Simulation of TD-LTE planning based on ray tracing model

Ma Simin1, Liu Qiang1, Yu Jiang1, Tian Qing1
1School of Information and Communication, National University of Defense Technology, Xi’an, China,710106
fcrobben@126.com

Abstract. Aiming at the problem of the network optimization of the signal base station in the urban environment, the ray tracing algorithm is used to model the urban cell and the wireless channel. By calculating the reference signal power of the receiving equipment, the received signal strength of each position in the cell radiated by different base stations is obtained. On this basis, the accuracy of calculation is verified with the measured data, and the countermeasures to solve the problem of poor channel coverage are given.

1. Introduction
With the development of mobile Internet technology and the rapid change of city appearance, communication service providers are facing the problem of how to plan the layout of mobile base stations reasonably. One of the important problems of base station layout and network optimization is to accurately estimate the RSRP (reference signal receiving power) under the influence of building reflection and diffraction within the base station coverage.

Many scholars at home and abroad have studied this kind of problem, mainly using three kinds of methods. One is to use various empirical and semi empirical formulas for estimation, such as ITU recommended estimation method [1], Okumura-Hata empirical formula [2]. The accuracy of this kind of early method is not high, although it can be applied in some calculation areas after several tests and corrections [3], it is still lack of general applicability; the second is parabolic equation method [4]. This method has been widely used in the ultra short wave and microwave band. It can accurately consider the shielding and primary reflection of the actual terrain to the radio wave, but the calculation accuracy is not high when solving the multiple reflection problem in the urban multi building environment. The third is ray tracing method [5], which is based on geometric optics and is solved by accumulating the signal field strength of direct and each reflection path. The algorithm has high accuracy, which is suitable for solving the problem of radio wave propagation in buildings and the field strength calculation in small-scale areas.

Therefore, in this paper, the ray tracing method is used to solve the RSRP of each area by building a three-dimensional cell model, and the analysis and calculation results provide countermeasures for the base station layout and network optimization.

2. Ray tracing method
The accuracy of the ray tracing method depends on the accuracy of the effective ray path and the calculation times of reflected and diffracted rays. By modeling the buildings in the calculation area, the buildings are simplified as regular or irregular polyhedron, the effective ray path is determined by judging the reflection, diffraction and diffraction points, and the field strength of several effective
paths on the target point is superposed to solve the field strength. The specific process can be summarized as the following four steps.

- **3D modeling of simulation area:** import the location and height data of buildings and vegetation in the calculation area into the computer, and establish the 3D model of the calculation area.
- **Effective ray path search:** according to the location information of the emission point and the occlusion of the nearby buildings, the direct ray path and the path that may produce reflection or diffraction are determined.
- **Determination of reflection and diffraction points:** the two-dimensional path is transformed into three-dimensional path, and the intersection of ray and occluded building is determined as reflection point and diffraction point. The number and type of ray are determined according to convergence rules and the position of reflection and diffraction point.
- **Solution of target position field strength:** according to the determined number and type of ray path, determine the electric field value vector sum of effective ray at the target position through the laws of reflection and diffraction, which is the target point field strength.

3. **Ray tracing method**

3.1 **simulation environment**

The simulation area is a typical urban community environment (580m * 430m), and the plan is shown in Figure 1. There are three base stations in the area, and one measuring point is set. See Table 1 for relevant information. The working frequency is 1815MHz.

![Figure 1. Plan of simulation area](image1)

![Figure 2. Terrain modeling](image2)

| Name     | Coordinate /m | Height and specific location                              |
|----------|---------------|----------------------------------------------------------|
| Site1    | (414.1, 361.2)| 15m, Set on top of the building                          |
| Site2    | (106.7, 186.3)| 30m, independent antenna tower                           |
| Site3    | (60.7, 40.1)  | 30m, Hanging on the outer wall of the building            |
| Measured point | (560.3, 164.8) | 55m, Set on top of the building                          |

Note: set the lower left corner of the simulation area to (0, 0)

The building data of this area is imported for modeling, and the result is shown in Figure 2.

In order to accurately model the ray tracing channel, based on the accurate measurement of the building structure of the community, it is necessary to consult the relevant data [6] to determine the surface electromagnetic characteristics parameters of the walls, vegetation and other structures.
The dry concrete wall (dielectric constant 2.48, conductivity 0.3), the indoor door is composite wood board (dielectric constant 2.95, conductivity 0.11), the door is metal (dielectric constant 1), the window is transparent glass window (dielectric constant 6.2, conductivity 0.1). In the calculation, the vegetation in the area will not reflect, diffract and other interaction on the radio wave, only will produce additional penetration attenuation on the radio wave.

3.2 simulation results

The ray tracing method is used to model and solve the area, and the field intensity distribution under the individual radiation of each base station is obtained as shown in Fig. 3 (a), (b) and (c).

From Fig. 3 (a) and referring to Fig. 1, it can be seen that the receiving power of the reference signal in the simulation area varies from -40dbm to -140dbm; the power in the position near the antenna is relatively high due to the concentration of rays, but there are many tall buildings in the south of the base station, so the power in most areas in the south of the road in the simulation area is relatively small, with the average RSRP[7] of about -100dbm The reason is that the main area that base station 1 is designed to cover is the area on the north side of the road.

From Figure 3 (b), it can be seen that the RSRP in the simulation area varies from -40dbm to -120dbm, and the overall RSRP is larger than that of the base station 1, especially most of the residential buildings on the south side of the road. This is because the base station is an independent antenna tower, which is relatively open nearby, and the surrounding buildings are mostly 6-7-storey low residential buildings of about 20m, which also have relatively small signal shielding, so the main part of the simulation area is within the scope of service of base station 2.

From Figure 3 (c) and referring to figure 1, it can be seen that the RSRP change range in the coverage area is also -40dbm - 140dbm; the power is basically the same as that in the radiation state of base station 1, because base station 3 is hung on the outer wall of the building, and the main radiation direction is the south side of the simulation area, so the RSRP is relatively small in the whole calculation area.

To verify the accuracy of the calculation, the RSRP simulation value at the location of the measured point is compared with the measured value, and the results are shown in Figure 4.

In Figure 4, the solid line is the simulation value of base station 2 radiation, the dash dotted line is the simulation value of base station 1 radiation, and the star scribed line is the measured RSRP of the...
measured point. It can be seen from Figure 4 that the measured value of RSRP is not a fixed value, but changes dynamically with time in the range of -89 to -105 dbm. When the measured RSRP is -89 dbm, according to the simulation value (-92.83dbm) of base station 2, it is judged that the signal is sent by base station 2; when the signal quality is poor or the service in base station 2 drops, the RSRP drops to about -102 dbm, at this time it can be considered that the base station has switched, and the RSRP is closer to the simulation value of base station 1. The accuracy of the calculation is proved by the above analysis.

Through comprehensive simulation and actual measurement, it can be seen that the location of the actual measurement point is at the junction of the coverage range of two base stations 1 and 2. According to the RSRP coverage standard[8], the coverage level of this area is from level 4 to level 5. The result is that the coverage is normal or poor. When the base station service is close to the peak, the receiver is prone to high drop rate, low data service rate and other phenomena. The user experience is poor and there are many complaints.

In order to solve this problem, we can consider to increase the power of base station 2 appropriately or set up additional indoor or roof distributed small base stations.

4. Conclusion
The RSRP of real cell phone signal [9] in urban area is solved by using ray tracing method, and the result is compared with the measured value, which proves the accuracy of calculation. According to the simulation results, the reasons for the poor signal coverage at the measured positions are given and the solutions are recommended. This method can provide technical support for the research of base station layout planning. It should be noted that the accuracy of the results is affected by many factors, such as the accuracy of urban building modeling, the number of ray reflections calculated by simulation, the modeling of base station antenna, the power of base station, etc.

Acknowledgments
The simulation results in this paper are solved by ray tracing mode in FEKO + winprop 2019 software.

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