

# **Throughput Analysis of IEEE802.11b Wireless LAN System**

**Sheikh Md. Rabiul Islam**

*Department of Electronics & Communication Engineering  
Khulna University of Engineering & Technology, Khulna , Bangladesh.*

## **Abstract**

Wireless Local Area Networks (WLAN) has proliferated in the last few years. This was possible due to the low cost of the Access points (AP) and PC cards and also due to the ease of installation of the network. However utilizing the capabilities of the system in providing a better service to the end user has been a huge concern. Improper network planning, security concerns, higher bandwidth requirements are some of the areas that are being worked on in both the academia and the industry. The goal of this work is to show the Access point configuration and performance analysis of 802.11b using NCB Access Point (AP) in laboratory. Using wireless Access Point (AP) connecting with Server, used WLAN facilities with satisfactory performance. The performance analysis of data transmission with UDP protocol and use *Iperf* for the analysis in the Linux operating system. This paper concern how does the set-up of the AP, server and the clients and to simulate over the client to access point and compare the theoretical throughput and practical throughput of IEEE802.11b from the simulation result.

**Keywords:** WLAN, AP, NCB, Iperf, IEEE802.11.

## **1. INTRODUCTION**

IEEE 802.11 is a set of standards for wireless local area network (WLAN) computer communication, developed by the IEEE LAN/MAN Standards Committee (IEEE 802) in the 5 GHz and 2.4 GHz public spectrum bands. It actually defines the two lowermost layers, which are Medium Access, and Physical Layer.

The 802.11 family includes over-the-air modulation techniques that use the same basic protocol. The most popular are those defined by the 802.11b and 802.11g protocols, and are amendment to the original standard. 802.11a was the first wireless networking standard, but 802.11b was the first widely accepted one, followed by 802.11g and 802.11n. In Europe 2.4000-2.4835 GHz band is used which are divided into 13 channels each of having 22 MHz of width but spaced only 5 MHz apart, with channel 1 centered on 2412 MHz and channel 13 on 2472 MHz. Channels 1, 6, and 11 are act as three non-overlapping channels but channel 1, 7, and 13 can also be used.

802.11b has a maximum raw data rate of 11 Mbps and uses the same media access method defined in the original standard. 802.11b products appeared on the market in early 2000. The dramatic increase in throughput of 802.11b along with simultaneous substantial price reductions led to the rapid acceptance of 802.11b as the definitive wireless LAN technology. Though 802.11b devices suffer interference from other products operating in the 2.4 GHz band includes: microwave ovens, Bluetooth devices, baby monitors and cordless telephones. In this paper we have worked with 802.11b.

This experiment contains two main parts. Firstly we have to configure the 802.11b compliant Access Point (AP) then we have to measure its performance characteristics. Since we got the configured AP to work with, we mainly emphasis on the second part. We have tried to see the throughput of the WLAN in a collision free domain by taking the readings by only one Station and then created a collision domain by two Stations.

In this paper, at first we have discussed about the experiment environment and its setup, which includes the Server, AP and the Stations. We have measured the performance of the 802.11b WLAN based on the different transmission speeds. For that, we have used a software tool

named *Iperf*. Then we will have done some analysis of the expected result comparing the theoretical and experimental outcomes.

## 2. CONFIGURATION OF THE ACCESS POINT, CLIENT AND SERVER

This paper have discussed how does the set-up of the AP, Server and the clients and to simulate over the client to access point and also compare the theoretical throughput and practical throughput of IEEE802.11b as model shown in Fig.1.

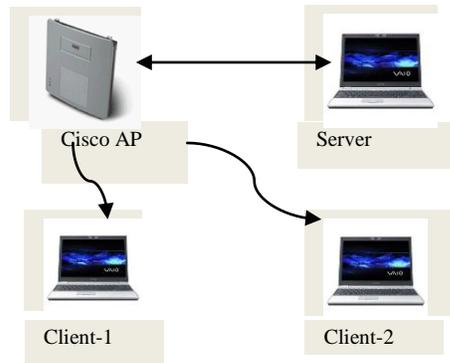


Fig.1: Connection between Server, Access point and clients

❖ The Cisco 1230 B series Access point was with IP: 192.168.10.10, SSID: NCB and password: Cisco.

❖ I have used Iperf software for the performance analysis of 802.11b WLAN using Linux operating system. The Iperf server was with IP: 192.168.10.30. To login in the server had to set *wifitest* for login id and *wifitest* for login password.

❖ To use only two clients and made login in the client laptop giving *utente* as user id and *utente* as user password. We used *Iperf* software to transmit data and for each transmission where there was one report containing the size of average data transferred, average throughput and total transmission time.

❖ The Iperf server was with IP: 192.168.10.30. To login in the server we had to set *wifitest* for login id and *wifitest* for login password. We used *sudo bash* in the terminal command to get the root privilege in the server.

❖ To join with the NCB access point given command in Linux: *sudo iwconfig eth0 essid NCB* in the client machines terminal.

❖ To given the command *sudo iwconfig eth0 essid NCB rate 1M* to join NCB Access point with 1Mbps data speed. We had also done it browsing the web interface of Cisco 1230 by writing <http://192.168.10.10/> and giving password *Cisco*, selected different data speed (one at a time) of the Access point.

❖ To take 20-sample data transmission report for each different data speed with one & two clients at a time transmitting data.

❖ From the client laptop we wrote *iperf -c 192.168.10.30 -u -b20M -i 5 -t 20* to transmit data wherein 5 means a report any 5 seconds, -t 20 means a simulation is 20 seconds long, -u means UDP transfer mode, -b 20M means a bandwidth of 20Megabits. Except these setup command, we used by default value for Access point, RADIUS server and client-server.

## 3. PERFORMANCE ANALYSIS

In this section concerned two sections one is for practical throughput analysis and second one is for theoretical analysis of IEEE802.11b from the simulation result.

### A. Practical Throughput Analysis

IEEE 802.11b supports the speed of 1 Mbps, 2 Mbps, 5.5 Mbps and 11 Mbps. Here took the sample data transmission report for different time slot and set that in every 5 second would get a report and also finally get a 0-20 second data transmission report where the transmitted data, throughput are reported. For each data speed, made the average, maximum, minimum and standards deviation for 20 times simulation result.

To make a data transmission performance analysis with UDP protocol used *Iperf* for the analysis. First time used one client to transfer data through Cisco access point and run the test for 20 times. The average value of 20 times with one client that found is given in the Table I. Here, consider 1000 bit=1 Kbit, 1000 Kbit=1Mbit in all calculations.

Table I: Average, Maximum, Minimum And Standard Deviation Of 20 Sample Data For Single Client

Speed (Mbps)	Average (Mbps)	Speed	Maximum (Mbps)	Speed	Minimum (Mbps)	Speed	Standard Deviation
1.0	0.793		0.820		0.674		0.0403
2.0	1.58		1.67		1.25		0.0837
5.5	4.08		4.16		3.86		0.087
11	6.57		6.99		5.99		0.287

In this work also taken the data while two clients access the AP at the same time and make collision in transferring data. The average throughput values for the two-client machine have shown in Table II.

Table II: Average, Maximum, Minimum And Standard Deviation Of 20 Sample Data For Two Clients.

Speed (Mbps)	Average Speed (Mbps)	Maximum Speed (Mbps)	Minimum Speed (Mbps)	Standard Deviation
1.0	0.439	0.504	0.339	0.037
2.0	0.820	0.872	0.750	0.0344
5.5	2.127	2.33	1.88	0.1214
11	3.28	3.46	2.12	0.3915

### B. Theoretical Throughput Analysis

In this paper tried to make the analysis of UDP data rates using *Iperf*. Considered there was no packet loss. *Iperf* was taking 1470 byte for a single datagram. In the calculation chosen 1500 byte for a single datagram. In theoretically should be get the following value calculated here for the following UDP frame:

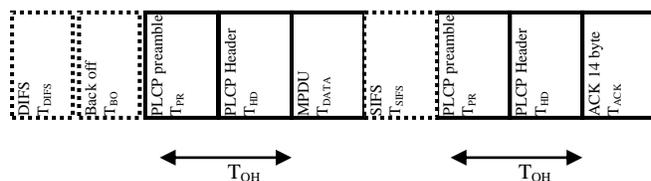


Fig.2 Successful transmission time of a single frame

To calculate the throughput[Mbps] we used the following equation[2]:

$$Throughput = \frac{Data (Bit)}{Time (\mu s)} \dots\dots\dots (1)$$

Where Data= Size of the packet in bit and Time= Total time in  $\mu s$  needed to transmit a packet successfully.

A successful UDP packet transmission does the following actions like a client station waits for a DIFS to generate the random *back off* value and after those transfers the data packet to the access point. After SIFS time, Access point (AP) sends an acknowledgement (ACK) for this successful packet transmission. Now the time calculation for a single packet transmission is given below:

$$Time = T_{DIFS} + T_{BO} + T_{PR} + T_{HD} + T_{DATA} + T_{SIFS} + T_{PR} + T_{HD} + T_{ACK}$$

Here we considered that  $T_{HD} + T_{PR} = T_{OH}$  where  $T_{OH}$  =overhead time. So now the total time will be,  $Time = T_{DIFS} + T_{BO} + T_{OH} + T_{DATA} + T_{SIFS} + T_{OH} + T_{ACK}$  all the values of time calculated are in microsecond ( $\mu s$ ). The description of the times is:

$T_{DIFS}$  = time for DIFS,  $T_{BO}$  = time for backoff,  $T_{OH}$  =time for overhead(time for preamble+ time for header),  $T_{DATA}$  =time for data transmission, time for SIFS, time for acknowledgement. Typical values are given below:

$T_{SIFS}$ =the SIFS is defined  $10\mu s$

$T_{DIFS}$ =the one SIFS time plus two slot time= $10 + (2 \times 20) = 50 \mu s$

$T_{BO}$ = Here (for single client) the *backoff* time is calculated considering random value 16( which is between 0 to 31) and multiplying it with slot time  $20 \mu s$ .

After that got the value of  $T_{BO} = 16 \times 20 = 320 \mu s$

$T_{DATA}$ =Consider each packet size is 1500 byte.

The time to calculate for each successful packet transmission by the following formula= $(1500 \times 8 \text{ bit}) / \text{Speed} (\mu s)$

$T_{ACK}$ =Consider each acknowledgement size =14 byte. So time is calculated by the following formula= $(14 \times 8 \text{ bit}) / \text{Speed} (\mu s)$ .

$T_{OH} = T_{PR} + T_{HD}$ =Summation of PLCP preamble time and PLCP header time and it is considered  $96 \mu s$  for short PLCP PDU.

Finally, I have arrived the following theoretical throughput value when I have used single client .For example, I attempt to calculation of theoretical throughput for the speed of 2.0 Mbps. Here,

$$T_{DIFS} = 50 \mu s$$

$$T_{BO} = 320 \mu s$$

$$T_{OH} = 96 \mu s$$

$$T_{DATA} = \frac{Data(Bit)}{Speed(Bit / \mu s)} = \frac{1500 \times 8 \times 10^6}{2 \times 10^6} = 6000 \mu s \quad T_{SIFS} = 10 \mu s$$

$$T_{ACK} = \frac{Data(Bit)}{Speed(Bit / \mu s)} = \frac{14 \times 8 \times 10^6}{2 \times 10^6} = 56 \mu s$$

$$Theoretical\ Throughput = \frac{1500 \times 8}{50 + 320 + 96 + 6000 + 10 + 96 + 56} = 1.8105 Mbps$$

In the same way calculated the following values given in the Table III and also Table IV for two clients.

When more than one hosts attempting to transmit, the channel will be sensed busy and hosts will apply collision avoidance techniques. After that the host executes the exponential backoff random interval distributed uniformly between  $[0, CW] \times SLOT$ . The congestion window ( $CW$ ) varies between  $CW_{min} = 31$  and  $CW_{max} = 1023$ . Each collision time a host doubles  $CW$  up to  $CW_{max}$  [1].

Table III: Comparison between Theoretical and Practical Throughput for Single Client

Theoretical throughput (Mbps) with single clients									
Speed (Mbps)	$T_{DIFS}(\mu s)$	$T_{BO}(\mu s)$	$T_{OH}(\mu s)$	$T_{DATA}(\mu s)$	$T_{SIFS}(\mu s)$	$T_{OH}(\mu s)$	$T_{ACK}(\mu s)$	TIME( $\mu s$ )	Through put (Mbps)
1.0	50	320	96	12000	10	96	112	12684.00	0.9461
2.0	50	320	96	6000	10	96	56	6628.00	1.8105
5.5	50	320	96	2181.818	10	96	20.363	2774.18	4.3256
11.0	50	320	96	1090.91	10	96	10.181	1673.09	7.1724

Table IV: Comparison between Theoretical and Practical Throughput for Two Clients

Collisions and collision avoidance (backoff mechanism) change the performance of 802.11b for an increasing number of hosts. The total frame transmission time done by

Theoretical Throughput (Mbps) With Two Clients										
Speed (Mbps)	$T_{DIFS}(\mu s)$	$T_{BO}(\mu s)$	$T_{OH}(\mu s)$	$T_{DATA}(\mu s)$	$T_{SIFS}(\mu s)$	$T_{OH}(\mu s)$	$T_{ACK}(\mu s)$	$T_{COL}(\mu s)$	TIME( $\mu s$ )	Through put (Mbps)
1.0	50	320	96	12000	10	96	112	1360	14044	0.8544
2.0	50	320	96	6000	10	96	56	1360	7988	1.502
5.5	50	320	96	2182	10	96	21	1360	4081	2.94
11.0	50	320	96	1091	10	96	10	1360	3033	3.956

a single host when competing with  $N - 1$  other hosts has to be increased by some interval  $T_{col}$  that happens for the time spent in contention procedures. In general transmission time will be:

$$Time = T_{DIFS} + T_{BO} + T_{OH} + T_{DATA} + T_{SIFS} + T_{OH} + T_{ACK} + T_{COL}(N)$$

If we consider that the hosts always sense a busy channel when they attempt to transmit data and that the number of transmissions subject to multiple successive collisions is negligible we find:

$$T_{COL}(N) \approx SLOTT \times \frac{1 + P_{COL}(N)}{2N} \times \frac{CW}{2} \text{ where } CW = \frac{CW_{MIN} + CW_{MAX}}{2} \text{ and } N = \text{No of client}$$

Where  $P_{COL}(N)$  is the proportion of collisions created for each packet successfully acknowledged at the MAC level ( $0 \leq P_{COL}(N) < 1$ )  $P_{COL}(N) = 1 - \left(1 - \frac{1}{CW_{MIN}}\right)^{N-1}$

$$T_{COL} \text{ calculation: } CW = \frac{31 + 1023}{2} = 527 \text{ and}$$

$$PCOL(2) = 1 - \left(1 - \frac{1}{31}\right)^{2-1} = 0.03225$$

$$T_{COL}(2) \approx 20 \times \frac{1+0.03225}{2 \times 2} \times \frac{527}{2} \approx 1359.98 = 1360 \mu s$$

#### 4. ANALYSIS OF MEASUREMENTS

The four measurement scenarios of IEEE 802.11b were chosen to reflect the effects of different usage of data rate. The four scenarios are identified as 1, 2, 5.5 and 11 Mbps. For each data rate, samples are taken by fixing a data rates to the above mentioned values. We have shown the theoretical and practical throughput regarding single client data transmission in Table V.

When we compared the experimental results with the theoretical results obtained from theoretical (original) decay trends obtained were far apart (see Fig. 3 and Table V) for a single client.

Table V: Theoretical throughput for a successful transmission of a single frame in 1, 2, 5.5 and 11 mbps with respect to single client and two clients.

Speed (Mbps)	Theoretical Throughput for Single Client (Mbps)	Practical Throughput for Single Client (Mbps)
1.0	0.9461	0.7933
2.0	1.8105	1.5815
5.5	4.3256	4.084
11.0	7.1724	6.5705

The difference between theoretical and practical throughput may happened due to an environment with active Access points(AP) except the one under test, signal strength issues such as radio interference and barriers as well as additional overhead related to wireless transmission that reduced real world throughput over the theoretical raw data rate.(see in Table VI) In addition, the performance of the IEEE 802.11 radio data link depends on many environmental factors such as distance between the different radio stations (i.e. radio signal attenuation with propagation), presence of noise or radio channel interference sources, physical obstacles like walls, windows, furniture, etc. radio signal reflections (radio signal multi-paths and scattering) [2].

In every case we have seen in Table.VI that theoretical values are more than the practical one. Theoretical throughput is the maximum one that can be achieved only theoretically. This is not possible in practical operation because there were interferences for channel overlapping between the clients and access points. When two-client machines request to transfer data at the same time and collision occurred .The contention period make long so the ultimate throughput go down as shown in Table VI and Fig.4. From the Table VI and Table III we observed that when two-client machine transmitted data then the throughput is going lower than the single one.

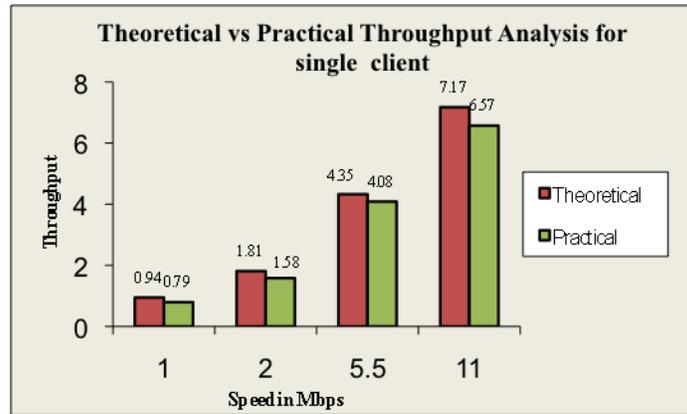


Fig. 3 Graphical analysis of theoretical and practical throughput for single client

Table VI: Comparison between Theoretical and Practical Throughput for Two Clients

Speed in Mbps	Theoretical Throughput for two Client (Mbps)	Practical Throughput for two Client (Mbps)
1.0	0.8544	0.439
2.0	1.502	0.820
5.5	2.94	2.171
11.0	3.956	3.28

Because of CSMA / CA (carrier sense to avoid collisions with access), a station that makes sense for the channel before being allowed to send a frame. The station can send, though the medium has been idle for at least DIFS. In the case of an average busy station starts a random backoff procedure, the binary exponential backoff. Establish a random *backoff time* = *slotTime* \* *random*, if it is a case full value of the pseudorandom uniformly distributed contention window [0, CW] with  $CW_{min} \cdot 255 \cdot CW$ . Initially  $CW = CW_{min}$  is set at 31 in 802.11b. If the media is still inactive for at least DIFS, the station decreases the backoff time to get busy medium. The station is authorized to send random backoff if time is zero [3].

The random backoff procedure should be initiated after each transmission. In the case of a successful procedure recognized the transmission will begin after receiving ACK (named after backoff). Otherwise, the process will start after the expiry of the ACK timeout interval. In this case, it is assumed a collision. A collision occurs when two (or more) stations have found that the average idle for DIFS, both are allowed to send and the transmission is to begin immediately. To avoid collisions, increasing CWmin must be chosen.

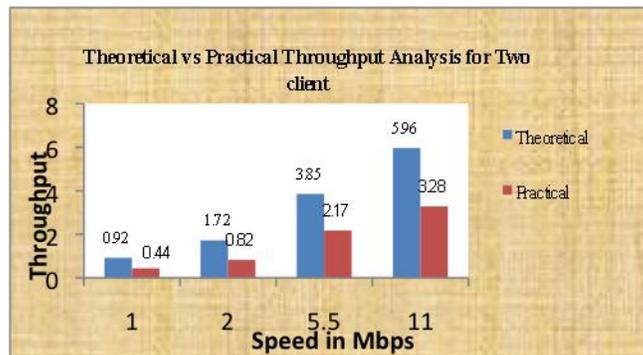


Fig.4 Graphical analysis of theoretical and practical throughput for two clients.

For the first up to the fourth retransmission the  $CW_{min}$ -value is set to  $CW_{min,new}=2 * CW_{min,old} + 1$  (31, 63, 127, ... and so on in 802.11b). This algorithm is denoted as binary exponential backoff. For five or more retransmissions the  $CW_{min}$ -value has to be set to  $CW_{max}=1023$ [1].

Some observation in Fig.5 and Fig.6 that the transmission speed increases as well as the throughput increased.

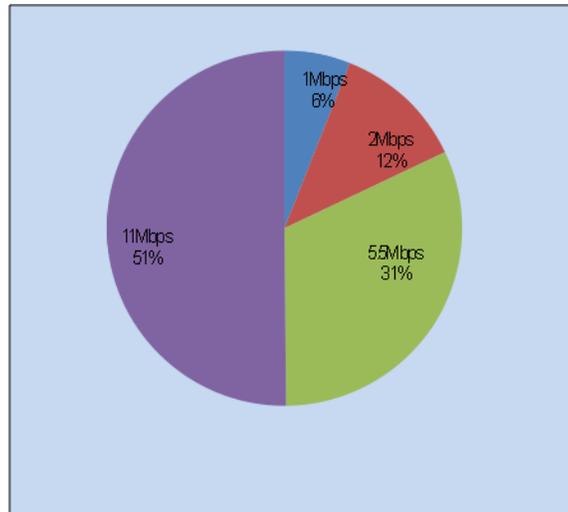


Fig .5 Throughput of single machine as a function of the transmission speed in UDP.

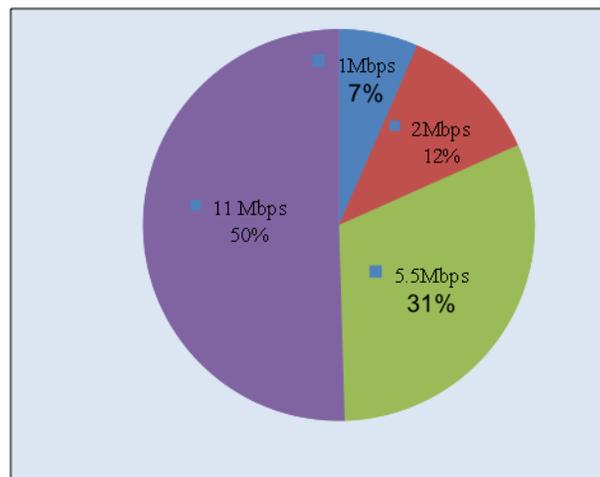


Fig.6 Throughput of two-client machine as a function of the transmission speed in UDP.

## CONCLUSION

Throughput is the main service that general wireless LAN users yearn for from AP. Different traffic condition with different environment produce different AP throughput. Therefore, throughput can generally have a very large variation. In order to maximize the throughput it is necessary to optimize the environmental conditions as well as the test conditions (no radio interferences, small close test environment, no obstacles between the radio stations, and maximum packet size for the test stream).

## ACKNOWLEDGMENT

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