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Evaluation of Multi-Channel Wireless Network Using Performance Metrics

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ABSTRACT

The aim of this research is to measure the performance of multi-channel wireless network using throughput and response time performance metrics with antenna separation, transmit power, TCP windows size, and UDP buffer size/datagram and frequency channel scheme factors. The main purpose to study the multi-channel wireless networks is to increase the bandwidth. In our research we have characterized the performance of multi-channel wireless networks consisting of IEEE 802.11b or IEEE 802.11g devices. We have conducted experiments on a simple topology consisting of two access points having same or non-overlapping frequency channels. Research study shows the effect of change in frequency channels, change in transmission power, and change in TCP windows size or UDP datagram size on performance. The results of this study are important contribution when configuring a multi-channel wireless network with non-overlapping frequency channels.

KEYWORDS: Performance Measurement, Wireless Network, Performance Metrics, WLAN, TCP, UDP, Throughput, Response time

1. INTRODUCTION

There is need to study the multi-channel wireless network due to their popularity and need to gain more bandwidth. Future wireless networks need to cope with the growing demand for increased data rates and robustness. Even though multiple non-overlapping channels exist in IEEE 802.11 networks which operate in the 2.4GHz and 5GHz spectrum, most networks utilize only a single channel. As a result, the aggregate bandwidth available is not exploited fully. Decreasing cost of radios has further motivated the design of communicating devices with multiple radios. Several architectures and routing schemes that show increased throughput on multi-radio multi-channel wireless mesh networks have also been proposed recently. They use efficient channel assignment schemes which relieve the interference effect of close-by transmissions; alleviate potential congestion on any gateways to the Internet, thereby improving per-client throughput. Multi-channel wireless mesh networks, consequently, are a promising solution to the “last mile” problem. Most of these networks are configured with the assumption that the non-overlapping channels do not interfere with each other. In IEEE 802.11g, channels 1, 6 and 11 are considered to be non-overlapping and hence the premise that these channels (or other sets with similar gaps) can be used such that multiple networks can operate in close proximity without interfering with each other [1].

In our study we have formulated the following research questions to evaluate the performance of multi-channel wireless network

R.Q.1 How large of a performance advantage can be achieved from multi – channel nodes?

R.Q.2 Which channel assignment yields optimal performance?

R.Q.3 How multiple antennas should be placed for a single node?

R.Q.4 What would be the effect of transmission power on the performance of wireless network?

The main aim of our study was to empirically evaluate the performance of multi- channel wireless networks using performance metrics like throughput and response time.

The rest of the paper is organized as follows. Section 2 discusses related work Section 3 gives a brief overview of performance metrics, research environment and software tools that we have used with research methodology followed in the study. Section 4 presents performance evaluation of multi access point network and finally section 5 concludes this paper.

2. LITERATURE REVIEW

Recent Studies explores the new dimensions of protocols based propagation or signals in the limited domain like; Doufexi and Armour, (2003) compared the performance and relative merits of 802.11a and 802.11g for the scenario of a corporate office wireless LAN application [3]. It was shown that for comparable scenarios 802.11g achieved superior range but 802.11a achieved higher data rates. Thus the two standards were found to have complementary strengths and weaknesses. The researchers use an unbiased and independent office environment to evaluate the 802.11a and 802.11b performance [4]. They used wireless laptops and access points to examine the impact of distance bandwidth. They also reported the security impact on performance of these protocols. Experimentation bases studies showed that 802.11g standard has data rates from 12 to 54 MPS per channel. The experiments show that it was possible to connect access points with 802.11g devices [5].

Liese & Mohapatra, (2006) conducted a research experiment to evaluate the relative performances of signal and multiple channels in both single hop and multi hop wireless mesh networks [6]. In one of their experiments, they studied

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the effect of antenna placement on the access point and determine the impact on performance. Their setup consisted of two ORiNOCO AP-2000 access points with internal PC card antennas less than one inch from each other. Observing unfavorable results even when the two access points were communicating on non-overlapping channels, they attached external antennas to the PC cards and varied the antenna proximity. They concluded that throughput varies significantly with antenna proximity. Transmission power, location of node, transmitted data size and rate are directly influential under 802.11 technologies [7]. Performance evaluation of multi-channel wireless networks consisting of IEEE 802.11g devices using non-overlapping channels can be calculated and transmission power and packet size have significant influence on the performance of multi – channel wireless network [8]. There are different parameters that actually affect the performance of 802.11g protocols [9]. Results against the parametric studies are significant in nature concluded as throughput can be achieved by controlling various key parameters [10].

Degradation of the performance 802.11 is analyzed in several researches [8], [10], [11] which leads the concept of performance degradation in dense wireless network by simulation and compared with other measurements approaches. Moltchanov, (2010) conducted a review of performance evaluation models proposed for wireless channels, highlighting their basic ideas, shortcomings, and advantages [12]. Important scaling properties that exist in today's 802.11-based wireless networks and set guidelines for designing future versions of such networks that can efficiently support a very large number of users were identified [13]. Wireless networking security technologies most commonly used in an office environment and by the mobile workforce of today [15]. IEEE 802.11 protocol can be re[resented in both a simulation and a test bed model of the same system [16] but the relevance of the parameters had the same values and that both were subjected to network traffic with the same characteristics [17]. Similarly the performance and relative merits of 802.11a and 802.11g can be compared for the scenario of a corporate office wireless LAN application [17], [18]. Thus, the comparison concluded that for comparable scenarios 802.11g achieved superior range but that 802.11a achieved higher data rates [19].

Characterization of an 802.11b wireless mesh network with 4 access point wireless mesh to gain some insight into its performance can result in to better performance based on certain parameters [18], [20]. The experiments included varying number of hops and flows in the network, as well as the number of channels and configurations. They quantified the good throughput when multiple clients transmit their data to a single server [21]. Free MAC, a framework for the design and implementation of a generic class of multi-channel wireless MAC protocols, on a typical Linux system using commodity 802.11 devices is used for the data packets transmission [22]. Six-node wireless test beds can be deployed to examine the quality of links in home wireless networks and the effect of transmission rate, transmission power, node location, type of house, and 802.11 technologies [21], [23]. Empirical evidence suggested that homes are challenging environments for wireless communication. Results suggested that creating an AP-based topology with maximum coverage and throughput in this environment is challenging [24].

Gurpreet and Dowdy, (2004) provided a methodical experimental evaluation of the 802.11a and 802.11b protocols, presenting an unbiased and independent performance review in a given office environment specifically, the bandwidths of the two protocols are compared as a function of distance between the wireless laptops and their access point (AP) [22]. The performance effects of using two different levels of security (i.e., 64 and 128 bit encryption schemes) were reported. These distribute coordination function [23] of 802.11 networks illustrate the different classes of Petri Nets used for modeling network protocols and their robustness in modeling based on formal methods [24]. Then proposed 802.11b model based on Object-oriented Petri Nets models precised back off procedure and time synchronization. Then, performance analyses are evaluated by simulation for a dense wireless network and compared with other measurements approaches [25]. Shahran and Rizman in proposed a modular model in the Journal of Basic and Applied Scientific Research that evaluate the impact of network performances on the performances of distributed discrete event systems [26].

3. RESEARCH MATERIAL AND DESIGN

This section describes the performance metrics, experimental setup environment and technology (hardware and software) used in this research to measure the performance of multi - channel wireless networks.

3.1 Performance Metrics

To quantify the performance of a wireless network performance metrics are the important considerations. We have selected the following performance metrics response time (sometimes called speed, reaction time), throughput (sometimes called capacity or bandwidth) to conduct our research.

Response Time: The response time is the time required to transmit data between two points in a network or the time interval between the user requests - response scenario as shown in Figure 1. Network distance, transmission power, security protocols, data size and frequency channels are the major factors that can affect the response time.

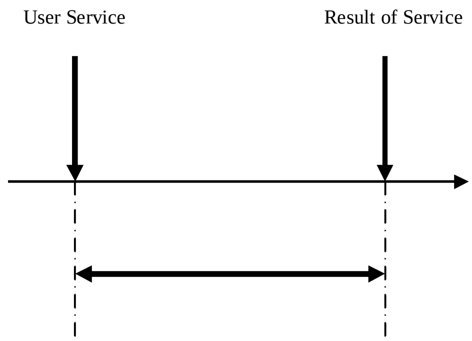

Figure 1: Typical Response Time Management

Throughput: The throughput is the measurement of amount of the data transmitted over a network in a specified period of time. It is measured in terms of messages per seconds (MPS), bits per second (BPS) and packets per seconds (PPS). Throughput is directly proportional to amount of data transmitted over a network.

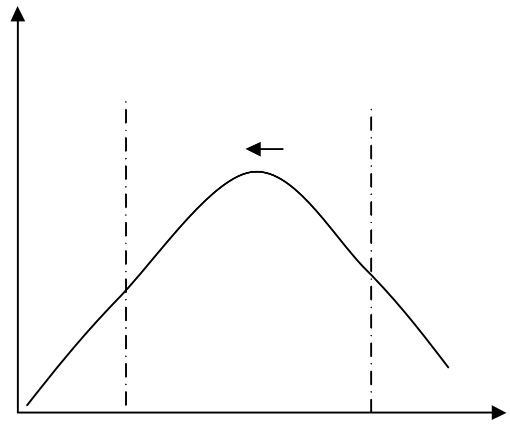

Figure 2: Throughput curves versus load quantity

We have evaluated the performance of multi- channel wireless network using above mentioned metrics on the basis antenna separation(antenna distance 0 inch to 60 inches) transmit power (Full, 50%, Minimum) TCP windows size:(window size 100 – 1000) , UDP buffer size(buffer size 1470 – 14700) and frequency channel scheme factors .

3.2 Experimental Setup Environment

Two testing locations (office and university environment) were selected with interference at 5 meters from test bed access points for research. The testing environment consisted of two 802.11b APs, two 802.11g APs, two 802.11b wireless cards, two 802.11g wireless cards, one network switch and two IBM ThinkPad T22 same configurations 900 MHz, 512 MB RAM laptops running Windows 7. Three 2 sets of experiments: a) Node1 – AP1 – AP2 – Node2 overlapping channel (1-1-1-1), b) Node1 – AP1 – AP2 – Node2 non-overlapping channel (1-6-11-1) was performed. Network tools ping and iperf were used to gather data. SPSS was used to analyze data.

3.3 Software Tools

Following software were used to evaluate the performance of network.

ping: ping, coded by Mike Muuss in 1983, is a network tool testing the reachability of a certain host within an IP network. It sends out ICMP echo requests (type 8, code 0) to which the receiving host answered with according ICMP echo replies (type 0, code 0).

iperf: For bandwidth measurements the open source tool iperf was used. Iperf either transmits UDP datagrams at a specific sending rate to measure the actual received speed, the packet loss, and the jitter or TCP streams with a configurable window size to evaluate the maximum reliable throughput. The program itself acts as sender and receiver. On one host it has to be started as the server to which another instance of Iperf (the client) connects and transmits data. Finally, the server displays the result.

SPSS: Statistical package SPSS was used for descriptive analysis

Performance Evaluation

In multi access point network, two network access points were used for throughput and response time measurements. The two access points were placed very close to each other, and distance were increased in inches. Measurement were done by 0, 10, 20 and 30 inches distance between antennas of two access points. Two access points were connected by a network switch. Two client laptops were connected to appropriate access points. The distance between access point and client laptop was 7 meters. Traffic was generated between laptops by iperf and ping tools. During these experiments an interference access point channel 6 was presented.

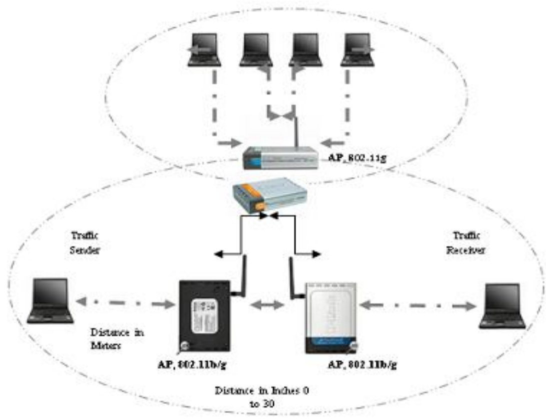

Figure 3: Multi Access Point Network

4.1 TCP Throughput Analysis of Multi-Channel Wireless Network

Distance between antennas in inches, frequency channel scheme, antenna transmit power were used as parameters during experiments with 802.11b and 802.1g devices for TCP throughput and response time analysis.

TCP Throughput Analysis by Distance: Summary of TCP readings by distance between antennas of two access points in Table 1 shows that throughput is increased in 802.11g standard by the increment in distance.

Table 1: TCP Throughput Analysis, by Distance

Distance between two Access Points in Inches	TCP Throughput(Mbits/sec)in WLAN Standard	
	802.11b	802.11g
	Mean	Mean
0	4.17	6.45
10	4.07	9.91
20	4.32	11.50
30	3.88	11.34

TCP Throughput Analysis by Frequency Channel: Results of Table 2 indicated that better throughput was achieved in 6-1-11-6 case in both 802.11b and 802.11g standard, which means that, we can achieve more bandwidth, using non-overlapping frequency channels

Table 2: TCP Mean Throughput Analysis, by Frequency Channel

Frequency Channel Scheme among Access Points in Laptops	TCP Throughput(Mbits/sec)in WLAN Standard	
	802.11b	802.11g
	Mean	Mean
6-6-6-6	3.15	8.42
6-1-11-6	5.07	11.18

Table 3 represents the sum of TCP throughputs with big difference in bandwidths. Using 802.11b devices with 6-6-6-6 frequency scheme, we achieved total sum of bandwidths 756.79, but in 6-1-11-6 case, we achieved total sum of bandwidths 1216.66.Moreove using 802.11g devices the difference between sums of throughput is also very critical.

Table 3: TCP Sum of Throughput Analysis, by Frequency Channel

Frequency Channel Scheme among Access Points in Laptops	TCP Throughput(Mbits/sec)in WLAN Standard	
	802.11b	802.11g
	Sum	Sum
6-6-6-6	756.79	2020.63
6-1-11-6	1216.66	2683.93

TCP Throughput Analysis by TCP Window Size: Figure 4 shows that there is approximately no change in 802.11b throughput, but a minute change is in 802.11g.A big difference has been observed between throughputs of 802.11b and 802.11g standards.

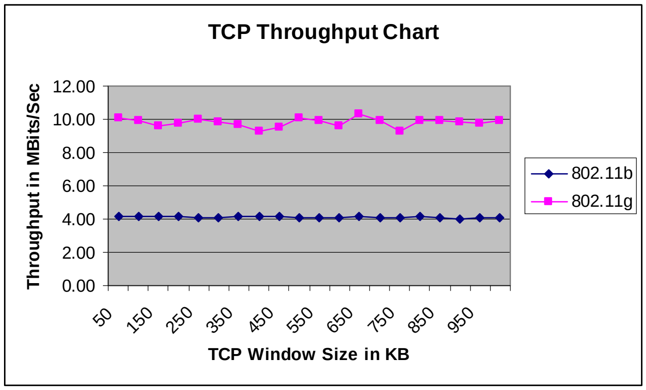

Figure 4: Overall TCP Throughput Analysis, by TCP Window Size

4.2UDP Throughput Analysis of Multi-Channel Wireless Network

UDP Throughput Analysis by Distance: It is observed from the results of Table 4 that UDP throughput increases with the increment in distance between antennas using 802.11g devices, whereas a minute change was observed in performance while using 802.11b devices.

Table 4:UDP Throughput Analysis, by Distance

Distance between two Access Points in Inches	UDP Throughput(Mbits/sec)in WLAN Standard	
	802.11b	802.11g
	Mean	Mean
0	2.39	3.08
10	2.34	5.01
20	2.43	6.55
30	2.48	7.62

UDP Throughput Analysis by Frequency Channel: Results of Table 5 indicated that better throughput was achieved in 6-1-11-6 case in both 802.11b and 802.11g standard, which means that, we can achieve more bandwidth, using non-overlapping frequency channels

Table 5:UDP Mean Throughput Analysis, by Frequency Channel

Frequency Channel Scheme among Access Points in Laptops	UDP Throughput(Mbits/sec)in WLAN Standard	
	802.11b	802.11g
	Mean	Mean
6-6-6-6	1.90	4.17
6-1-11-6	2.92	6.97

Table 6 represents the sum of TCP throughputs with big difference in bandwidths. Using 802.11b devices with 6-6-6-6 frequency scheme, we achieved total sum of bandwidths 456.64, but in 6-1-11-6 case, we achieved total sum of bandwidths 699.77. Moreover using 802.11g devices the difference between sums of throughput is also very critical.

Table 6:UDP Sum of Throughput Analysis, by Frequency Channel

Frequency Channel Scheme among Access Points in Laptops	TCP Throughput(Mbits/sec)in WLAN Standard	
	802.11b	802.11g
	Sum	Sum
6-6-6-6	456.64	999.61
6-1-11-6	699.77	1672.49

TCP Throughput Analysis by TCP Buffer/Datagram Size: Figure 5 showed that Throughput was increased with the increment in datagram size in both 802.11b and 802.11g devices. More data variation was seen in 802.11g devices.

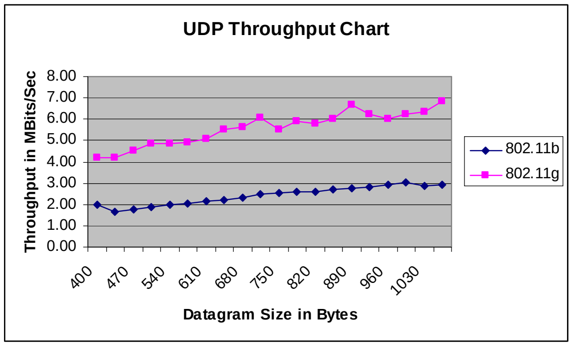

Figure 5: Overall UDP Throughput Analysis, by UDP Buffer/Datagram Size

TCP and UDP Throughput Comparision*:* Comparative analysis results in table 7 depicted that in both TCP and UDP cases overall better throughput was achieved by using non-overlapping (6-1-11-6) frequency channel scheme.

Table 7:TCP and UDP Throughput Comparison

Frequency Channel Scheme among Access Points in Laptops	TCP Throughput(Mbits/sec)in WLAN Standard		UDP Throughput(Mbits/sec)in WLAN Standard	
	802.11b	802.11b	802.11g	802.11g
	Sum	Sum	Sum	Sum
6-6-6-6	756.79	756.79	456.64	999.61
6-1-11-6	1216.66	1216.66	699.77	1672.49

4.3 Response Time Analysis of Multi-Channel Wireless Network

Ping tool was used to analyze response time. 20 packets of size 65500 bytes were sent from sender laptop to receiver laptop and response time in ms were collected. Experiments were done with both 802.11b and 802.11g devices. Distance between antennas, frequency channel scheme, antenna transmit power and packet size were used as parameters.

Response Time Analysis by Distance: There is fluctuatioan noted in response time with increasing or decreasing distance between access points using 802.11 b devices, while there is decreasig trend in respose time with increment in distance using 802.11g devices.

Table 8: Response Time Analysis, by Distance

Distance between two Access Points in Inches	Response Time in ms WLAN Standard	
	802.11b	802.11g
	Mean	Mean
0	195	131
10	180	86
20	207	74
30	190	84

Response Time Analysis by Frequency Channel: Results of Table 9 indicated that less response time noted when using non-overlapping frequency channels which showed good performance.

Table 9: Response Time Analysis, by Frequency Channel

Frequency Channel Scheme among Access Points in Laptops	Response Time in ms WLAN Standard	
	802.11b	802.11g
	Mean	Mean
6-6-6-6	232	96
6-1-11-6	154	91

Table 10 represents the sum repose time. Using 802.11b and 802.11g devices with 6-1-11-6 frequency scheme, we achieved less response time.

Table 10: Sum of Response Time Analysis, by Frequency Channel

Frequency Channel Scheme among Access Points in Laptops	Response Time in ms WLAN Standard	
	802.11b	802.11g
	Sum	Sum
6-6-6-6	55407	23098
6-1-11-6	37043	21908

Response Time Analysis by Transmission Power: Facts of Table11 reported, less response time at high transmits power and high response time at low transmits power using 802.11b devices. High response time was noted at moderate transmit power while using 802.11g devices.

Table 11: Response Time Analysis, by Transmission Power

Transmission Power in Percentage	Response Time in ms WLAN Standard	
	802.11b	802.11g
	Mean	Mean
100 %	182	83
12.5 %	186	118
50 %	211	81

Response Time Analysis by TCP Window Size: Figure 6 shows that there is approximately minor change in 802.11gresponse time, but a minute change is in 802.11b.A big difference has been observed between response times of 802.11b and 802.11g standards.

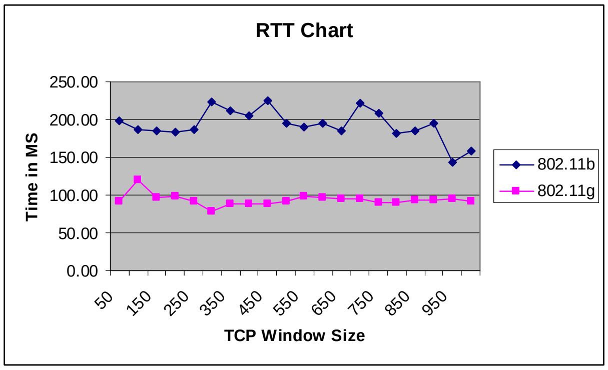

Figure 6: Overall Response Time Analysis, by TCP Window Size

Response Time Analysis by TCP Buffer/Datagram Size: Figure 7 shows that there is no change in response time with the increment in datagram size in 802.11g devices. More response time variation was seen with the increment in datagram size in 802.11b devices

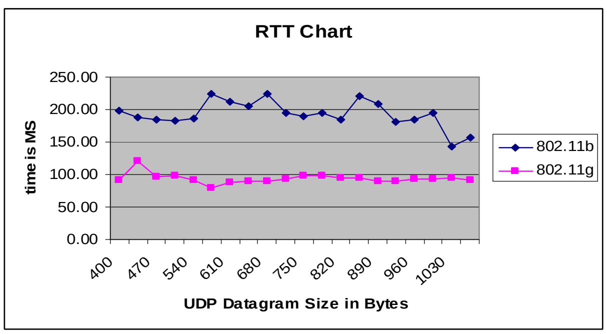

Figure 7: Overall Response Time Analysis, by UDP Buffer/Datagram Size

TCP and UDP Response Time Comparison: Comparative analysis results in table 7 depicted that in both 802.11b and 802.11g standards, for both TCP and UDP traffic, lesser response time was seen by using 6-1-11-6 instead of 6-6-6-6, which proved better bandwidth.

Table 12:TCP and UDP Response Time Comparison

Frequency Channel Scheme among Access Points in Laptops	TCP Response Time in ms WLAN Standard		UDP Response Time in ms WLAN Standard	
	802.11b	802.11b	802.11g	802.11g
	Sum	Sum	Sum	Sum
6-6-6-6	6564.70	2553.80	11333.10	6229.90
6-1-11-6	3973.20	2110.20	7157.10	4724.00

5. CONCLUSION AND FUTURE WORK

This research showed that overall high throughput and less response time was achieved in both 802.11b and 802.11g standards by using TCP and UDP traffic generated by iperf and ping when the access points were configured with non-overlapping frequency channels. Research study shows the effect of change in frequency channels, change in transmission power, and change in TCP windows size or UDP datagram size on performance. The results of this study are important contribution when configuring a multi-channel wireless network with non-overlapping frequency channels. Different experiments using different parameters like distance, antennas transmit power, TCP window size, UDP datagram size, frequency channel were conducted. Even though multiple non-overlapping channels exist in IEEE 802.11 networks which operate in the 2.4GHz and 5GHz spectrum, most networks utilize only a single channel. As a result, the aggregate bandwidth available is not exploited fully. High results were achieved by using non-overlapping frequency channels only. Here we used ping tool analyze response time and 20 packets of size 65500 bytes were sent from sender laptop to receiver laptop and response time in ms were collected. Experiments were done with both 802.11b and 802.11g devices. Distance between antennas, frequency channel scheme, antenna transmit power and packet size were used as parameters. For bandwidth measurements the open source tool iperf was used. Iperf either transmits UDP datagrams at a specific sending rate to measure the actual received speed, the packet loss, and the jitter or TCP streams with a configurable window size to evaluate the maximum reliable throughput. The program itself acts as sender and receiver. On one host it has to be started as the server to which another instance of Iperf (the client) connects and transmits data. Finally, the server displays the result. In future researchers can conduct experiments by using 802.11a standard. They can make comparison among 802.11a, 802.11b and 802.11g standards. They can use more combinations of frequency channels as 802.11a have more non-overlapping frequency channels as compared to 802.11b and 802.11g which may lead towards the high efficiency and perforce in the perspective of data rate and time to destine the data to the target node. Working the different frequency bands may explore new dimension of research for upcoming researches.

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