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Impact of Beamforming on the Average Throughput of 802.11ac in Wireless Local Area Network (WLAN)

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Abstract – The increasing density of WLAN access points in most office environments has started to reveal the negative effects and shortcomings of the original IEEE 802.11 standards. As a result of this impact, IEEE WLANs are unable to exploit all their potential. However, intelligent radio resource management (RRM) policies could be applied to minimize the harmful effects of interference and an uneven load distribution. This paper explores ways of understanding the performance issues that are endemic to IEEE 802.11ac, as well as profer ways of minimizing these negative effects by means of radio resource management. In this research, experiments were carried out to determine the impact of beamforming on the average throughput of IEEE 802.11ac in an office environment. Results showed that beamforming provides significant gain in average throughput of IEEE 802.11ac at distances close to the router.

Keywords – 802.11ac, beamforming, MIMO.

I. INTRODUCTION

The demand for high-speed communication network has been growing exponentially in the last decade and it is expected to continue growing even more in the future. The growth will be driven by unlimited possibilities in internet services and multimedia applications fueled by advances in the handheld and portable equipment. According to the study by Cisco, the traffic carried over mobile wireless networks will observe a 7x gt by 2021 [1]. To meet with current and future demands for reliable high data rates over the mobile networks, Institute of Electrical and Electronic Engineering (IEEE) 802.11 family was created from group of telecommunication association (Wi-Fi Alliance) to set a definition and standards for the future Generation mobile system. Wi-Fi was first released to consumers in 1997, the Institute of Electrical and Electronics Engineers (IEEE) created their first WLAN standard and called it 802.11 after the name of the group formed to oversee its development. Unfortunately, 802.11 only supported a maximum network speed of 2Mbps which was too slow for most applications. For this reason, ordinary 802.11 wireless products are no longer manufactured, this led to the introduction of 802.11b/a/g/n/ac/ax; increasing data rates from megabits per second (Mbps) to the upcoming gigabytes per second (Gbps), which was achieved by the cable technology [2]. The IEEE 802.11ac standard defines mechanisms and techniques for dramatically enhancing the speed and capacity that a Wi-Fi Access Point (AP) can deliver. Compared with the previous generation Wi-Fi, IEEE 802.11b/a/g/n, the 802.11ac standard contains several mechanisms to help ensure more efficient use of added capacity and support the growing number of fixed and mobile clients found in modern households and business environments. In this paper, we carried out experiment to determine the impact of beamforming on the average throughput of 802.11ac. In section II, we briefly discuss related work.in section III we describe our testbed network and in section IV, a discussion of our findings is presented. The last section is the conclusion and future work.

Related work researches and conference papers have been published on IEEE802.11ac standard since its adoption in 2013. According to Sur et al[3] worked on Practical MU-MIMO user selection on 802.11ac commodity networks. They designed MUSE which is a MU-MIMO-based rate selection scheme for IEEE 802.11ac commodity networks. This mechanism uses compressed beamforming feedback from IEEE 802.11ac users and identifies MU-MIMO groups providing the best throughput. MUSE also adjusts channel bandwidth and increases MUMIMO grouping opportunities. In this work, the evaluation shows that TCP and UDP throughputs are gained significantly over competing schemes mentioned in the work.

This is due to the use of MU-MIMO and channel bonding jointly on the basis of beamforming feedback. Swetank et al [4] worked on Power-throughput tradeoffs of 802.11n/ac in smart phones. They presented an experimental study of IEEE 802.11n/ac power consumption. The impact of different features of IEEE 802.11n/ac (MIMO, frame aggregation, channel bonding etc.) were analyzed by considering both power consumption and throughput Narayan et al. [5] also evaluated the performance differences between IEEE 802.11n and IEEE 802.11ac. They experimented for both IPv4 and IPv6. They implemented the 802.11ac network on two computers running the Windows operating system. The laptops were assigned static IP addresses and were connected wirelessly. They kept a distance of one to two meters between the stations and the access point to maintain the best signal strength. Their initial experiment evaluated the throughput metric of various application protocols such as UDP, TCP, DNS, VoIP, and Telnet traffic. Secondly, they evaluated the performance measure of the jitter of UDP, TCP, DNS, VoIP, and Telnet traffic. Also, they evaluated the delay metric for all protocols and network traffics. Lastly, they evaluated for the UDP drop rate. They concluded after evaluations that 802.11ac outperforms 802.11n for both ipv4 and ipv6. Also, the lower jitter values were measured on the ipv6 against the ivp4. The delay and drop rate metrics had also been measured and observed to be higher for the 802.11ac. Ravindranath et al[6]. in their work [16] evaluated the superior performance of the new IEEE 802.11ac standard concerning 802.11n. They used ns-3, an open source network simulator, version (ns-3.24.1), which is appended with features to support 802.11ac. The simulation outcome shows that the new 802.11ac standard outperforms the legacy 802.11n. 802.11ac features such as channel bonding, guard interval, and MCS were analysed. The performance measures such as jitter, throughput, and delay were used for evaluation.

Jonsson et al. [7] implement the features in ns-3 to simulate and evaluate the IEEE 802.11ac standard by making changes in the existing PHY model to support wider channel bandwidth. They performed all nine-modulation coding set (MCS 0–9) values in 802.11ac and support for bit error rate calculations for higher modulations. Several simulations were run and evaluated, with the enterprise scenario as their case of interest. However, other key features of the standard such as MIMO and MU-MIMO for 802.11n and 802.11ac and also beamforming for 802.11n and 802.11ac were not implemented and evaluated.

Empirical measurements of an 802.11ac system based on the beam forming technology were carried out by Juliet O. and Stuart W[8]. They conducted an empirical analysis to determine the effectiveness of Beamforming Technology as depicts in the quality of service (QoS) enhancement in the newest wireless technology deployed on IEEE802.11ac standard. The experimental outcomes revealed the quality of service (QoS) enhancement in IEEE802.11ac. Although the realized throughput in real application scenario fell below designed specification. Nevertheless there is a considerable data throughput improvement on the counterpart 802.11n. There remain opportunities for further enhancements in beam-forming technology. It is however important to still update research on wireless network performance

II. DESCRIPTION OF THE TEST-BED

Test-bed method was used to evaluate the the performance of IEEE 802.11ac WLAN. The experiment was conducted in the university of Nigeria Nsukka Data center located at the basement of Namdi Azikiwe University Library. The test-bed comprises of two PCs one serving as the server with intel core I7 quad core 760, 1.8 TGByte and the other serving as the client with intel core I5, 24Gbyte ram. Pfsense software was installed on the GLOROUTER where the measurement will be conducted. For the purpose of this experiment, ntopng application package was installed on the Pfsense which serves as the sever. The client have to enter a user name and password in other to gain access to the ntopng. While conducting the experiment, a huge amount of data was recorded in files and the data records the applications, L4 proto, client/server, duration, actual throughput, and packets in byte. Using wireshark an open source packet analyzer, the measured values were downloaded and saved in kml file format from the personnel computer and later extracted to Excel.xml.

Router Specification:

NAME	GLOROUTER
User	Admin (local database)pfsense
System Netgate Device ID	383feIe76fde7b8e53If
BIOS	Vendor. Hp Version: D22 Release Date: sun Jan 30, 2011. Version
Version	2.4.4 RELEASE- P3 (amd 64 built on wed may 15, 18:53:44EDT 2019 free BSD11.2. RELEASED- P10 the system is on the latest version version information updated on thurs Feb 27 8.06.03 WAT 2020
CPU Type	Intel ® Xeon ® CPU X5650 @2.67GHz 24CPUs. 2package(s) x 6cores x 2 hardware threads AES NI CPU Crypto: Yes (active)
RAM	1.8 TGByte
Temp	8.4 C

Sever client Experimental Testbed

2.1 Network Environment

This environment consist of several buildings used as offices, classrooms and laboratories. WLANs are deployed in these buildings, Staff and students are major users of this network. For these experiment, we consider only indoor network environment using staff browsing room at the ground floor of the Access ICT building. A wireless Radio named BACHAUL_NGREN with b/g/n/ac standard uses frequency 2.4GHZ in IEEE 802.11 b/g/n and 5GHZ in IEEE 802.11n/ac is used as the Access point. The staff usually use personal computers, smart phones to access the internet at a fixed position where chairs and tables are available. As result, the mobility of WLAN users is much lower than that of the cellular system users

2.2 Experimental Measurement and Data Collection

For this research, two wireless Access Points (APs) (Linksys WRT 3200AC and Linksys WRT 1200AC) were used.

The WRT 1200AC supports 2x2 MIMO while WRT 3200 AC supports Multi User - Multiple Input Multiple Output (MU-MIMO).

TP-Link Dual Band AC1750 and NETGEAR AC1750 adapters were used to allow the laptops to access IEEE 802.11ac and IEEE 802.11n (5GHz) networks respectively.

However, the TP-Link Dual Band AC1750 does not support beam forming, while NETGEAR AC1750 supports beam forming technology

In order to characterize the path loss in a real scenario, different measurements were carried out during the development of the work

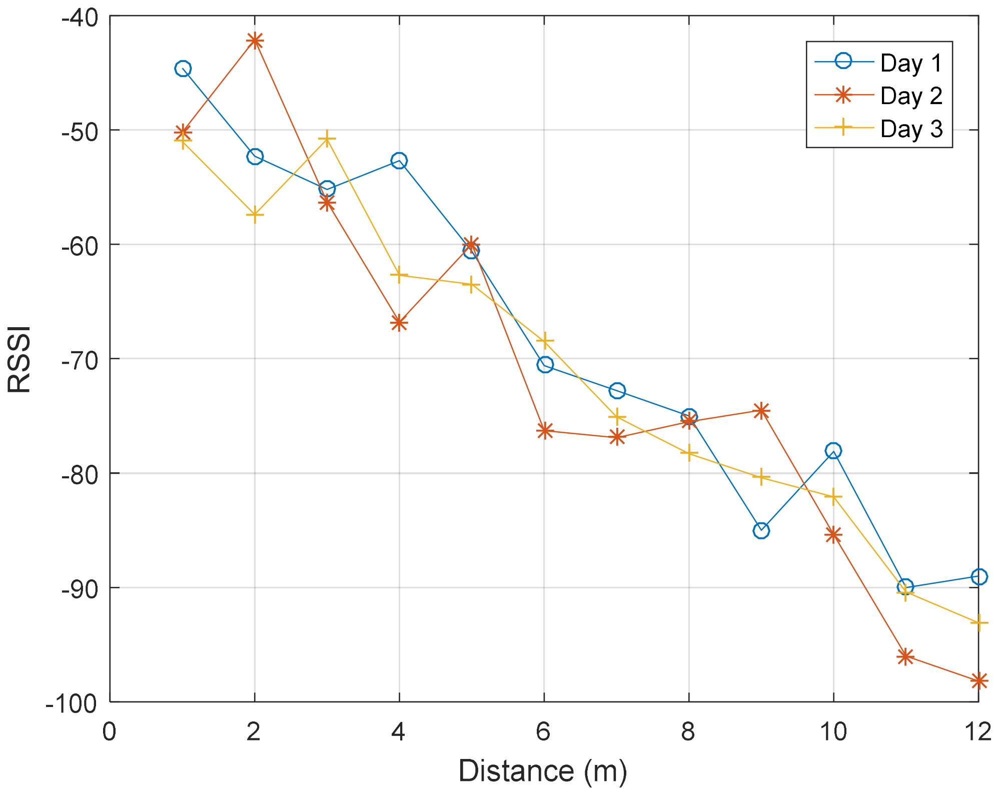


Figure 3.1 RSSI plot for three different days

The average path loss for an arbitrary transmitter to receiver separation is expressed as a function of distance as Smith,

$$L_p(dB) = L_p(d_0) + 10\eta Log(\frac{d}{d_0}) \quad (3.1)$$

Where: $L_p(d_0)$ is the estimated path loss at reference distance d_0, η is the path loss exponent and 'd' is the distance between the transmitter and receiver. The path loss exponent η, is obtained from measured data by applying the method of linear regression analysis, such that the sum of squared errors gives:

$$e(\eta) = \sum_{i=1}^{m}(L_p(d_i) - L_p(d_o))^2 \quad (3.2)$$

The value of η which minimizes mean square error can be obtained by equating the derivative of $e(\eta)$ to zero and making η subject of formular, thus:

$$\eta = \frac{\sum_{i=1}^{m}(L_p(d_i) - L_p(d_o))}{\sum_{i=1}^{m}(10\log_{10}(\frac{d_i}{d_o}))} \quad (3.3)$$

To compensate for shadowing effect from walls, the path loss beyond the reference distance can be written as:

$$L_p(dB) = L_p(d_0) + 10\eta Log(\frac{d}{d_0}) + Z_\sigma \quad (3.4)$$

Where, Z_σ is the shadowing factor and also a Gaussian random variable (with values in dB) and modeled as log normal with zero mean and standard deviation σ (also in dB)

The model for the propagation environment is:

$$L_p(dB) = 78.26 + 35.6\ Log(\frac{d}{d_0}) \quad (3.5)$$

The free space path loss model for the environment is given as:

$$P_L(dB) = 100 + 20Logd_i \quad (3.7)$$

The ITU-RP.1238 model is given as

$$L(dB) = 53.6 + 30log(d) \quad (3.10)$$

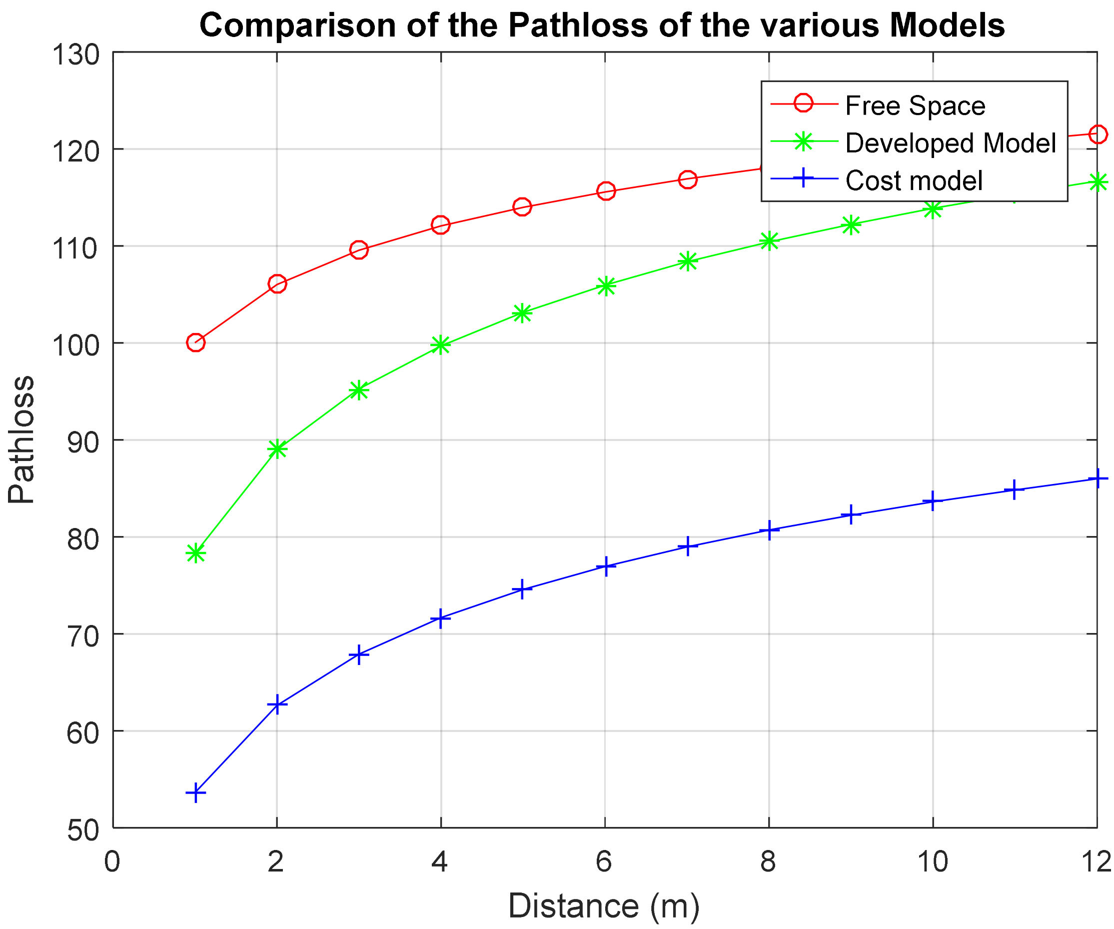


Figure 3.3 Comparison of the models

III. Result And Discussion

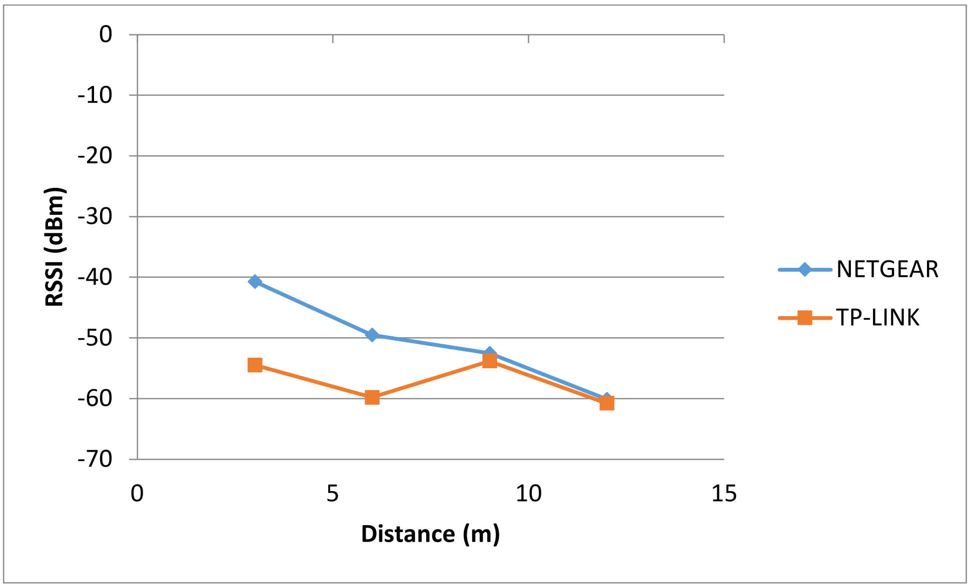
The simulated scenario consists of a 200 x 150 m^2 area with 2 APs and a varying number of randomly placed client stations.

Using an indoor propagation model with all stations (APs and STAs) transmitting 15 dBm with omni-directional antennas, the transmission range varies from 15 to 20 m due to the randomness introduced by the propagation model.

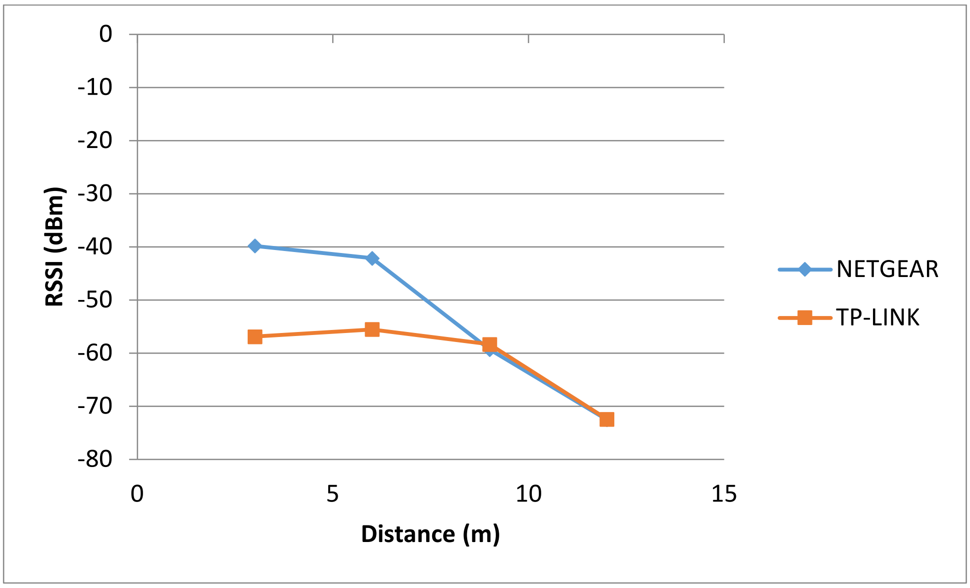
The Throughput and RSSI were measured for 3 different days and twelve times for each location

To verify the impact of beamforming on the average throughput of IEEE 802.11ac. The RSSI at all the positions indicated on the experimental test bed was measured.

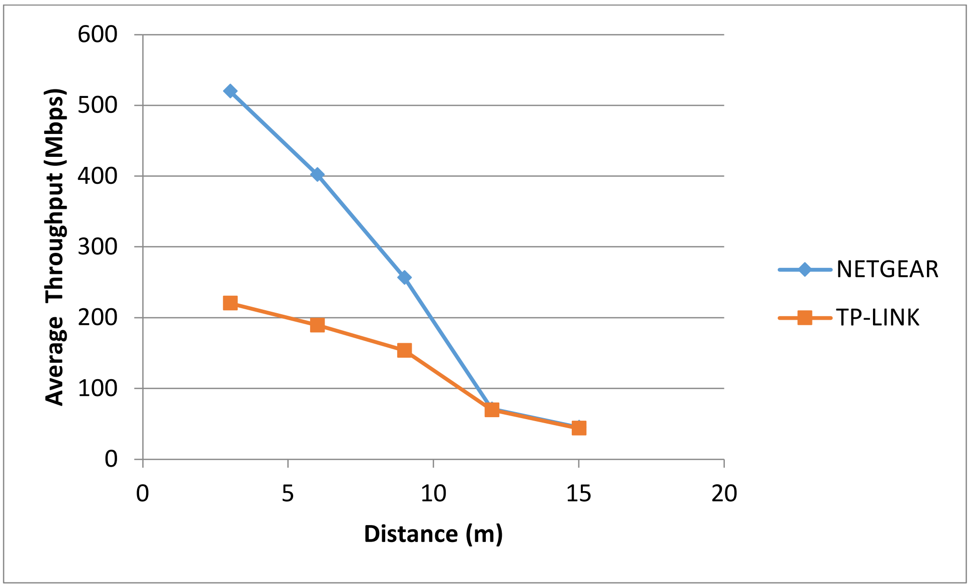
The measurements were carried out using both the TP-Link Dual Band AC1750 and NETGEAR AC1750



RSSI plot comparing the performance of NETGEAR and TP-Link



RSSI plot comparing the performance of NETGEAR and TP-Link



Plot of Average Throughput provided by Netgear and TP-Link Adapters

IV. CONCLUSION

This paper focused on the usage of IEEE 802.11ac by the home users and the impact of beamforming on the average throughput of IEEE 802.11ac. The results show that the beamforming technology is beneficial to only office users that are close to the router. However, beamforming does not provide any significant gain in average throughput at large distances (more than 12m in our test bed).

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