Comparative analysis of 802.11b&g WLAN systems based on Throughput metric

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Abstract - *This paper Examines the maximum data throughput performance of a wireless network 802.11b&g Using iperf for sending UDP data streams across each network thereby computing the experimental and theoretical parameters such as Throughput values, data loss and round trip time. The results were displayed in Graphical formats for comparative analysis which showed that theoretical throughput is higher than the experimental throughput in both 802.11 b&g. And that 802.11g has comparatively greater throughput metric than 802.11b*

Key Words: Throughput, payload, 802.11, WLAN,

1. INTRODUCTION

Wireless networking is considered to be an accepted complementary to the Ethernet wired Networking [1]. It involves wireless equipment for transmission of data and for effective communication. Its importance led to the fact that most current mobile and portable devices are currently empowered with wireless fidelity(Wi-Fi) capabilities , allowing end users to connect to access points in proximity for internet access or to setup Ad-hoc Networks for file sharing etc due to its low cost , easy setup and deployment.[2]

Wireless Networks are made by configuring Wireless access points. There 802.11 x standards which guide the description of Wi-Fi and are 802.11a, 802.111b, 802.11g and 802.11n. 802.11a has a typical data rate of 25Mbpsand reach 54Mbps with 100 as indoor range with operating frequency of 5GHz. 802.11 b has a typical data rate of 6.5Mbps that can extends to 11Mbsps with the same 100 feet of indoor range but with 2.4GHz operating frequency.802.11g, on the other hand, has a data rate of 25Mbps, peak rate of 54Mbps and indoor range of 100 feet having operating frequency of 2.4GHz. Note that 802.11b&g are mostly compatible with most wireless/router cards referred these standard as b/g or 802.11b/g. Furthermore, 802.11n has a typical data rate of 200Mbps that extends to 540Mbps with 160 feet indoor range operating at either 2.4GHz or 5GHz. Finally, Overhead has been described as the fundamental problem of Medium Access Control (MAC) inefficiency [3]

As more and more daily activities are carried out via Internet-based services and systems, modern civilization is becoming increasingly reliant on powerful and efficient communication networks. [3]. The IEEE produced the 802.11 series of specifications for wireless LAN technology. In 1997, IEEE approved the 802.11 specification. Due to the ease of installation and the growing popularity of laptop computers, wireless local area networks (WLAN) have become popular in the home. WLAN stands for Wireless Fidelity and is based on the IEEE 802.11 standard. The 802.11 working group's tasks have only generated a few extensions to the original specifications. These extensions' products are named by the task group and the original standard; for example, 802.11b is a task group b extension. 802.11b, 802.11a, 802.11g, and 802.11n are the most widely used 802.11 extensions [5]

IEEE 802.11b is an 802.11 extension that uses just DSSS and can transmit up to 11 Mbps (with a fall back of 5.5, 2, and 1 Mbps) in the 2.4GHz range. IEEE 802.11b is also known as wireless fidelity (WiFi) or 802.11 high rate.). The 802.11g standard uses the 2.4GHz band and can deliver speeds of up to 54 Mbps (with a fall back to 48, 36, 24, 18, 11, 5.5, 2, and 1 Mbps). The 802.11g varies from the 802.11b in that it can employ OFDM (the 802.11g draft demands the use of OFDM for rates greater than 20 Mbps). [4]

The IEEE 802.11 family is the most widely used standard that has numerous extensions while others are underway. IEEE 802.11 standards, which were first presented in 1999, were largely developed with the home and office context in mind for wireless local area connectivity. With the implementation of IEEE 802.11b [2], the maximum data rate per AP rose from 2Mbps to 11Mbps. Newer IEEE 802.11g and IEEE 802.11a extensions provided a maximum data rate of 54Mbps per AP using a variety of approaches to raise the maximum data rates [3-5]. Currently, WLAN equipment based on IEEE 802.11g support data rates of 100-125 Mbps [6]

Network steganography is now recognized as a new danger to network security that can be utilized for a variety of purposes, including data exfiltration and network attacks. The IEEE 802.11 standards did not regard wireless local area networks (WLANs) as a serious area for data concealing, owing to their restricted range (the range for 802.11a/b/g is 30m indoors and 100m outdoors)., the range of 802.11n is increased). IEEE 802.11 was, nevertheless, used to communicate secret data among Russian agents apprehended in the United States in June 2010 [1]. WLAN is also one of the various means of communication among soldiers on the battlefield from a military standpoint. [7]

802.11b

In July 1999, IEEE added the 802.11b specification to the original 802.11 standard. 802.11b allows for a bandwidth of up to 2.4 GHz.11 Mbps, comparable to traditional Ethernet. The original 802.11 standard uses the same uncontrolled radio signaling frequency (2.4 GHz) as 802.11b. Vendors frequently want to use these frequencies in order to reduce their production costs. Because 802.11b equipment is unregulated, it may cause interference with microwave ovens, cordless phones, and other 2.4 GHz-based gadgets. However, by placing 802.11b equipment at a safe distance from other machines, interference can easily be evaded. [8]

802.11g

WLAN solutions supporting a newer standard known as 802.11g first appeared on the market in 2002 and 2003. 802.11g tries to integrate the greatest features of 802.11a and 802.11b. 802.11g provides up to 54 Mbps of bandwidth and uses the 2.4 GHz frequency for increased range. Backward compatibility between 802.11g and 802.11b means that 802.11g access points will function with 802.11b wireless network adapters and vice versa. [9]

2.0 THEORITICAL THROUGHPUT DEVELOPMENT

2.1 PREAMBLE

Throughput of a Communication protocol can be defined as the number of information bits transmitted per transmission cycle (in bps).

Hence it can mathematically be simplified as;

$$\text{Throughput (Mb/s)} = \frac{\text{Amount of data (bits)}}{\text{Transmission Time } (\mu S)} \quad (1)$$

The iperf tool sends UDP data packets of 1470bytes (application data) by default.

Carrier Sense Multiple Access /Collision Avoidance (CSMA/CD) is a scheme defined by Distribution Coordination Function (DCF) where each mobile node has a fair chance to access the wireless medium in 802.11MAC. Short Inter-Frame Spacing (SIFS) is used in 802.11 to transmit high priority frames just like Request-to-Send (RTS) , Clear-To-Send (CTS) as well as Acknowledgement(ACK)[8]

Distributed coordinator Function Inter Frame Space (DIFS) this normally differentiates between two transmissions. The time associated with DIFS is given according to (Michele-Segata et al, 2009) as;

$$T_{DIFS} = T_{SIFS} + 2 + T_{SLOT} = 10\mu S + 2 * 20Ms = 50\mu S. \quad (2)$$

Slot time is Contention Window (CW) size is defined as the multiple of time slot and plays major role during back-off Procedure which has to be executed by each mobile node before transmission [9]

Transmission Control protocol (TCP) is an Example of responsive protocol providing responsive traffic while User datagram Protocol (UDP) is an Example of non-responsive protocol providing non-responsive Traffic [10]

More than 9.5 billion devices, which are IEEE 802.11 compliant are pervasive with United States alone having about fifty million Wi-Fi networks extensive IEEE 802.11 infrastructure devices. Internet of Things (IoT) challenges can be addressed by IEEE802.11 even though it comes with high consumption of power such that it has to powered via batteries or harvesting the power which was later solved through the introduction of power saving mode(PSM) that's hibernate the radio most of the time with the purpose of energy reduction. In order not to lose frames during hibernation period, the access point (AP) in the network stores those frames that were directed to the sleeping station (STA) which can be utilized during wake up process. [11]

Marcov chain is a mathematical model which is one of the most popular techniques that analyses the performance of IEEE802.11 Distributed Coordination Factor (DCF). Markov chain is normally classified in to three dimension as 1-Dimension, 2-dimension and 3-dimension that summarizes their characteristics. The idea is to choose the appropriate dimension in relation to complexity of the desired MAC protocol with respect to communication scenarios. Wireless LAN and Media and Access layers normally get their detailed specification from IEEE 802.11 Standard which directs the scheduling processes efficiently via two techniques named; DCF and PCF (point coordination factor.)[12]

The first release of IEEE 802.11 Standard was in June 1997 by the IEEE/MAN committee and subsequently upgraded to draw near the advances in communication technologies. The protocols started by 11a, 11b , 11g then upgraded 11n before coming up with 11ac. 11n provides improved features over the a, b & c while 11ac is better than 11n [13]

The IEEE802.11b, otherwise known as High rate (Wi-Fi), offers 11Mbps transmissions in the 2.4GHz band. Throughput is the average rate of victorious message release over a channel of communication. In 1999 approval release of the IEEE802.11b standard facilitated the frame fragmentation which is the procedure that allows 802.11 frames to be partitioned into lesser fragments to spread individually to the target destination where the frame reassembly takes place at the MAC layer. [14]

Transmission control protocol (TCP) accounts for over 80% of whole internet traffic. To understand the WLAN systems capability to utilize TCP in accessing the internet, it quite necessary to forecast TCPs throughput. (Aziz, O.A., etal 2020). Maximum throughput can be passed across a passageway which is known as bandwidth capacity, Available bandwidth is the amount of unused capacity at the same passageway. [15]

Even though it is not new technology per say, IEE802.11b WLAN system remains the top commonly used technology that equally offers the widest range in the wireless equipment deployment. Where IEEE802.11b is used in a network alongside other technologies, especially when the covered distance is favored over high throughput or bandwidth, IEEE802.11b is normally preferred over newer technologies because they are forced to make use of lower data speeds. [16]

2.2 COMPUTING THE THEORITICAL LIMITS

For 802.11b

The maximum throughput can be achieved under best case scenario by setting up an error free channel which is ideal for experimentation. There has to be only one active station for sending and accepting packets to another station which must acknowledge receipt. It also worth noting that maximum throughput should be higher than an ordinary throughput whereas Minimum delay should be lower than an ordinary delay.

$$MT = \frac{8L_{DATA}}{T_{D\_DATA}+T_{D\_ACK}+2\tau + T_{DIFS}+T_{SIFS}+CW} \quad (3)$$

Maximum delay in equation (3) is a function of payload size in bytes multiplied by eight, the result of which to be all be divided by a summation of transmission time for the payload (T_{D_DATA}), acknowledgement transmission time (T_{D_ACK}), twice the propagation delay (2τ) and SIFS time (T_{SIFS})as well as contention window (CW).

$$T_{D\_DATA} = T_P + T_{PHY} + \frac{8L_{H\_DATA} + 8L_{DATA}}{100000R_{DATA}} \quad (4)$$

Transmission time for the payload (T_{D_DATA}) in (3) can further be highlighted as a summation of transmission time of physical preamble (T_P) added to the transmission time of the PHY header (T_{PHY}) which is then summed along with the MAC overhead in bytes (L_{H_DATA}) plus payload size in bytes (L_{DATA}) and the summation to be divided by data rate (R_{DATA}) resulting to the formation of equation (4).

The other aspect of maximum throughput (MT) equation is the Acknowledgement transmission time (T_{D_ACK}) in (4) which is the result of the acknowledgement size in bytes (L_{ACK}) by the 100,000th value of control rate (R_{ACK}) to be added with the summation of T_P and T_{PHY}. This is how (5) was formed.

$$T_{D\_ACK} = TP + T_{PHY} + \frac{8L_{ACK}}{100000R_{ACK}} \quad (5)$$

The generalized formula can be simplified as shown below;

$$T = \frac{8P_{size}}{756 + 8 * \frac{(42 + Psize)}{11}} \quad (6)$$

From the above we can form the table for payload against Throughput

For 802.11g

The following notations were used:

T: Throughput, P_{size}: Payload size, DIFS: Distributed coordinator Function Inter Frame Space, PHY: Physical layer header, FCS: Fluorescence Correlation Spectroscopy, TAIL: Tail bits, PAD: Pad bits, ACK: Acknowledgement and MAC: Medium Access Control.
The throughput is given from the generalized formula given in equation (7) below, which presents throughput as the function of Payload size in respect of the summation of parameters including: T_{DIFS}, $T_{BACKOFF}$, T_{PHY}, $T_{SERVICE}$, T_{FCS}, T_{TAIL}, T_{PAD}, T_{ACK} and T_{MAC}.

$$T = \frac{P_{size}}{T_{DIFF}+T_{BACKOFF}+T_{PHY}+T_{SERVICE}+T_{FCS}+T_{TAIL}+T_{PAD}+T_{ACK}+T_{MAC}} \quad (7)$$

Substituting for the theoretical values from the paper and varying my packet size values from my experiment leads to (8);

NOTE

(T_{DIFF}=28µS, $T_{BACKOFF}$=138.5µS, T_{PHY} =20µS, $T_{service}$=0.3µS, T_{FCS}=0.59µS T_{TAIL}=0.11µS, T_{PAD}=0.33µS, T_{ACK} = 30µS, T_{MAC}= 3.56µS)

$$T = \frac{P_{size}}{28\mu S+138.5\mu S+20\mu S+0.3\mu S+0.59\mu S+0.11\mu S+0.33\mu S+30\mu S+3.56\mu S} \quad (8)$$

The formula can further be generalized as shown in (9) below;

$$T = \frac{8P_{SIZE}}{231.39 + \frac{8P_{SIZE}}{54}} \quad (9)$$

3.0 METHODOLOGY

3.1 EXPERIMENTAL EQUIPMENT

3.11: HARDAWRE

2No. Computer Laptop: The Computer laptop with a running Windows Operating System (OS) was used. It was a HP Elite book E50 G2, 2.60GB processor and 64-bit Operating system. We also used another laptop to run the iperf generation software tool. It was a MacBook Pro, Intel i5, 4G RAM, IOS.

1No. Access Point: (Linksys WRT10N Wireless router): The Access point (AP) was used for connecting the two laptops (server and client).

3.12 SOFTWARE

Iperf traffic generation software:

Iperf3 is a tool for actively measuring the maximum bandwidth achievable on IP networks. It allows you to fine-tune a variety of timing, buffer, and protocol options (TCP, UDP, SCTP with IPv4 and IPv6). It reports the bandwidth, loss, and other parameters for each test. This is a brand-new implementation with no code in common with the original iPerf, and it is also not backwards compatible.

Spectrum Analyzer (Chanalyser 4):

Chanalyser 4 is a software program by MetaGeek that gather data from two sources. The wireless adapter from a computer and the spectrum analysis from the Wi-Spy work together in order to give comprehensive look at our wireless environment.

3.2 EXPERIMENTAL METHODS

The experiment was carried out using two laptops and Linksys WRT10N Access Point set at a frequency of 2.4GHz at channel 6. A laptop was used as server using DHCP server for automatically assigning IP address to the Laptops in connection to the Access Point while the other laptop serves as client. We thereby sent out data using iperf traffic generating software which was run on both laptops and also used *chanalyser 4* Spectrum Analyser for monitoring the behaviour of the Network.

Data Packets were sent by running iperf on the two laptops to collect the data for the selected speed. Any packet sent on the iperf based client Laptop will be monitored on the server's laptop running the same iperf while the output results of the seven (7) tested payloads were recorded for analysis. The seven payloads tested in the experiment were 100, 250, 500, 750, 1000, 1250 and 1400 respectively measured in bytes. And the summarised throughputs results are accordingly noted in the table formats for plotting unto graphs.

4.1 RESULTS

The results obtained from our experimental and theoretical work.

Throughput analysis of 802.11b and 802.11g standards is hereby presented in graphs shown hereunder with supplementary snapshots of the outputs generated by the spectrum analyser. The vertical and horizontal axis of the graphs represents throughput in bits per seconds and Payloads in bytes respectively. Discussion on the results is described in the Next section of this technical paper.

Table 1: **802.11 b** Throughput against Payload

Payload (Bytes)	Theoretical Throughput	Experimental Throughput	Differential
100	0.93	0.45	0.48
250	2.07	1.48	0.59
500	3.48	2.48	1.0
750	4.51	3.26	1.25
1000	5.28	3.95	1.33
1250	5.90	4.26	1.64
1400	6.21	4.57	1.64

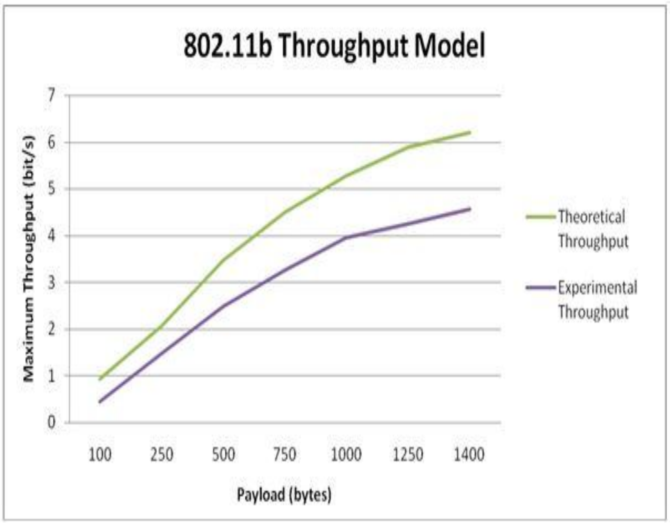

Figure1a: **802.11 b** Throughput against Payload

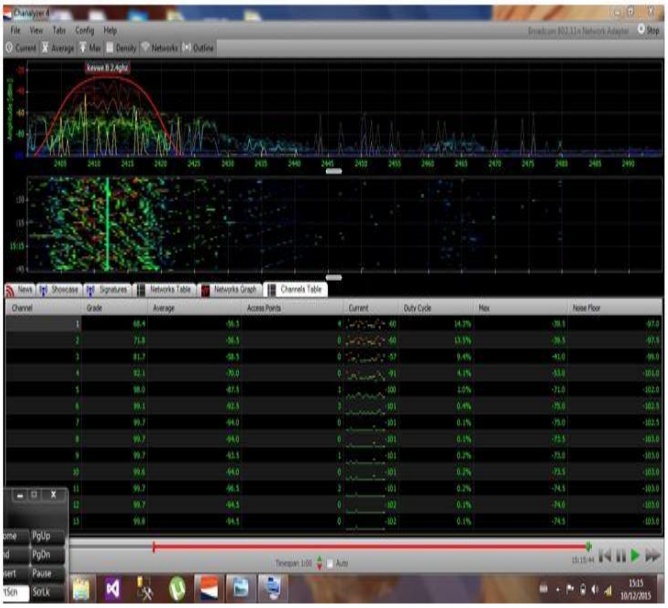

Figure 1b: Chanalyser output for **802.11 b**

Table 2: **802.11g** Throughput against Payload

Payload (Bytes)	Theoretical Throughput	Experimental Throughput	Differential
100	2.28	3.35	-1.07
250	7.45	6.95	0.5
500	13.10	9.79	3.13
750	17.51	13.00	4.51
1000	21.08	15.07	6.01
1250	24.01	20.96	3.05
1400	25.52	23.14	2.38

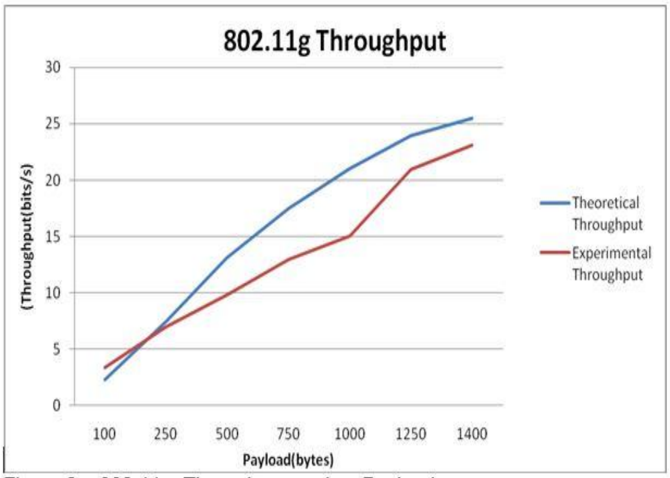

Figure 2a: **802.11 g** Throughput against Payload.

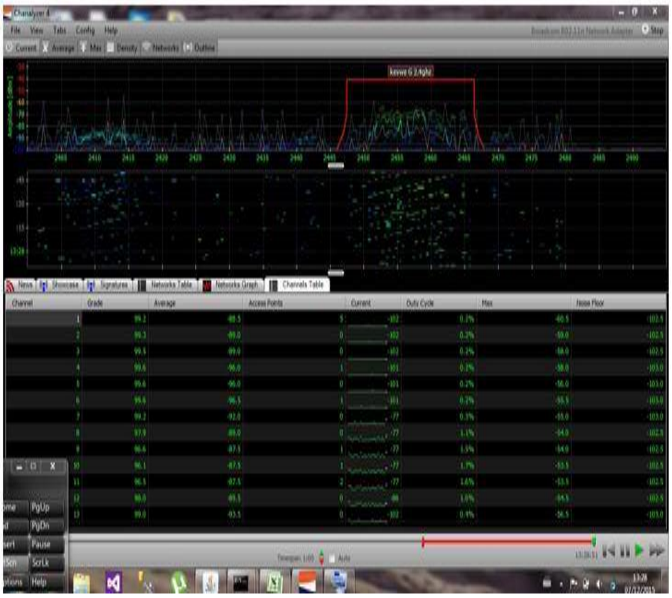

Figure 2b: Chanalyser output for **802.11 g**

Table 3: **802.11b & g** Throughput against Payload

Payload (bytes)	Theoretical Throughput – b	Experimental Throughput - b	Theoretical Throughput - g	Experimental Throughput - g
100	0.93	0.45	2.28	3.35
250	2.07	1.48	7.45	6.95
500	3.48	2.48	13.10	9.79
750	4.51	3.26	17.51	13.00
1000	5.28	3.95	21.08	15.07
1250	5.90	4.26	24.01	20.96
1400	6.21	4.57	25.52	23.14

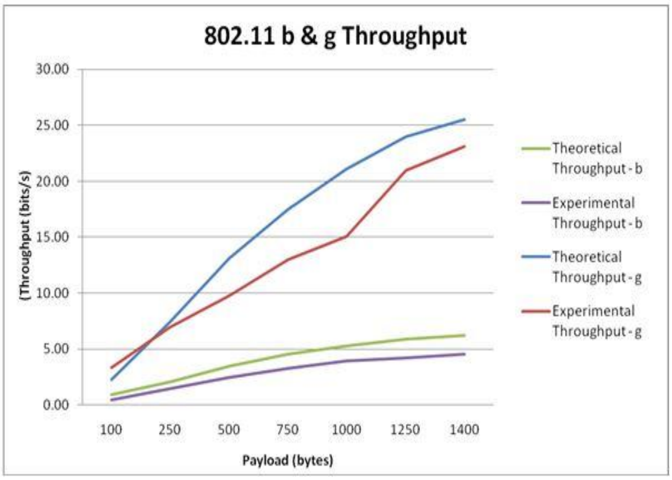

Figure 3: **802.11 b&g** Throughput against Payload.

4.2. DISCUSSION OF RESULTS

After plotting the throughput graphs for both the two standards that are 802.11b and 802.11g, I observed that in the case of 802.11b there exist fairly the same pattern for the theoretical and experimental throughput especially at lower payloads as seen in figure1a. For the 802.11g, both the theoretical and experimental throughput exhibited similar manner but the experimental throughput at 100bytes is higher causing an overlap where there is sudden drop of the experimental value slightly at 1000bytes of payload due to possible interference from the surrounding wireless devices as depicted in **table 2.** Generally 802.11g has higher throughput performance in both theatrical and experimental values compared to 802.11b as shown in Table 3 just as 802.11g traffic is also greater than 802.11b as captured by chanalyser in **Figure1b** and **Figure 2b** respectively.

While **table 1** showed the comparative values of both theoretical and experimental throughput associated with 802.11b, **Table2** showed the comparative values of both theoretical and experimental values of 802.11g. **Figure 1a** showed how theoretical throughput is higher than the experimental throughput in 802.11b whereas in 802.11g, the experimental throughput appeared higher in much lower payload but as soon as the payload started increasing, the experimental throughput maintained the dominance over the experimental throughput as in **Figure 2a**. The broader pictured was shown in **Figure 3** that depicted the general overview, comparing both the 802.11b and 802.11g such that the 802.11g was pictorially shown to be much higher than the 802.11b in both theoretical and experimental scenarios.

5.0 CONCLUSION

The paper presents the calculation of Maximum data Throughput by considering both the theoretical and experimental values of 802.11b and 802.11g Networks thereby graphically showing how 802.11g standard is higher than 802.11b in terms varying payloads. Effects of interference have been considered and all timing and frequency settings for calculating the throughput were accordingly implemented.