Mobile Subscriber Home Zone Billing

Sicong Huang
Yin Zhang
Abstract

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As a mean to increase the subscriber base, Mobile telecom operators are now trying to target also fixed network subscribers. The main idea is to use the mobile network to provide fixed network rates (cheaper) for the used telecom services when the mobile subscriber is at home and mobile network rates (more expensive) for the used telecom services when the mobile subscriber is not at home. The "home zone" area therefore shall be defined by individual subscriber and the service provider shall be able to determine whether the subscriber is within his home zone. This thesis work investigates the HZB issues and possible solutions, and implements a service prototype thereof exploring user experience of HZB functionality.

The thesis report starts with an introduction of related background concepts regarding GSM Mobile Network, Intelligent Network and mobile positioning technologies. Then a detailed technical solution of the HZB service is presented in terms of system requirements, design and implementation. Several major communication protocols in the mobile core network, such as CAP, SMPP and MLP, are involved in the HZB prototype. The prototype is implemented as a framework for future commercial product. Furthermore, some evaluations are conducted to explore the user experience during the call setup phase. Finally, the report discusses potential future work based on the accomplished system prototype and summarizes achievements as well as challenges of the project.
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<tr>
<td>AOA</td>
<td>Angle of Arrival</td>
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<tr>
<td>ARPU</td>
<td>Average Revenue Per User</td>
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<td>BSC</td>
<td>Base Station Controller</td>
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<td>BSS</td>
<td>Base Station Subsystem</td>
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<td>BTS</td>
<td>Base Transceiver Station</td>
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<td>CAP</td>
<td>CAMEL Application Part</td>
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<td>CDMA</td>
<td>Code Division Multiple Access</td>
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<tr>
<td>COO</td>
<td>Cell of Origin</td>
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<tr>
<td>E-OTD</td>
<td>Enhanced Observed Time Difference</td>
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<tr>
<td>ESME</td>
<td>External Short Message Entities</td>
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<td>GMLC</td>
<td>Gateway Mobile Location Centre</td>
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<td>GPRS</td>
<td>General Packet Radio Service</td>
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<tr>
<td>GPS</td>
<td>Global Positioning System</td>
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<td>GSM</td>
<td>Global System of Mobile communications</td>
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<td>HLR</td>
<td>Home Location Register</td>
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<td>HZB</td>
<td>Home Zone Billing</td>
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<td>IN</td>
<td>Intelligent Network</td>
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<td>LBS</td>
<td>Location-based Services</td>
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<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>MC</td>
<td>Message Center</td>
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<td>MMS</td>
<td>Multimedia Messaging Service</td>
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<td>MSC</td>
<td>Mobile Switching Centre</td>
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<td>NSS</td>
<td>Network and Switching Subsystem</td>
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<td>OSS</td>
<td>Operations Support System</td>
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<td>OTP</td>
<td>Open Telecom Platform</td>
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<tr>
<td>QOS</td>
<td>Quality of Service</td>
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<td>ROSE</td>
<td>Remote Operations Service Element</td>
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<td>SCP</td>
<td>Service Control Point</td>
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<td>SDP</td>
<td>Service Data Point</td>
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<td>SIGTRAN</td>
<td>Signaling Transport</td>
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<td>SIM</td>
<td>Subscriber Identity Module</td>
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<tr>
<td>SIP</td>
<td>Session Initiation Protocol</td>
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<td>Standard Location Immediate Service</td>
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<td>SMLC</td>
<td>Serving Mobile Location Center</td>
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<td>SMPP</td>
<td>Short Message Peer-to-Peer</td>
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<td>SMS</td>
<td>Short Message Service</td>
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<tr>
<td>SMSC</td>
<td>Short Message Service Center</td>
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<td>SRF</td>
<td>Specialized Resource Function</td>
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<td>Acronym</td>
<td>Description</td>
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<td>SS7</td>
<td>Signaling System No. 7</td>
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<tr>
<td>TCAP</td>
<td>Transaction Capabilities Application Part</td>
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<td>TLRS</td>
<td>Triggered Location Reporting Service</td>
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<td>TLV</td>
<td>Tag-Length-Value</td>
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<tr>
<td>TOA</td>
<td>Time of Arrival</td>
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<tr>
<td>USSD</td>
<td>Unstructured Supplementary Services Data</td>
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<td>VAS</td>
<td>Value-added Services</td>
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<td>VLR</td>
<td>Visitor Location Register</td>
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1 Introduction

1.1 Project Overview

This thesis is initiated by Mobile Arts AB with the purpose of investigating and developing a prototype of a telecom value-added service - Home Zone Billing (HZB). Operators can launch the HZB service package to provide their subscribers with a combination of the benefits of fixed-line telephony competitive rates and convenience of mobile communication.

The goals of this thesis are:

- Investigating the GSM mobile network and mobile location positioning methods.
- Propose possible solutions for the HZB service.
- Implement a prototype of HZB service to work with the existing components from Mobile Arts to prove the feasibility of the solution and explore the mobile subscriber experience of the HZB functionality.

Nowadays, Mobile telecom operators are faced with a sluggish user growth rate and dwindling revenues. Exploring various value-added services (VAS) became the central strategy of promoting their primary business. VAS encourages subscribers to use their mobile phones more often and thus allows the operators to drive up their average revenue per user (ARPU). Home Zone Billing service is one kind of value-added service which is intended to provide competitive fixed network rates if mobile subscribers use core services (phone calls, SMS, etc.) within their pre-defined home zone area.

As a Swedish telecommunication software company which provides inno-
ative messaging and location solutions to mobile operators in GSM and UMTS networks, Mobile Arts AB has great interest to research on the requirements of location sensitive billing service and how to provide this service at minimum cost. Thus Mobile Arts initiates this thesis project which focuses on investigating the current billing procedure and location positioning technologies to bring up a feasible solution which reuses the current GSM billing system as much as possible.

The implementation of this HZB service prototype is based on Erlang/OTP [Lab98] with an x86 PC running Ubuntu Linux distribution. It has been done mainly at Mobile Arts AB office in Stockholm, Sweden. This thesis report is written using the LaTeX typesetting software.

We would like to thank our thesis supervisor Lars Kari at Mobile Arts AB who guided us all through this project, our reviewer Arnold Neville Pears at the Department of Information Technology of Uppsala University who gave lots of valuable comments and suggestions to our thesis report, as well as all the engineers at Mobile Arts AB who helped us during our thesis work.

1.2 Project Background

Home Zone Billing is a mobile location sensitive billing service. It is intended to provide added value to mobile users in GSM network. Nowadays, value-added services are typically provided by Intelligence Network - an overlay network architecture which separates the services from the switching functions. In this section, brief introductions about the GSM network and the Intelligent Network are presented first. Home Zone Billing provides
favourable rate based on user’s location while using core services. Thus the common billing procedure in GSM network and different cell phone positioning technologies are introduced too. In addition, some related works regarding the location sensitive billing service are presented as well. These background studies are the foundations of the design of our Home Zone Billing service solution.

1.2.1 Overview of GSM Mobile Network

GSM stands for Global System of Mobile communications, which is a worldwide standard for mobile telephony systems. The most basic functionality of GSM is to offer normal (default) call service with voice. With its ubiquitous implementation, GSM also pioneered low-cost implementation of the short message service (SMS) which is now supported by almost all the mobile phones in the world. GSM network is structured into several discrete sections. Figure 1 is a schematic overview of the main components in a GSM network.

- Base Station Subsystem (BSS)

  BSS consists of the base stations (BTS) and their controllers (BSC). It is the section of a traditional cellular telephone network which is responsible for handling traffic and signalling between a mobile phone and the network switching subsystem.

- Network and Switching Subsystem (NSS)

  NSS is also called the core network. It is the part of GSM system that carries out call switching and mobility management functions for mobile roaming between different base stations.
Figure 1: The structure of GSM network

- **Operations Support System (OSS)**

  OSS is used by telecom service providers for maintenance of the network (such as maintaining network inventory, provisioning services, configuring network components, and managing faults).

- **GPRS Core Network**

  It is the optional part which allows packet based Internet connections.

The communications between all the components are through standardized interfaces, "Abis" between BTS and BSC for instance. The formal-labelled interfaces can improve the compatibility of devices of different operators, and they also can be used to add new logical or physical network entities into the GSM network.
In the network’s switching layer, there are two important components - MSC (Mobile Switching Centre) and HLR (Home Location Register).

MSC is the primary service delivery node for GSM/CDMA network. It is responsible for routing voice calls and SMS as well as other services (such as conference calls, FAX and circuit switched data). MSC controls the setup and the release of end-to-end connections, handles mobility and hand-over requests during a call and takes care of charging and real time pre-paid account monitoring. A GSM network has one or more MSCs which are geographically distributed.

HLR is another key entity of the GSM network. It is the core database that contains subscription record for each subscriber of the network. A GSM subscriber is normally associated with one particular HLR and that HLR is responsible for the sending of subscription data to other network components such as VLR (Visitor Location Register), MSC for further processing.

1.2.2 Intelligent Network and IN Services

Intelligent Network (IN) is a network architecture which allows network operators to provide value-added services in addition to the standard telecom services. In this architecture, network is presented as a layered system. The intelligence is provided by the service layer, which is separated from the switching layer of the core network. The traditional GSM network entities such as MSC and HLR are located in the switching layer of core network while the IN network entities such as Service Control Point (SCP) are located in the service layer. A multitude of nodes may exist in the service layer. But for IN, the SCP is the main entity through which control over the call may
be asserted. Figure 2 shows the IN control of a basic call.

Standard SCPs in the telecom industry today are deployed using SS7 [ITU93], SIGTRAN [LOS99] or SIP [JRS02] technologies. The SCP queries the service data point (SDP) which holds the actual database and directory. The SCP decides how and when to invoke different IN services, based on the received information and the data from SDP.

IN not only enables value-added services to provide a higher-level control over the core telecom services (phone call, SMS, etc) but also offers a flexible approach to implement and integrate these services in the GSM network. The IN services rely on the IN network entities and the service invocation, processing and termination are all controlled by IN network. Examples of such services are: Telephone number portability, Prepaid Calling, Premium Rate calls, Location Based Routing, Call Queuing, Call Transfer, et cetera.
1.2.3 Mobile Positioning Technologies

Mobile positioning refers to the technology used for approximating the location of a mobile device. The purpose of positioning the mobile is to provide location-sensitive services or location-based services (LBS), including wireless emergency services. Different quality of service (QOS) requirements are needed for various usages. As declared in 3GPP Technical Specification [3rd05], the QOS of mobile positioning technology includes both location accuracy and location acquisition time. For some applications it is sufficient to determine a relatively wide area of the mobile terminal but other services such as emergency calls or navigation systems require more accurate positioning within a certain responding time. A great variety of positioning technologies are developed to meet these different demands. These methods can be divided into three major categories - network based positioning, handset based positioning and hybrid methods.

The network-based techniques utilize the existing network equipments in service provider’s network infrastructure to identify the location of the mobile devices. The typical methods include Angle of Arrival (AOA) Method, Time of Arrival (TOA) Method, Cell of Origin (COO) or Cell ID and so forth. The advantage of these methods is that they entail the installation of hardware and software within the operator’s infrastructure and thus can be implemented non-intrusively (without affecting the user’s mobile phones). But due to historical reasons, most of the existing components of mobile networks are not originally designed for positioning usage. Thus this type of positioning has a large degree of uncertainty that should be taken into account by the applications to ensure the quality of service (QOS) requirements.
The handset based positioning methods require that the handsets are equipped with specific positioning devices and software. This technique determines the location of the handset with information such as cell identification, signal strengths of the home and neighbouring cells, which are continuously sent to the carrier. In addition, if the handset is equipped with GPS then more precise location information is then sent from the handset to the carrier. The typical handset based technologies are SIM Toolkit, Enhanced Observed Time Difference (E-OTD) and GPS. Thanks to those specialized devices and programmes embedded inside the handsets, this type of positioning provides a high precision of the location information. But the downside is that it depends on the mobile phone’s capacity and requires special active cooperation of the mobile subscriber for installing the extra programs in their handset. Service providers also need to pay high attention to deceptive data sent from the mobile phones in order to ensure service security.

The hybrid positioning methods use a combination of different methods (i.e. network based positioning, handset based positioning) to enhance precision. Usually, this type of methods spends more time on information collection and location computation. But they do provide the most precise location of the mobile devices.

1.2.4 Related Work

As the idea of zone based services was proposed, there are many projects developed within this context in the recent decade. In the early years of 2000s, operators launched a Home Zone Billing project in Samoa. The location information of this project is mainly based on Cell IDs, which introduced a large variation into the result of in/out zone judgement. Thus, due to
the limitation of the positioning methods and the sporadic nature of the 
service, the availability and reliability was unacceptable. Subscribers con-
tinuously complained about its billing problems. On the other hand, those 
“home zone”s of the subscribers in Samoa could be the whole town large, 
the operators therefore suffered huge economic losses.

After the silence of several years, along with the development of the po-
sitioning technologies, zone wide services become more and more mature. 
SeekerZone is one of those successful projects, developed by Seeker Wire-
less Ltd UK. The project uses the handset based positioning method, which 
loads an applet into the SIM card, and it calculates zone changes locally so 
as to reduce the network impact. It also has low impact deployment with 
nothing to install in the subscriber’s home. But instead it requires that the 
existing handsets have to be redesigned in order to meet new requirements, 
which means in this project the subscribers shall change the SIM card. The 
following are some claims of the Seeker Zone project:

- Zone sizes up to 50 times smaller than with Network Cell-ID
- 99.5% reliability ensures accurate billing and reduced customer care 
calls
- Supports both pre-paid and post-paid subscriptions
- Works with most 2G/GSM and 3G/UMTS handsets

Although SeekerZone can provide the accurate and reliable location infor-
mation for the subscribers and operators, it do need to make modification 
on the cell phone. This might make subscribers feel uncomfortable.
1.3 Report Structure

The rest of this report is organized as follows: Section 2 describes the main problems which should be solved in this thesis project and how we manage this project. An detailed technical solution of HZB, including system requirements, design and implementation, is presented in section 3. Section 4 describes the evaluation of the HZB service prototype. A discussion about future works is done in section 5 and section 6 is the conclusion.

2 Problem Description

2.1 Goals and Motivation

Nowadays most people use mobile subscription in their daily life for convenience. But fixed line subscription is still popular at people's homes and offices since telephone is still handy within these certain areas. And most importantly, fixed line provides cheaper rates than mobile phones. As a mean to increase their subscriber base and average revenue per user, mobile telecom operators are now trying to target also fixed network subscribers. The main idea is to use the mobile network to provide fixed network rates (cheaper) for the telecom services used within the mobile subscriber’s "home" area and mobile network rates (more expensive) when the mobile subscriber uses service outside his "home" area. Therefore the mobile subscriber will be encouraged to use their mobile subscriptions instead of any fixed line subscription while at their "home" area. And this "home" area could be anywhere as the subscriber prefers, such as his own house or work-
ing place.

Though the idea is clear, there are quite a few technical challenges for carrying out home zone billing. How to define and represent the subscriber’s Home Zone in the mobile network? How to know that the subscriber is within or outside his Home Zone when using a telecom service and how to inform him about the In/Out zone information? How to reuse, upgrade and integrate existing mobile network functionality in order to provide HZB service at a low cost? How to prevent/minimize fraudulent mobile subscriber use of Home Zone Billing? In this thesis project, we mainly focus on investigating the functional and non-functional requirements of the HZB service, designing a feasible solution and implementing a prototype of the HZB service. This prototype could be further used for developing a commercial location sensitive billing service.

The goals of the project are summarized as following:

1. Investigate the existing GSM mobile network (including architecture and network entities) and mobile location positioning methods.
2. Propose possible solutions for the technical difficulties in HZB service.
3. Implement a prototype of HZB service. The prototype shall reuse and be compatible with the existing components of Mobile Arts as much as possible.

The following is out of scope for the thesis:

1. HZB Service specific Operation, Administration and Maintenance support.
2. HZB Service specific product documentation.

3. HZB Service specific system testing with respect to stability, redundancy, OAM and charging.

2.2 Requirements and Management

General requirements of this thesis project are:

- Due to this thesis has a relatively wide background within the mobile telecommunication field; the research shall focus on the HZB-relevant parts;

- For future commercial use, the solutions should take account of the cost of deployment and user experience;

- As the prototype shall reuse and interact with several existing Mobile Arts’ network entities which are mainly based on Erlang/OTP, the implementation of HZB service node prototype shall also be based on Erlang/OTP;

- The thesis work requires close cooperation with system design at Mobile Arts. It shall therefore be done mainly at Mobile Arts premises in Stockholm, Sweden.

Management of thesis project:

1. Time schedule of the thesis project:

   - Creation and approval of Requirement Specification – 4 weeks
- Creation and approval of Implementation Proposal – 4 weeks
- Writing code for HZB service node prototype implementation – 6 weeks
- Writing code for necessary HZB service node prototype testing tools – 2 weeks
- Testing of HZB service node prototype – 1 week
- Creation, presentation and approval of Final University Report – 5 weeks

2. Documentation:

The necessary documentation including requirement specification and implementation proposal shall be kept.

3. Implementation:

All of the source code is daily updated and submitted to the CVS server of Mobile Arts during the coding phase.

### 2.3 Development Method

High performance (i.e. concurrent, distributed, scalable, fault-tolerant, robust etc) is always the core feature of telecom services. Considering the soft real-time demands for telecommunication software, Mobile Arts has been using Erlang/OTP [Lab98] for developing their service solutions. For easier integration with Mobile Arts’ existing components and further development into commercial product, we chose Erlang as the main development method for the implementation part of the thesis project.
Erlang is a functional programming language. Concurrency in Erlang is fundamental to its success. Multitude of processes can exist simultaneously and each process is lightweight and independent. Another big feature of Erlang is distributed computation, which means different Erlang nodes running on any operating system are able to communicate with each other through a heterogeneous network. In addition, although Erlang is a high-level language, it still can be used for tasks with soft real-time constraints. With garbage collection implemented on a per-process basis, storage management in Erlang is automated. This gives system response times on the order of milliseconds even in the presence of garbage-collected memory. Open Telecom Platform (OTP) is an Erlang library developed by Ericsson AB that provides modules which implement Erlang behaviours. These behaviours are the most common concurrent design patterns such as "Finite State Machine", "Supervisor". And these behaviours are widely used in the telecommunication projects. Other development tools are used:

- EMACS and MAKE for text edit and code programming
- CVS for code submission and version control
- Visio and LaTex for making diagram and writing documents

The development environment is x86 PCs with Linux Ubuntu 10.04 OS.
3 Technical Solution

3.1 System Requirements

We started by clarifying the functional and non-functional requirements of Home Zone Billing Service. Value-added services are supposed to bring benefits to both telecom operators and their subscribers, so is HZB service. Therefore we took into account the requirements of both mobile subscribers' and telecom operators while doing requirement analysis. For mobile subscribers, the requirements mainly focus on user experience and convenience; while for telecom operators, we pay more attention to the requirements which provide the service at minimum cost and prevent the revenue leakage.

Home Zone Billing service provides two central functionalities: one is handling mobile user subscription which defines their personal home zone area; the other is provide correct billing while subscribers are using core services (phone call & SMS). More detailed requirements are elaborated /derived based on these two core functionalities. The requirements are classified as functional and non-functional categories and labelled them with REQUIRED and DESIRED tags.

3.1.1 Requirements regarding HZB Subscription

Requirements regarding user subscription:

Following are the REQUIRED functionalities of HZB service subscription:

1. HZB service shall support subscription related operations from user. The subscription related operations shall include subscription creation, update, view, activation, deactivation and deletion.
2. User customized subscription shall be supported for user convenience.

3. HZB service shall be able to retrieve user’s location information while they are defining their home zone through user interface.

4. HZB service shall have a subscriber database with proper home zone information stored for zone based billing.

5. HZB service shall be able to support cell-id based zone representations.

6. HZB service shall be able to present the home zone information to the subscribers.

7. HZB service shall be able to notify the users whether they are in/out zone while using the basic telecom services.

8. HZB service shall prevent/minimize fraudulent subscriber usage of HZB service.
   - Support zone area check during subscription creation and update.
   - Support mobile number portability check during subscription creation and update.
   - Support subscription validity check during subscription creation and update.

Following are the DESIRED functionalities regarding HZB service subscription:

1. Help desk assisted subscription should be supported for handling normal subscription requests as well as customer complaint.
2. User web interface should be provided for supporting user subscription requests.

3. HZB service should be able to support coordinate based zone representations.

4. HZB service should support automatic update on zone representation based on network structure change.

5. HZB service should support administrative operations on user subscriptions, such as activate/deactivate the subscription by operators.

6. HZB service should allow users to customize certain features of their subscription, such as activate/deactivate the notification about In/Out zone during core service usage.

3.1.2 Requirements regarding Zone-based Billing

Following are the REQUIRED functionalities of HZB service regarding the core services (Phone calls & SMS):

- The Home Zone Billing Service shall support Phone Calls and SMS of the core telecom services.

- The HZB Service shall be able to determine that whether the subscriber is within or outside the Home Zone when using a telecom service.

- The HZB service shall be able to inform the subscriber that the subscriber is within or outside the Home Zone when using a telecom service.
– The HZB Service shall have the ability to adjust the billing information whilst the subscriber moves into and out of home zone during a living call.

– The HZB service shall provide a smooth user experience for the subscriber.

– The HZB service shall prevent/minimize fraudulent behaviors of using Home Zone Billing.

– Re-use, upgrade and integrate existing mobile network functionality in order to provide Home Zone Billing

Following are the DESIRED functionalities of HZB service in this phase:

– The notification of HZB Service shall be able to be activated or de-activated by service providers and subscribers themselves.

3.2 System Design

3.2.1 System Design Overview

Bear in mind that the Home Zone Billing service should provide all necessary functions to the mobile subscribers and this service should be implemented and launched with minimum cost, we studied the billing procedure in GSM mobile network, different location positioning technologies (as described in the project background section) as well as the existing functional components provided by Mobile Arts and came up with the following design of the HZB service.
For user subscription in HZB service, it is all about getting a geographic area which is the subscriber’s “home zone”. This could be done by old fashioned way such as give the service provider’s help desk your address and define the zone area based on that address. But is it is more popular and convenient to offer a way that user can just walk around their home and customize the subscription. In view of the fact that Mobile Arts has developed their own short message service center (SMSC) and a Gateway Mobile Location Centre (GMLC) which can retrieve the location of a given mobile subscriber in the mobile network, we chose to provide SMPP support in HZB service in order to interact with user use SMS/USSD for any subscription related requests and use GMLC to obtain user’s location during subscription procedure.

Thinking of Home Zone Billing as a special service which takes user location information into consideration in addition to the normal billing methods, we decided to reuse the current billing system and integrate the HZB functionality with the mainstream billing procedure.

Taking into account that currently many mobile networks use the CAMEL Application Part (CAP) [3rd09a] protocol towards a Service Control Point (SCP) in order to achieve on-line billing of the mobile subscriber when using services in the mobile network, one feasible solution is to utilize the control messages exchanged between MSC and SCP to carry extra location information for charging. Again HZB node can use GMLC to get user’s instant location information from GMLC during the basic telecom service and include In/Out zone information in the control messages. As long as the charging service on SCP side knows how to interpret the extra information and utilizes it for billing, the goal of the HZB service - provide billing according to user location - is achieved.
Based on the above thoughts, the solution links HZB service node between the MSC and the SCP. HZB node mainly supports CAP protocol to talk with MSC and SCP. It also provides support for SMPP [SMP03] to interact with subscribers through SMSC and MLP [Ope05] towards GMLC for location retrieving. Other interfaces can also be provided for advanced features: HZB node may contact HLR through MAP in order to support Number Portability; SDM can be used to manage HZB subscriber data from Provisioning system; MM7 towards MMSC could be used for providing Home Zone coverage map to subscriber; HTTP could be provided for subscribers' self management of Home Zone via HZB Web Portal. Figure 3 is the network architecture design for HZB service. Though the HZB service is describe as a single node here, it could be integrated with other entities (e.g. MSC).

### 3.2.2 Design of Subscription Handling

HZB service provides subscription related interfaces to support user requests for creating, updating and customizing their subscriptions to HZB service. Mobile users can freely define their own home zone areas and enable/disable different features of the HZB service. According to the system requirements, HZB service should be able to handling subscriber requests regarding subscription creation, update, view, activation, deactivation and deletion. We do consider both user customized interface and help desk assisted interface for HZB service subscription. Clearly, both interfaces shall support all the requests mentioned above.
Figure 3: Network Architecture of HZB Service
3.2.2.1 Subscription Interface

3.2.2.1.1 User customized interface

The convenience of user customized subscription interface is that it allows
subscribers to define and customize their home zone subscription by them-
selves. Subscribers can send requests to HZB service node and the sub-
scription function in HZB service will interact with user for completing the
request. In observation of ubiquitous support of SMS/USSD in normal mo-
bile phones, we decided to use SMPP protocol to support the SMS/USSD
requests/responses exchanges between the subscribers and the HZB service.

Introduction to SMS/USSD

Short Message Service (SMS) is a text communication service component
that using standardized communications protocols to allow the exchange of
short text messages between mobile phones and other SMS capable entities.
In GSM network, Messages are sent to a Short Message Service Center
(SMSC) which provides a "store and forward" mechanism. It attempts to
send messages to the recipients. If a recipient is not reachable, the SMSC
queues the message for later retry.

USSD stands for Unstructured Supplementary Services Data. It is a way
of sending short commands from the mobile phone to the GSM network. It
uses, like SMS, the signalling channel of the GSM connection. The difference
is that it does not use a store and forward architecture, but a session oriented
connection. USSD is commonly used by pre-paid GSM cellular phones to
query the available balance. The vendor's "check balance" application hides
the details of the USSD protocol from the user. Service providers usually
use USSD Gateway to route USSD messages from the signalling network to
service applications and back.

Why choose SMPP

SMPP is an open, industry standard protocol designed to provide a flexible data communications interface for the transfer of short message data between External Short Message Entities (ESME), and Message Centers. A Message Center (MC) is a generic term used to describe systems such as a Short Message Service Center (SMSC), GSM Unstructured Supplementary Services Data (USSD) Server. An ESME typically represents a fixed network SMS client, such as Email Gateway, or Voice Mail Server. Mobiles Arts has already developed their SMSC product which supports SMPP protocol to exchanges SMS between mobile clients and service entities. Thus the HZB service which acts as an ESME will be able to communicate with mobile clients through Mobile Arts’ SMSC using SMPP.

Though originally the plain SMPP protocol does not support the delivery of USSD data, TLV (Tag-Length-Value) parameters were added to version 3.4 of the SMPP protocol to extend the protocol with enhanced features. The ussd_service_op TLV is introduces for SMPP to carry USSD data.

In following paragraphs, we will depict the SMPP based service scenarios of the HZB subscription procedure. Though SMS is used as an example here, HZB service node may use USSD interface which cooperates with USSD gateway in a similar way.

Service Scenario

With the SMS interface provided by HZB service, subscribers can send SMS commands to HZB service to request subscription related operations. The communication between subscribers and HZB service goes through SMSC.
Mobiles Arts’ SMSC uses SMPP to talk with any ESME. And the SMPP protocol stack implemented by Mobile Arts is compliant with SMPP 5.0 specification from the SMS Forum.

The operations provided by HZB subscription function can be categorized into two separate classes: stateless operations which are handled by a single pair of request/response and stateful operations which require several requests/responses to accomplish.

The main stateless operations are subscription view, activation, deactivation and deletion. The service scenario is simple: the user sends SMS command to request an operation; HZB service process the operation and returns the result. Figure 4 shows the call flow of the stateless operations.

HZB service provides two stateful operations for the SMS interface - subscription creation and update. The procedure for handling these operations is identical. The only difference is creation is for first-time subscription and update is for subscription renewal. The subscriber sends command to
start the zone definition procedure. During then HZB service sends back instructions for guiding the user to complete this procedure. User may also interact with the service to cancel the procedure or indicate a stop. The whole process is considered to have different states and these states shall be managed by the HZB subscription function. Figure 5 shows the call flow of the stateful subscription operations.

There are two more assisting stateless operations for completing the subscription creation/update operation: confirmation and rejection. The service scenario is the same as other normal stateless operations. The purpose of providing these two operations is to allow user to determine whether the defined zone is correct. Due to the varying accuracy of positioning methods, the zone definition based on a collection of user locations may have large deviation comparing with the actual home area. Thus bring user decision into subscription procedure is necessary.

User web interface is another way to allow subscribers to customize their HZB subscription. HZB service may host a web server to provide web services for handling subscription operations. Mobile users may login to the HZB web portal and use street address to define a home zone through a map interface. The same map interface also provides the zone area information when the subscriber wants to view their current subscription. And activation/deactivation of particular subscription features can also be done through the web portal.
Figure 5: Callflow of Stateful Operations
3.2.2.1.2 Help Desk Assisted Interface

An old fashioned way of doing subscription is to use Help Desk. Service providers may have service centers where mobile users can drop in and get support from the help desk. What help desk provides is mainly the same services that subscriber’s can do through the SMS interface or user web interface. It is achieved by the same web service used for user web interface. The web service provides administrative account for the help desk. With the subscriber id and location information provided by mobile user, the help desk can help them to process their subscription.

A more significant meaning of having help desk assisted interface is that it can handle customer compliant. Due to the mobile network complexity and the accuracy of the positioning method, the defined home zone may have certain deviation from the real zone area. Customer can call the help desk in case they were charged with mobile rate while within their home zone. The help desk may try to locate the user and manual adjust their zone area if necessary.

3.2.2.2 Zone Representation

Define a home zone in mobile network is a big challenge. The zone areas should be sufficient to cover the subscriber’s home or office to satisfy the user and also not too large to cause operator’s revenue leakage.

Considering the infrastructure of the GSM network (described in section 1.2.1), it is nature to use cells to represent user’s home zone area. Each cell covers a certain geographic area and a mobile phone always connects to the dominant cell in its current location. While using the basic telecom service,
the cell to which the user is connected can denote the user location. Thus the list of cells which cover user’s home/office area can roughly represent his "home zone". For subscriptions made through the HZB web service, once user has defined his home zone through the map interface the cell list which covers the zone can be obtained by searching the cell database (described in section 3.3.5). For users subscribe through SMS/USSD interface, HZB service will guide the user to walk around his home/office and collect the cells to which the phone connects to during the zone definition process. Here the dynamic location information is obtained from GMLC (described in section 3.2.4). The reality is that during the walking around process, the handset may only connect to some dominant cells in that region because of the limitation of the zone definition period. There could be other cells which also cover the home zone area and the subscriber may connect to those cells while making phone calls from their home zone in the future. These cells should also be included in the cell list for keeping integrality of subscriber’s home zone. Thus an internal cell DB is required for deriving other cells which also cover the home zone. Details about the Internal Cell DB design is described in DB design section.

But cell based location indication is coarse-grained since cells are of different sizes. It is obvious that it is inappropriate to use a macro cell which covers a whole town to represent someone’s home zone.

A fine-grained way is to use geographic coordinates to describe the zone area. Using the coordinates of the centre point and other variables, we are able to represent user’s home zone in different shapes (circular area, square, circular arc, etc). The longitude and latitude can present a more precise area than the cell ids. For subscriptions made through the HZB web
service, HZB service shall convert the area on map interface into geographic coordinates. For users subscribe through SMS/USSD interface, while the user is walking around his house/office, location information in terms of coordinates is collected instead of just cell ids. And HZB service shall convert all these coordinates into a geographic area which ultimately shows the subscriber’s zone area. GMLC is still the source to get user’s instant location in coordinates and the details are described in section 3.2.4.

In face of the fact that not all mobile phones today assists precise positioning such as GPS, GMLC may only able to get the cell info when trying to locate the user. Thus cell id based zone representation should always be the basic and fall-back choice for the subscribers with ordinary cell phones.

### 3.2.2.3 Zone Rendering

The home zone area should be rendered to the subscriber at the end of the subscription phase to let the user confirm whether the defined zone is correct. Also the users may want to view his subscription to check what the current zone area is. Zone rendering through the web interface is trivial since the map interface can be utilized to show the zone area in an intuitive way. But for the SMS/USSD interface, it is quite difficult to describe the zone in an understandable way in text data. One alternative could be generate a piece of map graph containing the zone and send it to user using MMS (Multimedia Messaging Service). But on account of not all mobile phones are MMS capable, render the zone with text should always be the fall back option. One compromising choice could be providing a map which represents the zone area through the HZB web service and send the link to the subscriber with SMS for viewing it.
3.2.2.4 Fraud Check

In order to prevent subscribers from misbehaviours while using HZB service, HZB application provides fraud checks in various aspects.

Zone Area Restriction

On one hand the home zone should be at a reasonable size which covers user’s home/office so that user can truly benefit from this subscription. On the other hand the zone area should not be too large so that the service can bring expected revenue to service providers.

It would be telecom operator’s decision to define the zone area limitation in order to attract more subscribers as well as to maximize the profit.

The map interface of the HZB web service should provide a limitation on the maximum area of the zone. The zone definition procedure of the SMS interface should check the final zone area to see whether it exceeds a certain limitation.

Update Interval Limitation

There could be such attempts from user which switch the home zone frequently in order to further enjoy the cheaper rate (e.g. define the office as the home zone during working hour and renew the zone to his home after work). This can cause serious revenue leakage to the service provider since the mobile user excessively takes advantage of the HZB service. Of course service providers can launch other service packages which allows user to have multiple home zone/work zone. But that would be another story. Particularly, in basic HZB service, subscription should be renewed on a monthly basis. Each subscription should keep an activation time stamp indicates
when it became effective. HZB subscription function checks this time stamp while handling subscription update requests and rejects the operation if this renewal is made within the update time limit.

3.2.3 Design of Zone-based Billing

3.2.3.1 Zone based Billing Interface

Presently, with the help of IN network, many mobile networks achieve on-line billing through a Service Control Point (SCP). The SCP applies different charging rates for miscellaneous services. For HZB billing service, it is desirable to re-use the current on-line billing infrastructure of GSM mobile network. As we mentioned before, this is mainly because of the compatibility and cost consideration.

In order to provide the billing information for SCP and collect subscriber information from MSC, the HZB service is linked in between MSC and SCP. And to be able to communicate with the MSC and SCP, HZB service shall use the standard communication interface between them, which is CAMEL Application Part (CAP) protocol.

CAMEL [3rd09b] stands for Customised Applications for Mobile networks Enhanced Logic. In general speaking, it is a set of standards designed by 3GPP for telecommunication operators. By following these standards, the operators may define their own services over and above standard GSM services/UMTS services. The CAMEL architecture is based on the Intelligent Network standards, and uses the CAP protocol.

CAP is a signalling protocol used between Intelligent Network and Mobile Network such as GSM. It is an application level protocol and it is categorized
as Remote Operations Service Element (ROSE) user protocol [wik]. The underlying network is Transaction Capabilities Application Part (TCAP) of the SS#7 protocol suite [Rus06]. CAP consists of various operation messages and the CAP stack can be functionally classified into two parts: CAP client and CAP server.

Normally, the CAP client resides with MSC which is in the Mobile Networks and on the contrary, the CAP server is located in SCP which is in the IN networks. The message interaction between CAP client and CAP server, which is called CAMEL dialog is maintaining during the whole call. Through the CAMEL dialog, the service logic in SCP can add control during a call.

As mentioned above, there are loads of operation messages can be used in CAP, and to summarize in a simple way, the design of HZB billing service mainly is to re-use the proper operation messages and mostly follow the current billing message flow between MSC and SCP.

### 3.2.3.2 Zone Based Billing Mechanism and Messages

According to the CAP specification [3rd09a] and the original usage of CAP operation messages [Nol06], the following operation messages shall be used in the billing part of the HZB service. All these messages will first be received by HZB service, and eventually they will be sent to MSC or SCP according to their origin sequence. The call flow is shown in Figure 6.

- “InitialDetectPoint”, or IDP for short. In CAMEL, most services are invoked by this operation message. It is sent from CAP client towards CAP server. And IDP contains vast call and service related information such as “MSC address”, “bearer capacity”. As HZB service is an
Figure 6: Callflow of Zone-based Billing
IN service, it shall also be triggered by IDP.

Normally, the subscription information (CSIs etc) will be sent from HLR to the MSC during the location update procedure. This location update procedure means the subscriber wants to register with the MSC. If there is any CAMEL service associated with the subscriber in the subscription, the MSC encapsulates an IDP contains the subscription information and sends it to SCP through CAP client. As a result, the SCP begins the corresponding CAMEL service. In HZB scenario, the IDP is first captured by HZB node and the following information shall be obtained:

- Service Key – indicates which CAMEL service shall be invoked. In real case, the HZB service might be assigned a unique service number. This number is stored in subscriber’s subscription. The service key helps HZB node to distinguish its valid subscriber. If HZB node receives an IDP with its service key, the service shall continue; Otherwise (i.e. receives an IDP with other service key than HZB), the HZB service node shall directly relay this IDP;

- Calling Party Number – encoded identifier of calling party. This Calling Party Number contains the MSISDN which shall be used by HZB service node to query instant location information from GMLC (described in section 3.2.4).

- Location Information – The IDP may also contain the location information of the calling subscriber. This location information is a backup for HZB service in case it can not obtain the current location information from GMLC.
When HZB service node first receives a HZB IDP from MSC, it applies a quick in/out zone measurement procedure, which includes the following steps:

- Request subscriber’s current location information from GMLC. Due to different positioning method has different precision of the location information, the response time of GMLC is subject to the location precision (more precise positioning requires more time). The fundamental principle is to make this acquisition time as short as possible so that the subscriber would not perceive the delay. To achieve this, the quality of the position and the location type may be specified in request.

- Compare the location information with pre-defined home zone definition. As the home zone definition is formed by cell IDs and geographic coordinates, hence the comparison is mainly based on these two aspects. Similar to the step above, this comparison may also take time, especially with coordinates. The HZB service may choose an effective algorithm to minimize the time of the step.

- Add an in/out zone indicator into IDP as result. This indicator shall be recognized by SCP so that it can apply the proper charging rates.

Although the in/out zone measurement is designed to perform rapidly, it may still take time due to any special cases (e.g. network problems). In this situation, regarding the user experience, the HZB service node is desirable to play special tone for the subscriber during the measurement period. And after the in/out zone measurement, the HZB may also notify the subscriber of the in/out zone result. At last, the IDP
is sent to SCP.

- ConnectToResource (CTR), PlayAnnouncement (PA), Cancel (CAN).
These three CAP operation messages can be used to play special tone or notification for the subscriber. In general speaking, there is a specialized resource function (SRF) resides with MSC. These SRF resource include tones, pre-recorded voice announcement, text messages and so forth. When HZB service needs to play a specific tone or a notification for the served subscriber, it shall first send a CTR operation message to MSC, this CTR will connect the subscriber to the SRF. And then, HZB service shall send a PA operation message with a specific tone ID to MSC, This tone ID indicates which tone or announcement shall be played for the subscriber. When the HZB service needs to stop the special tone (i.e. the location positioning procedure and the comparison is completed), it shall send a CAN operation message to MSC.

- “RequestReportBCSMEvent”, or RRB for short. During the progress of the call, the SCP needs to be informed of several special time points and takes proper actions to ensure the logic of the call behaves correctly. These time points are called “Detect Point” or “BCSM event” [Nol06]. Generally, after receiving IDP, the SCP sends a RRB which asks MSC to monitor a few specific BCSM events such as “oNoAnswer” (the called party doesn’t answer the call) so that the MSC will report these events when they occurred. For HZB service, there are two type of BCSM events shall be monitored: “oAnswer” (the called party answers the call), which means the call is established and “oDisconnect” (any party disconnects from the call), which means the call
is released. The HZB service shall start and stop the periodically location positioning according to these events.

In case, the RRB from SCP may not request MSC to report “oAnswer” and “oDisconnect”. The HZB service node shall modify the RRB properly to ensure these two type of events will be reported to HZB.

− “EventReportBCSM”, or ERB for short. As the response of RRB, the ERB is used to report the specific events when they occurred. It is sent from CAP client(MSC) towards CAP server(SCP). If the reported event is not requested by SCP, the HZB node shall not send this ERB to SCP.

− “ApplyCharging”, or ACH for short. “ApplyChargingReport”, or ACR for short. In CAMEL, the on-line charging mechanism is achieved mainly by using ACH and ACR operation messages during the call. ACH is sent from SCP towards MSC and ACR is the opposite direction. Generally, when SCP receives the ERB of “oAnswer”, it will reserve certain credits for certain period (e.g. 3 mins) according to the charging rate of different CAMEL service. And build an ACH with the duration to tell MSC the call can keep continuation in the next period. As the response of ACH, when the certain time period expires, MSC will use ACR to report the period call charging result to SCP and ask another ACH to get more time for the call. If the credits are sufficient for the next period, the SCP will send out ACH again. This procedure takes place repeatedly until the call is release or there are not enough credits.

For HZB service, the duration information, which is called “max call
period duration” shall be retrieved from the first ACH, because the interval of the periodical location report shall be on the basis of this duration. The strategy is to ensure that in the period of each ACH there is one location report at most.

On the other hand, in order to adjust billing rate during a living call, HZB service shall take advantage of the ACR to fulfill the purpose. Each time HZB node receives the ACR from MSC, it applies the in/out zone measurement and add an in/out zone indicator as result into the ACR, then send it to SCP. SCP therefore can apply appropriate charging rates during the call.

There is a slight difference between the in/out zone measurement in ACR and the one in IDP. The HZB service first is trying to obtain the current location information from GMLC in IDP, but in ACR, since the location report is received periodically, the HZB service stores this latest location information, and when performing the in/out zone measurement, it directly uses the stored location information.

### 3.2.4 Design of Mobile Location Retrieval

One key functionality needed by both HZB subscription procedure and zone based billing procedure is obtaining subscriber’s instant location information. Nowadays, with different positioning methods, many mature solutions are developed for supporting mobile location retrieval. There exist network elements such as serving mobile location center (SMLC) and gateway mobile location center (GMLC) which provide integrated functionality for mobile positioning. In the following sections, we introduce the GMLC and Mobile Location Protocol (MLP) which are the two core components for retrieving
the mobile location in HZB service.

**What is GMLC**

GMLC stands for gateway mobile location center. It is a computer processing device that can receive and process requests from a location service client which are forwarded to the serving mobile location center. The GMLC is used to discover and communicate with location servers that determine the position of the mobile device. Mobile Arts has their own Gateway Mobile Location Centre - a state-of-the-art combined location and presence server for GSM, UMTS and CDMA networks. It can further consult serving mobile location center to retrieve the location of a given mobile subscriber in the mobile network.

**Introduction to MLP and its services**

The Mobile Location Protocol (MLP) is an application-level protocol for getting the position of mobile stations (mobile phones, wireless personal digital assistants, etc.) independent of underlying network technology. It serves as the interface between a Location Server and a Mobile Location Service Client. One possible realisation of a Location Server is the GMLC. Mobile Arts GMLC also chose to provide MLP interface to handle the requests from MLS client. MLP is an XML based layered protocol. The protocol structure is shown in Figure 7. The service layer defines the actual services offered by the MLP framework while the elements layer defines all common elements used by the services in the service layer. Details of these elements are defined by a set of XML DTDs. On the lowest level, the transport protocol defines how XML content is transported. As a ubiquitous protocol for location services, MLP is intending to support diverse transport mechanisms. Possible transport protocols include HTTP, WSP, SOAP and others.
MLP works in a Client/Server mode. Location services use MLP client to send requests to location servers. Answers/responses are provided by the location server through MLP server side. All the MLP messages are in the format of XML document.

There are several different types of location services. Each implementation of location server may decide which services it wants to support. Regarding the capacity of MA GMLC and the functionality required by HZB service, the services used by HZB node are Standard Location Immediate Service (SLIS) and Triggered Location Reporting Service (TLRS). Standard Location Immediate Service is a standard query service which is used when a single location response is required immediately (within a set time). It is used at the beginning of the zone definition procedure during subscription as well as the start point of the zone based billing procedure. This service consists of a request and a corresponding response. Standard Location Immediate Request is sent by HZB service to request for a subscriber’s instant
location. Standard Location Immediate Answer is sent back from GMLC with the location information.

Triggered Location Reporting Service a service used when the mobile subscriber’s location should be reported at a specific time interval. HZB service uses this service to get subscriber’s location information periodically during the zone definition procedure and the zone based billing procedure. This service consists of a request, a response and a series of reports. Triggered Location Reporting Request (TLRR) is send by HZB service to request GMLC to provide a subscriber’s instant location information periodically. The result of the request is presented in a Triggered Location Reporting Answer (TLRA) from GMLC. Also there could be a set of Triggered Location Report (TLREP) which carries the subscriber’s location information sent from GMLC at the specified interval.

In our solution, HZB service acts as a location service client which consults Mobile Arts GMLC to get subscriber’s instant location information. On HZB side, an MLP client is needed for sending SLIR and TLRR as well as handling the SLRA, TLRA and TLREP from GMLC.

The current MLP specification is standardized by Open Mobile Alliance [Ope05].

3.2.5 DataBase Design

HZB service provides two internal databases: one is the Subscriber DB which stores HZB subscriptions; the other is the Internal Cell DB which is used by subscription function for generating cell based zone representation.

HZB Subscriber DB stores all the information regarding user subscriptions.
The HZB SDB contains a single subscription table where each entry is the subscription for a mobile user. The subscription contains a unique subscriber ID, the defined home zone area (with cell list representation or coordinates representation or both), a list of activation indicators shows service feature status (subscription/notification status) and a time stamp indicating when this subscription became effective. User’s MSISDN is chosen as the subscriber ID and is used as the primary key in subscription table. MSISDN stands for Mobile Subscriber Integrated Services Digital Network Number. It is a number uniquely identifying a subscription in a GSM or a UMTS mobile network. Simply speaking, it is the telephone number of the SIM card in a mobile/cellular phone. During subscription procedure, MSISDN can be derived from the source address of the SMPP message from subscriber. When providing zone based billing, MSISDN can be retrieved from InitialDP operation which comes from MSC. Thus it is suitable to use MSISDN as the primary key for the subscription table.

HZB Internal Cell DB contains basic information about the cells in the operator’s network. It has a single cell table which each entry is the information of a single cell. The cell information contains a unique cell id, the coverage area of the cell and a list of complementary cells which has certain overlap with current cell. A GSM Cell ID (CID) is a generally unique number used to identify each sector of a cell site within a LAC if not within a network and it is used as the primary key of the HZB cell table.

During zone definition process, HZB service uses this cell DB to generate the cells that form the user’s zone area. One trivial way of getting all the cells that covers the subscriber’s home zone is to go through all the cell data and collect the cells that overlap with the user’s zone area. But
considering the high cost of traverse the cell db which might contains tens of thousands of cells, we need a better solution to generate the cell based home zone. An efficient approach is to generate the complementary cell list for each cell while initializing the Cell DB. In this case, when HZB service obtained the fundamental cells (the cells that the mobile phone got connected to) during the subscription process, the only thing need to be done is to get their complementary cells. The fundamental cell set together with the complementary cell set forms the subscriber’s zone area.

3.3 System Implementation

3.3.1 System Implementation Overview

In this thesis project we implemented a prototype of the HZB service for validating the feasibility of our design and exploring the relevant user experiences. As mentioned in the system design section, Mobile Arts has developed many network components (e.g. SMSC, GMLC) and protocol stacks (e.g. SMPP, CAP Client, MLP Server). Our HZB prototype has to work with these existing products to carry out this location sensitive billing function. In order to let HZB cooperate with the standardized interfaces provided by the existing MA components in mobile network, we reused their existing SMPP stack and implemented the CAP Server side and MLP Client side.

Though the design of HZB service is quite comprehensive and covers the requirement specification we made at the beginning of the thesis project, we chose only the core features of the HZB functionalities for the implementation of the prototype. The prototype focuses on the SMS interface for subscription handling and chose the basic cell id for zone representation and
in/out zone measurement. Also the extension parameter in InitialDP and Apply Charging Report message is utilized for delivering the In/Out zone indicator to the billing service.

Mobile Arts has been using Erlang/OTP as their primary programming language. Therefore the implementation of the HZB prototype should also be based on Erlang. While implementing our HZB prototype, we adopted two main design principles in Erlang - Supervision Tree and generic Finite State Machine (FSM).

**Supervision Tree**

Supervision tree, along with the supervisor behaviour in OTP, provide a mechanism for building concurrent and fault-tolerant system. It is also one of the features which make Erlang an excellent candidate for telecom services development. The supervisor mechanism is designed to deal with process start/termination in an organized way. Processes in Erlang can be classified as two categories: workers and supervisors.

- A Worker is a process which performs computations, that is, it does the actual work.

- A Supervisor is a process which monitors the behaviour of a set of workers (its children). It is aware of the status of its children and can restart them under different circumstances.

- The supervision tree is a hierarchical arrangement of code into supervisors and workers, making it possible to design and program fault-tolerant software.

HZB prototype is a telecom service which raises high demands in its concur-
rent capacity. Multiple subscribers should be able to use the HZB service at the same time. With the light-weighted process in Erlang, it is possible to simply spawn a worker process for individual subscribers and handling the interaction within each process. The processes are structured in HZB’s supervision tree to achieve the robustness of the system.

**Finite State Machine**

A finite-state machine (FSM) is an abstraction used in computer program design and development. It is a model for describing behaviours of different complexity in a product. Usually FSM is composed of a finite number of states, transitions between those states, and actions, similar to a flow graph in which one can inspect the way logic runs when certain conditions are met. Erlang/OTP provides a behaviour named gen_fsm. It is intended to provide a standardized way of implementing service logics using finite state machine.

In either subscription scenario or zone-based billing scenario, the worker process needs to keep track of the current status of the service procedure. Messages arrive at different stages of the service should be handled differently. Therefore it is nature to use FSM to design and implement the two main service scenarios in HZB node - user subscription and zone-based billing. The details of the finite state machine design come with the later sections.

**Session Control in HZB service**

We call HZB's worker processes "sessions". HZB node creates and maintains its sessions in session tables. There are two types of sessions designed to fulfill the service requirement: subscription session and zone-based billing session.
Sessions are created when HZB node receives requests for subscription handling or zone-based billing. Each message received by HZB node will be matched and dispatched to an existing user session for further processing. If a message cannot be matched to any session and it is not a message for initiating a new session, it will be discarded (error message will be sent to the originator of the message if necessary). Figure 8 illustrated the session control mechanism in HZB node.

3.3.2 Implementation of HZB Subscription

In the design section, we categorized subscription related operations in HZB service into two groups: stateful and stateless operations. Therefore two master processes are implemented for managing each group of subscription processes: one is HZB subscription stateless manager that monitors the processes which handle stateless operations; the other is HZB subscription stateful supervisor which manages all the stateful sessions regarding sub-
scription creation and update. Considering the nature of the stateful and stateless operations, different approaches are used for implementing them and their master processes.

For HZB subscription stateless operations (view, activation, deactivation, deletion), only a pair of request/response is needed for completing them: user sends the request; HZB processes the request and returns the result. These operations are implemented in simple operations functions, since they are simple enough to leave aside any Erlang behaviours. The HZB subscription stateless manager is created in order to manage these stateless processes in an organized way. Erlang provides two useful build in functions (BIFs): spawn and monitor. Whenever a new process is started using the spawn BIF, it can be monitored by a master process which calls the monitor function. Simply, the HZB subscription stateless manager uses this mechanism to get notified about the termination of its children for further management.

Although HZB subscription stateless manager is seen as a worker in HZB supervision tree, it plays a role as a special ”supervisor”.

HZB subscription stateful operations (creation and update) are complex procedures which involve user interactions in terms of requests/responses. Hence subscription session is designed to describe the service logic of the procedure. The subscription session is described with FSM and implemented using Erlang gen fsm behaviour. Figure 9 reveals the internal state and state transitions of the stateful subscription session.

- init_session

It is the initial state of the subscription session. The process does all the initialization and transit to pre_process state.
Figure 9: Stateful Subscription Session State Machine
pre_process
It is the state when all the prerequisite check is done to determine whether the new subscription is allowed. When all the pre-check passes, the session transits to location_tracing state. Otherwise the subscription session terminates.

location_tracing
In this state, HZB collects a series of instant user position from the GMLC. There is a time limitation on this state which means user has to walk around his home area within this timer. User can send a stop request to indicate he has finished walking around the zone. On receiving user stop request or state time out, the session transits to zone_calculation state.

zone_calculation
HZB service applies algorithms on the gathered location information to calculate the actual zone area in this state. Once the zone calculation is finished, the session will transit to zone_rendering state.

termination
This is the end state of the session. It does all the final process for clean up and terminates the session.

As the implementation of stateful subscription session complies with the OTP design principles, it is nature to let the master process - HZB subscription stateful supervisor - to inherit Erlang supervisor behaviour. In this way, the subscription sessions are well managed in the HZB supervision tree.
MSISDN Structure

MSISDN normalization

Subscriber’s MSISDN is used as a unique identity for HZB subscription as well as the key for the subscription session table. Figure 10 reveals the structure of MSISDN (Country Code, National Destination Code, subscriber number). MSISDN can be of different format (international, national and unknown). HZB service may get any of these formats. For SMS based subscription interface, MSISDN is retrieved from the source address of the SMPP message. The address information comprises of three parts, namely the TON (Type of Number), NPI (Numbering Plan Indicator) and Address (Digit sequence) for presenting the full MSISDN. In this prototype, number normalization is implemented thus a uniform MSISDN format - international format is used to uniquely identify the subscription session and the subscription.

The number normalization process converts unknown format to national format and then to international format. Usually the unknown format has a certain prefix. First step is to strip the prefix to get the national format. By adding the country code, we get the international format of MSISDN.
3.3.3 Implementation of Zone-based Billing

The HZB billing service implementation is composed of three major components: Zone Based Billing (ZBB) module, CAP stack and MLP client. The CAP stack is responsible for receiving and sending CAP messages. The MLP client is mainly used for obtaining the subscriber’s location information. The ZBB module is the main service logic, it handles the messages received from CAP stack and give the command to CAP stack to send corresponding messages. The ZBB module also performs the location positioning through MLP client.

Due to process is lightweight and independent in Erlang, hence we spawn a new process for handling each call. A billing session for one call consists of one instance of ZBB, one instance of CAP client and one instance of CAP server.

3.3.3.1 Implementation details of CAP stack

Because the HZB service needs to talk with MSC and SCP, so both side (CAP server and CAP client) of CAP stack shall be implemented. Mobile Arts already has a CAP client, but as it is used in other context, we slightly modify it so that it can be used for HZB service logic. On the other hand, we mainly focus on the implementation of CAP server. Because the main responsibility of CAP server in our HZB service is only to receive and send CAP messages, it does not have too much other control logic. So we implement it in a flexible and simple way. We use finite state machine design pattern to implement it. By using Erlang behavior “gen_fsm”, the CAP server has four states:
− init – The initial state of the fsm, in this state, the fsm loads configuration and initialize the loop data.

− wait_for_ind – After initiation, the fsm transit into “wait_for_ind” state. In this state, the fsm is waiting for the incoming messages. Once the message is received, after basic processing (i.e. decode, pattern match, etc), the fsm notify the uplayer ZBB module of the incoming messages. Then the fsm transits into “wait_for_ins” state.

− wait_for_ins – When ZBB handles the messages, it is supposed to send commands to CAP server to tell it what to do next. In this state, the CAP server is waiting for those instructions from ZBB module.

− terminate – The fsm is terminated in this state.

According to the design purpose, the CAP server in HZB service is dedicated to receive IDP, ERB, ACR from MSC and send CTR, PA, CAN, RRB, ACH to MSC. The CAP client in HZB service is dedicated to send IDP, ERB, ACR to SCP and receive RRB, ACH from SCP.

3.3.3.2 Implementation details of ZBB

3.3.3.2.1 ZBB session

The ZBB logic is the “brain” of the billing part. We implement it as a finite state machine as shown in Figure 11. The state machine strictly follows the requirements and the system design. The ZBB logic is responsible for handling the incoming CAP and MLP messages, and performing properly functions according to these messages. The ZBB session has the following states:
Figure 11: Zone-based Billing Session State Machine
init – The initial state of the zone-based billing session. When CAP IDP is received by CAP server, it will initialize the ZBB session.

pre-process_default – In this state, the CAMEL dialog is about to setup, ZBB session performs the first In/Out zone measurement by sending a SLIR to GMLC and waiting for the reply, during which it sends instructions to CAP server in order to communicate with MSC and ask MSC to play special tone for the subscriber. As a result, the CAP server will send out the CTR and PA messages. When the measurement procedure is done, the ZBB session sends instruction to CAP server to stop the special tone (i.e. The CAN message is sent out.) and play a pre-recorded voice announcement which tells the subscriber about the In/Out zone result, this is implemented by sending another PA message to MSC. Meanwhile, the ZBB session adds in/out zone indicator in IDP, send it to MSC to trigger the CAMEL service. The RRB message is also handled in this state. The ZBB session checks the RRB, and ensures that the “oAnswer” and “oDisconnect” are in it. Then the ZBB session passes it to MSC.

When the “oAnswer” event is reported by ERB and receives the first ACH from SCP, the ZBB session sends out the TLRR to GMLC to start the periodical location reporting service through MLP client. and then it transits to “Active–Online” state.

Active–Online – In this state, ZBB session performs the billing adjustment procedure. It collects subscriber location and provides appropriate billing to SCP while CAMEL service dialog remains active. The ZBB session handles CAP ACH, CAP ACR and MLP TLREP.
It receives the location information through TLREP periodically and stores it in the loop data for the in/out zone measurement. After the in/out zone measurement, the ZBB sends modified ACR to SCP. This state remains until it receives ERB of “oDisconnect”, then it transits to state “terminated”.

− Active–Offline – The state when the CAMEL dialog terminated because of any communication error. Since the call is still proceeding, HZB node generates special logs in the CDR for offline charging. Since this project mainly focus on the on-line billing part, we only implement an interface of this state for further development.

− Relay – The state when the user is a non-HZB subscriber or the GMLC failed to support location reporting for the HZB subscriber, the CAMEL dialog still exists but the HZB node just relays all messages between MSC and SCP just as it is transparent.

− Terminated – The final state of the zone-based billing session.

### 3.3.3.2.2 In/out zone indicator

In the design part, we mentioned each time when in/out zone measurement applies, the HZB service logic will add a in/out zone indicator into IDP or ACR. This in/out zone indicator is implemented in the following ways:

− Initial DP Extension: This approach works for the setup phase measurement. The prerequisite is that HZB service and the SCP agree on the way of interpreting the Extension parameter in IDP message. The Extension parameter in IDP message can be used to carry any
vender-specific information. Thus when HZB made the setup phase In/Out zone measurement, it can modify the extension parameter in IDP message to include indicators such as INZONE or OUTZONE. As long as the CAMEL service knows how to interpret this parameter to know whether the subscriber is within or outside his home zone, it can decide the correct billing rate for the user.

- Apply Charging Report Extension: This approach works for the active call measurement. The prerequisite is that HZB service and the SCP agree on the way of interpreting the Extension parameter in ACR message. The Extension parameter in ACR message can also be used to carry any vendor-specific information. Since HZB will make periodical In/Out zone measurement within a live call, when it receives ACR message from MSC, it can modify the extension parameter in IDP message to include indicators such as INZONE or OUTZONE. As long as the CAMEL service knows how to interpret this parameter to know whether the subscriber is within or outside his home zone, it can adjust the billing rate accordingly.

### 3.3.4 Implementation of MLP Client

HZB service needs MLP client side to communicate with the GMLC. Considering build it as a reusable component, MLP client is implemented as a separate application and was started along with the HZB service core application. Mobile Arts GMLC uses http as the transport protocol for MLP messages. Thus in our prototype, we also chose http as the bearer for MLP requests. The main functionalities of MLP Client side are encoding and sending service requests, receiving and decoding service answers/reports.
Message encoding and decoding

Request encoding is trivial - nothing more that wrap parameters into an XML document according to the DTD. But decoding the answers/reports requires the ability to parse the XML content of the responses and it needs much more effort. Erlang provides a very useful library xmerl [Lab10] which can parse XML documents according to the XML 1.0 standard. As default it performs well-formed parsing (syntax checks and checks of well-formed constraints). Optionally xmerl can be used as a validating parser (validate according to referenced DTD and validating constraints). The parsing result given by xmerl is a record, displaying the structure of the document. The record also holds the data of the document. Our program extracts the location information from the result record for zone definition or in/out zone measurement.

Message transportation

The MLP client in our prototype uses http to transport MLP messages. HTTP functions as a request-response protocol in the client-server computing model. MLP client needs both http client and http server to communicate with GMLC. HTTP client is used to send request to GMLC and receive the immediate answers from GMLC. Besides the immediate answers, GMLC also sends back reports (e.g. TLREP) using HTTP POST to HZB service. In this case, MLP client also uses an HTTP server for handling these POST requests.

Erlang has an application named inets which is a container for Internet clients and servers. It includes an HTTP client and server. The client and service are viewed as service. They can be configured to be started at application startup or started dynamically in runtime. We implemented
MLP client as an erlang application and started the http client and server services by configuring the MLP startup profile as following:

[inets, [services, ListofConfiguredServices]].

ListofConfiguredServices contains the services should be started with the application. Service description is in the format of erlang tuple. Following is an example of configuring an http client and an http server:

[inets, [services, [httpc, PropertyList, httpd, [proplist_file, "http_server_props.conf"]]]]

### 3.3.5 Implementation of Databases

Erlang has a distributed Database Management System (DBMS) named Mnesia. It is appropriate for telecom applications and other Erlang applications which require continuous operation and exhibit soft real-time properties. Mnesia is chosen for the HZB subscriber DB and the Internal Cell DB because it provides following important and attractive capabilities:

- A relational/object hybrid data model which is suitable for telecommunications applications.
- Extremely fast real time data searches.
- Schema manipulation routines. It is possible to reconfigure the DBMS at runtime without stopping the system.
- Other features such as atomic transactions, location transparency, persistence storage, table replication, QLC (a specifically designed DBMS query language).
The basic database operations such as creating tables, add/remove entries and query the database are all provided by Mnesia APIs.

HZB utilized Mnesia APIs for database access. For HZB subscriber DB, store/update new subscriptions and subscription query are needed. Internal Cell DB is built once and accessed by the subscription module in a read-only mode.

Besides these the SDB and CDB, HZB service also need some internal storage for its sessions. Both stateful subscription session and zone-based billing session need session table. It records all the current live sessions.

Erlang has another kind of data storage name ETS (Erlang Term Storage). Data is organized as a set of dynamic tables, which can store tuples. Each table is created by a process. When the process terminates, the table is automatically destroyed. It is suitable to use ets tables to store HZB sessions. The HZB top supervisor creates a subscription session table and a billing session table. As long as the top supervisor is alive, the session tables are available. Once the top supervisor terminates, the session tables are gone too, since it is there is no point to keep the session references when the service is down. And when HZB service is restarted, new session tables will be created for any upcoming sessions.

4 Evaluation

Some basic evaluations of the HZB service prototype are done for exploring user experience. As mentioned before, HZB service provides In/Out
Zone information to the billing service in SCP by performing In/Out zone measurement in the call setup phase as well as during a live call. Therefore, except for the extra In/Out Zone notification received from HZB service, the HZB subscriber should have similar experience as the non-HZB subscribers while using basic services. The major concern is that this measurement procedure may introduce delay into call setup which results in long wait during call establishment. Thus one main aspect of the evaluation is to measure the call setup delay introduced by HZB service. We sampled a couple of timing data by running our HZB service on two virtual machines in Mobile Arts. The detail evaluation environment is:

- two virtual machines with Linux 2.6.18-128.el5 kernel
- SS#7 protocol suite which is pre-installed in these two machines
- Erlang/OTP with version R13B04

We deploy our HZB service node on one of the virtual machine, and all other external nodes such as MSC, SCP and SMSC on the other machine. We collect the sample data by using Erlang IO print. Actually, the IO print might enlarge the duration of sample timing, but in real case, more network transmission delay should be taken into account. We run our HZB service several times and measure the interval of following phases:

- Duration between IDP sent from MSC(CAP client) and received by SCP(CAP server), through which we can observe the time mainly used for performing location procedure and database query;

- Duration between RRB sent from SCP(CAP server) and received by MSC(CAP client)
Duration between SLIR sent from HZB and SLIA received by HZB, through which we can observe the time used for location positioning.

The total duration between IDP sent from MSC (CAP client) and RRB received by MSC (CAP server), which is the call setup delay by using our HZB service.

The sample data is shown in Figure 12.

The statistics in Figure 13 shows that, due to database operation, location positioning and in/out zone measurement, the duration between IDP sent from MSC and received by SCP is the largest time gap introduced by HZB service. The average of the total delay during call setup phase is around 0.55 second. Comparing with the normal call establishment, the introduced delay is almost imperceptible to common users. Thus it is reasonable for the service providers to expect that the subscribers will accept this small delay when making phone calls.
This thesis project produced a prototype for HZB service by implementing only the basic functionalities using some simple algorithms. The current implementation can be refined with better algorithms and more features can be added to this prototype in order to provide a real commercial product. Generally speaking, the future work may be launched on following three aspects:

1. Zone-definition with Higher Precision
   - Automated Zone Update
     Telecom operators may change cell deployment periodically by removing old base stations/antennas and deploying new ones. Since cell-based zone representation is always supported as a fallback choice, HZB service shall provide automated zone update along with the
cell changes in the operator’s network. The discarded cells should be purged from users’ zone representations and the new cells which cover the original zone area should be added.

– Map-assisted Zone Rectification

Extra map information could be used for rectifying the home zone area. Since the position information returned by GMLC is a likely area where the subscriber is current in. Thus the convex hull formed by those boundary points actually represents an "extended" zone area. One rational assumption is that the subscriber usually walks around his "home zone" along the walking path and his home zone usually won’t span over the road. Thus the road information around subscriber’s "home zone" can help to identify more reasonable zone boundaries for the subscriber. For example, the boundary points may distribute on both sides of the road. If the boundary points on one road side is less than a certain percentage, we may identify them as "outliers" and these points should be approximated by some corresponding points on the road to rectify the original home zone. But if the boundary points are distributed quite evenly on both sides of the road, then we should consider that his home zone did span over this road.

2. Mobile Number Portability Check

This feature might be desired by network operators that supports Mobile Number Portability (MNP). Mobile Number Portability is a service feature which enables mobile telephone users to retain their mobile telephone numbers when changing from one mobile network operator to another. Different service providers run their own HZB services. At the beginning
of the HZB subscription procedure, HZB service should check whether the user is still a valid subscriber of this operator and maintain the SDB accordingly. This check can be done by sending a specific request "SRI-SM" (Send Routing Information for Short Message) to HLR use Mobile Application Part (MAP) protocol.

3. Global Title Diversion:

Service providers may deploy different billing services on different SCPs. Therefore it is a desirable feature that the HZB service is able to decide which billing service it should invoke and deliver the CAP operations accordingly. The Global Title (GT) in CAP operations is used to reach the destination of the operation. When MSC sends out an Initial DP operation for triggering a CAMEL service, the GT in IDP indicates the SCP on which the CAMEL service resides. Since the IDP message first arrives at HZB service node before it can be further directed to the destination SCP, HZB service can perform global title diversion and invoke the correct CAMEL services on different SCPs according to operators configuration. This can be achieved with a global title diversion table which help HZB service to derive the correct GT. If the HZB service is going to support several service providers who have different CAMEL billing services on different SCPs or even a service provider who has deployed different CAMEL billing services on separate SCPs for different subscribers, the global title diversion table should have more complicated rules for deriving the new GT. The process for deducing the new GT may be base on the original GT, the ID of the subscriber, the original service key or any other conditions as required by the operator.
6 Conclusion

6.1 Academic Challenges

6.1.1 Erlang and OTP

The thesis project is required to use Erlang functional programming language in implementation so that it can be compatible with Mobile Arts' existing components. Erlang/OTP supports the key properties such as concurrent, distribution for telecom services. These conceptions and the language itself are pretty new to us. Therefore it is necessary for us to research deeper in the Erlang and OTP (Open Telecom Platform) including the usage of the various libraries and the design principles of Erlang/OTP. Although the study takes time, it is really beneficial to us. It makes our prototype more robustness, easy for further maintenance and development.

6.1.2 Telecom Service Design

Because of our limited knowledge about telecom network and its services and the lack of experience in telecom software development, we do need to do a lot of reading in order to understand the global picture of the mobile network before we can start to investigate the HZB service issues. As the project went on, we got a better understanding about the crucial requirements of telecom services - high availability, robustness and soft real-time capability. As a value-added service, both subscribers’ interest and operators’ benefit should be taken into account in order to make the service truly valuable. It is a big challenge to apply these principles in the requirement analysis and implementation proposal phase. With active brainstorming and close
cooperation, we carefully designed an optimized solution which fulfills those requirements.

6.1.3 Reusing and Integrating with Existing MA Components

We are supposed to re-use Mobile Arts’ existing protocol stacks (such as CAP client, SMPP client) in our HZB prototype. And the prototype should be compatible with the network components (SMSC, GMLC etc) provided by MA. But "reuse" requires far more effort than it sounds like. Protocols are standardized, but there could be thousands of different ways to implement them. Due to the lack of documentation of some modules, we have to dig deeper into MA’s product source code to understand its behavior and then make use of it in our own code. Mobile Arts has also developed a comprehensive mechanism for configuring and managing their system. Many components have internal dependencies with each other and require specific configurations to work properly. It took us quite a few days to study the application management structure, configure and set up a running system at the beginning. Then we implemented the HZB prototype in a compatible way which makes it possible to start up the service and run it within a robust management structure. With the help of Mobile Arts’ engineers, we finally implemented the HZB prototype and integrated it with their existing components. Our implementation also inherited the coding style and system structure from MA’s existing products.
6.1.4 Standardized Interfaces

The interfaces between different network components are standardized by organizations such as 3GPP and IETF. The implementation of HZB service strictly follows the technical specifications for product compatibility and extension in future.

6.2 Summary

This thesis work investigated the requirements of the Home Zone Billing service and proposed a feasible solution which allows network operators to launch the service at minimum cost. A prototype has been implemented for validating the main features and functionalities of our HZB solution. The main principle of the solution could be summarized:

- The HZB service uses Cell-ID and Geographical Coordinates to represent the subscribers’ home zones.

- The HZB service obtains the location information mainly from GMLC. When the GMLC is not available or the location information does not meet the requirements of service quality, the HZB uses the Cell-ID as backup location information.

- The HZB service performs comparison on Geographical Coordinates first when the coordinates meet the QOS. In any cases, if the coordinates are not available or can not be used, the HZB service makes comparison between the instant served Cell-ID when the subscriber is using a telecom service and the subscriber’s pre-defined the Cell-ID list of Home Zone Area.
− The HZB service is able to notify subscriber of his/her home zone area by SMS or MMS. It also could notify the subscriber of the result of in/out zone measurement by pre-recorded tones or voice announcement.

− The HZB provides means to prevent fraudulent mobile subscriber use of Home Zone Billing. For subscription, a max zone area is set by the service provider to restrict the user defined Home Zone area. In billing procedure, the HZB service collects the subscriber’s instant location information and make in/out zone comparison periodically. Other means such as mobile number portability check and region check can also be supported.

− The HZB service re-uses the current billing infrastructure, SMS centre and location positioning centre (GMLC). The HZB service node therefore is compatible with CAP, MLP, SMPP protocols.

− The HZB service is designed and implemented in a flexible way. It can be used as a framework, which means it is easy to change or optimize the internal modules (such as algorithm module, billing module etc) of HZB service.

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