Experimental Throughput Analysis for 802.11n System and MIMO Indoor Propagation Prediction

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ABSTRACT

This paper presents an analysis of a commercial 802.11n MIMO 2x3 dual band (2.4 & 5 GHz) system focusing on the operational throughput performance over an indoor environment with Line of Sight and Non Line of Sight scenarios. Although many authors have provided evidence on the effectiveness of this technology in field strength distribution, throughput or propagation-simulation environments, efforts on all parameters combined is limited. This paper also intends to elucidate the comparison of these metrics by evaluating a MIMO 2x3 dual band (2.4 & 5 GHz) system, focusing on physical measurements of the operational performance, in comparison with simulations of the field strength distribution over an indoor environment.

1. INTRODUCTION

Recent studies have evaluated the commercial performance of hot-spot connections using 802.11abg [1] and 802.11e using simulations to identify the quality of the connection through the Medium Access Control (MAC) [2]. In the same context the recent release of the 802.11n standard needs to pass through similar studies for its in-depth evaluation. Researchers in [3], investigated throughput using one transmitted stream to determine how it behaves in the ISM bands in an office environment.

A 3D FIT approach was applied in [4] to radio propagation calculations over an area of 400 m². Results showed that error standard deviation was in the range 2- 3.7 dB which demonstrates a useful level of accuracy for modelling. A similar approach was reported [5] in which the simulation frequencies considered were below 1GHz for compact scenarios providing insufficient reliability at higher frequencies or for greater areas. Such techniques clearly require a substantial computational effort which provides a substantial limitation in applications where wider areas and higher frequencies are required, making the FIT model impractical [6], especially in terms of prediction accuracy and spatial detail.

Finite Difference Time Domain (FDTD) methods may be used to compute the electromagnetic response of a variety of arrangements and types of walls in a building. FDTD provides simple programming and simple data base structure; however the excessive running time (55 hours) and memory requirement makes this technique limited. Ray tracing can be used to model the propagation but usually requires complex programming to determine the geometry of the traced rays [7].

2. THROUGHPUT MEASUREMENTS SETUP

The throughput measurement campaign was developed to measure the data rate achievable at different locations on the 3rd floor corridor from Chesham Building B Block at the University of Bradford campus. The measurements were computed by two stationary personal computers (PC), each one connected via Ethernet to a commercial 802.11n wireless router having a 1x3 MIMO antenna array, evaluating the throughput obtained from MIMO2 to MIMO1as shown in Figure 1, which can operate at different frequencies and bandwidths.

The evaluation of each set of measurements, that is from 10m-50m, was performed in compliance with the 802.11n standard [8]. Two different scenarios were established to evaluate the throughput performance on the MIMO antennas. The LOS scenario was implemented by installing the Tx antenna in a corridor in such a manner that all the measurement locations from the Rx antenna were able to achieve LOS reception. Five receiver locations were established for this scenario, separated by 10 m from each other in a linear distribution as shown in Figure 2. The NLOS Scenario was implemented by installing the Tx antenna in the corridor in a way that all measurement...
locations from the Rx antenna were able to achieve a NLOS reception. The same five receiver locations were established for the NLOS scenario as it was for the LOS scenario. In each scenario, the antenna height was always 1m above the floor, for both the mobile (Rx) and the fixed unit (Tx).

3. THROUGHPUT MEASUREMENT RESULTS

Each value represented in the following graphs was averaged over 5 measurements per location. Figure 3 describes the average (mean) and the maximum (peak) values obtained from the throughput measurements obtained from the LOS scenario at each of the 5 locations. A particular observation on the achievable throughput using 40MHz bandwidth is that at some points it doubles the 20 MHz throughput. In the majority of cases using 40 MHz, 5.2 GHz achieves higher date rates compared with the 2.4 GHz frequency configurations.

Figure 4 shows the mean and the peak values obtained from the throughput measurements obtained from the NLOS scenario with the system operating at 2.4 and 5.2 GHz frequencies, using 20 and 40 MHz transmission bandwidth at each of the 5 locations. In this scenario there is a noticeable decrease of throughput as the distance between the Tx and the Rx increases. Still at around 50 meters distance (location 5) the throughput is 90-100 Mbps (5GHz-40MHz), which is considered a very good performance for a NLOS scenario.

4. SIMULATION MODEL

The simulation was performed through the 3D Shoot and Bounce Ray (3D SBR) technique, using 0.2° ray spacing, 7 reflections, 2 transmissions and 0 diffractions, which allowed evaluation of the paths launched from the
transmitter. Following the basic multipath mechanisms (reflection, diffraction, transmission and scattering), it was possible to determine the rays reached by the receiver and therefore to calculate the path loss. Applying the image method approach the ray tracing technique captures precisely the large structure. The Wireless InSite model included the configuration of specific parameters for its complete simulation: waveform, antenna, transmitter, receiver, model, materials and output.

The construction of the model was corroborated by the corridor layout used for the physical measurement. The model therefore has the same dimensions as the building corridor corresponding to 64 x 26 x 3 meters. The model was successfully completed by detailed modeling as shown in Figure 5, establishing two types of walls: 20 cm thick and 12 cm thick (block material) according to the floor layout.

5. RSSI MEASUREMENT AND SIMULATION RESULTS

The first measurement campaign was developed to evaluate the field distribution strength using a laptop and the MIMO 2x3 system along the corridor of Chesham Building section B, 3rd Floor, at the University of Bradford. The physical model was performed in a layout with the total corridor space divided into 1m² sections obtaining a total of 90 locations. Each section was evaluated for 5 Received Signal Strength Indicator (RSSI) values over two frequencies (2.4 and 5GHz) using the 802.11n standard at 20 MHz bandwidth.

The 3D RSSI Scenario comprised of 90 receiver locations was divided into the Rx Route (69 locations), and the Rx Grid (21 locations) for practical analysis. The Rx Route is a route of receiver locations along the entire corridor; every single one with the same characteristics. The Rx Route has a part of LOS and NLOS receivers. The Rx Grid is a 7x3 Grid of receiver locations set in LOS as shown in Figure 6.

![Figure 5. 3D Indoor Environment Model.](image1)

![Figure 6. 3D RSSI Scenario Simulated Results.](image2)

Figure 7 shows the field strength distribution obtained from RSSI Measurements campaign along the corridor. The graph shows 13 scales from -9 to -100 dBm values, each scale using a 6.9 dBm range. The distribution was implemented for 2.4 and 5GHz measurements. Both distributions show that in 5.2 GHz configuration, the signal strength is distributed over a less coverage area compared with 2.4 GHz, but achieving a higher intensity over closer areas. Figure 8 show the comparison of the received signal strength measured per receiver location and the simulation of the 3D RSSI Scenario results. The simulated results is an average of the received signal of the maximum and minimum transmission power of the antennas. At 2.4 was from 17 to 11 dBm, and for 5 GHz from 18 to 9 dBm, confirming the similarity of the values simulated.

6. CONCLUSIONS

The analysis of throughput values obtained from Line of Sight and Non-Line of Sight scenarios provide an experimental insight into the performance of MIMO systems deployed using the 802.11n standard in a typical multi-storey office building, reaching 250 and 296 Mbps for NLOS and LOS respectively (for 10 m distance). The achievable bit rate for a MIMO system is much more reliable when compared to a SISO connection. Furthermore the 802.11n channel bonding option provides remarkable throughput increase, compared with 802.11a/b/g. The Implementation of a simulated propagation model using 3D SBR provides a good estimation of the channel...
propagation without demanding an extraordinary computational effort. The investigation found a high correlation for 2.4 GHz and 5.2 GHz frequencies (86% and 96% respectively) between measured and simulated data. By modelling a MIMO system in an indoor environment, it was possible to determine the signal strength distribution and its achievable throughput for different locations. Despite the accuracy of the results obtained in this investigation, the modelling process remains rather complex, which might limit its applicability in future work.

7. REFERENCES


