Automated Area Construction Employing Horizontal-Plane Antenna Pattern Control

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1. Introduction

Area construction of mobile communication systems generally requires many propagation measurements to define the base station (BS) parameters such as the transmission power of the pilot signal or the antenna tilt angles. In recent years, to reduce the amount of area construction and optimization work, automated area construction methods were proposed [1-5]. However, these methods only considered controlling the transmission power or the antenna tilt angles of the BS and only control the cell size. Therefore, when applying these methods to complicated environments such as those requiring arbitrary shaped cells, BSs must be sufficiently sectorized beforehand to achieve flexible coverage area design. Achieving a flexible design is a difficult task because the BS is stationary under normal conditions and to achieve sufficient sectorization large, complex, and high cost instruments and control system would be required. In order to address this issue, this paper proposes a new automated area construction method that controls the horizontal-plane antenna pattern of the BSs. This method utilizes data reported from mobile terminals to define the antenna pattern. Since the proposed method not only controls the cell size but also the cell shape, more flexible area design is achieved.

2. Automated Area Construction Method

In this paper, we assume that a BS can obtain the field strength (FS) of its own pilot signal from terminals located among the BS and the signal to interference ratio (SIR), which is the ratio of its own pilot signal to the pilot signals from the adjacent BSs. We also assume that BSs can estimate the angle of arrival (AOA) of the radio wave from each terminal. The antenna configuration of the BS is assumed to be a circular array in this paper.

Figure 1 shows a flowchart of the proposed pattern configuration method. In this method, when initiating communications with a BS, the BS first stores the FSs and SIRs reported from terminals located around the BS (Step 1). Then, the BS estimates the AOA of the incident wave from each terminal and stores the AOA data corresponding to the FS and SIR data (Step 2). To determine a radiation pattern, the above information is required for all the considered directions. Thus, collection of the above data is repeated until a sufficient amount of data is collected for each direction.

After collecting the data, the gain fluctuation is determined by using the stored information (Step 3). To determine the gain fluctuation, we introduce the evaluation function shown in Fig. 2. This is determined by the FS, SIR, and the total transmitting power of the BS. A value greater than 0 for the evaluation function represents an increase in gain and that less than 0 represents a decrease in gain.

In this method, the initial transmitting power of the BS (P) is set to less than the maximum transmitting power (Pth). As shown in Fig. 2, when the SIR is less than the threshold value of the SIR (SIRth), which is defined according to the required transmission quality, the output value of the evaluation function (gain fluctuation) is determined according to the FS. In the case that the SIR is greater than the threshold, when the BS transmitting power is less than the maximum transmitting power, the output value of the evaluation function is set to 0.5 (the maximum value). When the BS transmitting power reaches the maximum level, the output of the evaluation function is set to 0 when the corresponding FS is greater than the FS threshold (FSth), and the output is set according to the FS when the corresponding FS is less than the FS threshold.

Figure 3 shows the relationship between the evaluation function output values and AOAs of each set of stored data. The gain fluctuation is determined by regressing the distribution of the evaluation function output value as shown in Fig. 3 (Step 4). Locally weighted scatter plot smoothing (LOEWSS) is used to regress the distributed evaluation function output values [6].

The target radiation pattern is produced by adding the gain fluctuation to the current antenna pattern. Then the array antenna weights, which produce the radiation pattern corresponding to the target radiation pattern, are determined (Step 5). The weights obtained in Step 5 are applied to the actual array antenna. This process is repeated until the radiation pattern stabilizes.

3. Simulation Evaluation

The effectiveness is evaluated by comparing the area availability obtained using the proposed algorithm to that obtained by controlling only the BS transmission power with a fixed omni-antenna pattern. Table 1 gives the simulation specifications.

The analyzed environment is an indoor office, which is 14 m × 25 m × 3 m as shown in Fig. 4. The office comprises ten 5 m × 5 m rooms and one 4 m × 25 m corridor. The outer walls are concrete and the inside walls are plaster. The windows and the doors in each room are glass. A BS is located 2.5 m high at the center of each of the four rooms indicated in Fig. 4. The terminals are moved inside the 14 m × 25 m area uniformly and the FSs and SIRs are measured at each measurement point. The total number of measurement points is 350. Each BS antenna is a six-element circular array. In the initial state, the BS antenna patterns are omni-directional and the transmitting power is –25 dBm. The maximum transmitting power is –10 dBm. The propagation is calculated based on a ray-tracing simulation. The parameters are given in Table 2. To simplify the simulation, the AOA of the maximum incident wave from each MS is assumed to be estimated ideally in this simulation.

Figure 5 shows the sufficiently converged (after 30 iterations) array antenna pattern of each BS. Each antenna beam is formed in a discrete direction and the interference between BSs is reduced. Figure 6 shows the cumulative probabilities of the FS and SIR. For both control algorithms, all the FSs of the terminals are higher than the maximum FS threshold. Therefore, the area availability of the FS is the same when either using the pattern control or the power control. The proposed algorithm improves the cumulative probabilities over the entire range of the considered SIR values, and for example, the availability improves 17% at the SIR of 2 dB.

4. Conclusion

We proposed an automated area construction method that controls the horizontal-plane antenna pattern of BSs by using the measurement reports from terminals. The simulation results show that the proposed method improves the availability considering the coverage and quality compared to that obtained using the conventional power control method.

References

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Table 1: Simulation Specifications

Frequency	2 GHz
Analytic area	25 m×14 m
Number of BSs	4
Number of measurement points	350 (Uniform)
BS antenna	6 element circular array
Transmission power of BS	-25 dBm (Initial state)
Antenna gain of terminal	0 dBi
FS threshold	-78 dBm
SIR threshold	0 dB
FS max threshold	-74 dBm
Lower limit of terminal sensitivity	-82 dBm
Propagation model	Ray tracing simulation

Table 2: Ray-Tracing Simulation Parameters

Maximum number of reflections	2
Maximum number of transmissions	3
Materials	Outer walls (concrete) Dielectric constant 5.99×10^{-11} Electric conductivity 2.30×10^{-3} Inside walls (plaster) Dielectric constant 3.54×10^{-11} Electric conductivity 1.00×10^{-3} Windows and Doors (glass) Dielectric constant 4.43×10^{-11} Electric conductivity 1.00×10^{-12}

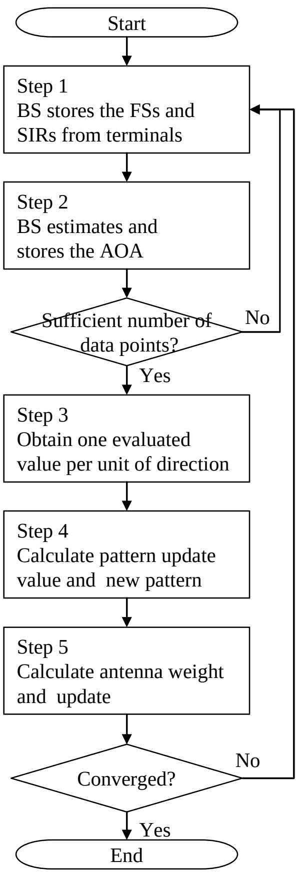


Figure 1: Flowchart of Proposed Algorithm

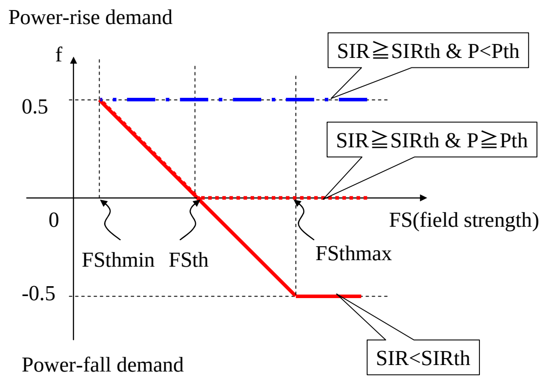


Figure 2: Evaluation Function

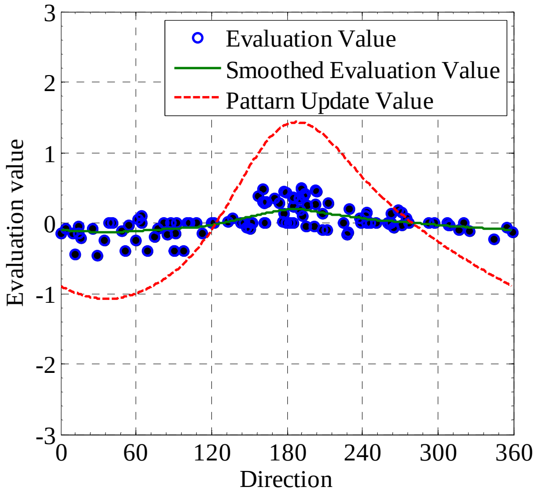


Figure 3: Relationship Between DOA and Evaluation Value

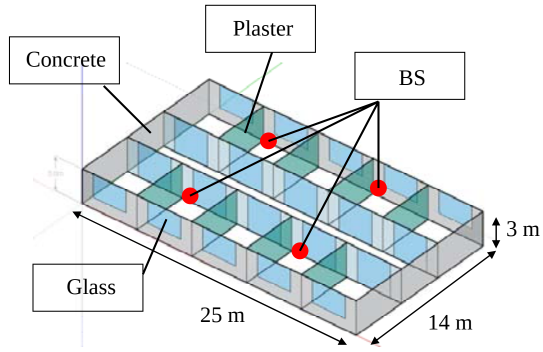


Figure 4: Simulation Environment

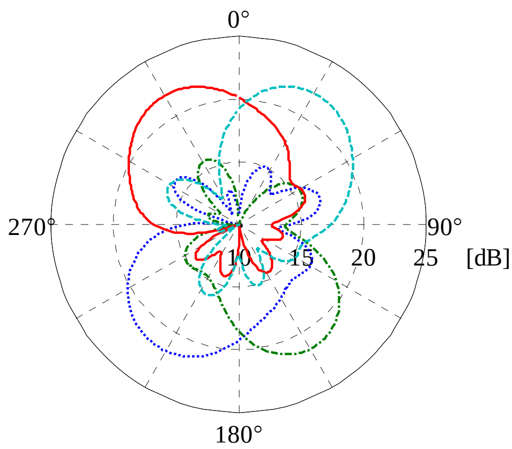
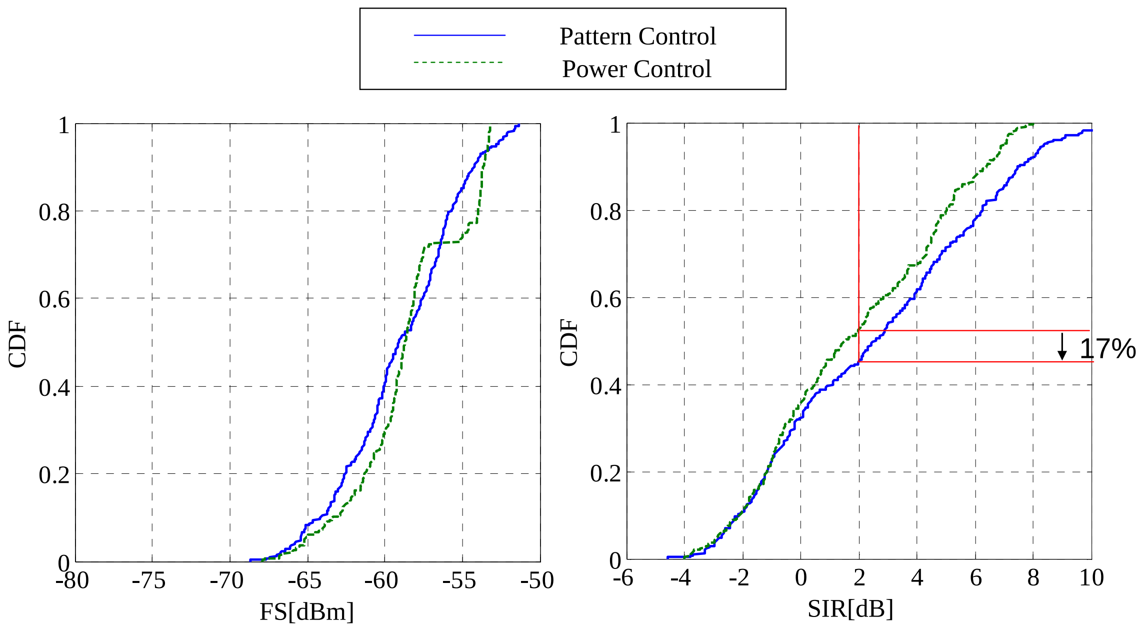


Figure 5: BS Antenna Pattern After Pattern Control



(a) Field Strength

(b) SIR

Figure 6: Cumulative Probability