Radio Wave Propagations through Floors in the Adjacent of a High-speed Indoor Wireless Local Area Network Office Environment

[#]Hirokazu Takeno [1], Yuto Nakatsu [1], Tomotsugu Hasegawa [1], Manabu Omiya [2]
[1] Graduate School of Information, Science and Technology, Hokkaido University
Kita 14, Nishi 9, Kita-ku, Sapporo-shi, 060-0841 Japan
straycat054@gmail.com, {yuto-nakatsu@frontier,hase@iic}.hokudai.ac.jp
[2] Information Initiative Center, Hokkaido University
Kita 11, Nishi 5, Kita-ku, Sapporo-shi, 060-0811 Japan
omiya@iic.hokudai.ac.jp

1. Introduction

In recent years a high-power and high-speed wireless LAN router based on the IEEE802.11n standard with a data transmission rate of 300 Mbps has been developed [1]. Using this equipment as an access point makes it possible to multicast HDTV videos between floors in the adjacent as well as between rooms in the same floor [2]. Therefore, optimum wireless system designs are required to provide reliable and low-cost services. The accurate estimation of pass-loss is useful in the optimization of the access point location [3],[4]. This paper discusses relationships between received signal strength indication (RSSI) and throughputs as well as indoor propagation characteristics in the realistic office environment.

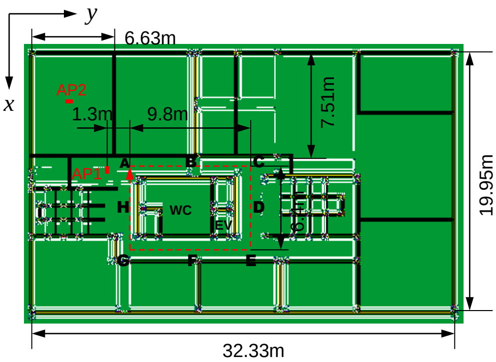
2. Experimental Environment and Measurements

Figure 1 shows floor plans of the wireless local area network office environment. The measurement is carried out in the three floors from the second to the fourth in Information Initiative Centre, Hokkaido University. This building consists of four stories, and all floors are the same structures except the additional areas of the first floor and the second floor. There are an elevator, pipe space, and basic equipment in the center of each floor surrounded by the public space such as the passages. Also, conference rooms, laboratories and officers' room enclose them. The area of the third floor is about 645 m^2. Measurements of propagation losses were mainly carried out in the passages. A wireless local area network (LAN) router is placed in either passage (AP1) or the laboratory (AP2) in the third floor as shown in Figure 1(a).

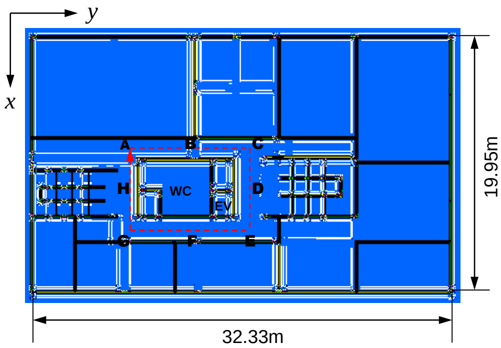
The measurement equipments are shown in Fig. 2. We use the Buffalo WZR-HP-G300NH as an access point [5] which supports the IEEE802.11n standard at the frequency of 2.4 GHz. This device achieves the transmission rate of 300 Mbps for the frequency bandwidth of 40 MHz and the high-speed mode. The transmission speed is automatically changed from 300 Mbps to 6 Mbps depending on the communication environment. In the experiment, we choose the channel 7 whose frequency corresponds to 2,442 MHz and use the channel 11 as an additional channel for the 40 MHz bandwidth. We assume the AP consisting of a conductive box of 170 mm × 150 mm × 30 mm and two monopole elements of 30 mm long which are installed in the box. The AP is set up so that the antenna elements direct downward as shown in Figure 2(a) and (b). The observation points are chosen at the center of the passages whose total length is 32.4 m depicted by the broken line in Fig. 1. Three kinds of the passage have the width of 1.4 m, 2.4 m and 1.64 m. The observation points are denoted as A to H in Fig. 1.

In the measurement, two mobile personal computers (PC) are used. One is the server PC which is connected by a 1000 Base-T network cable with the AP. It is SONY VAIO VPCX11AVJ whose processor is Intel Atom Z540 (1.86 GHz) with the main memory of 2 GB and operating system is

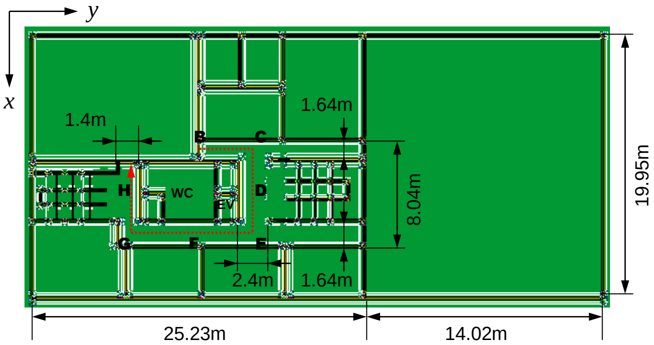
Microsoft Windows XP Professional SP3. On the other hand, another is the client PC which communicates with the AP by the wireless LAN module of IEEE802.11n, Buffalo WLI-UC-G300HP [5]. It is Panasonic CF-T5 whose processor is Intel Core Duo U2400 (1.06GHz) with the main memory of 1.5 GB and operating system is Microsoft Windows Vista. The client PC in the wagon moves to the specified direction and measures RSSI automatically. We use two kinds of open source software for the measurements, WiFi tool inSSIDer version 1.2.8 for the RSSI and Iperf version 2.04 for the average throughput. The measurement of throughput is carried out more than twice, and then we calculate the average throughput as a mean value of those measurement results.



(a) Third floor

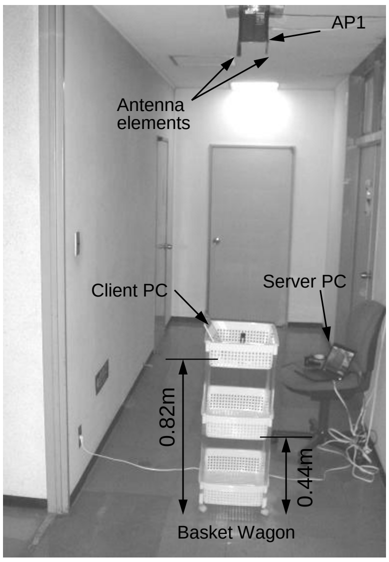


(b) Fourth floor

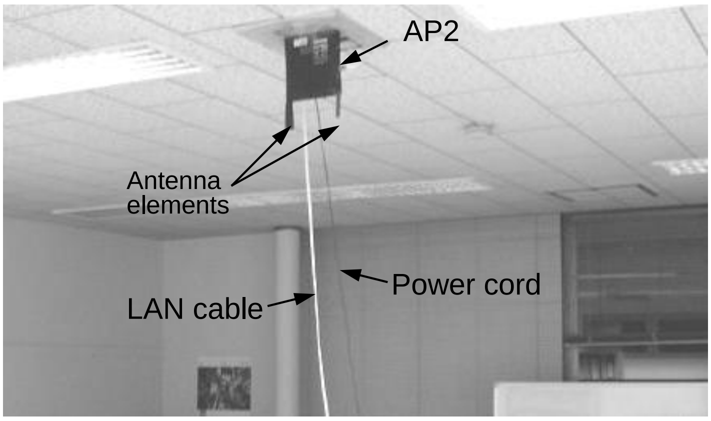


(c) Second floor

Figure 1: Floor plans of the experimental environment



(a) Access point 1 (AP1)



(b) Access point 2 (AP2)

Figure 2: Access point and measurements

3. RSSI and Averaged Throughput

RSSI and averaged throughput are measured for two AP locations, AP1 and AP2. Each results and discussions are presented below.

3.1 The Access Point, AP1

Figure 3 shows correlation between RSSI and the average throughput assuming AP1 where the AP is set on the passage ceiling shown in Fig. 1(a) and Fig. 2(a). In Fig. 3, the horizontal axis denotes average throughput, and the vertical axis denotes RSSI. Three markers are used to distinguish the floors. It is seen fro the figure that a straight line approximates the relation between the averaged throughput and RSSI. The relation is expressed as

$$y = 1.01\,x - 84.4 \qquad (1)$$

where y is RSSI (dBm) and x is the average throughput (Mbps). It can be seen that the average throughput can be estimated from the measured RSSI using Eq. (1). There is a feature that RSSI can be measured easily than the average throughput because the RSSI measurement requires only the client PC.

Figure 4 illustrates comparisons of measured results with calculated ones [6]. Three kinds of marker denote measured results and solid and dashed lines denote computed results. Both results give good agreements and it confirms the validity of the measurement results and the effectiveness of the numerical simulations.

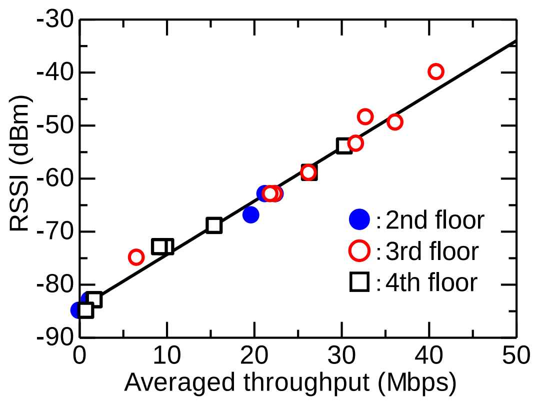


Figure 3: Correlation between RSSI and average throughput for AP 1.

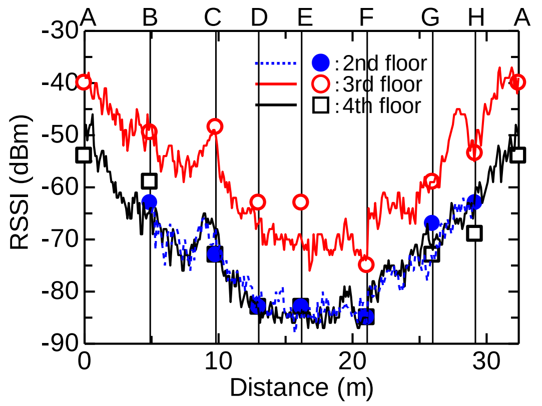


Figure 4: Comparison between measurement result and analytical result of RSSI with AP 1.

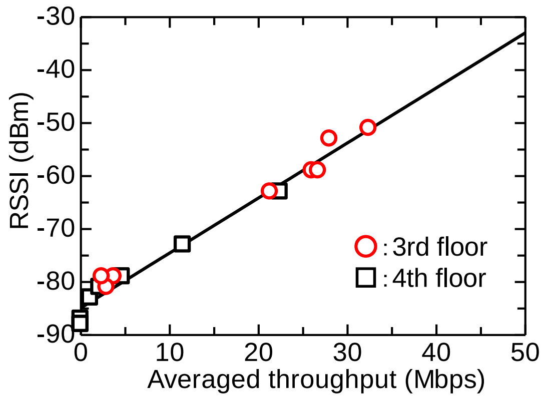


Figure 5: Correlation between RSSI and average throughput for AP2

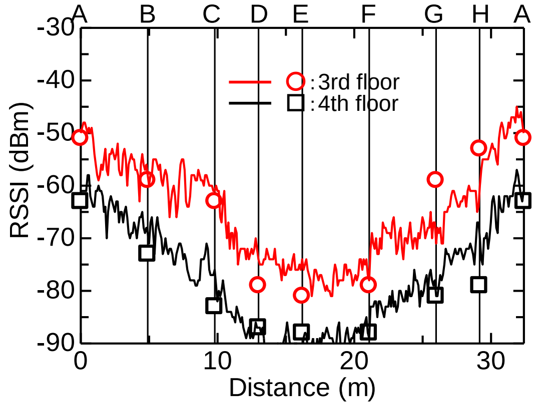


Figure 6: Comparison between measurement result and analytical result of RSSI with AP2

3.2 The access point, AP2

The AP is set up in the laboratory for the case of AP2 shown in Figs. 1(a) and 2(b). Figure 5 illustrates the correlation between RSSI and the average throughput where the measurements are carried out in the third and the fourth floors. It is clear from the figure that the measurement results show correlation between RSSI and the average throughput as well as in Fig. 3. The relation can be well approximated by the equation expressed as

$$y = 1.04\,x - 84.9 \tag{2}$$

The coefficient in Eq. (2) is slightly different from those in Eq. (1). It is thought that the difference is not important in practical use. Therefore, the relation between RSSI and the average throughput is independent upon locations of AP. Figure 6 shows comparisons of measured results with calculated ones. They agree well with each other. Therefore, the effectiveness of the experiment result can be confirmed again.

4. Conclusions and Future Work

In this paper, the indoor propagation in an office environment is discussed for a high-speed wireless local area network system with the IEEE802.11n standard. The relations between RSSI and the average throughput are derived from the measurements. It is clarified that the correlation between RSSI and the averaged throughput is strong and are approximated by the simple linear equation. In addition, verifying the validity of the measurement result, large-scale electromagnetic field computations based on the FDTD technique are carried out. As a result, the calculated results agree well with the measurement results. So, the average throughput is enabled to be estimated easily by using calculated RSSI and the above linear equation. In addition, it is shown that the derived linear equation is independent upon AP locations. These discussions are effective to decide locations and number of high-speed wireless LAN systems in office environments.

Similar examinations and discussions will be done for large office environments [7], houses and so on as future works.

Acknowledgements

Computations were performed using the resources provided by the High Performance Computing System at Information Initiative Centre, Hokkaido University.

This work is supported by Japan Society for the Promotion of Science (JSPS) KAKENHI, Grant-in-Aid for Scientific Research (C) 21500065.

References

[1] Association of Radio Industry and Business (ARIB), ed., Second Generation Low Power Data Communication System/Wireless LAN System, ARIB STD-T66 Version 3.5, Apr., 2010.

[2] M. Morikura and S. Kubota, 802.11 High-Speed Wireless LAN Textbook, The Impress Japan, Tokyo, 2004.

[3] C. Takahashi, Z. Yun, M. F. Iskander, G. Poilasne, V. Pathak and J. Fabrega, “Propagation-Prediction and Site-Planning Software for Wireless Communication Systems,” IEEE Antennas and Propagation Magazine, vol. 49, no. 2, pp. 52-60, Apr.2007.

[4] S. Zvanovec, P. Pechac, and M. Klepal, “Wireless LAN Networks Design: Site Survey or Propagation Modeling?” Radio Engineering, vol. 12, no. 4, pp. 42-49, Dec. 2003.

[5] Buffalo Technology, Inc., Air Sation, WZR-HP-G300NH Product Specifications , http://www.buffalotech.com/products/wireless/routers-and-access-points/nfiniti-wireless-n-high-power-router-access-point-wzr-hp-g300nh/, 2009.

[6] T. Hasegawa, T. Shoji, M. Omiya and T. Hikage, “A Numerical Analysis of Cumulative Probability of Incident Wave Indoor Propagation,” 2008 International Symposium of Antennas and Propagation (ISAP 2008), TP-A03, 1644976, pp. 746-749, Oct., 2008.

[7] Y. Nakatsu, H. Takeno, T. Hasegawa and M. Omiya, “An Estimation of Indoor Propagation Characteristics of Wideband Wireless LAN,” Research Group Report, the Image Information and Television Engineers, Japan, Jul. 2010.