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A Design of Discount Zone Area Configuration for Fixed Mobile Substitution Services

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Abstract

We address a discount estimated area configuration problem under the Fixed Mobile Substitution using RF Fingerprint. We try to find center directions of sector antenna formation and angular width of sectors in RF fingerprint data. The cell-ID, as the form of reference Pilot Number (PN), and Radio Signal Strength Index (RSSI) are contained in RF fingerprint data. We show a fingerprint map of cell-ID and estimate zone configuration: center direction and angular width of sectors. By the proper estimation of center direction and angular width, FMS subscribers are efficiently planned for Fixed Mobile Substitution. The scheduled subscriber penetration plan is essential to radio resource planning for commercial service providers.

Keywords: Zone configuration, RF fingerprint, Cell Planning

1 Introduction

The Fixed Mobile Substitution (FMS) is the use of a mobile phone (cellular phone) instead of a fixed and wired telephone. Calls originated on a designated zone (usually a single cell) are served with preferential tariff. The designated zone usually can be selected by the subscriber's pre-specification. European countries are widely adopted the FMS. More than in 30 countries FMS is provided with successful market penetration. Vodafone, O2 and T-mobile in Germany serve FMS named as “Home Zone”. In South Korea, more than one million subscribers are registered “T-zone” service supported by SK Telecom. The FMS is useful solution to serve the user service continuity. Required network facility and operation software package are simple to implement in commercial wireless networks. The higher resource consumption of FMS is a main challenge for efficient commercial operation. FMS uses always same wireless medium to connect network resources in both of pre-specified zone and other area. The effective radio resource planning and managing appropriate number of users in discount zones are essential to FMS operation management.

In this article, we address an efficient FMS zone configuration problem. We try to find sector formation: center directions of sector antenna formation and angular width. The RF fingerprint data contains cell-ID, as the form of reference Pilot Number (PN), and Radio Signal Strength Index (RSSI). We construct a RF fingerprint map with reference PN and calculate sector formation: center direction and angular width. By the appropriate estimation of center direction and angular width, An Economic planning for FMS subscriber penetration is performed. The scheduled subscriber penetration plan is essential to radio resource planning for commercial service providers.

2 RF Fingerprint Map

The counting of FMS subscribers in each sector is inevitable to ensure the service quality for subscribers. Both of FMS subscribers and other mobile service users in same sector share the wireless resources. FMS subscribers have strong tendency to consume higher wireless resource compared to general service users (preferential tariff strategy of FMS). Thus, exact counting of FMS subscribers in each sector is important to manage wireless resource on both of short-term re-allocation of network resource and long-term frequency planning.

To estimate the FMS subscribers in each sector, the proper estimation of sector area is required. When a mobile user joins FMS service, he or she specifies his or her fixed residential address. The fixed residential address is used to know user’s specified position for applying preferential tariff. Service providers could estimate expected traffic load of each sector using exact sector area with registered subscriber’s address. Figure 1 shows the relationship between 1) estimating sector area and 2) counting the number of FMS subscribers.

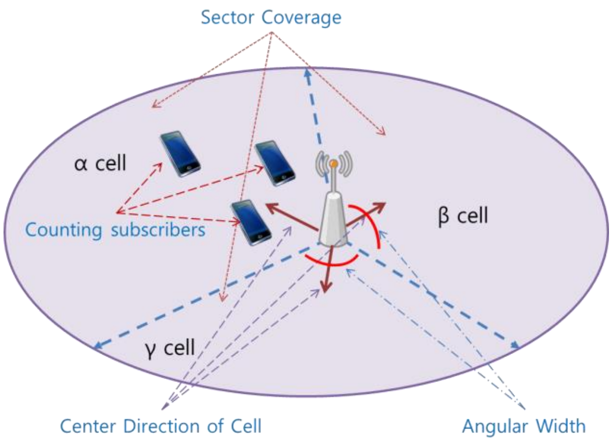

Figure 1. Sector formation and FMS subscriber

The determinants of sector formation are a) center direction and b) angular width (see Figure 1). The angular width is usually estimated using the radio propagation path-loss model [1]. The radio propagation models contain lots of errors and uncertainties. In addition, we need manual operations for center direction measurement for each base station. The RF fingerprint can resolve the limitation of radio propagation model and manual operation. The RF fingerprint data contains pilot number (generally denoted as Primary Scrambling Code Number in 3G WCDMA systems, Physical Cell ID for 4G LTE) and signal strength (Received Signal Strength Index: RSSI). The RF fingerprint data are collected by Wardriving [2]. In figure 2, we can see the characteristic pilot number which is specified by the radio propagation from base stations (The pilot number has range from 1 to 512. Each base station radiates broadcast signal which contains its specific pilot number). We estimate the angular width and center direction by the distribution of pilot numbers of grids. The exemplars of center directions are shown in following figure 2.

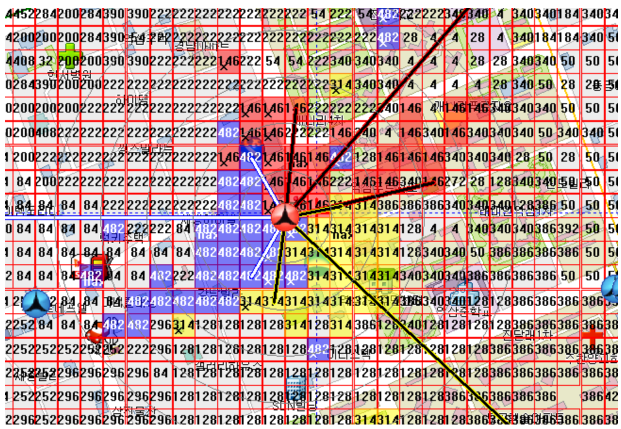

Figure 2. Distribution of Pilot Numbers

The designated number of each grid denotes the pilot number with highest signal strength. Usually there are many interference factors: multiple base stations, multiple sectors, and radio relay stations. Thus, a single grid can have multiple pilot numbers with different signal strengths. We select the single as a reference pilot number (ref.PN).

3 Configuration of Zone Area

To configure appropriate zone for FMS, we construct a simple but effective tools of zone estimation. Figure 3 shows the whole process of FMS zone configuration.

Preparation: Analyzing Area Setup
Set Circular Boundary for Counting: 500,400,300,200,100

Iteration

Step 1: Ref.PN Cleansing
Clean Outlier ref.PN in Analyzing Area

Step 2: Angular Width Calculation
Counter the # of grids with ref.PN
Calculate the ratio of Angular Width

Step 3: Center Direction Calculation
Measure the Boundary Grid Directions
Calculate the Center Direction

Arrangement: Sector Area Estimation
Leftmost area = Center Direction- Angular Width / 2
Rightmost area = Center Direction + Angular Width / 2

Figure 3. Zone Area Configuration

In *preparation*, we set analyzing area to estimate determinants (i.e., center direction and angular width). A series of circular areas from the cell origin (usually located with a base station) can be selected as analyzing area. For example, circles with 100m, 200m, or 500m radius can be target analyzing area. The larger area contains larger number of grids and gives sufficient ref.PN information to estimate the determinants. However, the larger area contains many outlier ref.PN which subjects to clean. The *iteration* is an essential part of proposed method. The fingerprint map of rer.PN has so many irregular data because of radio interference and complex structure of base stations/relay stations. We eliminate the irregular ref.PN to determine exact angular width and center direction. We propose an intuitive and effective cleaning scheme. Figure 4 shows the detailed process of Step 1: Ref.PN Cleaning

Step 1: Ref.PN Cleansing

Sequence 1: Leftmost/Rightmost Boundary Determination
Leftmost Boundary = Center Direction- Angular Width / 2
Rightmost Boundary = Center Direction + Angular Width / 2

Sequence 2: Outlier Ref.PN Cleansing
Clean ref.PN located in Outside of Leftmost/Rightmost Boundary

Figure 4. Process of ref.PN Cleansing

We obtain current proper data for ref.PN using the cleansing. The angular width for each sector is calculated with the current ref.PN data in step 2. The angular width can be calculated by counting the number of grids with sector ref.PN. For example, the angular width of α sector is calculated by "360 * (the number of effective grids with α sector ref.PN) / (total number of effective grids in analyzing area)". The effective grids mean the grid with current proper data for ref.PN (the proper data is obtained by data cleansing in step 1). We estimate the center direction of each sector in step 3. With the identifying leftmost and rightmost grids and measuring the angular direction of boundary grids, we can obtain center direction by the simply lining of center of boundary grids. We finally obtain sector area in *arrangement*. In whole process of zone configuration, an iterative method is applied to adjust center direction of sectors. The ref.PN cleaning is re-activated by the result of estimating of center direction and angular width of sectors. The re-cleaning ref.PN gives new proper ref.PN data set to determine center direction and angular width. The iterative process, from step 1 to step 3, continuously enhance accuracy of estimating center direction and angular width of sectors.

4 Numerical Results

To test the proposed method, we develop a zone estimation program which has a map of urban (Gangnam) area in South Korea. The test area has total 47,439 grids and we completely collect ref.PN data. The zone estimation program includes all ref.PN data of grids and position data of base stations. The collection and sample application of estimation is described in our former work [3]. The positions of base stations are obtained using an information database of a commercial 3G system.

A total of 10 test districts are selected for the test. The zone estimation method is applied at 10 test base station for each district. The analyzing zone area is fixed to 300m. The results prove the effectiveness of the proposed method in various diversified environments of an urban area.

Table 1: Results for FMS Zone Configuration Estimation

Test District	Center Direction	
	Average Difference	Standard Deviation of Difference
1	7.8	2.1
2	6.2	3.4
3	8.9	1.9
4	4.3	4.6
5	5.7	3.7
6	7.5	2.6
7	6.2	3.5
8	5.1	4.2
9	6.7	3.9
10	4.9	4.2

5 Conclusions

We have dealt with the FMS zone configuration problem. The problem is to find FMS zone to estimate and control the number of FMS subscribers. We can make a map of reference pilot numbers by complete gathering RF fingerprint data in test area. Based on the RF fingerprint map, we can estimate the center directions of sector antenna formation and angular width of sectors. As the results of appropriate estimation of center direction and angular width, the economic planning for FMS subscriber penetration is applicable. The scheduled subscriber penetration plan is essential to radio resource planning for commercial service providers. The zone estimation program contains huge amount of RF fingerprint data and entire procedure for estimation. The usefulness of developed algorithmic procedure and estimation program is proven in a commercial FMS service, T-zone in South Korea. The field engineer can estimate center direction of sector of base station without manual operations and FMS service manager can estimate the number of FMS subscribers in given sector by simple zone estimation program and registered user addresses.

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