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Expert system for sectorized cell configuration by radio fingerprint data analytics in wireless cellular networks

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ABSTRACT

We built an effective estimation method for sectorized cell configuration in cellular networks by focusing on a holistic radio fingerprint map that contains cell identifiers and signal strength measurements on grid segmentation. The antenna orientation and beamwidth of each sectorized cell can be estimated by the precise determination of valid fingerprints. The proposed iterative fingerprint data management detects the valid fingerprints and makes a coherently compensated fingerprint per grid. A proper weighting scheme for linear regression approach can efficiently estimate the sectorized cell configuration of each base station without difficult manual field measurements. The mobile service providers can economically plan network configurations and manage subscribers using these advances in the estimation of sectorized cell configuration.

1. Introduction

A sectorized cell configuration is adopted as the general form for base stations. Each base station has a directional antenna that shapes a typical cell as a form of circular sector (Catedra and Perez, 1999; Lee and Kang, 2000). The circular sector form of a cell is designated from the basic sectorized cell configuration (i.e., antenna orientation and beamwidth) of a base station. The radio signals, which radiate from the orientation of the directional antenna and disperse within the beamwidth, are attenuated through geographical objects. The attenuation can be estimated by path loss models. From the estimation of radio signal attenuation, we can characterize an irregular circular sector form of a cell. The precise estimation of the circular sector form of a cell provides cell-coverage information. Combining the path loss model and sectorized cell configuration under the given geographical map data, network operators can optimize cell coverage for their wireless service systems. The works of Jaffres-Runser et al. (2006), Whitaker et al. (2005) presented a few methodologies to plan wireless cell coverage. The study of Jaffres-Runser et al. (2006) proposed a multi-objective algorithm to determine the access point locations of wireless local area networks (WLANs) to maximize coverage and quality of service (QoS). In addition, a multi-criteria genetic algorithm (Whitaker et al., 2005) presented to maximize cost-efficient coverage while constraining pairwise cell overlap.

Cell coverage is fundamental information for wireless network management such as base station positioning. Fig. 1 shows the concept of base station positioning and a tool for network management. The network management tool contains three major factors ((1) geographical data, (2) path loss model, and (3) sectorized cell configuration) to characterize the circular sector form and coverage of each cell. The geographical map data is usually obtained from professional geographic data companies. The path loss models are adopted from the literature and from field practices. The Okumura-Hata (Medeisis and Kajackas, 2000) or COST-231 (Mardeni and Priya, 2010) models are generally utilized as path loss models. The path loss models contain the various link budget parameters (an example of a parameter is shown in Holma and Toskala (2011)) as input factors. The sectorized cell configuration is usually measured by manual operations of field engineers. In installing base stations, each engineer should manually measure the antenna orientation, and then report to a central department of network operation. Considering the large number of base stations and cells (there are roughly 3000 base stations, and more than 10,000 cells are installed by a single nationwide mobile operator in South Korea), the manual measuring process is laborious for network operators, and the process can contain several erroneous measurements caused by manual operation. Even worse, the initial configurations are often changed by field engineers without reporting to the central department of network operators. In the planning phase in particular, it is relatively easy to obtain a concrete sectorized cell configuration of each base station from manual measurements. Thus, network operators can estimate the

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cell coverage using the manually measured configuration. However, cell-coverage estimation is more important to an ongoing operational phase. In urban areas, we usually observe serious fluctuation in population and foot traffic. Decisions of cell split, addition, or reconfiguration in an ongoing operational stage should be performed by combining effective cell-coverage estimation with the traffic fluctuation of a particular area. Incorrect information of a sectorized cell configuration causes a serious problem for effective cell-coverage estimation in an ongoing operational phase. Because of the importance of efficient and exact estimation of cell coverage in the ongoing operational phase, we should maintain accurate sectorized cell configurations for each base station using an efficient and convenient method. In this paper, we propose a novel sectorized cell configuration estimation method using radio fingerprint data, which concentrate on the ongoing operational phase. Based on the measured fingerprint data, we build a complete fingerprint map and apply the customized data analytics.

A large amount of fingerprint data is stored to the grid segmentation of the fingerprint map. Each grid contains a reference cell identifier in the form of a Physical Cell ID (PCI for 4G LTE) or reference Pilot Number (ref, PN for 3G WCDMA). In addition, grid segmentation also has its signal strength measurement value. A customized data analysis method (cleansing and compensation) is applied to the fingerprint map for validity of fingerprint data. Erroneous fingerprint data are eliminated by the iterative data cleansing method, and the data compensation keep fingerprint data integrity. After the cleansing and compensation of the fingerprint data, a series of weighted regression methods can be used to find the most likely sectorized cell configuration: we can determine the antenna orientation with beamwidth of each sectorized cell. This effective estimation for sectorized cell configuration creates great advantages for network planning and operation of cell splitting, adding, and reconfiguration in an ongoing operational phase. All fingerprint data used in the developed test-bed and operation tool are harvested from actual radio fingerprint measurements taken throughout Seoul, Korea. This demonstrates the practical usefulness of the proposed framework.

2. Circular sector configuration by radio fingerprint maps

A beam lobe model is the basic framework of the estimation of a sectorized cell configuration. Using the path loss model, the propagation shape of a radio beam can be roughly estimated as a lobe (Abhayawardhana et al., 2005). The lobe of the radio beam is calibrated by considering geographical objects (e.g., buildings and roads) to estimate the actual sectorized cell shape (Fig. 2).

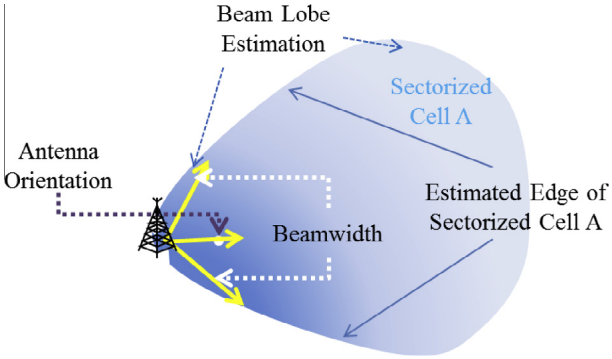
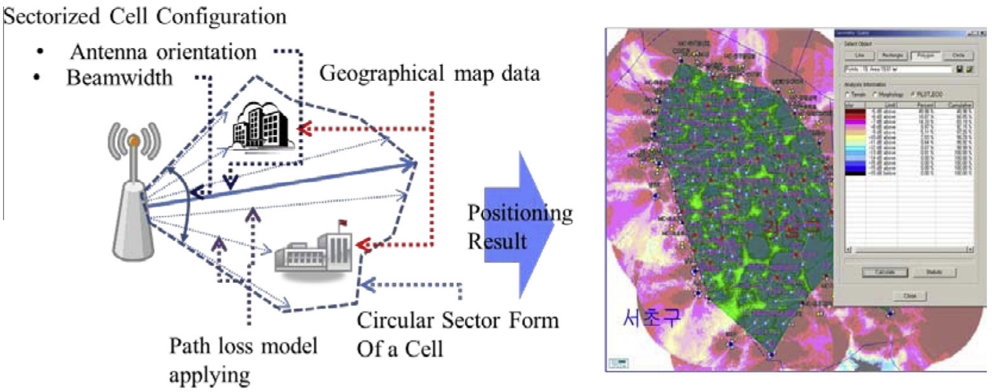


Fig. 2. Beam lobe model application for cell estimation.

The essential part of a beam lobe model is the estimation of two basic parameters of the sectorized cell configuration: antenna orientation and beamwidth. As we mentioned in the Introduction, a manual measurement of the physical antenna orientation is a difficult job for field engineers. In the ongoing operational phase in particular, there can be many operational mistakes in measurements, which can adversely affect practical system performance. Moreover, the actual beamwidth is difficult to measure, even when using manual measurements. Because of attenuation, noise, and other complexities in the environment, the formal beamwidth stated in the physical specification cannot be guaranteed in the actual operation. The proper cell configuration was investigated from the early stage of wireless networks. The study of Amaldi et al. (2002) addressed the general problem of optimizing base station locations as well as their configurations, such as antenna height, tilt, and sector orientation. They described a mathematical programming model and used the Tabu search method to obtain the practical cell configuration. Siomina et al. (2006) presented automated optimization of service coverage and radio base station antenna configuration. Staring from an initial configuration, the Simulated Annealing algorithm is activated in the solution space of possible configurations. The more recent works (Draexler and Karl, 2014; Uwano et al., 2014; Yigitel et al., 2014) developed the cell coordination with backhaul limitation, the beam-tilt technique under co-channel interference, and the cell configuration planning under energy minimization, respectively. They used a heuristics or nonlinear programming to solve the given problem. The most of previous works put a focus on the initial planning phase. For optimized network planning, they have sufficient freedom to configure the many variable parameters.



(a) Base Station Positioning (b) Network Management Tool

Fig. 1. Wireless network management: base station positioning.