Throughput Measurements and Numerical Prediction Methods for IEEE802.11n Wireless LAN Installations at 2.4 GHz in a Residential Two-Story House

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Abstract

This paper discusses how to predict indoor propagation characteristics in a two-story house by measurements and numerical simulations. Measurement campaigns in two different locations of access point are made to obtain a relationship between RSSI and throughput. In addition FDTD calculation results are compared with measured ones to confirm the effectiveness of measurements.

Keywords : Mobile network, IEEE802.11n, Indoor propagation, FDTD simulation

1. Introduction

Low cost commercial wireless local area network (WLAN) products based on the IEEE802.11n standard are available to consumer recently [1]. They are expected to provide both of wider range coverage and higher throughput at the same time than IEEE802.11a/b/g devices and to have flexibility to construct wireless networks [2]. IEEE802.11n standard adopts MIMO-OFDM that improves the data throughput using many multipath channels in the communication environment even for low received signal strength indications (RSSI) [3].

In several references [4]-[6] measurement campaigns were performed to assure the excellent performance of MIMO-OFDM and to propose its improvements. These reports measured the indoor propagation characteristics with a 4×4 MIMO-OFDM consisting of a four-element array antenna with a half-wavelength element-to-element spacing operating at 5 GHz, and showed to achieve relatively well data transmission rate [6]. However it is not clarified whether the commercial WLAN systems always have desired characteristics comparable with those reported in the references or not because they are fabricated under considering the market forces pushing for low cost, miniaturization and device performance.

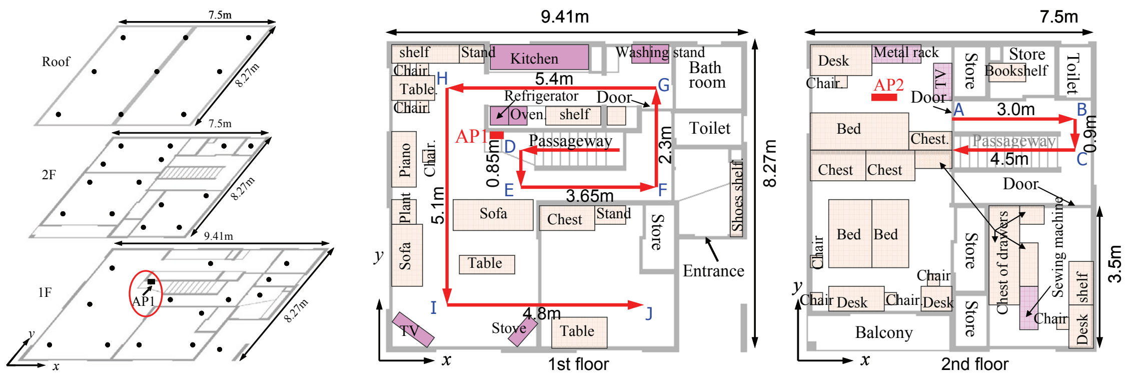
For this reason it is important to evaluate the actual throughput of commercial IEEE802.11n devices. In our previous works [7], [8] we carried out the measurement campaigns of the indoor propagation characteristics in the two different office environments in the 2.4 GHz band using the commercial IEEE802.11n WLAN devices. As a result, the distinct relationship and high correlation between RSSI and data throughput were observed throughout all of measurements. Moreover, FDTD simulations using the precise models of communication environment were reported to predict well the actual RSSI profiles. From such discussions a useful method was proposed to estimate data throughput incorporating the FDTD-calculated RSSI profiles without the site survey.

This paper discusses how to predict indoor propagation characteristics in a residential two-story house using the similar manner mentioned above. For such a purpose, measurement campaigns in two different locations of an access point are taken to derive a relationship between RSSI and throughput. In addition, FDTD calculation results are compared with measured ones to confirm the effectiveness of measurements.

2. Experiment Method for a Residential Two-Story House

Figure 1 shows the overhead views of a residential two-story house under consideration. The area is 9.3 m wide and 8.27 m long. The access point locations are shown with AP*x* where *x* is either 1 or 2. The figure (b) displays physical layouts of furniture and fixture in the house. Figure 2 shows setups of an access point and a client PC. The access point on the telephone desk of 1 m high beside the staircase is referred to as AP1 and on ceiling of the second floor referred to as AP2. The 37 dots in Fig. 1 (a) represent the measurement locations for AP1. On the other hand, measurements for AP2 are taken along the A-to-J arrows shown in Fig. 1 (b) where the distance is 30.5 m long.

We use the Buffalo WZR-HP-G300NH as an access point [9]. This equipment supports the IEEE802.11n standard in the 2.4 GHz band and achieves the data transmission rate of 300 Mbps. The transmission speed is automatically tuned from 300 Mbps to 6 Mbps depending on the radio environment. In the experiments, we choose the 7th channel whose center frequency corresponds to 2442 MHz. We assume that the AP consists of a metal box of 170 mm × 150 mm × 30 mm and two planar sleeve antenna elements of 30 mm long attached on the box. The AP is set up so that the antenna elements direct normal to the ceiling as shown in Fig. 2 (a) and (b). In the measurement, two laptop personal computers (PC) are used. One is the server PC connected with the AP by a 1000 Base-T network cable. Another is the client PC linked to the access point by an IEEE802.11n wireless handset, Buffalo WLI-UC-G300HP [11]. It has two planar sleeve antenna elements with an inter-element spacing of 20 mm corresponding to the 0.16 wavelengths at 2442 MHz. We use two kinds of open source software for the measurement, WiFi tool *inSSIDer* version 1.2.8 for the RSSI and *Iperf* version 2.04 for the average throughputs.



(a) (b)

Figure 1: Residential Two-story House. An Overview (a) and Overhead Views (b).

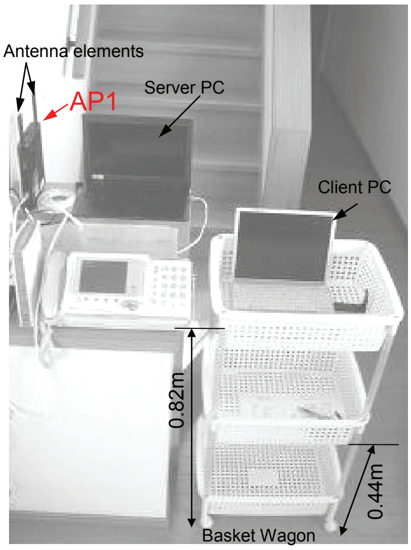
3. Measurements and Numerical Evaluations

Figure 3 depicts relationships between RSSI and average throughput measured for both AP1 and AP2. Four different markers are used to identify the measurement conditions and AP locations. The measurement of throughput is performed several times, and then we calculate the average throughput as a mean value of those measurement results. As can be seen in the figure, the relationship between RSSI and the average throughput is approximated by the linear formula, $y = 1.0\,x - 90$. The RSSI of more than −66 dBm and the average throughput of more than 23 Mbps are observed for both AP1 and AP2 because the radio waves tend to pass through the walls easier in the residential house than in office buildings.

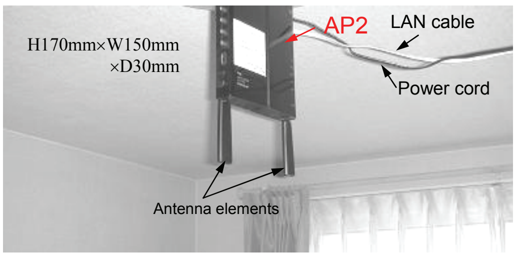
Figure 4 shows both of measured and calculated RSSI profiles in the case of AP2. In this figure experimental and computed results are denoted by a solid line and a solid marker. Here the finite difference time domain (FDTD) method and modeling are employed [10]. A cubical cell with space-cell size as small as 5 mm is assumed in FDTD simulations due to the precise modeling of fixture and furniture. The FDTD model shown in Fig. 5 is comprised of five billion cells. It is seen from the figure that the FDTD results of RSSI profile agrees well with the measurement. Especially the feature of RSSI distribution around the observation point H under the AP2 location is well predicted by the FDTD modeling. Hence we confirm the validity of FDTD calculations and reasonability of the measurement.

Figure 6 visualizes the FDTD-calculated RSSI profile (log scale) along planar cuts through each floor. It shows that electromagnetic fields radiated from AP2 pass through the walls and floors, and go out of the house with high levels of intensity.

Considering the relationship between RSSI and throughput shown in Fig. 3, throughput at arbitrary point can be easily predicted by the calculated RSSI. Since the relationship shown in Fig. 3 is similar to that in the case of the office environments, it indicates that it is independent of the measured sites and depends upon the IEEE802.11 WLAN products.



(a)



(b)

Figure 2: Setup of Access Point. AP1 near the Staircase (a) and AP2 in the Room (b)

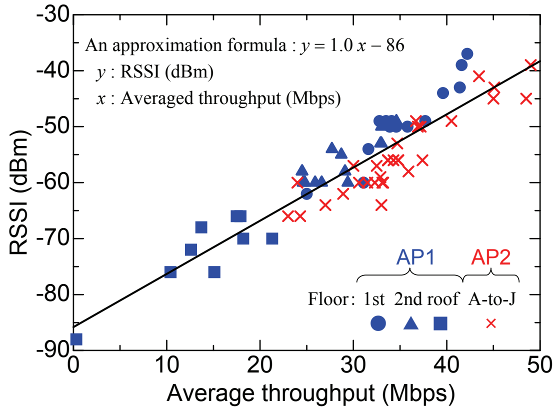


Figure 3: Relationship between RSSI and Averaged Throughput

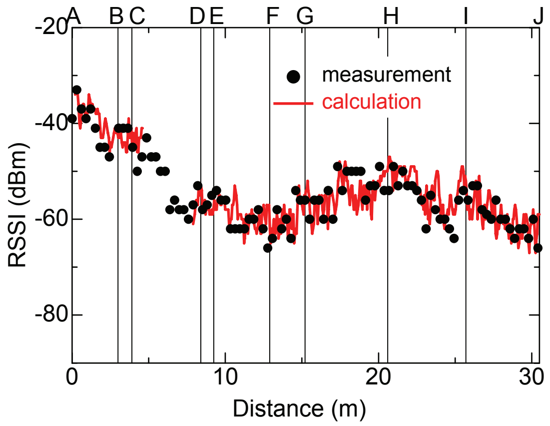


Figure 4: Comparison of Measured and Calculated RSSI Profiles for AP2 at 2442 MHz.

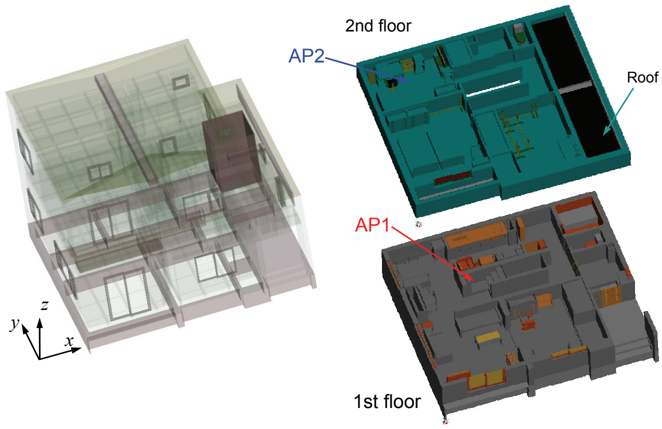


Figure 5: FDTD Model of the Residential House.

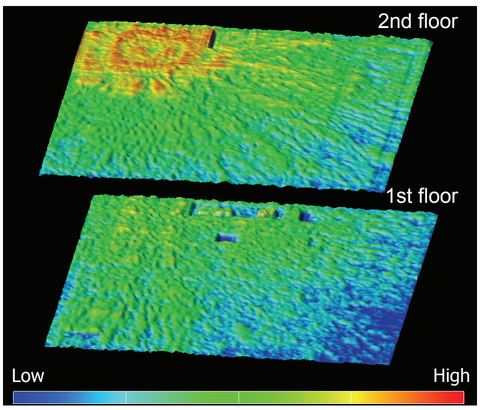


Figure 6: FDTD-Calculated RSSI Profile in the House at 2442 MHz.

4. Conclusions and Future Work

The WLAN system based on the IEEE802.11n standard achieves high output power by occupying a wide frequency bandwidth as well as high data throughputs in the indoor multipath communication environment by adopting MIMO-OFDM. However, requirements for commercial WLAN systems are low cost and compactness as well as an excellent communication performance. It is important in the construction of the mobile network to understand the performance of commercial WLAN systems.

This paper discusses the indoor propagation in a residential two-story house by the measurements and the numerical simulations of a high-speed WLAN system operating at 2.4 GHz based on the IEEE802.11n standard. The linear relationship between RSSI and data throughput is derived from the measurements, and it is similar in the cases of two different office environments reported by authors. In order to confirm the validity of the measurement results, the FDTD simulations are carried out. The numerical results agree well with the measured ones. As a result, we propose how to predict data throughput at any location combining the derived formula with calculated or measured RSSI profiles. The throughput value in an arbitrary place can be presumed from the RSSI distribution obtained by the numerical simulation. Similarly, it is an effective design approach so that the installation position and the number of access points are estimated.

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Acknowledgments

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.