Optimal Location and Number of Access Points based on Ray-Tracing and Particle Swarm Optimization

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1. Introduction

With development of wireless technology such as WiFi (IEEE 802.11) and WiMax (IEEE 802.16), services of indoor wireless communications have been increased. In deployment of wireless network, one of the important issues is the optimal location and number of access points (APs) which could satisfy enough received signal strength at all desired location. To begin with searching for these optimal APs, it is required accurate understanding of radio propagation in the interested area. To find precise optimal APs, deterministic methods such as the ray tracing, which considers effectively geometrical structures, could be employed.

To search for optimal APs, it is required to consider not only the ray tracing method which analyze the indoor radio environment over the variation of APs but also the optimization technique obtaining the optimal location and number of APs in the interested area. The Particle swarm optimization (PSO), one of the metaheuristic, has been known for effective computational method in optimizing difficult multidimensional discontinuous problems in a variety of fields [1]. In addition, this method, based on the analogy of bird flocks or fish schools movement, has been shown that it performs similarly other methods of optimization such as genetic algorithms [2].

There are several papers which have studied for optimal APs or transmitting antennas. Some of optimization methods have been proposed to look for optimal location of transmitting antennas [3], and a method of optimization associated to ray tracing for optimal antenna positioning has been suggested in [4]. Since none of these papers have been suggested in terms of the optimal minimum number of APs in a given area, in this paper, we propose a method for determination of APs considering the minimum number of APs in the interested coverage as well as optimal locations, using the optimization technique and the ray tracing method.

2. Optimization Method

The deterministic ray tube (DRT) method [5], one of the ray tracing method, is implemented in this optimization procedure. It is fundamentally a point-to-point tracing technique based on the image concept, and can find all propagation paths from an AP to a receiver extensively. In addition, the optimization method used in this paper is based on the PSO. In the PSO algorithm, each particle is assigned to position information of each AP, as optimization variable. As shown in Fig. 1, the optimization algorithm begins with setting parameters, such as the number of APs, particles, and iteration, and the interested coverage area. In order to investigate fitness for each particle, received power of receiver points is calculated using the ray tracing technique. In case of one more APs in a given area, the highest value in received power from each AP is chosen. As well, we set the threshold level which a chosen AP could not meet the acceptable power, and then take account the number of receiver points not satisfying the threshold level. We propose the fitness function using weighted sum of average of all of the received power in a given area and in the receiver points where received power is less than threshold level. Thus, it is written as

$$f = \alpha \frac{1}{N}\sum_{i=1}^{N} \max_{j=1,\cdots,M}\left[P_{ij}\right] + (1-\alpha)\left\{\frac{1}{L}\sum_{i=1}^{N} \min\left[0,\, \max_{j=1,\cdots,M}\left(P_{ij}-t\right)\right] + t\right\}, \qquad (1)$$

where *N, M,* and *L* are the total number of receiver points, APs, and receiver points where received power is lower than threshold, respectively. *t* is the threshold level, *α* is weighting factor, and P_{ij} is the received power for i^{th} receiver point related to j^{th} AP.

The first term of right hand side represents the overall quality of a given coverage area, and the second term means the average received power which does not satisfy the threshold, that is, the quality of bad locations not satisfying threshold level. Therefore, this fitness function of the PSO algorithm results in the optimized APs, which are obtaining more uniformly distributed received power in a given coverage area. When a given iteration is over, it is needed to check the number of receiver points which is less than threshold level. If there are any receiver points lower than the level, the number of APs is increased by 1 and then, searching for optimized locations again with the increased number of APs. In consequence of this optimization procedure, therefore, we could get optimized location and the minimum number of APs in a coverage area of interest.

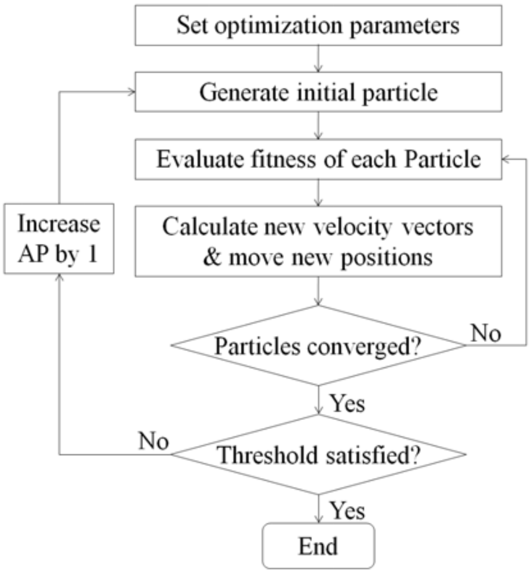


Figure 1: Optimization procedure.

3. Simulations and Results

In order to verify if the location(s) of APs obtained by proposed approach are optimal, we have conducted a simulation using proposed method and compared the result of example 1 scenario in [4]. In case that α was set zero and threshold level was -60 dBm, our optimal position of AP is (18.74, 14.13) m. Fig. 2 shows that our result of optimal position corresponds with that of the position, compared with the optimized antenna position of the scenario in [4],

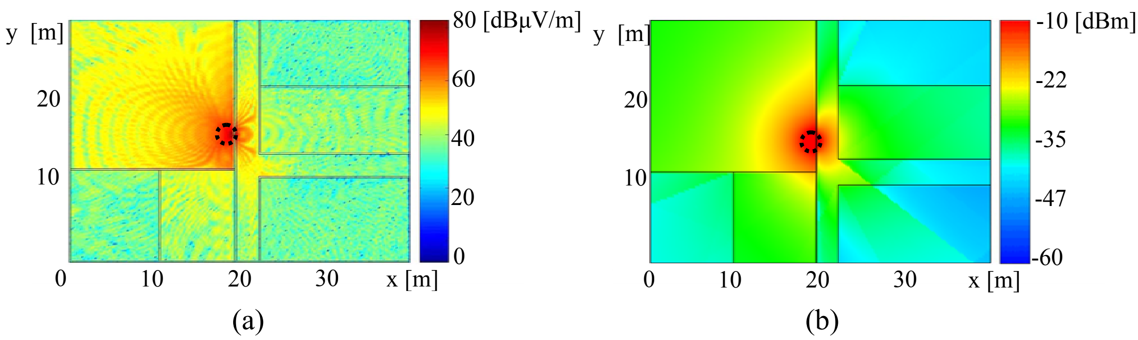
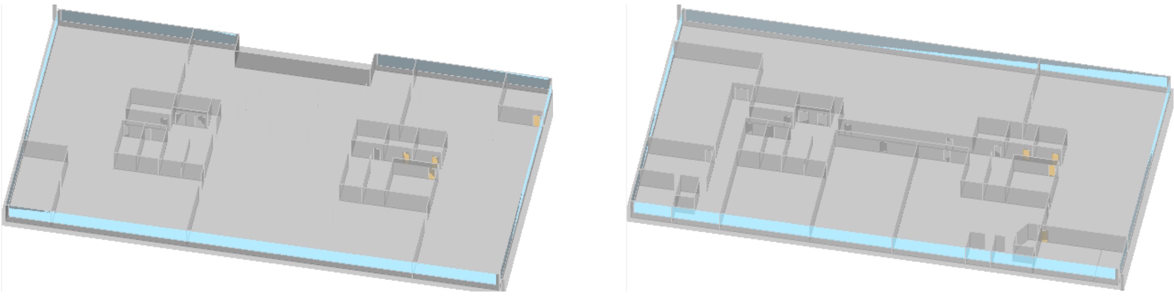


Figure 2: Comparison of optimized antenna position. (a) example 1 in [4], (b) proposed method.

To illustrate our optimization method more specifically, we simulate the scenarios shown in Fig. 3(a), (b). In this case, 2.4 GHz WLAN (Wireless Local Area Network, IEEE 802.11 b/g) system with half-wave dipole antennas radiating power of 20 dBm and receive sensitivity of -75 dBm threshold level is considered as specific simulation conditions. As well, the heights of each AP and receiving antenna are required to obtain received power from the 3-D ray tracing technique. In practice, most of the APs are installed at the ceiling of the building, in this simulation of 3.5 m height building, as well, APs are located at 3.3 m height, 20 cm bottom from a ceiling and receiving antennas are placed at 1 m bottom from a floor. Due to the large interest area, total 517 receiver points are uniformly distributed in the entire region. In the PSO, we set 75 particles, 120 maximum iterations and the cognition and social acceleration coefficient are selected to be equal value, 2.

Fig. 4 represents the received power distribution of Fig. 3(a) for the two APs located at the optimal positions which the optimization method results in. The optimal positions of APs are (24.48, 20.13) m and (63.09, 25.72) m. In this case, the simulation result means that only two APs are needed to be sufficiently covered in a given entire interested area.



(a) (b)

Figure 3: Layout of a library building. (a) the second floor, (b) the third floor.

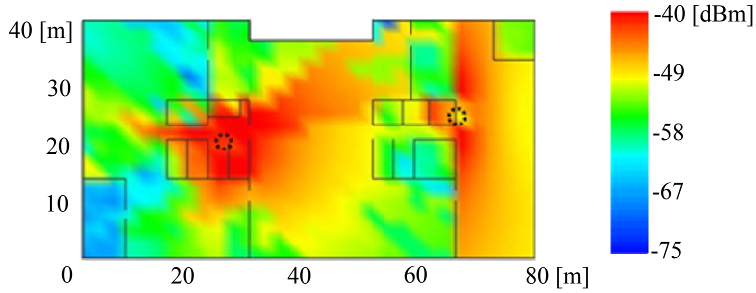
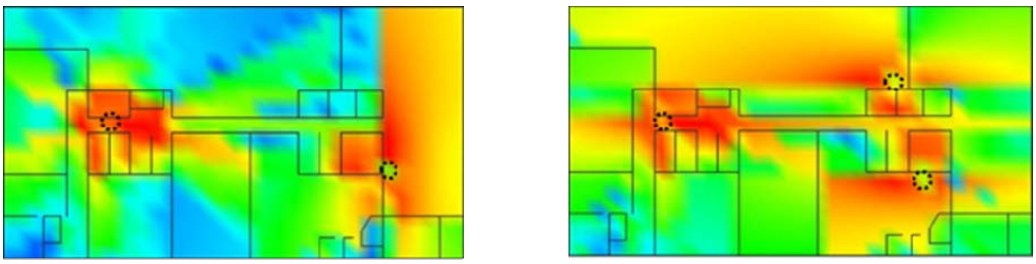


Figure 4: Received power distribution of Fig. 3(a) corresponding to the optimal two APs (⁛).



(a) (b)

Figure 5: Received power distribution of Fig. 3(b). (a) optimal two APs, (b) optimal three APs.

Fig. 5(a) depicts the power distribution of Fig. 3(b) for two optimal APs positions which the optimization method is intermediately chosen in only case of two APs. The interested area is almost same as Fig. 3(a), however, inside of the building such as materials of walls and wall structures are different and more complex. Thus, radio propagation environment in this structure becomes poor, compared with Fig. 3(a), and this case is more challenging propagation environment. The result of simulation also shows that a given area could not be covered completely by only two APs. Consequently, It is required one more AP to obtain better propagation environment which all of a given coverage area satisfies the threshold level of received acceptable power. Fig. 5(b) shows the received power distribution for the three APs located at the optimized positions which the optimization method is finally chosen. The optimal positions of APs are (22.62, 26.40) m, (61.41, 31.15) m, and (66.15, 16.90) m. In this case, the simulation represents that three APs are needed to satisfy the above threshold level in a given entire interested region.

These two simulations illustrate the situation that radio propagation environment undergoes a large change depending on indoor structures of a building, though each building has a same size. According to this, we could account for changes of the required minimum number of APs and optimal locations in the interested area.

In the case up to three APs, the algorithm converged on optimal locations sufficiently in 120 iterations as shown in Fig. 6. That means it provides efficient computation compared with the exhaustive grid search. If N APs are implemented by the grid search method with 517 acceptable AP positions, the ray tracer is needed to run ${}_{517}C_N$ times. Therefore, it represents this method becomes efficient as increasing APs.

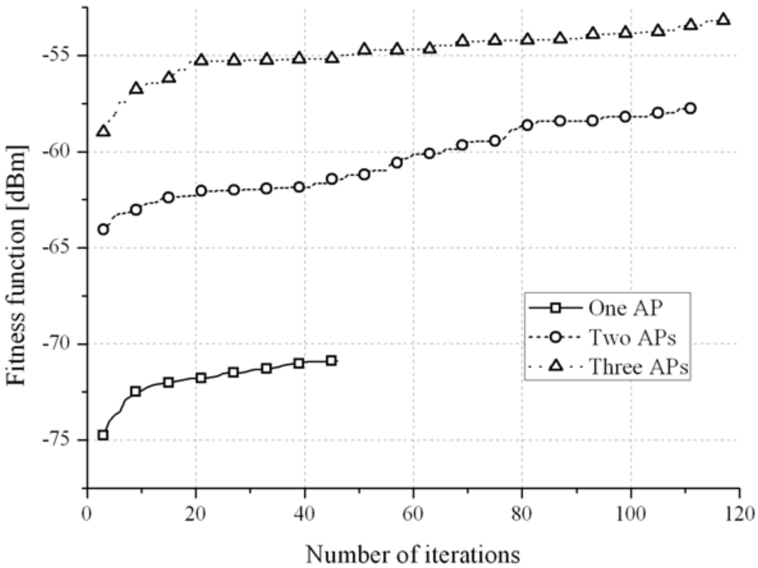


Figure 6: Convergence of fitness function of Fig. 3(b).

4. Conclusion

This paper investigated optimal APs for an indoor environment, based on the ray tracing technique and the PSO algorithm. It is represented that the combined method of the ray tracing technique and the PSO provides efficient performance for finding minimum number and optimal locations of APs in real environment.

Acknowledgments

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