IP Subnet Mobility over General Packet Radio Service

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Abstract: The growth of the mobile network system of which the cellular systems like Global System Mobile Communications (GSM) and Personal Digital Cellular (PDC) are representative and the IP network attracts worldwide attention. The IP network access through the mobile data network system is required strongly to use the useful IP services anytime and anywhere. Therefore on the mobile data network system such like General Packet Radio Service (GPRS), there has been the necessity for realizing the mobility over IP level. This paper focuses to combine the proprietary mobility management of GPRS and Mobile IP. In our proposal the mobile terminal only treats the GPRS mobility management and doesn't recognize the location of IP level. The GPRS core network manages the movement between IP subnets using the information of the GPRS mobility management. One of the advantages is no additional control message on the radio I/F necessitated by the IP mobility.

Keywords: GPRS, Mobile IP, Mobile data network

1. Introduction

Currently, gathering information from the Internet and selecting the useful and necessary information are getting to pervade [1]. And there are various services to realize it, for example the access of the e-mail server and the web server on the Internet and the Intranet, the access of the private database on the Intranet, the information delivery service using the push technology and the electronic commerce such as banking service and reservation service. As the result, the IP packet traffic is increasing remarkably, and it is forecasted that IP packet traffic is going to be over 160 Gbps in the year of 2001 [2]. So the next generation IP network should become to consist of the network which is advanced from the heterogeneous network such as the telephone network and the mobile network in addition to the growth of the IP network itself.

On the other hand the mobile network system such as the cellular systems that is called GSM or PDC is paid attention to as the telephone network. Because the mobile subscribers are increasing rapidly, too, and the access with the fixed IP network over the mobile network system is very attractive in order to take advantage of get the above-mentioned service anytime and anywhere [3]. So the mobile data network system is required and anticipated.

As the infrastructures of the data service on the current mobile network system that provides the circuit-switched service has the following limitation. First, the transmission speed of Short message Services (SMS), that transmits short data messages each up to 160 alphanumeric characters long, cannot reach 1 Kbps and the data service over the circuit-switched service cannot reach 10 kbps. Secondly, the circuit-switched service isn't suitable for IP traffic that has a characteristic of the burst traffic. In this service, the radio resource remains being assigned while there is no IP traffic. And the same bandwidth is allocated for the upstream and the downstream even if the subscriber downloads the much information from the Web server. So the circuit-switched service can't use the radio resource effectively when IP packet traffic is transmitted. And thirdly, the cost that is in proportion to the time of occupying the radio resource is a problem to show a tendency to be getting higher.

To solve these problems, the new infrastructures appear. Using the current radio resource efficiently, the High-speed circuit switched data (HSCSD) and GPRS that provides the packet-switched services have been standardized by European Telecommunications Standards Institute (ETSI), and they are expected to be launched in the year of 2000 [4]. The 3rd generation mobile network systems that are called as International Mobile Telecommunications–2000 (IMT-2000) and Universal Mobile Telecommunication System (UMTS) are standardized by International Telecommunication Union (ITU) and ETSI [5][6][7].

In the meantime the IP community recognized the need for mobility handling between IP subnets as portable computers become more and more popular. This effort resulted in Mobile IP specifications and Ipv6 [8][9]. At present the users have to chose between two different solutions in order to combine IP network access and mobility: the GPRS world where the user's terminal address belongs to the address space of a GPRS operator or an Internet, and the IP world where the terminal address belongs to the address space of its home network.

This paper looks at the integration of IP mobility based on Mobile IP and GPRS. In this framework the user's terminal retains its home address while roaming under the coverage of a wireless GPRS network. The proposed solution does not impose additional signaling traffic on the radio interface between the terminal and the fixed infrastructure. It has an impact on the GPRS equipment that should handle the functions of the Mobile IP protocol. This leads to architecture the GPRS network not only by defining Routing Areas (RA) but also by grouping the RAs into IP subnets. The expected benefit of this approach is a transparent way to communicate between a roaming terminal and other correspondent terminals.

Section 2 shows GPRS architecture and the mobility management procedure. Section 3 describes the way to combine the mobility between IP subnets (IP subnet mobility) with the peculiar mobility management defined in the GPRS. And section 4 shows the impact of the proposed architecture on the performance of the system.

2. Outline of GPRS

The purpose of GPRS is to efficiently accommodate burst data sources. Another important goal of the technology is to make it possible for GSM operators to share physical resources between packet data services and other GSM services. It means that the GPRS shares the GSM frequency bands with telephone and circuit-switched service, and makes use of many properties of the physical layer of the original GSM system such as the time-division multiple access (TDMA) frame structure, modulation technique and structure of GSM time slots.

Section 2.1 shows the GPRS architecture, and section 2.2 and section 2.3 describe the Attaching procedure and PDP activation procedure, and the location management procedures as the represent of GPRS mobility management procedures [4][10][11].

2.1 GPRS Architecture

GPRS provides the packet-switched service to transfer the burst traffic in an efficient manner. GPRS introduces two network nodes in the GSM core network. The Serving GPRS Support Node (SGSN), which is at the same hierarchical level as the MSC, keeps track of the individual MTs' location and performs security functions and access control. The SGSN is connected to the base station system (BSS). The Gateway GPRS Support Node (GGSN) provides the interworking with external packet network like the IP network or X.25 network. And the GGSN is connected with the SGSNs via IP-based GPRS backbone network. The HLR is enhanced with GPRS subscription data that includes the packet network address like the IP address. Fig. 2.1.1 shows the GPRS architecture.

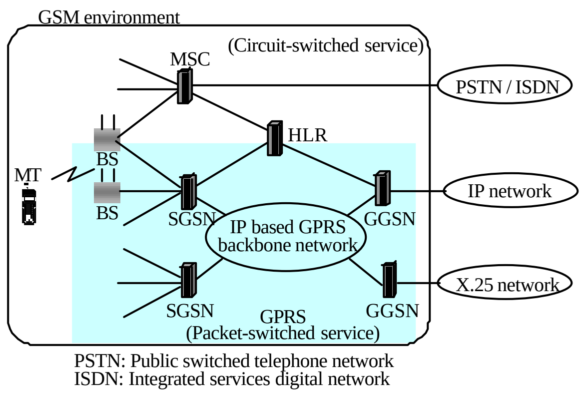


Fig. 2.1.1 GPRS Architecture

2.2 GPRS attaching procedure and PDP activation procedure

Before the MT starts transmitting packets, it has to initiate the GPRS attaching procedure and the Packet Data Protocol (PDP) activation procedure. In the GPRS attaching procedure (Fig. 2.2.1), the MT shall provide its identity. After receiving "Attach Request" with Packet Temporary Mobile Subscriber Identity (P-TMSI) or International Mobile Subscriber Identity (IMSI) from the MT, the SGSN identifies the MT and then the authentication procedure and the equipment checking procedure are initiated between the MT and the HLR via the SGSN. As the result, the SGSN gets the GPRS subscription data that includes the PDP contexts and then creates the mobility management (MM) contexts. The MM Contexts consist of the GPRS subscription data including the IMSI and the information of the authentication and the ciphering, and the mobility information like the identifications of the area and the cell where the MT exists. The PDP contexts consist of the information of the packet data protocol like the IP address of the MT and the attaching GGSN that are registered in HLR beforehand.

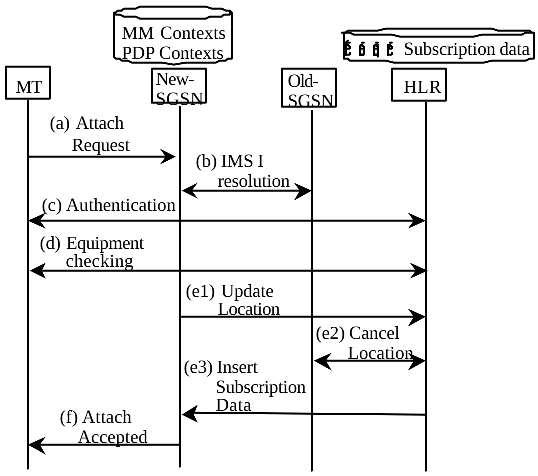


Fig. 2.2.1 GPRS attaching procedure

In the PDP activation procedure (Fig. 2.2.2), the MT indicates the attaching GGSN and its IP address registered in the HLR. A null IP address means that the MT wishes the dynamic IP address. So the dynamic IP address is assigned through the attaching GGSN in the PDP activation procedure. As the result of the PDP activation procedure, the information to route the IP packet to the MT such like IMSI, IP address of the MT and the attaching GGSN address, is added to the PDP contexts in the

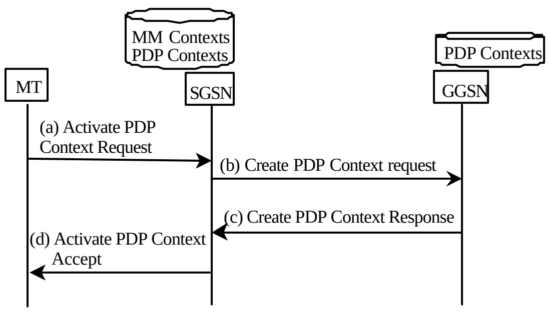


Fig. 2.2.2 PDP Activation Procedure

SGSN. And the GGSN had the information to route the IP packet as the PDP contexts that includes the SGSN address instead of the GGSN address.

2.3 Location Management Procedure

When the packet is received for a MT, the packet has to be routed to the cell in which the MT is located. In the circuit-switched service, the mobile network system is split up into a number of location areas that consist of a number of cells. In this way the core network can keep a registration of the current location area of each MT, and therefore it will only need to call the mobile within that area. In the packet-switched service of GPRS, the registration area is called as the routing area (RA), and this RA is defined to be smaller than the location area. Because the radio resource is only assigned while packet is transferred, so the frequency of paging per the MT has a tendency to be increasing in comparison with the circuit-switched service.

Whenever the MT receives the packet system information which is broadcasted by the core network, the MT have to check whether it has entered into a new RA by comparing the identification of the RA included in the above-mentioned information. When the MT detects that it has entered a new RA, the MT must initiate the location management procedure. Fig. 2.3.1 shows the location management procedure when the MT moves into a new RA that is managed a new SGSN.

As the result of GPRS attaching procedure and the PDP activation procedure, the SGSN that the MT has attached with has the MM Contexts and the PDP contexts. In the location management procedure, the PDP contexts and the MM contexts are created in the new SGSN as follow:

(a) After the MT detects the movement into the new RA, the MT sends “Routing Area Update Request” to the new SGSN.

(b) The new SGSN gets MM contexts and PDP contexts from the old SGSN. And the old SGSN starts the timer and the old SGSN transfer the PDP packets to the new SGSN until this timer expires.

(c) The SGSN updates the PDP contexts in GGSN.

(d) The SGSN registers the new SGSN address in the HLR.

(e) The HLR deletes the GPRS subscription data from the old SGSN. After the timer mentioned in (b) expires, the MM contexts and the PDP contexts are removed from the old SGSN.

(f) The HLR sends the subscription data to the new SGSN.

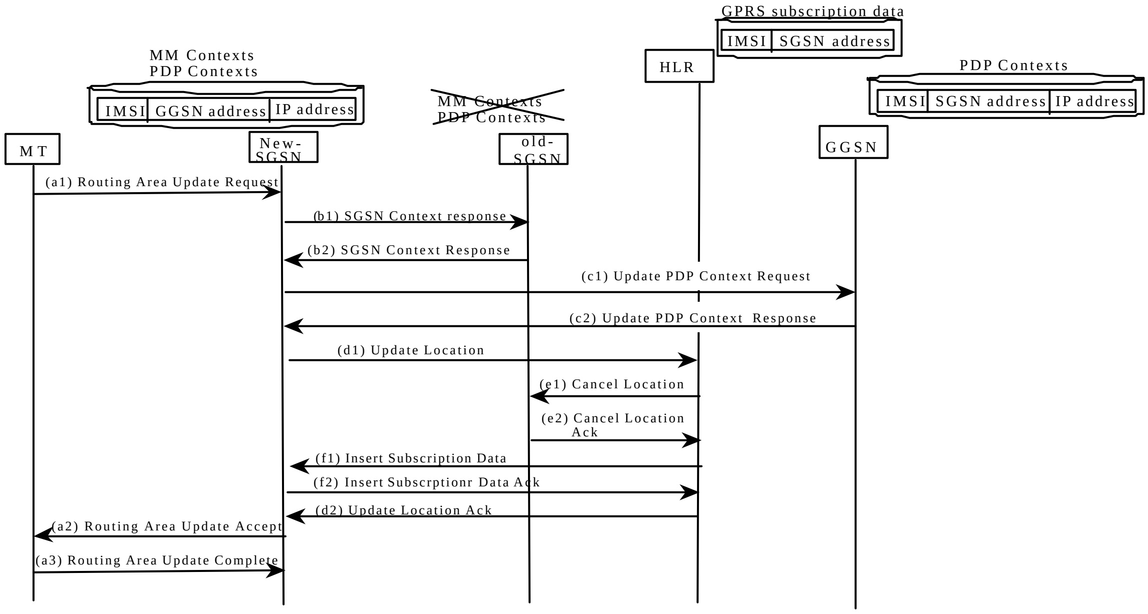


Fig. 2.3.1 Location Management Procedure

And after attaching the GGSN and being assigned IP address, even if the MT moves far from the attaching GGSN, the MT uses the same IP address and transfers the IP packets via the same GGSN. In order to support the same environment as the fixed IP networks and consider the migration to the next generation IP network, the IP subnet mobility, that provides the IP packet routing mechanism and the terminal movement regardless of the IP network and GPRS, is required. The IP subnet mobility management over GPRS realizes the optimal route selection that means to change the GGSN and the seamless environment between GPRS and the IP network.

3. IP subnet mobility management over GPRS

In order to realize the IP subnet mobility management over GPRS, combining the peculiar mobility management defined in GPRS and the IP subnet mobility defined as the Mobile IP in IETF is necessitated. This section shows how several IP subnets could be allocated in GPRS environment. And the way to support IP subnet mobility is described.

3.1 IP subnet concept within GPRS

To use IP subnet concept within GPRS as same as IP network that consists of several IP subnets, each GGSN manages one IP subnet as shown in Fig. 3.1.1 and connects with the IP network directly. And the relationship between the GGSN and the SGSN is defined beforehand. As the result, one IP subnet consists of the several routing areas that are managed by each SGSN, and the all MTs that exists in the same subnet can access with the IP network though the optimal route. So the GPRS core network has to support the following new functions, to select the corresponding GGSN automatically.

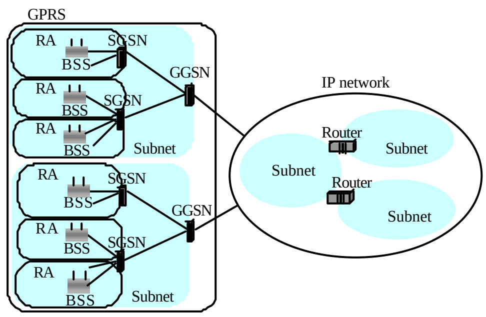


Fig. 3.1.1 IP subnet concept within GPRS

(1) When the SGSN receives the request of attaching IP network from the MT, the SGSN make a new connection with the GGSN following the above-mentioned relationship.

(2) When the MT moves into the new RA that is managed by the new SGSN and the new SGSN is allocated in the different IP subnet from the IP subnet where the MT stayed before moving, the new SGSN makes a new connection with the corresponding new GGSN. So the SGSN has to initiate the PDP activation procedure. And the new SGSN deletes the PDP contexts on the old GGSN that manages the old IP subnet.

3.2 Combining the IP subnet mobility management and GPRS mobility management

To support the IP subnet mobility inside GPRS and between GPRS and the IP network, the Home Agent (HA) and the Foreign Agent (FA), of which the functions are defined as Mobile IP, have to be assigned on the GGSN in Fig. 3.2.1. The HA is assigned on the GGSN or on the router in the home subnet into which MT belongs. The IP address of the MT is assigned by the home subnet. The FA is assigned on the GGSN in the visiting subnet where the MT moves.

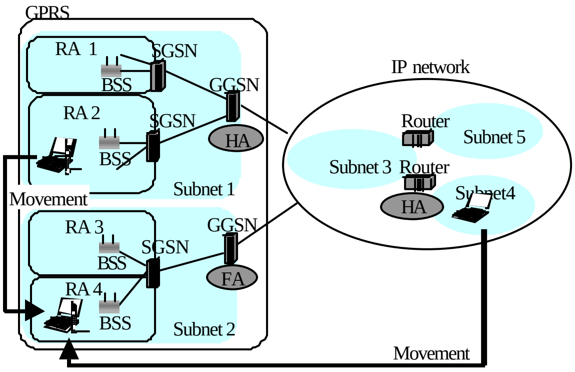


Fig. 3.2.1 GPRS structure with Mobile IP

There are two possible scenarios to identify the movement between the IP subnets, the detection of the movement between the IP subnets by the MT or the detection by the GPRS core network.

1) Scenario 1: The MT detects the movement

In this scenario the MT has to support IP subnet mobility management (MM) function. In Fig. 3.2.2, the IP subnet MM is performed as follow:

(a) When the MT moves into the new RA that belongs into the new IP subnet, the MT only detects the movement into the new RA and initiates the location management procedure.

(b) After receiving "Routing Area Update Request", the new SGSN make a new relationship with the corresponding GGSN according to the IP subnet concept (see section 3.1).

(c) After the MT receives "Router Advertisement" from the new GGSN, the IP subnet mobility management function on the MT detects the movement into the new IP subnet after the MT compare own IP address and the IP subnet prefix notified by the Router advertisement from the GGSN. And the MT initiates the Mobile IP procedure.

Therefore the control messages related with IP subnet mobility management are transferred on the radio I/F in addition to the control messages of GPRS mobility management. As the result the overhead of the radio I/F is higher than the current GPRS.

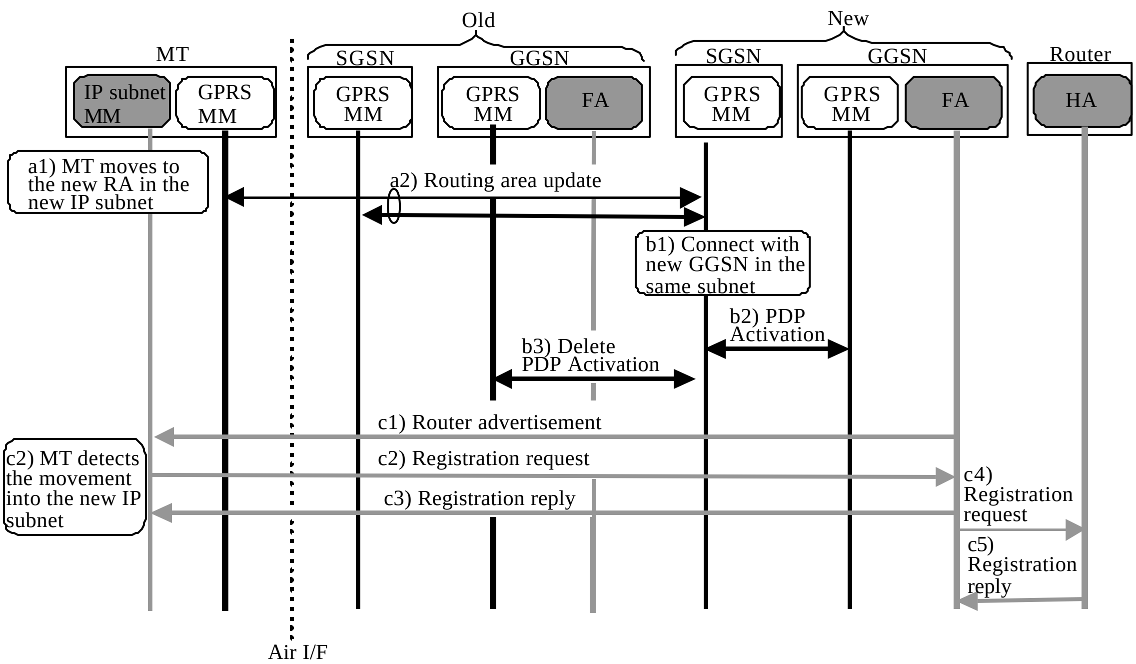


Fig. 3.2.2 IP subnet mobility management procedure
(Scenario1: the detection by the MT)

2) Scenario 2: The core network detects the movement

In this scenario the MT only support the GPRS mobility management function that has already prepared by the MT attaching GPRS. But the GGSN has to support the new function, mobility management mapping (MM mapping) function, to detect the movement and initiate the Mobile IP procedure. In Fig. 3.2.3, the IP subnet mobility management as follows:

(a) When the MT moves into the new RA that belongs into the new IP subnet, the MT only detects the movement into the new RA and initiates the location management procedure. This procedure is same as scenario 1.

(b) After receiving "Routing Area Update Request", the new SGSN makes a new relationship with the corresponding GGSN according to the IP subnet concept (see section 3.1). This procedure is same as the scenario 1, too.

(c) The MM mapping function on the new GGSN detects the movement into the new IP subnet as the result of the comparison between the IP address of the MT and the IP subnet prefix address of the corresponding IP subnet. And then this function initiates the Mobile IP procedure.

The advantages of the detection by the GPRS core network are as follows:

i) the overhead of the radio I/F is as same as the GPRS without IP subnet concept, and

ii) the processing time of IP subnet mobility after the MT moves into the new IP subnet is shorter than the detection by the MT (scenario 1).

After taking into consideration about the MM mapping function on the GPRS core network, the detection by GPRS core network should be selected as the identification of the movement between IP subnets over GPRS environment.

4. Impact of the IP subnet mobility management on the GPRS

This section presents the impact of the IP subnet concept on the GPRS in terms of access rate to the databases of the system (HLR, SGSN, GGSN) when users are roaming. The numbers of accesses that the HLR, the SGSN and the GGSN must handle are calculated using the Fluid flow mobility model [12][13]. The Fluid flow mobility model assumes that the subscribers are moving at an average velocity of v and their direction of movement is uniformly distributed over [0, 2p]. Assuming that the subscribers are uniformly populated with a density of ? and the registration area boundary is length of L, the rate of registration area crossing, R is given by

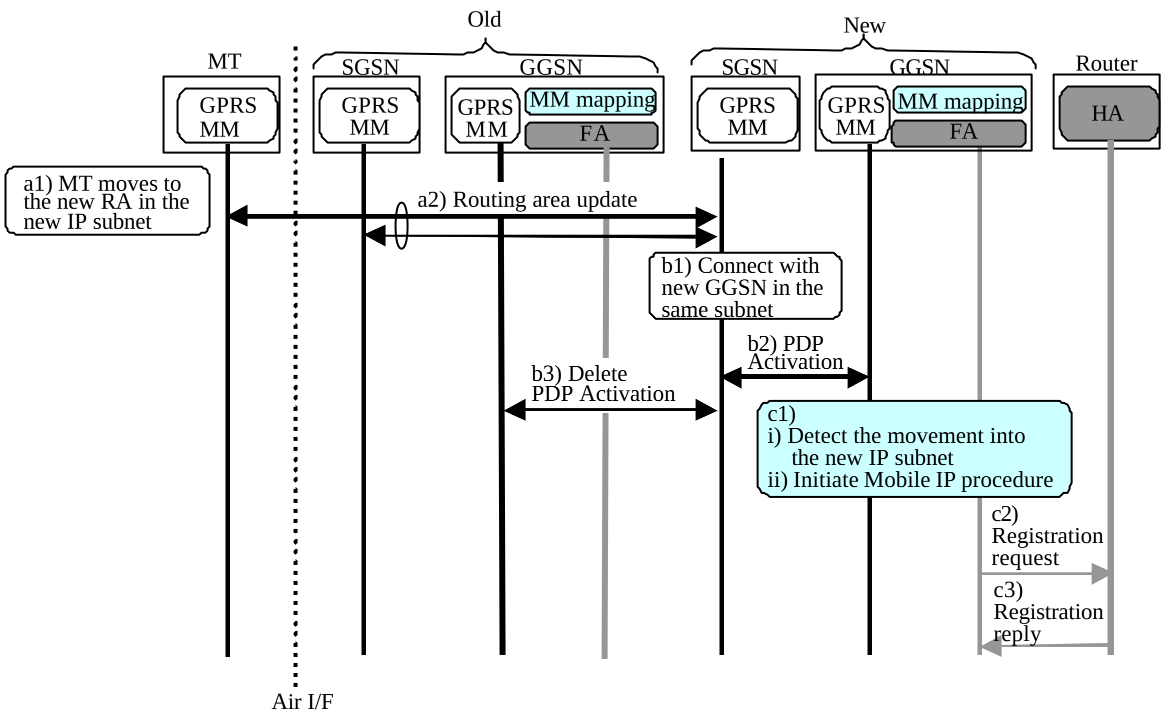


Fig. 3.2.3 IP subnet mobility management procedure
(Scenario2: the detection by the GPRS core network)

$$R = \frac{\rho\, v L}{\pi} \tag{4.1}$$

Using the Eq. (4.1), the number of the routing area crossing is calculated. The crossing number gives the entering number into the corresponding routing area, and this entering number gives the access rates to the HLR, each SGSN and each GGSN.

4.1 Assumptions

Table 4.1.1 shows the based assumption of the evaluation. The attached subscribers are distributed equality in the system. In this assumed GPRS system, only one HLR is arranged. And the subscribers who move out from this system aren't considered under the analysis of access rate to the HLR and the GGSN.

Table 4.1.1 Assumption of the mobile data network system

#	Parameters	Values
1	Total number of subscribers	200,000 ~ 20,000,000
2	Percentages of attaching terminals	50%
3	Average moving speed	6km/h
4	Cell radius (hexagonal cell)	1km
5	Number of cells in Routing Area	4, 8, 12
6	Number of cells each SGSN	1200
7	Number of GGSNs	1~12
8	Total number of cells	14,400

The routing area and the IP subnet consists of several cells, *N*. So the length of boundary is calculated based on [14]. In this paper, *Np* shows the number of cells on the perimeter, and the number of cell sides exposed is *Ns*. So if *r* is the length of a cell side, then the length of the location area perimeter, *L* is given as

$$L = Ns\, r \tag{4.2}$$

Np and *Ns* are given as follows:

$$Np = \begin{cases} 1 & a=1, j=0 \\ 6j - 3 & a=0 \\ 6j + 4a - 4 & otherwise \end{cases} \tag{4.3}$$

$$Ns = \begin{cases} 6 & a = 0 \\ 2Np + 6 & a \geq 1 \end{cases} \tag{4.4}$$

Use the fact that $N = (j+a)^2 + (j+a)j + j^2$. j and a are integer, so N shows the dispersed value.

The number of crossing the routing area, the number of crossing the area managed by the SGSN and the number of crossing the IP subnets are calculated using Eq. (4.1) and the above-mentioned assumption. To get the number of access to the HLR, the SGSN and the GGSN per second (the access rate), the following movement should be considered.

1) The movement between the intra RAs that are managed by the same SGSN
Only the SGSN is accessed to update the routing information in the SGSN.

2) The movement between the inter RAs that are managed by the different SGSNs
In Fig. 2.3.1, the old SGSN is accessed to deregister the MT, the new SGSN is accessed to register the MT and the information of GGSN and HLR is updated.

3) The movement between the IP subnets
The movement between the IP subnets means the movement between the inter RAs. In addition, the old GGSN is accessed to deregister the MT and the new GGSN is accessed to register the MT in Fig. 3.2.2 and Fig 3.2.3.

4.2 Results

Firstly, the access rate to HLR, the SGSN and the GGSN in the GPRS environment are shown. Then the overhead of scenario 1 and scenario 2 supporting IP subnet mobility is compared to normal GPRS operation.

1) The database access rate in normal GPRS operation

In this GPRS environment, one HLR and one GGSN are arranged. As the result, the access rate to the HLR has the same value as the access rate to GGSN. And the number of cells that consist of the RA significantly influences the access rate to the SGSN, and each access rate is increasing remarkably in proportion to increasing the number of attaching subscribers. Therefore the size of RA and the number of attaching subscribers are the important factors to construct the GPRS. In the GPRS environment, Table 4.2.1 shows the example access rates when the attaching subscribers are 1,000,000 people/system. And Fig. 4.2.1 shows the influence of the number of the attaching subscribers on the database access rate.

Table 4.2.1 Example database access rate in normal GPRS operation

Attaching subscribers: 1M people/system

Activity	HLR	GGSN	SGSN 4cell/ RA	SGSN 8cell/ RA	SGSN 12cell/ RA
Update/ Registration	40.8	40.8	59.5	46.7	34.0
Deregistration	-	-	3.4	3.4	3.4
Total	40.8	40.8	62.9	50.1	37.4

[times/sec]

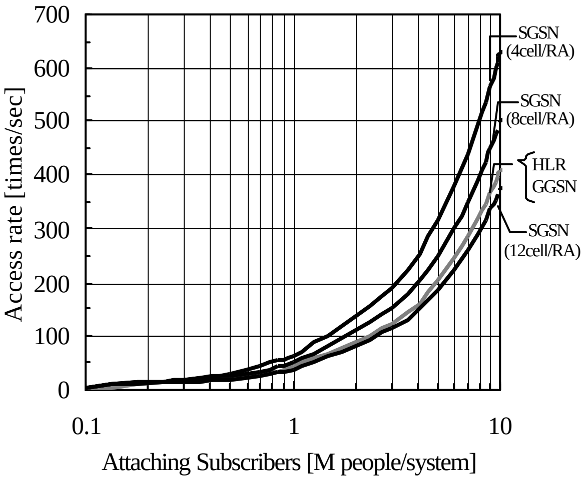


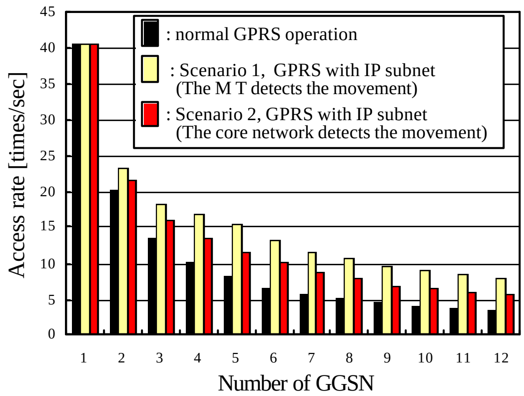
Fig. 4.2.1 Influence of attaching subscribers in normal GPRS operation

2) IP subnet MM overhead

The IP subnet mobility influences to only the database access rate to GGSN. Fig 4.2.2 illustrates the access rates to GGSN of the scenario 1, the scenario 2 and the normal GPRS operation.

In the normal GPRS operation, the attaching GGSN with the MT is fixed while the MT attaches with the GPRS. When the attaching subscribers with each GGSN are assumed to be equal, the access rate to GGSN is decreasing in proportion to increasing the number of GGSN.

In scenario 1 and scenario 2 that support IP subnet MM, the movement between the IP subnets has to be considered. The registration and deregistration caused by the movement between IP subnets influence to the number of access to GGSN. The access rate to GGSN in scenario 2 gives better result than scenario 1. In scenario 2 GGSN is accessed in the location management procedure, but scenario 1 should regard the additional access of GGSN in the Mobile IP procedure. Considering only the access rate to GGSN, the detection by the GPRS core network (scenario 2) should be selected as the identification of the movement between IP subnets over GPRS environment with IP subnet mobility management.



Attaching subscribers: 1M people/system

Fig.4.2.2 Access rate to GGSN

5. Conclusion

In this paper, the combining the mobility between IP subnets and the peculiar mobility management defined in GPRS is discussed in order to provide the same environment as the fixed IP network on the mobile data network system and to realize the terminal movement regardless of the fixed IP network and the mobile network system. In our proposal, the MT only supports the GPRS mobility management, and the GPRS core network detects the movement between the IP subnets based on the control messages of GPRS mobility management, and initiates the Mobile IP procedure instead of the MT. This combining method isn't influential in any additional control messages transferred on the radio I/F. But one of disadvantages is the additional access to the GGSN owing to the handoff between the GGSNs.

We have assumed the fixed IP address that is assigned by the home subnet of the MT. Even if the MT is assigned the dynamic IP address by the IP subnet with which the MT attaches at first, our proposal can provide the IP subnet mobility with same benefit such as no additional control message on the radio I/F.

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