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Comparison between Measurement and Simulation for an Outdoor-Indoor Scenario in WiMAX System

Navarat LERTSIRISOPON, Yukiko KISHIKI, Akiko KOMATSU, Masahiko KAWAMURA
ICT Business Planning Department, KOZO KEIKAKU ENGINEERING Inc.
4-5-3 Chuo Nakano-ku Tokyo Japan 164-0011, [#joy, y-sanoh, komatsu, kawa]@kke.co.jp

1. Introduction

In 2011, a project under the Japan Ministry of Internal Affairs and Communications (MIC) conducted measurement campaigns for Worldwide Interoperability for Microwave Access (WiMAX) in different scenarios in order to verify and improve the existing deterministic methods for estimating WiMAX system coverage in Japan [1]. Both outdoor urban and outdoor-indoor scenarios were considered in that project. In this paper, only the received signal strength indication (RSSI) and throughput results of the outdoor-indoor measurement will be discussed. In addition to the measurement results, comparisons with a site-specific simulation technique (ray-tracing) will be presented.

2. Measurement Scenario and Equipment

A WiMAX measurement campaign for outdoor-indoor scenario was carried out in Nakano-ku, Tokyo. This scenario was chosen since it represents a large actual activity of WiMAX users. In the following subsections, we will describe the measurement scenario and employed equipment.

2.1 Scenario

The base station (BS) was located at the top of Kozo Keikaku Engineering Inc.(KKE)'s head office (new annex) with a height of 42 m from the ground, while the mobile station (MS) was always 1 m above the floor which in this case is located on the 5th floor of KKE's head office (located 12.6 m from the ground) as shown in Fig. 1. The distance between BS and MS horizontally is around 240 m. Photos A to D show what the indoor scenario looks like taken from specific directions as indicated by the arrows in the indoor floorplan layout.

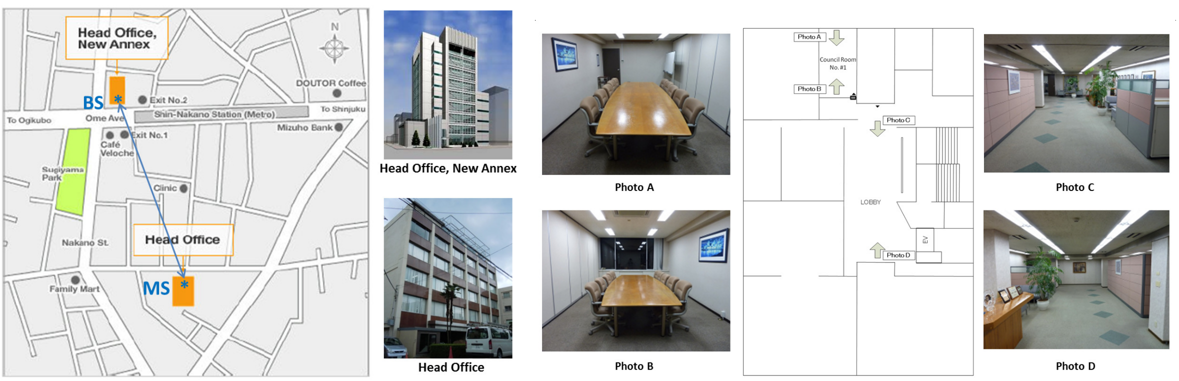

Figure 1: Measurement Scenario

2.2 Employed equipment

The WiMAX system as shown in Fig. 2 was setup to accomplish this measurement campaign and the related parameters can be found in Table 1.

Table 1: Specifications of measurement

Center frequency	2587 MHz
Bandwidth	10 MHz
Tx power	37 dBm
Tx antenna	Sector antenna (Gain: 17 dBi, Tilt angle: 4° pointed down, Rotation angle: 136° from North)
Rx antenna	Omni antenna

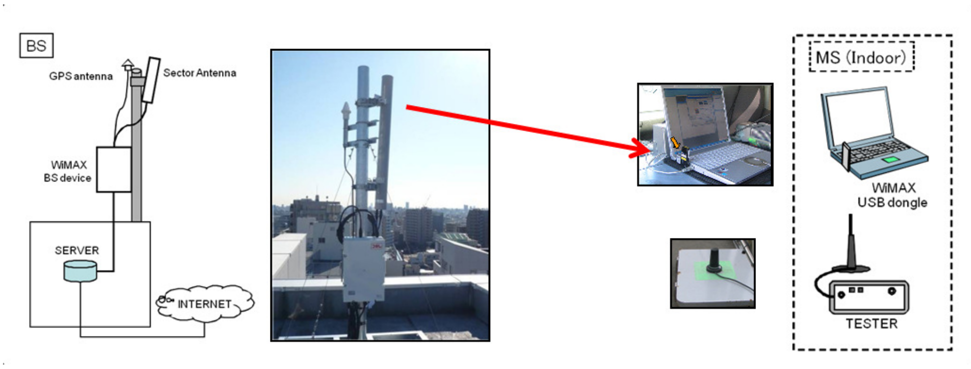

Figure 2: Setup

3. Ray-Tracing Simulation Model

In this paper, a ray-tracing simulator called "Wireless InSite" [2] was used to predict detailed path parameters, i.e. complex path gain, received level, direction of departure and direction of arrival in both azimuth and elevation, and delay. The simulator considers the 3 dimensions of space and finds the propagation paths from the BS to each MS point by including the effects of reflections, transmissions, and diffractions on the electric field. The formulation of reflected and diffracted rays are carried out based on geometrical optics (GO) and the uniform theory of diffraction (UTD) [3] [4] [5] to evaluate the complex electric field associated with each ray path.

The model used for the simulation including the building is shown in Fig. 3. The room layout for the indoor model corresponds to 35 m x 23 m x 3 m while the electrical properties and thickness of the materials used are shown in Table 2. The simulator was set to launch paths at 0.25 degree spacing over the full elevation and azimuth range, with a maximum number of 3 reflections, 2 transmissions and 2 diffractions between BS and MS. This allowed evaluation of outdoor to indoor paths. Moreover, the simulator is also capable of estimating the maximum available throughput based on the received level. So this value will also be compared with the measured throughput.

Table 2: Material database

Type	Material	Permittivity	Conductivity	Thickness [m]
Wall	Concrete	15	0.0015	0.3
Partition	RC wall	6.2	0.00691	0.15
Door	Freespace	0	0	0.3
Window	Glass	2.4	0	0.003

4. Results and discussion

Based on the measurement results of 2011 WiMAX project report of the Japan MIC [1], 20 MS locations for RSSI measurements and 8 MS locations for throughput measurements were used to discuss as shown in Fig. 4. In the ray tracing simulation, 347 MS points were used to have a better insight of the coverage area. Figure 3 shows the simulation results. The left figure depicts how the paths travel from

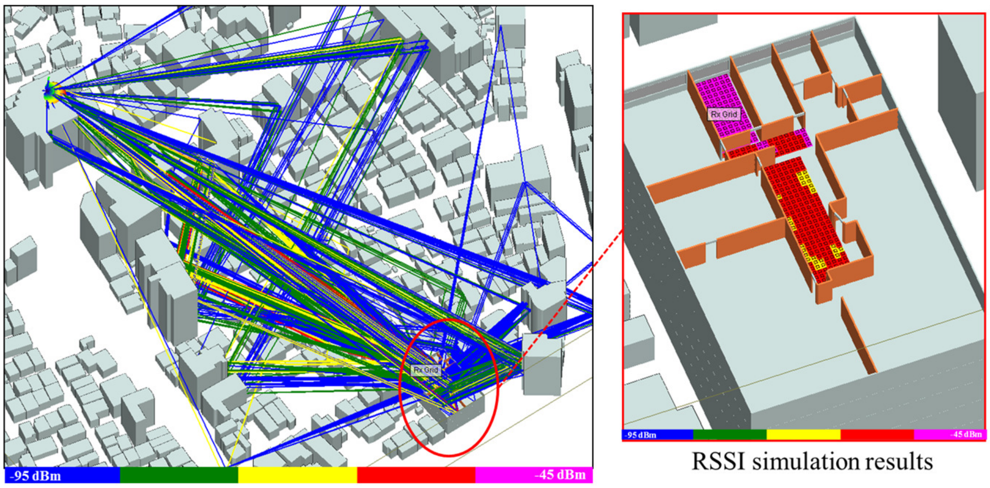

Figure 3: Simulation results

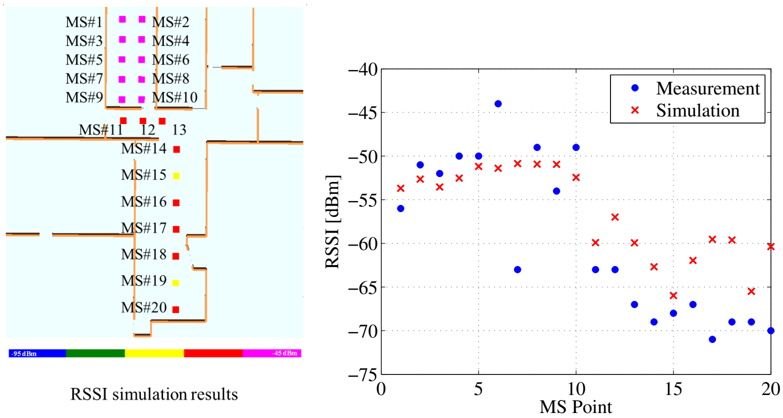

Figure 4: RSSI comparison between measurement and simulation results

the BS to the MS, while the right figure shows the variation of the received level. As can be seen from the figure, the MS points inside the room near the BS (and separated with one wall) have received levels around -55 dBm, and the level drops by about 10 dB when the MS are located in the middle of the floor.

4.1 RSSI comparison

In the simulation, the power of each ray path is combined to determine the total received power (as shown in Fig. 3) using the following equation.

$$P_R = \sum_{i=1}^{N_P} P_i \tag{1}$$

where N_P : the number of paths, P_i : the time averaged power in watts of the i^{th} path
Figure 4 shows the RSSI results obtained from both measurement and simulation. It can be seen that the ray-tracing simulation can predict well the received level, when the MS points are inside the room near the BS. However, for MS points in the middle of the floor, the deviation is big and maybe due to multiple wall transmissions. Since the wall material properties might be different from the actual wall due to its configuration. Multiple transmissions will magnify this error and may cause RSSI degradations for indoor scenario.

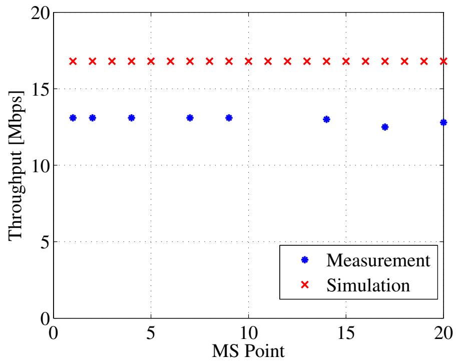

Figure 5: Throughput comparison between measurement and simulation results

4.2 Throughput comparison

Figure 5 shows the throughput result obtained from both measurement and simulation. In Wireless InSite, to compute the throughput for the download link, the signal to noise ratio (SNR) is first computed based on a noise power density and the strongest transmitter power. Then the best modulation and coding scheme (MCS) that achieves a burst error rate of 0.01 for the given SNR, is selected [6]. Based on this MCS, the throughput is then estimated. Hence the simulation throughput values are discrete and the results vary with the measurement values which are calculated in a different manner.

5. Conclusion

Ray tracing is a common technique to simulate outdoor and indoor scenarios. In this paper, the RSSI and throughput of an outdoor-indoor scenario for WiMAX system is simulated and compared with measurement. For the RSSI comparison, it can be seen that the ray-tracing technique can predict the trend of the outdoor-indoor scenario. However, further investigation should be considered for MS points that are not near the outer walls of a building since multiple wall transmission may affact the results. For the throughput comparison, the simulation results give the best possible throughput, and therefore differ with the measurement results.

References

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[6] C. Eklund and et al., *WirelessMAN : Inside the IEEE 802.16 standard for wireless metropolitan area networks*, IEEE Standards Information Network/IEEE Press, first ed., May 2006. Table 14-30