

Customizing WLAN Access Point's Indoor Coverage and Throughput with Corner Reflector

Omar Abdul Aziz^{1*}, Jafri Din¹, Rozeha A. Rashid², Mohd. Adib Sarijari² and Nur Aqilah Yusri²

¹Wireless Communication Centre, Universiti Teknologi Malaysia, 81310 UTM Skudai, Johor, Malaysia.

²School of Electrical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia.

*Corresponding author: omar@utm.my, Tel: +607-5536093

Abstract: Careful control of indoor wireless coverage is crucial to ensure better signal reception at user-end, mitigate interference to other adjacent wireless systems plus reduce possibility of signal reception by unintended users. Existing solutions are either costly or difficult to configure. This paper presents empirical IEEE802.11 indoor coverage and Transmission Control Protocol (TCP) throughput analysis for WLAN Access Point with corner reflector. The integration of two corner reflector configurations to Access Point was shown to successfully weaken signals by up to 19 dB and 100% of TCP throughput while strengthening signals by up to 6 dB and 40% of TCP throughput for respective intended regions. The results demonstrate potential application of corner reflector to customize indoor coverage and regulate reliable internet connectivity of Access Point.

Keywords: TCP throughput, RSSI, wireless signal strength, Access Point indoor coverage, corner reflector

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1. INTRODUCTION

Current and emergence technologies heavily depend on wireless communication and internet connectivity. The advancement of wireless communication has allowed its application for numerous human activities. The development of Internet of Things (IoT) for example, allows physical objects to be linked wirelessly inside cyber space via electrical components that aid communication between those physical objects [1]. Wireless Local Area Networks (WLANs) provide an alternative link between internet source to users within a specific geographical locality, where physical links are costly to be considered. WLANs operate commonly in an indoor setting. The primary WLAN standards are IEEE802.11, or widely known as Wi-Fi [2]. One of the mostly used Wi-Fi system, the IEEE802.11g system, could conventionally be set up to permit information transmission up to 54Mbps.

Transmission control protocol (TCP) make up more than 80% of the entire Internet's traffic. Forecasting TCP's throughput is therefore essential to improve our understanding of WLAN system's capacity that use TCP to access the internet. In TCP, data packet losses trigger congestion control algorithm to retransmission these lost packets while reducing the sending rate [3]. Nevertheless, evaluating the performance of WLANs is a tremendously difficult task due to variations in interference scenarios as well as the complexities of wireless signal propagation. The physical layer of the Wi-Fi standards stipulates various communication data rates that are dependent on the quality of wireless communication link, or signal-to-noise ratio (SNR) [4]. Generally, indoor signal propagation is more difficult to predict as compared to outdoor signal

propagation. This is because signal is affected by more factors, namely building materials, movement of human and machines, walls and obstacles such as furniture. signal wave would experience more scattering, reflection, diffraction and even absorption by building materials. [5-7].

To regulate wireless signal propagation as per the intended use, several research works have demonstrated better control through smart walls that are made of special materials, but require infrastructure-level renovations [8]. Research work in [9] propose placing several metal plates that may enhance wireless performance but involve a considerable environment changes. A less expensive solution includes incorporating custom-made reflectors to Wi-Fi's Access Point (A.P.).

The proposed reflectors solution presented in [10] however functions with complex reflectors design that are fixed for certain coverage. The corner reflector is an easy-to-design reflector that could be easily incorporated with current Wi-Fi's A.P. [11]. Due to the nature of the corner reflector structure, a change in propagation coverage could be easily achieved through position-change of the reflector relative to the A.P. This paper intends to present indoor coverage as well as signal throughput inspections of commercial A.P. with corner reflector through empirical analysis.

2. MEASUREMENT SETUP

2.1 Location

We conducted measurement campaigns within the ground floor of Wireless Communication Centre (WCC), Universiti Teknologi Malaysia building block. The

workspace scenario is a 30 m × 21 m floor area with different room layouts as in Fig. 1. that consists of (a) a **spacious indoor lobby** area that connects several research laboratory spaces and office rooms. The A.P. is located within this lobby area. 40 measurement points were designated within the lobby with each point being a line-of-sight (LOS) scenario. (b) **Non-LOS region 1** that is separated from the lobby by a brick wall. There were 8 designated measurement points within this space. (c) **Non-LOS region 2** with 12 designated measurement points. This space is separated from the lobby by a dry wall with glass windows. Cumulatively, there were 60 measurement points, represented by the red / blue circle dots in Figure 1.

Received Signal Strength Indicator (RSSI) measurement campaign were conducted twice at different time in order to observe stability of recorded data. At 12 out of the 60 measurement points (represented by the red circle dots in Figure 1), downstream TCP throughputs were recorded up to four times and averaged during each measurement campaign. Location 1 to 8 were expected to experience drops of RSSI, hence drops of throughput, when corner reflector was applied. On the other hand, location 9 to 10 were where RSSI were expected to increase, hence the throughput as well. Measurement campaign were conducted during working hours with sporadic moving building occupants.

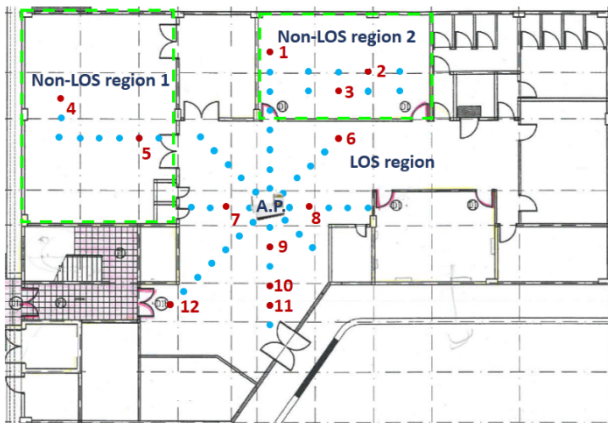


Figure 1. Layout of measurement site for the RSSI and TCP throughput measurement campaigns.

2.2 Equipment and Tools

TP-link TL-WR941HP (IEEE 802.11g) was used as A.P. in the measurement campaign. The TL-WR941HP comes with three external 9 dBi omnidirectional antennas operating at 2.4 GHz frequency band. It is worth noting that for this measurement campaign, only one antenna was fixed to the A.P. in order to easily applied the corner reflector as in Figure 2. Impact of applying all three antennas and suitable corner reflector configuration is not covered in this paper.

The A.P. was configured to transmit at ~ 30mW. To minimize interference from external A.P.s, channel usage analysis was performed and the A.P. was set to operate on the least used channel (channel 6 for the aforementioned environment). The A.P.'s antenna was positioned 2 m from the ground, whereas the laptop used as user equipment (UE) was positioned 1.4 m from the ground.



Figure 2. TL-WR941HP with a 30° corner reflector configuration.

In order to capture the intended data, modern software tools [12] were installed on a laptop that operated as UE. Acrylic WiFi Scanner and Totusoft's LAN Speed Test (LST) software tools were used to record RSSI and TCP downstream throughput respectively. For throughput data, another laptop with installed LST server software tool was used as a server and connected via RJ45 ethernet cable to the A.P. Tested data packet size was varied with minimum size of 50 KB and maximum size of 100KB.

2.3 Corner Reflector Design

A corner reflector was developed using heavy-duty aluminum film on a hard board. Aluminum film was selected based on its easily shaped nature, inexpensive, and ability to strongly reflect signal wave as demonstrated in [10]. It has been experimentally observed that a number of rule of thumbs can be used as a guideline when designing an optimized corner reflector antenna. The corner reflector's aperture is commonly made between one and two wavelengths ($\lambda < D_L < 2\lambda$) of the operating frequency. The length of feed to vertex, S , is usually made to be $\lambda/3 < S < 2\lambda/3$. The height of the reflector is usually taken to be 1.2 to 1.5 times greater than the total length of the feed element in order to mitigate radiation to the rear region.

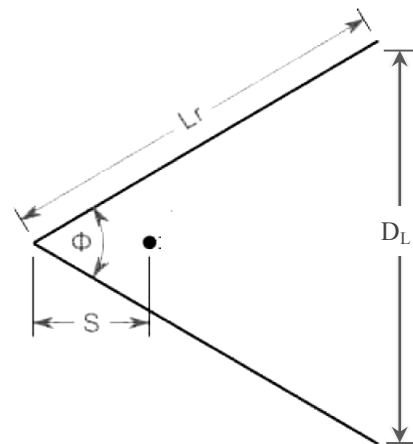


Figure 3. Corner reflector dimension specifications [13].

The angle of the reflector, θ , is commonly made to be $\theta = \pi/n$ with n being an integer for proper computation of expected radiation field strength. In most applications, the angle chosen for corner reflector is 90° . Smaller angle reflectors may exhibit better directional characteristics, with consideration of suitable fitting of the feeding element [13]. For this corner reflector dimensions, works in [14] was referred for suitable reflector design as presented in Table 1. The corner reflector's opening angle, θ , was varied to be 90° and 30° . The corner reflector height was set to be 1.2 times the antenna's length as per the reference, which is $\sim 40\text{cm}$. The A.P.'s omnidirectional antenna functions as the feed to the reflector.

Table 1. Corner reflector parameter [13]

No.	Parameter	Value
1.	Operating frequency	2.4 GHz
2.	Feed to Vertex Distance (S)	0.67λ
3.	Angle (θ)	90° and 30°
4.	Length (Lr)	0.75λ

3. RESULTS AND DISCUSSIONS

Figure 4 presents the recorded RSSI for the two measurement campaigns carried out. The figures show that both measurement campaigns recorded rather similar RSSI trends against separation distance between A.P. and UE.

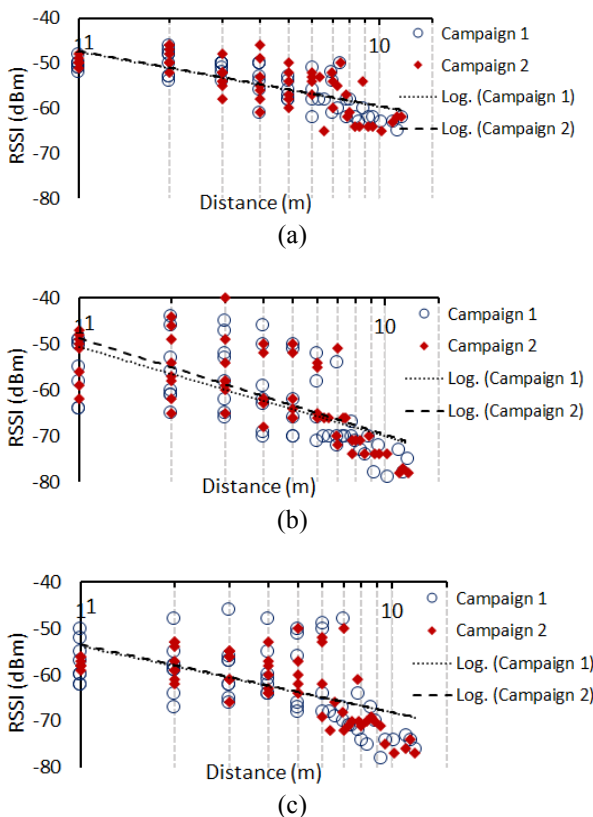


Figure 4. Recorded RSSI at all 60 measurement points for A.P. (a) Without corner reflector (b) With 90° corner reflector and (c) With 30° corner reflector.

Standard deviation of recorded data between the two campaigns were 2.3 dB, 1.8 dB and 2.5 dB for A.P. without reflector, with 90° and 30° reflector respectively. Some observations from fig.4 include; variation of RSSI values at a specific distance becomes greater with the application of corner reflector given that several of the locations experience increase in RSSI while at other locations of similar distance experience decrease in RSSI.

Figure 5. presents the coverage of A.P. based on plotted average RSSI recorded from the two measurement campaign, at each investigated setting. Generally, the application of corner reflector was shown to clearly reduce and improve RSSI at the back and front regions of the corner reflector.

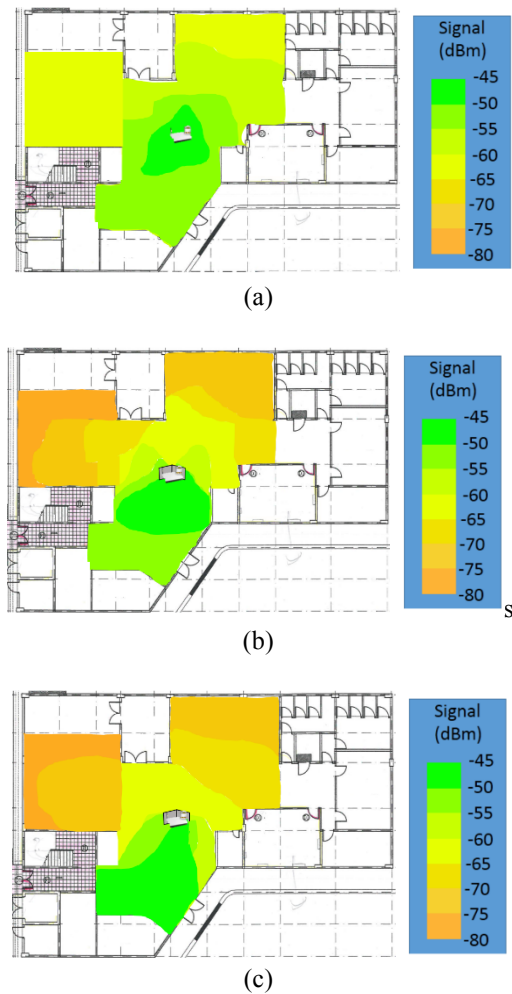


Figure 5. Indoor coverage for A.P. (a) Without corner reflector (b) With 90° corner reflector and (c) With 30° corner reflector.

With the design of corner reflector used, the 30° corner reflector configuration was shown to have reduced backlobes, narrower beamwidth plus greater gain when compared to the 90° corner reflector. Figure 6 presents the SNR at the 12 selected points where throughput data was recorded. Conforming to findings in [10], signal strengthening demonstrated smaller change (up to 6 dB) when compared to signal weakening (up to 19 dB) with the application of corner reflector investigated.

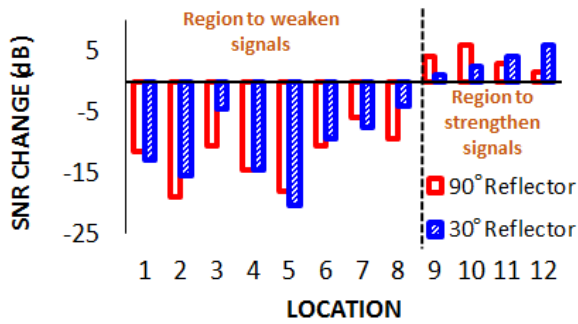


Figure 6. SNR change with corner reflector at the A.P.

Figure 7 (a) and (b) present average TCP downstream throughput change when corner reflector is applied at the 12 selected points in Mb/s and corresponding percentage change. An increase or decrease in SNR correspond directly to an increase or decrease in throughput at all settings except for location 12 with 90° corner reflector, where a drop of 0.1 Mbps was recorded, thus showing the dynamic involve in throughput evaluation in this investigation. Average throughput improvement for region with signals strengthened was about 18 % and 22% for the 90° and 30° reflector respectively. On the other hand, the average throughput drop for region with weakened signals are 69 % and 86% for the 90° and 30° reflector respectively. It should be noted, that several of the locations with weakened signals recorded throughput decrement of 100% from when no reflector was applied.

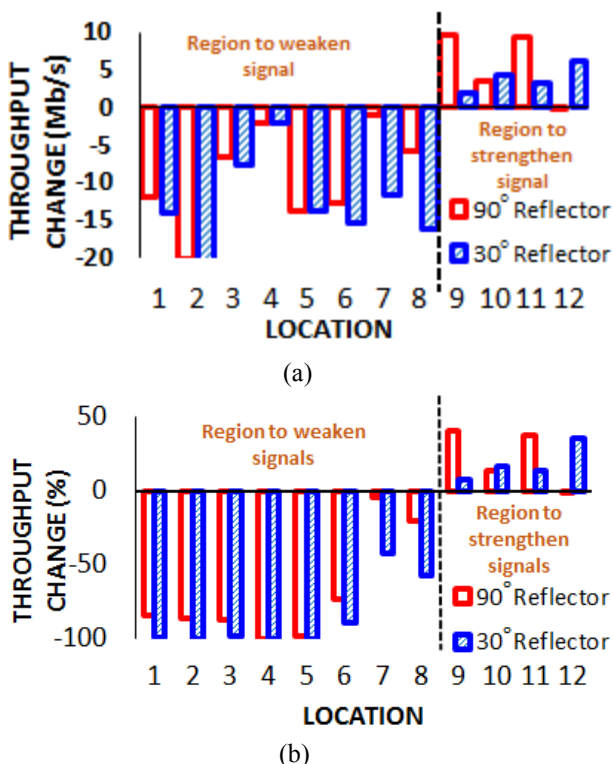


Figure 7. Throughput change with corner reflector at the A.P. in (a) Mb/s and (b) percentage.

4. CONCLUSION

This paper has presented empirical investigation of coverage and throughput evaluation for two corner reflector configurations. The findings demonstrate that corner reflector aperture may also influence performance

of A.P. The percentage throughput change was in fact better than the complex design presented in [10]. Changes in corner reflector aperture, and orientation could be easily applied to A.P. in order to customize coverage, hence SNR plus throughput for the A.P. in operation.

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