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Comparative Analysis of IEEE 802.11b WLAN Computer Simulation Results with Real Time Data

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ABSTRACT

This research is a comparative analysis of IEEE 802.11b WLAN computer simulation results with real time data. The Model was developed and validated using Matlab simulation environment. The scope of this work covers both the physical layer architecture and MAC layer architecture. The Distributed Coordination Function (DCF) Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), the RTS/CTS mechanism, MAC protocol specifications, physical layer description and specifications, frame structure and addressing, WLAN spectrum allocation and network performance management are also addressed. Logical Link Control (LLC) layer, Centralized Coordination Function (CCF) and Hybrid Coordination Function (HCF), power management, security etc., are not

considered. Results from the study reveals that although various enhancements to the original IEEE 802.11 protocol have been proposed recently, the problem of efficient channel utilization, higher throughput, lower mean delay and good fairness has not been fully solved yet. Also, from the simulation model, it is evident that the throughput performance of IEEE 802.11b WLAN can be improved by using efficient frame aggregation mechanism.

Keywords: Network Performance Management, Quality of Service (QOS), Data Capture Center, Network Throughput, Mean packet Delay

1. INTRODUCTION

Wireless Local Area Networks (WLAN) is a flexible data communication system implemented as an extension or as an alternative to a wired LAN within a geographical region using radio frequency technology [7]. The wireless local Area Network (WLAN) is expand ing rapidly as a result of the advances in digital communications, portable computers and semi conductor technology. The adoption of WLAN is very vital due to the ease of the mobility offered to the end users to access a wireless network within a limited location usually one kilometer.

Wireless network is currently a limited megabit-capacity technology prone to channel errors which include; low throughput, packet delay/loss or error rate. It is important that careful consideration be made when deciding on the Quality of Service (QoS) for wireless networks. The high traffic load induced on the network as a result of the influx of new mobile technologies must not reduce the network performance to the extent that communication over the network becomes very slow or unreliable.

Over the years there has been a continual increase in the number of wireless networks deployed, and many organizations prefer these networks. This means that such networks should be able to handle QoS-sensitive applications, such as voice calls. However, the original wireless networks were designed for data only and not to handle much of real-time traffic like VoIP. These raise the need to determine the influence of traffic distribution on IEEE 802.11g QoS parameters.

In today's Internet, the emerging widespread use of real-time voice, audio, and video applications makes Quality of service (QoS) a key problem. Meanwhile, the Internet is getting heterogeneous due to the explosive evolution of wireless networks and technology. QoS support in wireless networks is more challenging than in the wired networks since bandwidth is scarce, latency and bit error rate are high and characteristics of the wireless channel vary over time and space. The IEEE 802.11 standard is the most widely deployed wireless local area network (WLAN) infrastructure. However, it is finding it difficult to provide QoS support for the increasing number of multimedia applications. Thus, this research works is going to be carried out on comparative analysis of IEEE 802.11b WLAN computer simulation results with real time data.

1.1. Need for Traffic Models and Network Performance Management

The design of robust and reliable networks and network services is becoming increasingly difficult in today's world. The only path to achieve this goal is to develop a detailed understanding of the traffic characteristics of the network.

Managing performance of networks involves optimizing the way networks function in an effort to maximize capacity, minimize latency and offer high reliability regardless of bandwidth available and occurrence of failures [14], [15]. Network performance management consists of tasks like measuring, modeling, planning and optimizing networks to ensure that they carry traffic with the speed, capacity and reliability that is expected by the applications using the network or required in a particular scenario.

Networks are of different types and can be categorized based on several factors. However, the factors that affect the performance of the different networks are more or less the same. These involve parameters like Latency, Packet Loss and Throughput. In order to design high performance networks or guarantee performance of any type of network detailed analysis of the above factors is a crucial step. Often the foremost step in such an analysis is the study of the traffic on the network. As a consequence the type of traffic model used to understand the flow of traffic in the network, and how closely the model depicts the real-time characteristics of the network, become vital parameters. Choosing a model that does not describe the real-time characteristics of the traffic in the network can be as disastrous as not analysing the traffic at all.

1.2. Quality of Service (QOS)

The term Quality of Service, in the field of networking, refers to control procedures that can provide a guaranteed level of performance to data flows in accordance to requests from an application/user using the network [9, 12]. A network that provides QoS supports usually agrees on a traffic contract with an application and reserves a finite capacity in the network nodes, based on the contract, during the session establishment phase. While the session is in progress, the network strives to adhere to the contract by monitoring and ensuring that the QoS guarantees are met. The reserved capacities are released subsequently after the session. There are several factors that might affect such QoS guarantees. Hence, to design a network to support QoS is not an easy task. The primary step is to once again have a clear understanding of the traffic in the network. Without a clear understanding of the traffic and the applications that might be using the network, QoS guarantees cannot be provided. Therefore, modeling of traffic becom es a crucial and necessary step.

1.3. Traffic Models

Analysis of the traffic provides information like the average load, the bandwidth requirements for different applications, and numerous other details. Traffic models enables network designers to make assumptions about the networks being designed based on past experience and also enable prediction of performance for future requirements. Traffic models are used in two fundamental ways: (1) as part of an analytical model or (2) to drive a *Discrete Event Simulation (DES) [4]*.

Simple traffic comprises of single arrivals of discrete entities, viz., packets, cells, etc. This kind of traffic can be expr essed mathematically as a *Point Process*. A point process consists of a sequence of arrival instants *T1, T2, T3... Tn* (by convention, *T0 = 0*). Point processes can be described as a *Counting Process* or *Inter-Arrival Time (IAT) Process.* A counting process *N(t)* is a continuous time, non-negative, integer-valued stochastic process, where $N(t) = max\{n: T_n \le t\}$ denotes the number of (traffic) arrivals in the time interval *(0,t]* [11]. An inter-arrival process is a non-negative random sequence *{An}*, where $A_n = T_n - T_{n-1}$ is the length of the time interval separating the nth arrival from the previous one [9]. Discrete-time traffic processes are characterized by slotted time intervals. In other words, the random variables A_n can assume only integer values.

1.4. WLAN Traffic Model

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Data network traffic model was well characterized using ON-OFF process mainly because it reflects the notion of self-similarity [5]. Therefore, in this research, traffic modeling was based on the ON-OFF process. The packet generated during the ON period is random and is assumed to have been distributed following Poisson distribution law [10]. The ON and OFF intervals distribution follow the exponential service distribution [5]. The modeling of the data traffic consists of two parts-the arrival process to the access point for user activities and the process describing the activity phase which is traffic within the network [11].

For most of the data applications, the arrival process has been modeled using the ON-OFF process or the Poisson process. The activity phase model differs from one application to the other. The traffic model was designed and translated into computer simulation model using the MATLAB Simulink environment. The traffic model is shown in the figure1.

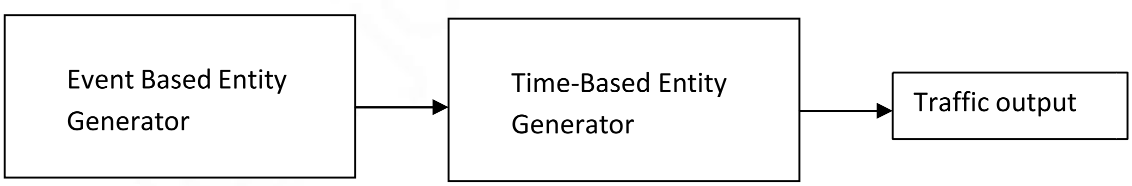

Figure 1 ON-OFF Traffic Generator

Event-based entity generator blocks were employed and the distribution needed for the model specified. The generator blocks (event based) in each case, produces the required output traffic.

1.5. Poisson Distribution Model

The Poisson Model is one of the most widely used and oldest traffic models. The Poisson distribution is the foremost model used for evaluating traffic in traditional telephony networks [14]. The Poisson process is described as a renewal process. In a Poisson process the inter-arrival times are exponentially distributed with a rate parameter λ: $P\{An \le t\} = 1 - exp(-\lambda t)$. The Poisson distribution is suitable if the arrivals are from a large number of autonomous sources, referred to as Poisson sources [10, 13]. The distribution has a mean and variance equivalent to the parameter λ. The Poisson distribution can be envisaged as a limiting form of the binomial distribution, and is also used widely in queuing models [1, 6]. Poisson processes display a number of interesting mathematical properties. Basically, superposition of self-determining Poisson processes results in a new Poisson process whose rate is the sum of the rates of the independent Poisson processes. Further, the independent increment property renders a Poisson process memory less. Poisson processes are common in traffic applications scenarios that include a large number of independent traffic streams. The motive behind the usage stems from *Palm's Theorem* which states that under suitable conditions, such large number of independent multiplexed streams technique, a Poisson process as the number of processes grows, but the individual rates decline in order to keep the aggregate rate constant [9]. However, it is to be noted that traffic aggregation need not at all times result in a Poisson process.

The two basic assumptions that the Poisson model make are [8]:
ai. The number of sources is infinite
b. The traffic arrival pattern is random

The probability distribution function and density function of the model could be given as:

$$F(t) = 1 - e^{-\lambda t}$$
$$f(t) = \lambda e^{-\lambda t}$$

There are also further variations of the Poisson distributed process that are commonly used. These comprise the Homogeneous Poisson process and Non-Homogeneous Poisson process that are used to designate traffic characteristics [2].

2. METHODOLOGY

Saturated traffic condition means that all stations on the access point always have a packet available for transmission. Throughput under saturated traffic situation is the upper limit of the throughput achieved by the system, and it represents the maximum load the system can carry in the stable condition.

It is important to mention that if the packet sizes in a flow are known, then the average service time is no longer a stochastic process, but is deterministic. This is very interesting since many applications produce known packet sizes. Therefore, application developers can run simulations of the model to study the throughput and delay that is imposed by the wireless AP for differen t flow patterns of the application.

In this research, a saturated traffic loading design for IEEE 802.11b DCF was depicted using computer simulation to create a model and representing a wireless network system for performance measures and comparison purposes. In order to reach the objectives, MATLAB Simulink package, which has the basic structures for simulating much kind of computer networks including WLAN DCF which is the framework for this research? The traffic loading design from the source and to the link is built over MATLAB Simulink package, simulated, validated and the results obtained was analyzed to establish enhanced WLAN performance.

2.1. Modeling Assumptions and Configuration

A simulation model has been developed using MATLAB Simulink to study the network throughput and mean packet delay, performance of the IEEE 802.11b DCF protocol.

To simplify the simulation model, the research considered (assumed) a perfect radio propagation environment in which there is no transmission error due to interference and noise on the system, and no hidden and exposed station problems. The following assumptions were made regarding the data traffic:

1) No hidden stations are considered.
2) The network consists of a finite number of stations, *n*.
3) Each station always immediately has a packet available for transmission (saturation conditions).
4) Packet Generation**:** Streams of data packets arriving at stations are modeled as independent Poisson processes with an aggregate mean packet generating rate » packets/s.
5) Packet Size: Packets are of fixed length. The time axis is divided into slots of equal length, and the transmission of one packet takes one slot time.
6) Buffer size: The access point and stations in the network has a large buffer, modeled as a buffer of infinite size, to store packets. This assumption means that packets cannot be lost due to a buffer overflow when the system is under manageable input loads.

7) Destination addresses: The research assumed that packet arrives at a station are uniformly destined to $N - 1$ other station in the network.

Table 1 Parameters used in simulation and calculations

Parameters	Values
Data rates	1, 2, 5.5, 11 Mbps
SIFS	10 µsec
DIFS	50 µsec
Slot time	20 µsec
Packet Size	1500 bytes
Traffic distribution	Gamma, Exponential and Geometric.
PHY modulation	DSSS
CWmin	31
CWmax	1023
Simulation Time	60 Seconds

Table 1 lists the parameter values that was used in the simulation, The simulation was run for 60 seconds in other to achieve the required stability during which throughput and mean packet delay were computed for varying number of workstations and network resources (medium transmission rate - bandwidth). The workstations generate packets with exponential time distribution; the exponential parameter has 0.15 mean values. Network loading was varied from 10 to 100 workstations. The workstations have a finite buffer capacity while the transmission rate was varied from 1Mbps to 11Mbps.

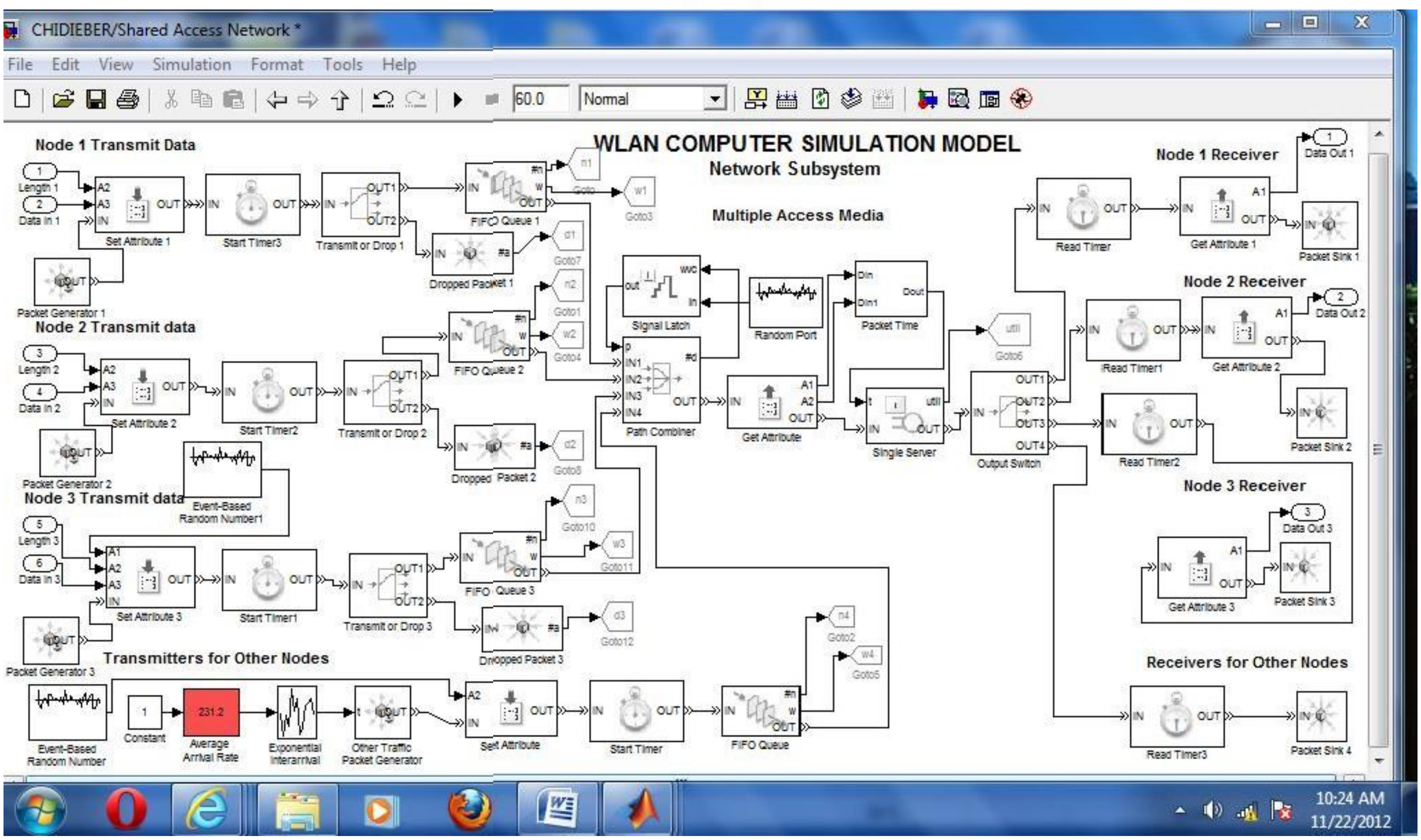

Figure 2 WLAN Computer Simulation Model

2.2. Experimental Environment

This experiment was carried out at Cristus ICts & resources Ltd, Awka, Nigeria. It's an indoor environment. Three different cases were considered in the experiment. Their network is divided into three regions namely; Data Capture Center (Ground Floor), Date Update Center, and Date upload/card center which also houses the main Server. These three regions have different ranges from the access points. Each of these centers house between 15 to 40 fixed desktop computers and few laptops. Some mobile smart phones were also used as host. All the systems have wireless LAN features and are IEEE 802.11b compliant.

These three Centers are located in the same building but are separated with few meters way from each other. The measurements are carried out in these three locations. In all the three regions, three different network sniffer software (NetStress, Wireshark and Jperf) were used to take measurement on the network.

The network was transmitted to the three regions, each via Nanostation M5 radio, which brings the network to the wireless Cisco router and distributed via a wireless AP and a LAN switch (LinkSys).

2.3 Test Bed Environment

2.3.1. Test bed one: Data upload/card Center

The first experiment was carried out in Data upload/card Center which houses the main servers. The Data upload/card Center is located on the first floor of the old secretariat two storey building and was used for the measureme ts; first was with five hosts, second was with ten host, third was with 20 and it continues in that order till we have fifty mobile stations. The measurements were carried out using the three different network sniffers one at a time.

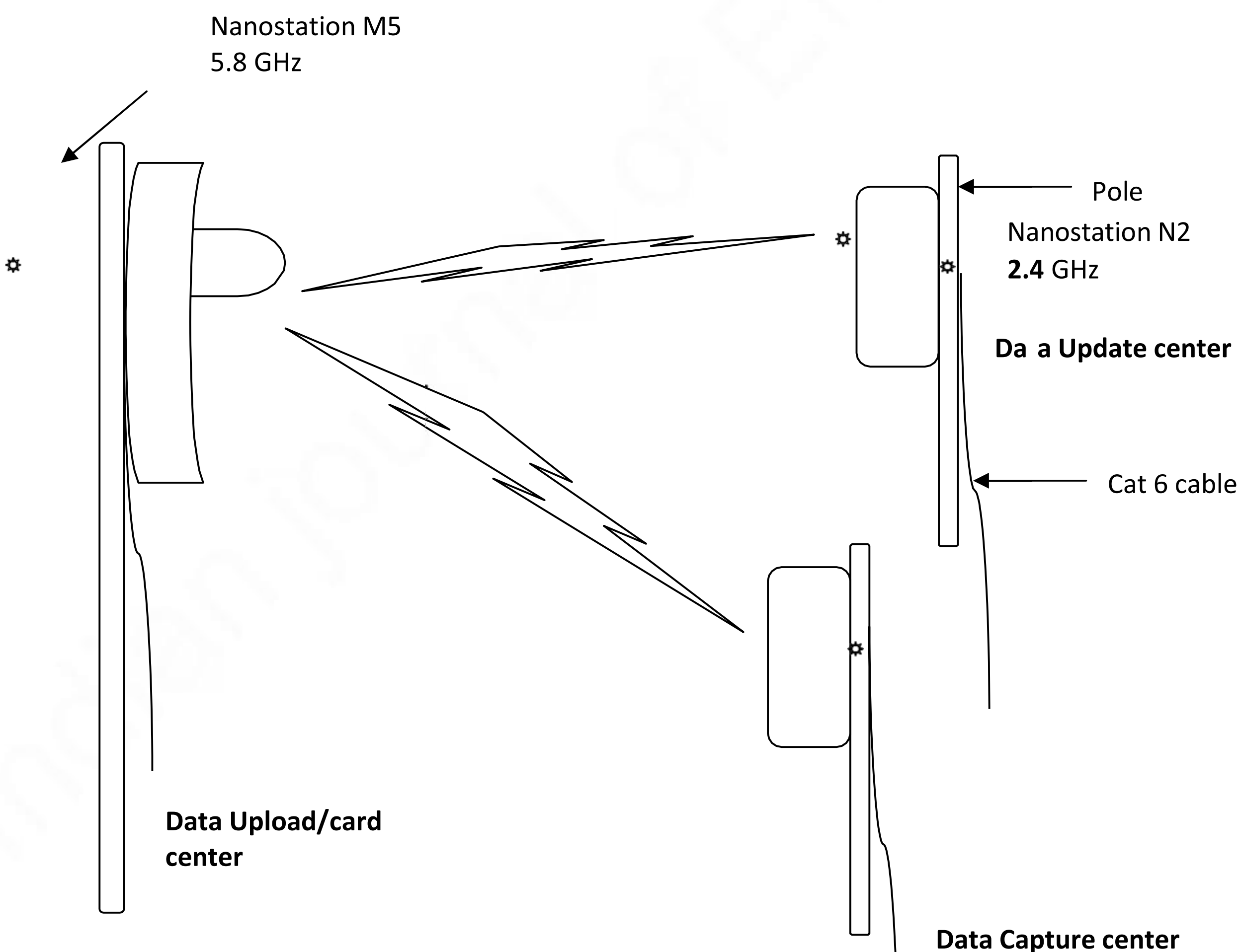

Figure 3 Experimental Network Architecture

2.3.2. Test bed Two: Data Update Center

The second experiment was carried out in Data Update center, which is about 50meters from the data upload center. It's also located at the 2nd floor of the building. The same procedure was also used here to carry out measurements in this center. In the first scenario, five hosts were used; as the second ten were used; in the third fifteen were used and so on up to fifty mobile hosts.

2.3.3. Test bed Three: Data Capture center

The third experiment was carried out in the data capture center which is located at the ground floor of the building. It's about 100meters away from the access point. Signal measurements were taken and recorded accordingly. Five host were used in the first scenario; ten were used in the second scenario while fifteen, twenty, and up to fifty mobile stations were used respectively.

Considering the assumptions made earlier in the research, Measurements were carried out on each of the test beds using three network sniffers viz; NetStress, Whireshark and Jperf. The settings of the access point (Wireless Router) have been configured and the network sniffer was used to measure the network throughput and delay. Other measurements carried out in the course of this experiment which were not within the scope of this research include Network strength, MAC address, data transfer rate, date size, ACK size and so on.

The accuracy of the model presented was verified using MATLAB simulation results. The network parameters used in these results are shown in Table 1 above, and it is assumed that every station was able to listen to each other and there are no hidden stations in the systems. For the model validation, the proposed model simulation results with the experimental throughput and delay results collated via the three network sniffers for IEEE 802.11b DCF was compared. A close match between MATLAB simulation results and the experimental results validates the model. The simulation results of the IEEE 802.11b protocol are discussed next.

3. DISCUSSION OF RESULTS

3.1. Network throughput

Fig 4 compares the proposed model simulation result and field work result of IEEE 802.11DCF by plotting the Network throughput against number of workstations at 11Mbps packet data rate. In this graph, at minimum number of stations and low traffic, the proposed model significantly increases the Network throughput under network load of 80%. In other words, the simulation results report the steady-state behavior of the network and have been obtained with the relative error less than 15%, and at the 85% confidence interval.

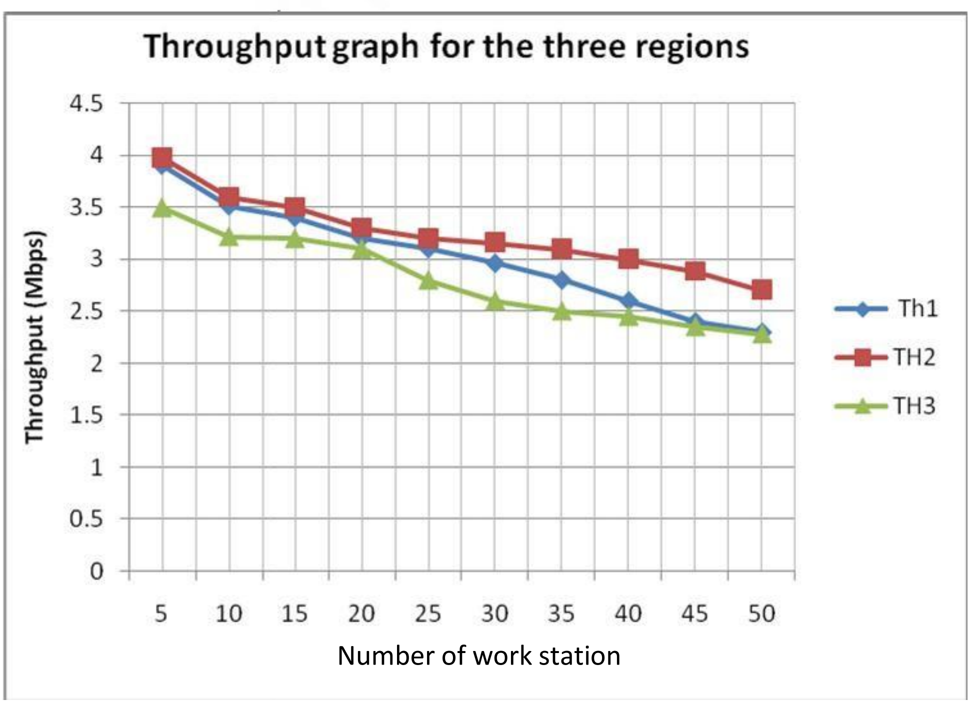

Figure 4 Graph of Throughput for the three regions

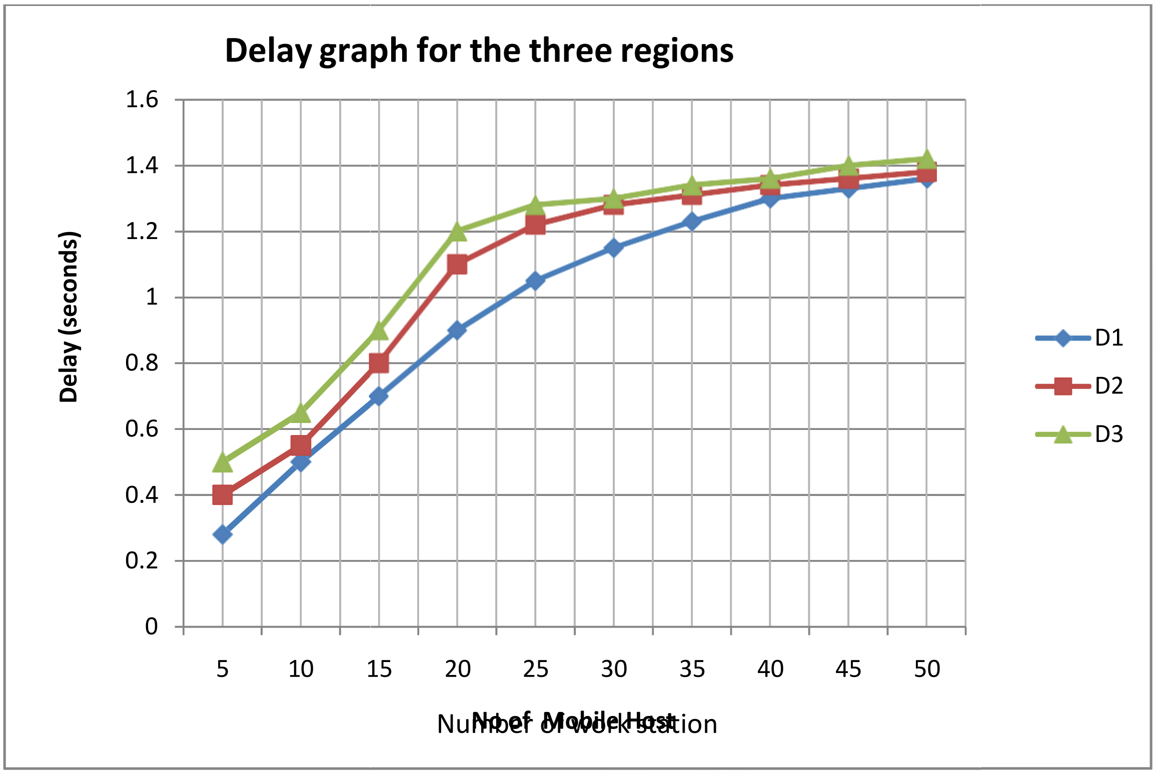

Figure 5 Graph of delay against number of work stations

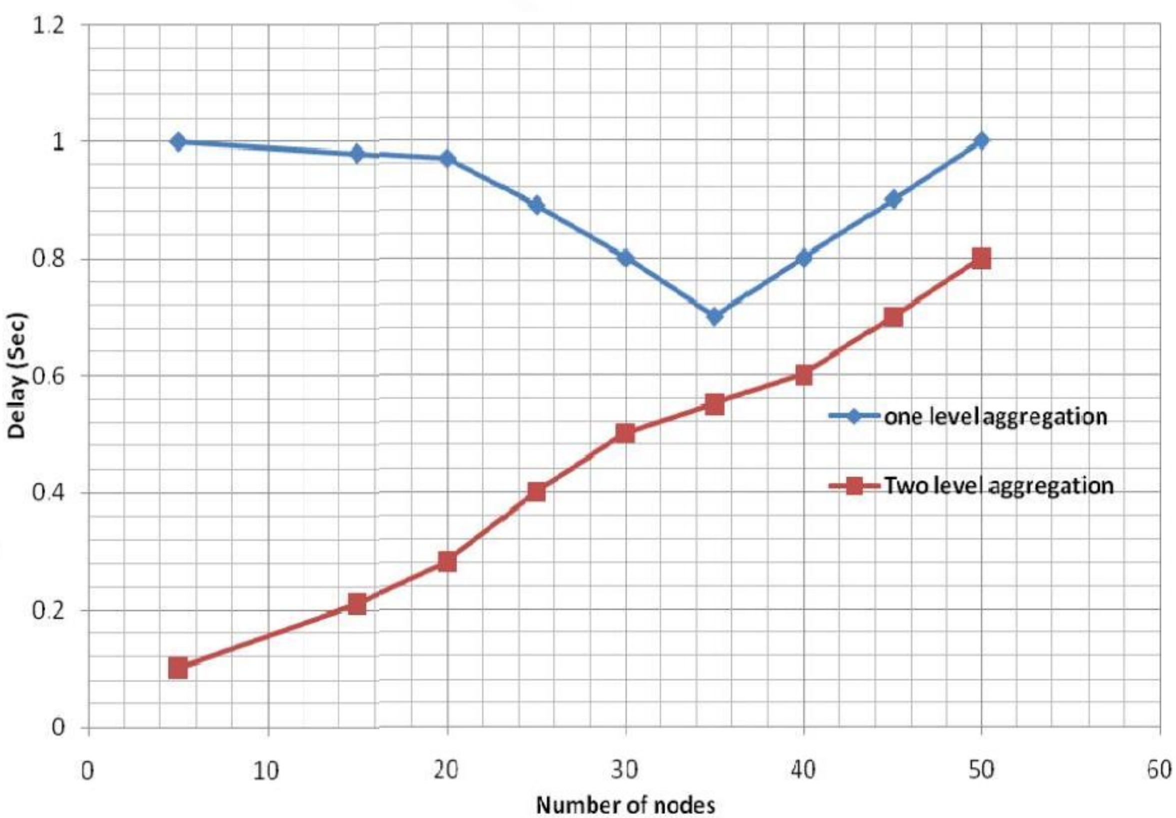

Figure 6 Delay vs. increased Number of nodes

3.2. Mean packet delay

Fig. 5 compares the proposed model simulation result and field work result of IEEE 802.11DCF by plotting the mean packet delay against number of workstations at 11Mbps packet data rate. In this graph, at minimum number of stations and low traffic, the proposed model significantly increases the mean packet delay under network load of 80%. In other words, the simulation results report the steady-state behavior of the network and have been obtained with the relative error less than 15%, and at the 85% confidence interval.

3.3. Delay

In figure 6, we compare delay with two frame aggregation thresholds. We can notice that Frame aggregation is very effective in the case of saturated traffic; otherwise it has to wait for further packets to arrive which increase the delay. Especially, packets that arrive earlier suffer more due to this that is what caused the sudden rise in delay for both curves when the offered load is below 10Mbps. The delay for the one level aggregation initially was highest suggesting that few frames were available for concatenation and slowly reduces as the sources were further increased to saturation when the delay started increasing exponentially again.

3.4. Overhead

Figure 7 and Figure 8 depicts the overhead for various frame aggregation schemes. For both aggregation schemes, each transmitted frame is followed by a distributed inter-frame space (DIFS), which denotes the maximum waiting time for receiving an acknowledgment frame. The overhead encountered in one level as well as in the two-level aggregation shows that the two level aggregation mechanism provides much enhancement by reducing the packet overhead. When the payload is 1Kbyte, the two level aggregation mechanism achieved about 11% reduction in overhead while the one-level aggregation achieved about 1% reduction in overhead.

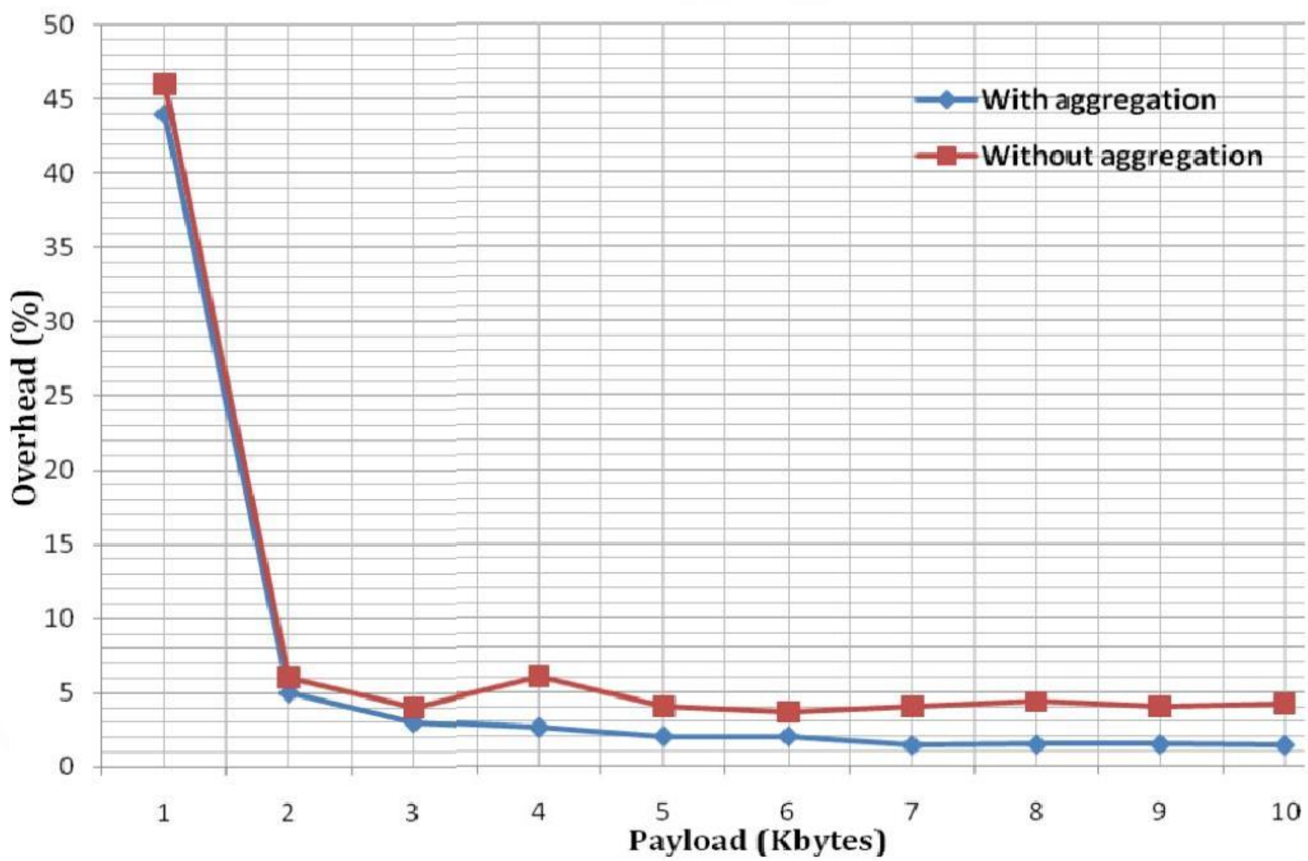

Figure 7 Overhead vs. increased payload (one level aggregation)

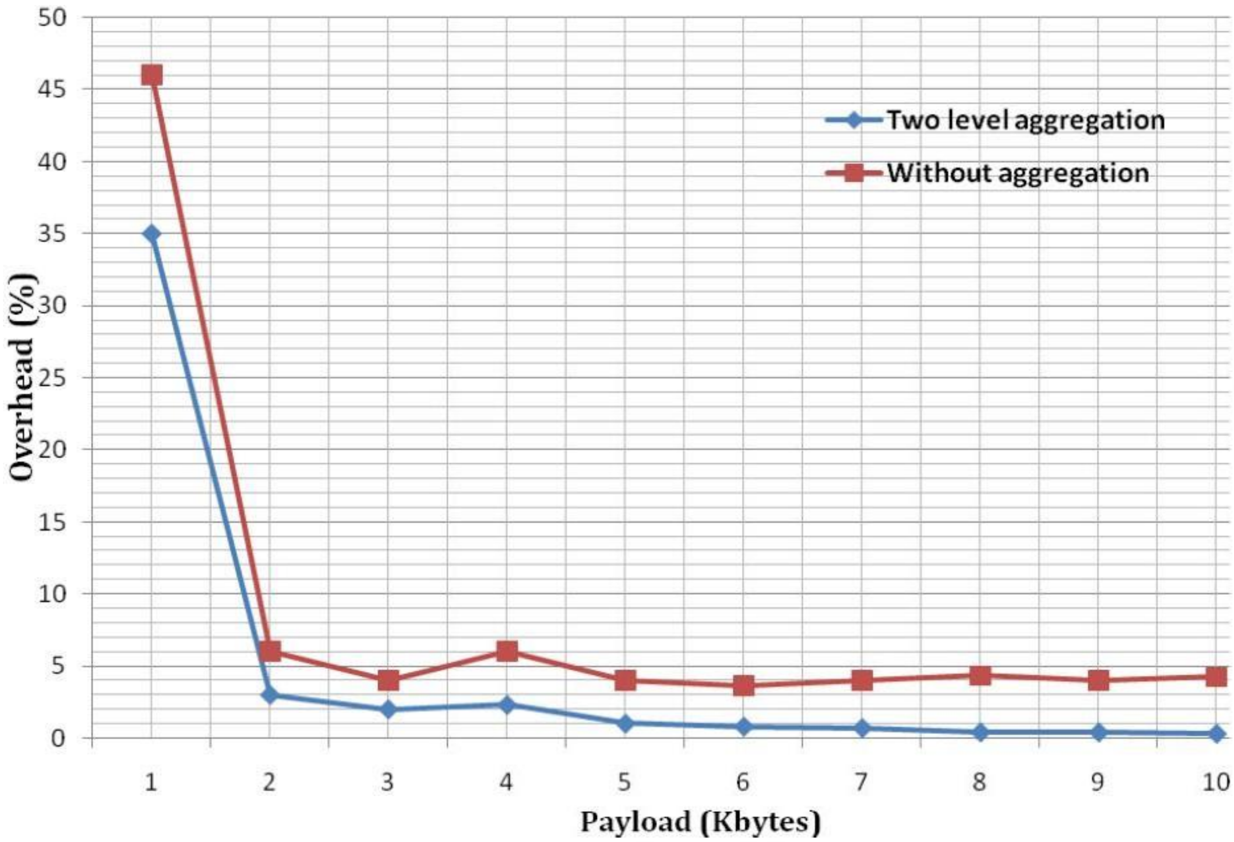

Figure 8 Overhead vs. increased payload (Two level aggregation)

3.5. Simulation Results

In this research, two important network performance metrics were considered:

(1) Network throughput; and

(2) Mean packet delay

The throughput (measured in Mbps) is defined as the fraction of the total channel capacity that is used for data transmission. The mean packet delay at station is defined as the average time (measured in seconds) from the moment the packet is generated until the packet is fully dispatched from that station. A packet arriving at station *i* experiences several components of delay including queuing delay, channel access delay and packet transmission time.

Efficient techniques in the analysis, monitoring, evaluation and design of networks requires communication networks capable of providing an ever increasing spectrum of services. More often times than not, analyses are continually faced with ever increasing user demands and ambiguity about the evolution of the network systems. To meet the requirements of users, three different traffic distributions were used, in order to ascertain the best traffic distribution for the proposed model. Since, Traffic Analysis is a vital component to understand the requirements and capabilities of a network. As a result, the study of traffic models to explore the features of the models and discover eventually the best traffic model, for a concerned environment has become a crucial and beneficial task. Consequently, good traffic modeling is also a basic condition for precise capacity planning. The result of the three traffic distributions shows that Gamma traffic distribution has the best performance in terms of throughput and mean delay whereas Exponential traffic distribution has the least performance in terms of throughput, while geometric traffic distribution also has the least performance in terms of delay.

In other words, Gamma traffic distribution was used for the proposed model because of its high performance amongst the three traffic distribution listed above.

4. CONCLUSION

Using simulation experiments we gained an insight into the performance of IEEE 802.11b WLANs under high traffic load conditions. Clearly, the existing IEEE 802.11b WLANs cannot be used for high bandwidth real time applications serving large number of users.

Therefore, to achieve an optimum network performance the IEEE 802.11b WLAN requires an improvement. Although various enhancements to the original IEEE 802.11 protocol have been proposed recently, the problem of efficient channel utilization, higher throughput, lower mean delay and good fairness has not been fully solved yet. More research is needed in the areas of MAC protocol design and performance improvement of IEEE 802.11b-based WLANs. Also, from the simulation model, it is evident that the throughput performance of IEEE 802.11b WLAN can be improved by using efficient frame aggregation mechanism. It was shown that the throughput performance depends on a number of parameters which include but not limited to the number of nodes, exponential back-off, physical transmission rate, delay and overhead. These parameters determine the throughput performance of the WLAN. We therefore conclude from our simulation results that the throughput performance of IEEE 802.11b WLAN can be improved to a maximum throughput of about10.6 Mbps using two-level frame aggregation.

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