it updates the forwarding entry in its mobile host table (MHT), and then forwards the later coming datagrams to the H-MH's current location.
- Next, the previous MSG sends a RELEASE_IP datagram to inform the previous previous MSG to release the entry occupied by the H-MH.

  Although the hand-off process of the H-MH is completed, the corresponding host of the H-MH may not learn the H-MH's new T-IP. Hence, the corresponding host may still send datagrams depending on its routing information in its internal cache to the H-MH's previous MSG (or an obsolete MSG) where the H-MH previously was. Under these circumstances, the datagrams will be routed to an incorrect MSG. Therefore, routing information should be updated in the later data transmission process.

  We first consider the case that the corresponding host sends datagrams to the previous MSG which has a forwarding entry in its MHT.

  - After the hand-off process, if the corresponding host sends datagrams to the H-MH's previous MSG, then the previous MSG forwards the datagrams to the H-MH's current MSG via looking up the forwarding entry in its MHT. At this time, it also informs the corresponding host's local MSG of the H-MH's current T-IP via a REDIRECT datagram.
  - After the corresponding host's local MSG receives the REDIRECT datagram, it tunnels the following datagrams destined to the H-MH's current location.

  In the following, we consider the case when the corresponding host sends datagrams to an obsolete MSG.

  - Under this circumstance, the datagrams will be routed to an obsolete MSG which does not have any H-MH entry.
  - Once an MSG receiving a datagram destined to its unknown MH, it sends back an OBSOLETE datagram to the corresponding host.
  - On receiving an OBSOLETE datagram, the corresponding host learns the routing information if its internal cache is obsolete. Therefore, if it wants to send datagrams to the H-MH, it restarts a data transmission process as mentioned in Section 3.2 to communicate with the H-MH.

After the processes as mentioned above, the delivery path of the subsequent datagrams is established again.

4 Evaluation and Analysis

4.1 Overhead Estimation of CDPD System and Our Proposed System

This subsection compares the data transmission time in the CDPD system with the data transmission time in our proposed system. Since the current mobile-IP proposals lack a wide-area backbone, some of them, e.g., the mobile-IP proposed by Johnson et al. [14, 7, 5], uses CDPD as the backbone to link two off-campus mobile-IP subnetworks to provide wide-area mobility. However, in CDPD, all datagrams destined for an MH must be initially routed to the MH's home MSG (Mobile Data Intermediate System, MD-IS in CDPD), and then be forwarded to the MH's current location. Therefore, the CDPD encounters a triangular routing problem [9] which makes the routing inefficient. In contrast to the CDPD system, our proposed system can resolve the triangular routing problem, thereby providing a more efficient routing than CDPD.

The data transmission time spent in the CDPD system is compared with that in our system from the routing path's perspective. Conforming the protocols proposed by the CDPD system [8] and our proposed protocols in Section 3, we estimate the total datagram transmission time according to the current locations of the sender (SH) and the receiver (DH) as follows.

- **Both at the same area:**
  Either in our proposed system or in CDPD, all datagrams sent from a sender can be delivered to the destination host directly through their common local MSG according to the location information in its local Mobile Host Table (or CDPD's Directory). Therefore, the routing path in our proposed system is identical to that in CDPD. Therefore, the total datagram transmission time in our proposed system can be assumed to be identical to the total data transmission time in CDPD.

- **Both at their homes:**
  When both the sender and the receiver are at their home areas, the routing path of datagrams in CDPD is identical to that in our system no matter whether the sender and the receiver are at the same registration area or not. Therefore, the total data transmission time in our proposed system is identical to that in CDPD.

- **At different areas, but at least one not at home:**
  Finally, the remaining cases are considered in which the sender and the receiver are not at the same area but at least one of them are away from their home areas (see Figure 8). Under these conditions, the CDPD system delivers all datagrams first to the mobile host's home area, and then the datagrams are encapsulated and tunneled to the MH's current location by the MH's home MSG. Therefore, in CDPD, the routing paths of all datagrams are triangular (i.e., non-optimal). In contrast, in our proposed system, the triangular routing exists only before the REDIRECT notification sent from the receiver's home MSG arrives to the sender. After the sender's MSG receives the REDIRECT notification, it learns the receiver's current T-IP address, and then the subsequent datagrams sent from the sender will be directly tunneled to the receiver's current location. The single datagram transmission time along a direct route is here assumed to be T and the single datagram transmission time along a triangular route is $T + T_{\Delta}$. Additionally, we assume that N is the total number of datagrams sent from the sender, N_1 is the number of datagrams sent before the sender's local MSG is notified of the receiver's current T-IP address, and N_2 is the number of datagrams generated after the sender's local MSG learns the receiver's current T-IP address. That is, N is equal to N_1+N_2. Since all datagrams are delivered through triangular paths in CDPD on these conditions, the total data transmission time in CDPD is equal to $(N_1 + N_2) * (T + T_{\Delta})$. In contrast, the total data transmission time in our proposed system is only required $N_1 * (T + T_{\Delta}) + (N_2 * T)$.

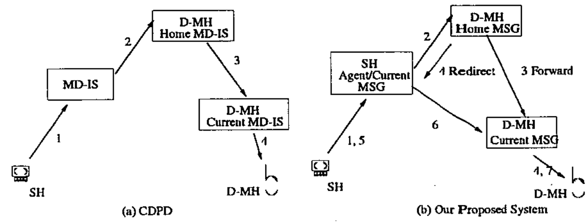

Figure 8: CDPD Vs. Our System on Transmission Path

SH and DH are not both at their home areas.

SH	DH	DH at home	CDPD	Our Proposed System
-	-	Yes	$N * T$	$N * T$
-	MH	No	$(N_1 + N_2) * (T + T_{\Delta})$	$N_1 * (T + T_{\Delta}) + N_2 * T$

-: Dont' care, x: Impossible case

Table 1: Comparison of the CDPD and Our Proposed System

Table 1 lists the differences between the CDPD system and our proposed system. As shown in Table 1, in our proposed system, the total data transmission time will be minimum. That is, our proposed mobile-IP proposal provides more efficient routing than CDPD.

4.2 Comparison of GPRS System and Our Proposed System

Next, we compare our system with the GPRS proposal. Since the GPRS proposal three has better routing efficiency than the GPRS proposal one and two [12], we focus on comparing the GPRS proposal three and our proposed system.

The GPRS proposal three suggested that no hand-off and rerouting functions are required. Every data unit (i.e., datagram) is routed according to the content in location registers (HLR/VLR). Therefore, all datagrams will be delivered to the current location of the mobile host. However, this routing mechanism has an obvious overhead to look up location register for every datagram. To reduce the overhead, this proposal suggests to equip every GPRS router with a cache memory for location information to enable a fast routing of the datagrams. This cache method can accelerate the datagram routing; however, it encounters cache entry updating problem. That is the problem how to maintain location information in cache up-to-date without too heavy updating overhead. In our proposed system, the entry of an MHT is updated only when there is an initial request or a hand-off request of a mobile host. Consequently, the updating overhead will be minimum and the content of the MHT can be ensured to always be up-to-date.

On the other hand, another common problem in GPRS is that the location information in GPRS location registers may not be exchangeable with that in other mobile-IP proposals. Thus, GPRS may also incur triangular routing problem which makes the routing and interworking mechanism between GSM and Internet ineffective. Moreover, datagrams must be routed only on the GPRS-specific data networks which can use GPRS routing information. In contrast, our proposed mobile-IP protocol uses IP routing mechanism to route datagrams. It can easily interwork with the hosts on the Internet and can use Internet to transport datagrams. Similarly, since the other mobile-IP proposals also uses IP routing mechanism to route datagrams, such that the proposed MSG can easily cooperate with the MSSs in the other mobile-IP systems. Our system provides an environment in which the data transmission between a GSM subscriber and a non-GSM subscriber is more efficient than the other proposals (either GPRS proposal or the other mobile-IP proposals).

5 Conclusions and Future Work

In this paper, we have presented an effective infrastructure which supports wide-area mobility for mobile computing systems. Our system integrates the existing GSM system with the TCP/IP Internet system. We have also proposed a novel mobile support gateway to support efficient routing in the proposed infrastructure. In addition, we also have proposed a suite of mobile IP protocols, including the datagram format and message types.

This work can be extended in the following two directions: security and multi-tier extension. Security have been an increasing important issue in data/voice networks, especially wireless network. Therefore, we are going to develop an effective authentication procedure, which can provide the high degree of security to our proposed system. Moreover, to increase wireless transmission capacity and provide better service availability, our system shall be designed to accommodate a multi-tier system.

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