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PERFORMANCE EVALUATION OF WIRELESS LOCAL AREA NETWORK (WLAN)

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Abstract

Communications and data networking fields have being greatly influenced by the use of wireless networks which provides flexibility and mobility for end users for peer to peer as well as client server architectures. With Wireless Local Area Networks (WLANs), applications and services can easily be provisioned to users. In order to analyze the performance of WLANs effectively, it is imperative to identify and study those network settings that can impede the network performance under its physical characteristics. Low throughput, high packet loss rate, delayed round trip time (RTT), increased retransmissions, bit error rate, signal to noise ratio (SNR) and increased collisions are the network characteristics to understudy so as to guide against poor network performance. Using OPNET Modeler as the simulation platform, a simulation test-bed with varying load intensities is presented in this research work to evaluate the performance of 802.11 WLAN and the impact of the four major metrics namely: throughput, SNR, packet loss ratio and delay on the performance of WLAN. The results of the simulation study indicates that appropriate adjustment of the protocol parameters will enhance the performance of Wireless LAN and improve the services that IEEE 802.11 provides to various common applications.

Keywords: WLAN, throughput, IEEE 802.11, packet loss

1. Introduction

The technological advances in the field of information, communication and technology have pushed the wireless networks in to a league, where these are spearheading the all other current technologies because of the ease, mobility and transmission and reception of the timely as well as secured data [1]. In recent years, WLANs have been widely deployed to provide high bandwidth wireless connections for various applications [2], but it is known that Internet traffic in such networks is delivered end-to-end between hosts by Internet protocol (IP) [3]. The following situations justify the use of wireless technology particularly WLANs:

- To span a distance beyond the capabilities of typical cabling.
- To provide a backup communications link in case of normal network failure.
- To link portable or temporary workstations that are Wi-Fi enabled.
- To encourage mobility and overcome situations where normal cabling is difficult or financially impractical.
- To remotely connect mobile users or networks.

The Institute of Electrical and Electronics Engineers IEEE have developed the 802.11 standard families, in order to deal with the modern wireless connectivity needs. Over the years, the IEEE 802.11 protocol has become a mature technology, achieved worldwide acceptance and turned into the dominating standards for WLANs. The 802.11b standards support dynamic data rates up to 11 Mbps, using Direct Spread Spectrum Sequence (DSSS) and Complementary Code Keying (CCK). It defines a set of overlapping 22MHz wide channels in the unlicensed 2.4GHZ industrial standard medical (ISM) band. And it is backward compatible with 802.11 DSSS up to 2mbps [4]. The IEEE 802.11 standard includes detailed specifications for both the medium access control [MAC] and the physical layer [PHY]. The MAC incorporates two different medium accesses. Methods for WLANS the compulsory Distributed Co-ordination function (DCF) and the Optional Point Co-ordination Function (PCF) . DCF defines two access mechanisms to be employed during packet transmission. The default scheme is called the Basic access method mechanism, which is based on Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), in which stations transmit data packets after deferring when the medium is busy.[5] The 802.11 standard also provides an optional way of transmitting data packets, namely the request to send/clear to send reservation scheme. This scheme uses small RTS/CTS packets to reserve the medium before large packets are transmitted in order to reduce the duration of a collision. Also the RTS/CTS reservation scheme is used to combat the hidden stations problem [6].

An effective method to study wireless networks is network simulation which has been used by researchers all over the world in recent years. However, it is evident that in WLANs, the wireless signal propagation includes some intrinsic effects such as multipath fading, path loss, and shadowing fading, which are dynamic, random, and relevant to environments. Thus, it has become a challenge to obtain accurate performance evaluations of WLANs via modeling and simulation, especially in packet-oriented simulations. Some simulation experiments seldom consider the effects of Rayleigh fading and shadowing fading in wireless signal propagation, so lead to over-optimistic simulation results. This research carries out an analysis of WLAN signal propagation effects as well as using throughput, SNR, packet loss ratio, and delay as important metrics in a developed case scenario.

In [7], the authors identified the various effects on radio signal strength due to the change in antenna height, elevation change, and the distance between the transmitter and the receiver. Consequently, a Terrain Modeling Module (TMM) base on OPNET was proposed. The TMM was used to characterize the channel of the wireless communications using Free Space propagation model and Longley-Rice propagation model. The first contribution of the work was to simulate radio signals being distributed over the varying terrain to see the changes in the signal strength. These signal strength are observed as the receiver is moved over a simulated path that goes through many elevation changes. Secondly the work simulated the RTS/CTS mechanism to evaluate the performance of IEEE 802.11 MAC protocol. The performance evaluation was ascertained by analyzing the different network statistics such as data traffic sent/received, WLAN Delay, network throughput.

Gerd Vandersteen et al in [8] opined that OFDM modulation schemes are widely used in telecommunication systems. Examples are Asynchronous digital subscriber line (ADSL) modems, WLAN applications. The paper in essence presented an approach for efficient estimation of the BER in multicarrier systems such as OFDM-based WLAN transceivers. A figure of merit for the quality of a digital telecom transceiver is the bit-error-rate (BER). This is typically determined using an end-to-end Monte-Carlo simulation, that comprises the digital part of the transmitter, the analog front-end of the transmitter, the transmission channel, the receiver front-end and the digital part of the receiver. At the receiver side it is checked whether these symbols have been transmitted correctly. For low bit-error rates (values of 10-5 or lower), a large amount of symbols needs to be transmitted, leading to lengthy simulations. The work discussed the characteristics of OFDM signal as follows:

$$x(t) = \sum_{i=1}^{N} a_i(t)\cos(\omega_i t) + b_i(t)\sin(\omega_i t) \qquad (1)$$

Where all carriers are modulated using a separate modulation scheme such as Phase Shift Keying (PSK), Quadrature Amplitude Modulation (QAM). From equaution (1), the modulations are represented by a_i and b_i. For some values of a_i and b_i, large peaks can occur. The large signal peaks can lead to severe nonlinear distortion (e.g. clipping), which can increase the BER significantly. A practical measure to characterize an OFDM signal is the crest factor (CF). This is the ratio of the maximum amplitude of the transmitted symbol over the root-mean-square value of all possible symbols and it is given by CF=MAX(x)/rms.

The work explained that starting from the probability density function (Pdf) of the crest factor, the best linear approximation and the noise level of the in-band nonlinear distortion; the BER can be estimated using:

$$BER = \int BER(x) f_{CF}(x)dx \qquad (2)$$

This method shows an the efficient estimation of the BER in multicarrier systems such as OFDM-based WLAN transceivers.

P. Chatzimisios et al in their work in [9] presented a performance analysis of WLAN in presence of bit errors. In the work, their major goal was to derive a formula for the throughput and packet delay of IEE 802.11 WLAN under an error-prone environment; in a realistic environment, under the assumption of an error-free channel is not always true and accurate. The work used Markov chain in [10] and [11] under the assumption that packet retransmissions are unlimited Assuming that the network consists of *n* contending stations, each one always having a packet available for transmission. The key assumption is that the collision-error probability of a transmitted packet is constant and independent of the retransmissions that this packet has suffered in the past. Saturation throughput, average packet delay, Bit error rate (BER) and packet error rate were considered for the for the Orthogonal Frequency Division Multiplexing (OFDM) physical layer used in the 802.11a [12]. The authors concluded that their analytical model can calculate throughput and delay performance for IEEE 802.11a WLAN protocol in the presence of transmission errors. Their analytical results illustrate that transmission errors considerably affect protocol performance. When BER increases, throughput degrades and packet delay increases. Furthermore, the work indicated that the performance of RTS/CTS scheme is less sensitive on the network size than the basic access scheme but is highly affected by transmission errors.

This research work is focused on a one stage BSS model considering an FTP and HTTP services transacting under characteristic physical conditions like fading and path losses. A simulation test-bed that will provide stable throughput, SNR, packet loss ratio, delay, and utilization for APs with lower packet losses and a fair level of Quality of Services for all traffic sources is developed. Also, the considered parameters in this research includes namely: throughput, SNR, packet loss ratio, delay, and utilization in the scenarios. OPNET modeler will be used to achieve this scope.

2. Overview of WLAN

According to [3], a WLAN is a data transmission system that has the ability to provide location independent network access between communication devices. It uses high frequency radio waves for communication and operates in the unlicensed Federal Communications Commission (FCC) 2.4 GHz and 5 GHz Industrial, Scientific, and Medical (ISM) frequency bands. The Institute of Electrical and Electronics Engineer (IEEE) 802 committee wrote the IEEE 802.11 standard that specifies the 802.11 MAC layer protocols. IEEE 802.11 standard outlines Medium Access Control (MAC) and Physical (PHY) layer functionality for fixed as well as mobile devices and defines Basic Service Set (BSS) as the building block of an 802.11 WLAN that consists of any number of 802.11 stations (STAs). There are several 802.11 standards for WLANs technology, including 802.11a, 802.11b, and 820.11g [6]. Main characteristics of these standards are summarized in Table 1. The 802.11 standards share many characteristics; they all use the same medium access protocol, use the same frame structure for their link layer frames, have the ability to support multiple transmission modes in order to reach out over greater distances and allow for both infrastructure mode and ad hoc mode. However, as can be from Table 1, 802.11 standards have some major differences at the physical layer.

Table 1: Summary of IEEE 802.11 Standards

Standard	Frequency range	Data Rate
802.11a	5.1-5.8GHz	Up to 54Mbps
802.11b	2.4-2.485Ghz	Up to 11Mbps
802.11g	2.4-2.485Ghz	Up to 54Mbps
802.11n	2.4-5Ghz	Up to 248Mbps

The 802.11a WLANs operate in the 5 GHz frequency range and can offer transmission rate up to 54 Mbps, but they have a shorter transmission distance for a given power level and suffer more from multi-path fading. The 802.11b WLANs have data rate of 11 Mbps and operate in the unlicensed frequency bands of 2.4 – 2.485 MHz, competing for frequency spectrum with 2.4MHz phones and microwave ovens. 802.11g WLANs operate in the same lower frequency band as 802.11b, but with the higher transmission rate of 802.11a. They employ Orthogonal Frequency Division Multiplexing (OFDM), the modulation scheme used in 802.11a/g WLAN, to obtain higher data rate and can fall back to speeds of 6 Mbps. This feature makes 802.11b and 802.11g WLAN devices compatible within a single network. The 802.11n is a proposed amendment, which improves upon the previous standards by adding multiple-input multiple-output (MIMO) and many other new features.

2.1 The 802.11 Architecture

Figure 1, depicts the principal components of the 802.11 WLAN architecture. An 802.11 WLAN is based on a cellular architecture where the system is subdivided into cells. Each cell, called Basic Service Set (BSS), is controlled by a Base Station called Access Point (AP). When a WLAN is formed from several BSSs, APs are connected through a backbone network, typically Ethernet, called a Distribution System (DS). The whole interconnected WLAN including the different BSSs with their respective APs and the DS is called an Extended Service Set (ESS). Wireless LANs that deploy APs are often referred to as infrastructure wireless LANs.

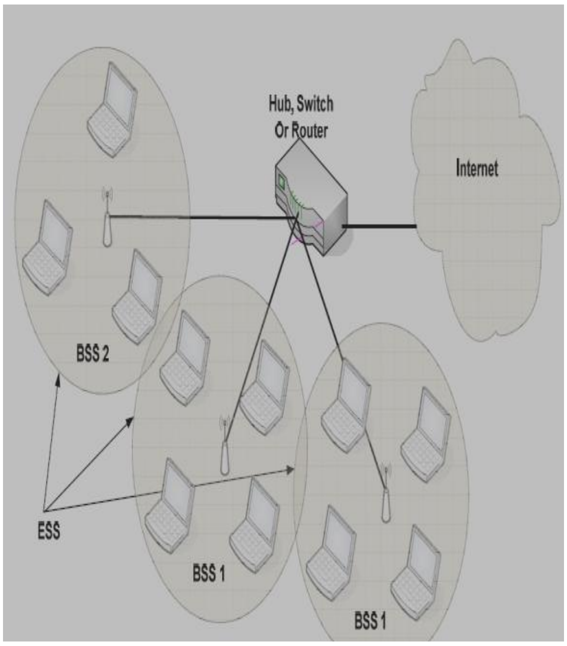

Figure 1. IEEE 802.11 WLAN Architecture [6]

Each Wireless LAN cell requires some communications traffic management. This is coordinated by an Access Point which communicates with each wireless station in its coverage area. Stations also communicate with each other via the AP so communicating stations can be hidden from one another. In this way, the AP functions as a relay, extending the range of the system.
The AP functions as a bridge between the wireless stations and the wired network and the other wireless cells. Connecting the AP to the backbone or the other wireless cells can be extended by cascading several wireless links one after the other. When any area in the building is within the reception range of more than one access point the cells' coverage is said to overlap. Each wireless station automatically establishes the best possible connection with one of the access point.
The Roaming facility allows mobile users with portable stations to move freely between overlapping cells, constantly maintaining their network connection. Roaming is seamless; a work session can be maintained while moving from one cell to another. Multiple access points can provide wireless coverage for an entire building or campus. When coverage area of two or more APs overlap, the best possible connection is established. In order to minimize packet loss during switch over, the "old" and "new" APs communicate to co-ordinate the process.

Basic service set (BSS)

The smallest building block of a wireless LAN is a Basic Service Set (BSS), which consists of some number of stations executing the same MAC protocol and competing for the access to the same shared medium. A BSS may be isolated or it may connect to a backbone distribution system through an Access Point (AP) which in a typical LAN configuration, is a transmitter/receiver (transceiver) device. The Access Point functions as a bridge. It receives buffers and transmits data between the wireless LAN and the wired network infrastructure. A single Access Point can support a small group of users and can function within a range of less than one hundred to several hundred feet. The Access Point (or the antenna attached to the AP) is usually mounted high but may be mounted essentially anywhere as long as radio coverage is obtained. End user access the Wireless LAN through Wireless-LAN adapters, which are implemented as PC cards.

Extended Service Set (ESS)

An Extended Service Set (ESS) consists of two or more basic service sets interconnected by a distribution system. The ESS appears as a single logical LAN to the Logical Link Control (LLC) level [6]. A station in the extended service set can either be mobile or stationary. The mobile stations are the normal stations in basic service set e.g laptop or any handheld device, while the stationary stations are stations like the access points which are not moved about in the network.
However, when we have two basic service sets connected together, two stations in the two different basic service sets can communicate through the two access points in the basic service sets. But the two stations can as well communicate without the use of the access points.
The reliable coverage range for 802.11 WLANs depends on several factors which are:

- Data rate required and capacity.
- Sources of RF interference.
- Physical area characteristics.

Theoretical ranges are from 29meters (11Mbps) in a closed office, to 485meters (1Mbps) in open area. Through empirical analysis, the typical range for connectivity of 802.11equipment is approximately 50 meters (163 feet) indoors. A range of 400 meters, nearly ¼ mile makes WLAN the ideal technology for many campus applications. It is important to recognize that special high gain antennas can increase the range to several miles [5]. Figure 2, shows that 802.11 stations can actually group themselves together to form an Ad hoc network; a network with no central control and with no connection to the Internet. In this type of network, several wireless stations join together to establish a peer-to-peer communication. Each client communicates directly with the other clients within the network. Ad hoc mode is designed such that only the clients within the transmission range of each other can communicate. If a client in an ad hoc network wishes to communicate outside the cell, a member of the cell must operate as a gateway and perform routing. They typically require no administration and share the network resources without a central server. However, this research will focus its studies on the BSS WLAN architecture.

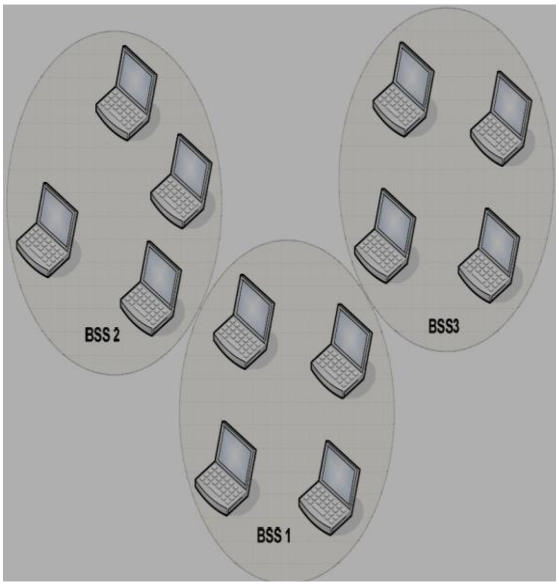

Figure 2: An IEEE 802.11 Ad hoc network (Independent Basic Service Set Topology) [6]

2.2 Advantages and Limitations of WLAN

The following are the advantages of wireless LAN over Wired LAN;

- Flexibility
- Simplicity
- Mobility
- Increased productivity
- Cost savings compared to wired networks
- Ease of installation and expansion.

There are certain limitations associated with wireless local area networks. These include;

- Range and coverage depends on the transmission power and receiving capabilities of the transceiver. They also depend on the path to be taken for the data.
- Radio interference can cause degradation in throughput. So design considerations are important fact in the case of wireless local area network.
- Throughput is affected by the number of users, range and type of wireless local area network systems used. If the number of clients increased for a particular access point throughput will reduces.
- . Products that transmit energy in the same frequency spectrum can potentially provide some measure of interference (devices like Micro Owen).
- . It is a major consideration related to wireless local area network, but now complex encryption techniques gives greater security provisions equivalent to wired network.

2.3 Evaluation Metrics

Throughput

Throughput in communication terms is defined as the average rate of successful message delivery over a communication channel. It is a useful term in both packet radio (which includes WLANs) and Ethernet. This data may be delivered over a physical or logical link, over a wireless channel, or one that is passing through a certain network node, such as data passed between two unique computers. Throughput is usually measured in bits per second (bit/s or bps) and sometimes in data packets or frames per second. Other variants of throughput that are measured depending on the context include: aggregate throughput, Maximum throughput and Good put. Goodput is a better measure of if one is particularly concerned with the amount of actual useful information that is delivered. The throughput can be analyzed mathematically by means of queuing theory, where the load in packets per time unit is denoted arrival rate λ, and the throughput in packets per time unit is denoted departure rate μ. Factors affecting throughput include analogue limitations (such as RC losses, skin effects, termination and ringing and wireless channel effects), IC hardware considerations, protocol considerations and multiuser consideration amongst others.

Delay

Delay in communication terms is a measure of the delay in the delivery of data to the endpoints. It is measured in the unit of time (typically in milliseconds). Delay could be in form of processing delay, queuing delay, transmission delay, and/or propagation delay.

- Processing delay –This is the time routers take to process the packet header

- Queuing delay – This is the time the packet spends on the routing queues
- Transmission delay – This measures the time it takes to push the packet's bits onto the network link
- Propagation delay – This is the time it takes for the signal to propagate through the medium it is being transmitted through.

Packet Loss Ratio

This refers a situation where packets in a network fail to reach their destination due to break in the link, corruption of packets, or buffer overflow. The amount of packet loss in a network is typically expressed in terms of the probability that the network will discard a given packet. The loss is measured by rate – the number of packets lost, out of the total number transmitted.

Signal to Noise Ratio

Signal-to-noise ratio (often abbreviated SNR or S/N) is a measure used in science and engineering that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power. A ratio higher than 1:1 indicates more signal than noise.

3. Research Methodology

In this work, a BSS Baseline WLAN experimental test-bed that has the characteristic PHY models discussed above was constructed by altering the OPNET 802.11 standard WLAN model and incorporating a number of features into the OPNET MAC attribute. The architecture modeled is that of an infrastructure BSS in three sites with a single fixed AP per site and a variable number of mobile STAs starting from 0-30 nodes. The infrastructure BSS was chosen vice the independent BSS as it will likely be the configuration of choice in home, office, or campus environments. The 802.1l MAC and PHY layers are identical in both the AP and the STA node models with the exception of several user defined attributes that will be covered in greater detail later. Layers above the MAC in the node models are somewhat different, since the AP has to interface with the other sites. Traffic was injected into the three BSS architectures during the simulation setup. Trace files of captured wireless traffic from the model was used in the analysis.

From figure 3, a single fixed AP and thirty mobile stations (STAs) were chosen as the WLAN configuration for the simulation. This small WLAN was selected both to limit the scope of the simulation and to achieve reasonable simulation durations.

The two arrows in Figure 3 represent the path of each station as the simulation progresses, with STA distances from the AP varying. In general, thirty STAs are closing the AP while the AP is moving away from it in the model. Throughout the course of the simulation, each STA remains within 35m of the AP so as to maintain the SNR required supporting the data rate of 11-54 Mbps used in the simulation as well as to optimize and analyze the BSS baseline metrics used in this work. The effects of extended ranges and their impact on the link SNR, throughput, packet sizes, utilization, delay and data rate are explored

In the test-bed, each WLAN 802.1 STA node model is called wlan_wkstn_adv_ll, while the AP node model is called Wlan_ethernet_router_adv_ll. These two node models are used in tandem to create an 802.11 BSS infrastructure WLAN within the OPNET design environment. The WLAN_ethernet_router_adv_lla has three interfaces for connection to the distribution system, (DS) linking WLAN site 1, 2 and 3. Again, a wlan_mac_lla node object represents the 802.11 WLAN MAC in each node model, while the wlan_port_tx and wlan_port_rx objects represent the components of the WLAN transceiver. The wlan_mac_l1, wlan_port_tx, and wlan_port_rx node objects and their interactions form the basis of the OPNET 802.11 baseline test-bed.

The behavior of wlan_mac_11 was modeled to be governed by a number of user-defined parameters, lumped under the Wireless LAN Parameters attribute and selected via an OPNET graphical user interface. Again, the OFDM Physical characteristics attribute ensures that the correct values for the SIFS time, slot time, and minimum and maximum contention window size are defined when the simulation begins. It also provides for the definition of the 802.11 PLCP preamble and PLCP header transmission durations, which are used by the stations to correctly set their NAVs when RTS/CTS is enabled by selection of a non-zero RTS threshold value. The RTS Threshold can take any value up to 2347. The short and long retry limits delineate the number of times a STA may attempt to retransmit frames that are shorter or longer, respectively, than the RTS Threshold value. The AP functionality parameter lets the user identify the AP in a BSS if the WLAN is an infrastructure WLAN.

The data rate attribute is provided for the user to select the maximum operational rate for the exchange of data frames within the WLAN by a given STA. To determine the correct control frame rate, a function was added to the wlan_mac_lla process model to select the highest possible control frame speed given the data frame transmission rate. In addition, the STA may receive frames from another STA that might not be operating at the same data transmission rate. The receiving STA must

then determine the speed at which to respond with either a CTS or ACK frame based on the incoming frame type. The capability to deal with this scenario was added to the wlan_Mac_lla process model Proto-C code using a mechanism similar to the function described above.
Once the transmission data rate of a given frame has been determined, the frame must then be passed to the PHY layer for transmission. The use of transmitter and receiver node objects to model the PHY layer facilitated the process model design. Again, the overhead associated with the PHY layer under high traffic condition is ignored since the goal is just to analyze the amount of MAC layer traffic handled by the WLAN vis-à-vis SNR,PLR and BER.

3.1 BSS - Baseline Model Simulation Description

The BSS baseline model in figure 4 was used in an OPNET simulation to test and verify WLAN performance vis-à-vis throughput, Signal to Noise ratio, packet loss ratio and load delay. The goal of the simulation methodology is to confirm proper operation of the model in relation to the analysis of the BSS test-bed behavior or examining a specific network performance characteristic. The simulation was conducted using a variation of the OPNET 802.11 standard model's wlan_deployment scenario for WLAN case_30Nodes, 20Nodes and 10Nodes. In these scenarios, the behavior of a single infrastructure BSS test-bed WLAN comprising an AP, terminal nodes (30) each was examined within the framework of a deployed WLAN to better emulate the configuration of an actual network. The scenario consists of a wireless and a remote TCP server network. The purpose of the scenario in context is to demonstrate the inter-communication between the wireless and the remote network through the internet backbone while evaluating the performance of the WLAN tested.
This work varied the load intensities for the three case scenarios, namely: WLAN_CASE_30Nodes, WLAN_CASE_20Nodes, and WLAN_CASE_10Nodes. In all cases, the site_1 and site_2 subnets each contain 30 wireless stations per subnet; all stations comply with the wireless LAN (802.11) protocol for OFDM carrier scheme. The Access Point nodes in site_1 and site_2 connect each subnet to the remote network. The clients in the Wireless LAN are configured to communicate with servers at the remote site via IP cloud. The physical characteristics for baseline WLAN such as buffer sizes, fragmentation threshold, RTS threshold, data rates and channel settings were fixed for AP nodes in the two subnets.
In the BSS baseline WLAN design, two dynamic data rate agility mechanisms were considered and implemented in the test-bed. The first mechanism is based on the link SNR while the second is based on the frame loss rate at the transmitting STA. Each technique is first explained and then the simulation results are obtained for each with appropriate comparisons in the context of SNR, PLR and BER. In reality these two mechanisms are not mutually exclusive and they would likely be used in tandem to present the best possible criteria for rate adaptation leading to performance improvements. Furthermore, instead of using a lower threshold, the frame/packet loss rate-based mechanism analyzed in this work used a steady-state waiting period during which the STA may not attempt to increase the data rate after it has been decreased. The drawback to this approach is that a STA might not be able to immediately take advantage of improving link conditions and increase the data rate; however, the advantage in terms of preventing rate oscillations outweighed the potential drawbacks. The threshold for the acceptable frame loss rate was chosen based on the dropped frame rate observed in several trials conducted with the BSS baseline test-bed model.
The first trial scenario consisted of a single high data rate link between a STA and an AP. The traffic profile was that of a continuous low-resolution VTC session between the mobile STA and a client terminal external to the BSS. The STA was given a trajectory that took it beyond the maximum allowable range for successful communications at 6 Mbps. A link failure condition was subsequently observed and the STA then moved back within range of the AP again.
Consequently, for the BSS baseline WLAN model, the simulation carried out in the context of rate agility based on Link SNR and rate agility based on the Frame/Packet Loss Rate will guide WLAN designers on the best design approach considering the effects of throughput, SNR, packet loss ratio and delay.

4. Simulation Result, Analysis and Performance Evaluation

The attributes and parameters of the STAs and AP were configured within the guidelines outlined earlier. Specific WLAN settings used during the simulation are delineated in Table 2. These settings were applied to each STA and AP in the BSS baseline. Channel 52 was chosen here since it is part of the middle UNII band and is ideal for use in a typical office environment so as to analyse the performance metrics outlined in this project. Note that the transmitter output power is set at the value specified for use in the middle UNII band.

Table 2: User Defined PHY WLAN Parameters and simulation characteristics

WLAN PARAMETERS	SETTINGS
BSS Baseline WLAN Data rates	11-54Mbps-802.11a/b/g
Modulation Scheme	OFDM_11-54Mbps
RTS Threshold (Bytes)	2347
Fragmentation Threshold (Bytes)	2500
Bandwidth (KHz)	16kHz
Base frequency (MHz)	5251.7
Transmitter Output Power(W)	0.2
Receiver Noise Figure diB	5.01
AP Functionality	Yes

The data rate attribute is provided for the user to select the maximum operational rate for the exchange of data frames within the WLAN by a given STA. The BSS baseline WLAN model simulation was completed successfully. A number of model performance statistics were collected by the OPNET simulation kernel during the runs. Of those, several are critical indicators used to determine that the model operated correctly. The total load on the WLAN as a function of time as the simulation progressed is one of the more important results. The overall WLAN performance with respect the selected metrics is display in the figures below, for the various load intensities (WLAN_Case_senarios) given in bits per second.

Throughput

Figure 5 shows maximum throughput achieved in BSS topology for the considered case scenarios. It illustrated the maximum throughput achieved in BSS topology for the considered case scenarios. Essentially, this work defined throughput as the data quantity transmitted correctly starting from the source to the destination within a specified time (seconds). The importance of analyzing this QoS parameter is attributed to the fact that an increase numbers of WLAN AP nodes in the wireless domain accounts for increased possibility of interference. This works also, argues that throughput is quantified with varied factors including packet collisions, obstructions between nodes and the type of used topology. During the simulation, throughput as a global statistics was measured for the three WLAN cases scenarios. The plot depicted a general idea of the overall throughput of the system. The case of WLAN_case_30Nodes was observed to give the best throughput curve while the WLAN_case_10Nodes has the lowest throughput response in normalized situations. The plot in normalized mode has the throughput response proportional to the load limits regardless of other network constraints. The reason for this behavior is that the BSS topology communicates on the basis of the enhanced WLAN nodes and APs placement which is efficient in relation to the load limits. Also in BSS topology, total load of the network is divided among the local nodes and APs as a result of which lesser collisions and lesser packet drops takes place. This results in good throughput for the WLAN cases in the BSS topology. A considerable deviation of the nodes from the APs could possibly alter the throughput a careful placement of the AP nodes in WLAN designs will significantly impact the throughput of the WLAN design.

Delay Response

Figure 6 shows the end-to-end delay result of the three case scenarios. End-to-end delay is a measurement of the network load delay on a packet and is measured by the time interval between when a message is queued for transmission at the physical layer until the last bit is received at the receiving node. By inspection, as shown, the network case with 30Nodes and two other cases for BSS baseline have similar end-to-end delay results, while WLAN 10Nodes has lowest end-to-end delay. The reason for this is that in the broadcast domain of WLAN_Case_30Nodes, there are additional convergence constraints which contributes for waited time delay for transmission particularly as they move away slightly from the APS, hence large nodes have much delays compared with lesser nodes in the other subnets in initializing connection to the BSS APs using their service set identifiers (SSIDs). They all have similar end-to-end delay in this simulation, however, the end-to-end delay of the WLAN_case_30Nodes is higher for more than 90% compared with other two BSS cases.

Packet Loss Ratio

Packet loss occurs when one or more packets of data travelling across the network coverage fails to reach their destination, hence affect the line throughput. Packet loss is distinguished as one of the three main error types encountered in BSS Baseline WLAN model. Firstly packet error rate (PER) is the number of incorrectly received data packets divided by the total number of received packets. A packet is declared incorrect if at least one bit is erroneous. The expectation value of the PER is denoted packet error probability p_p, which for a data packet length of N bits can be expressed as

$$p_p = 1 - (1 - p_e)^N \qquad (3)$$

assuming that the bit errors are independent of each other. For small bit error probabilities, this is approximately

$$p_p \approx p_e N. \qquad (4)$$

Under low traffic condition in figure 7, a spurious Packet loss ratio was observed and this was caused by signal degradation over the network medium due to multi-path fading and in figure 10, under high traffic condition, the packet drop ratio was evident because of channel congestion, alongside with corrupted packets rejected in-transit. Other possible causes could be faulty networking hardware, faulty network drivers or normal routing routines. From figure 10, it was observed that WLAN_Case_30Nodes has the highest packet loss ratio owing to oscillatory collision under channel fading conditions followed by WLAN_case_20Nodes and WLAN_case_10Nodes. As such, under fading channel conditions, it will be advisable isolated loads to an optimal number so as to mimize the possiblitity of packet lossses and consequently enhance the throughput expectations

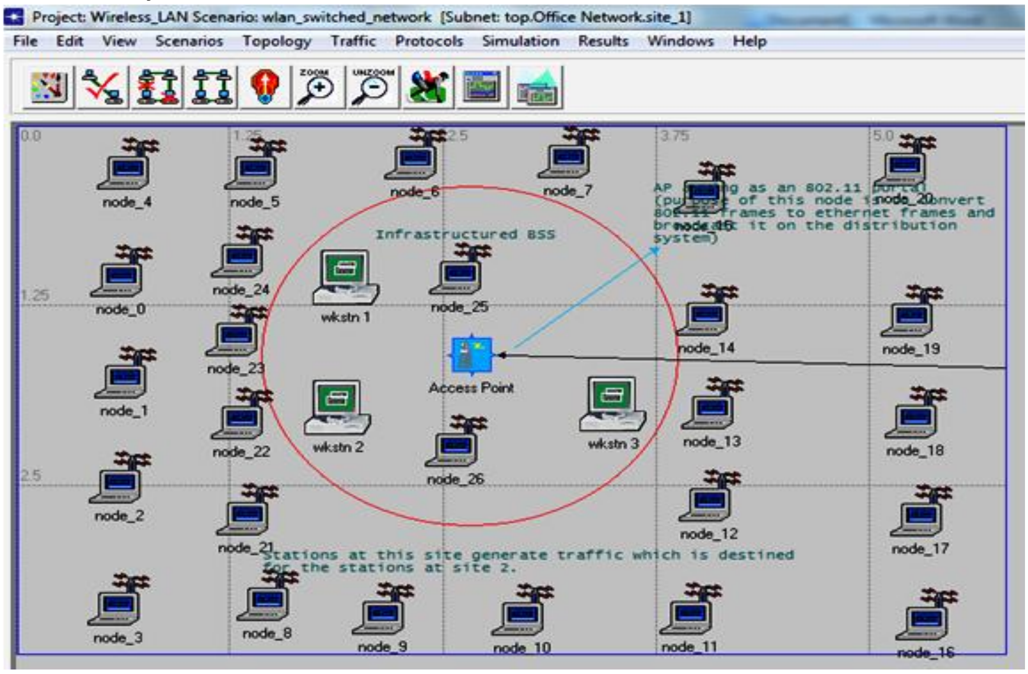

Figure 3: The Simulated 802.11 WLAN BSS baseline testbed STAs in Site_1

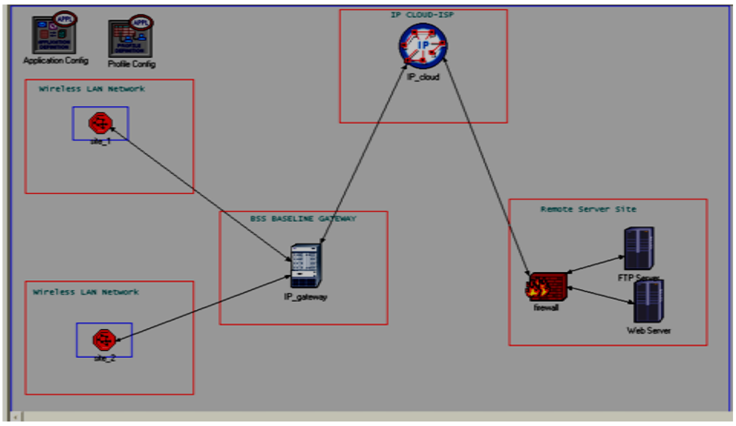

Figure 4. WLAN BSS Baseline Test-bed

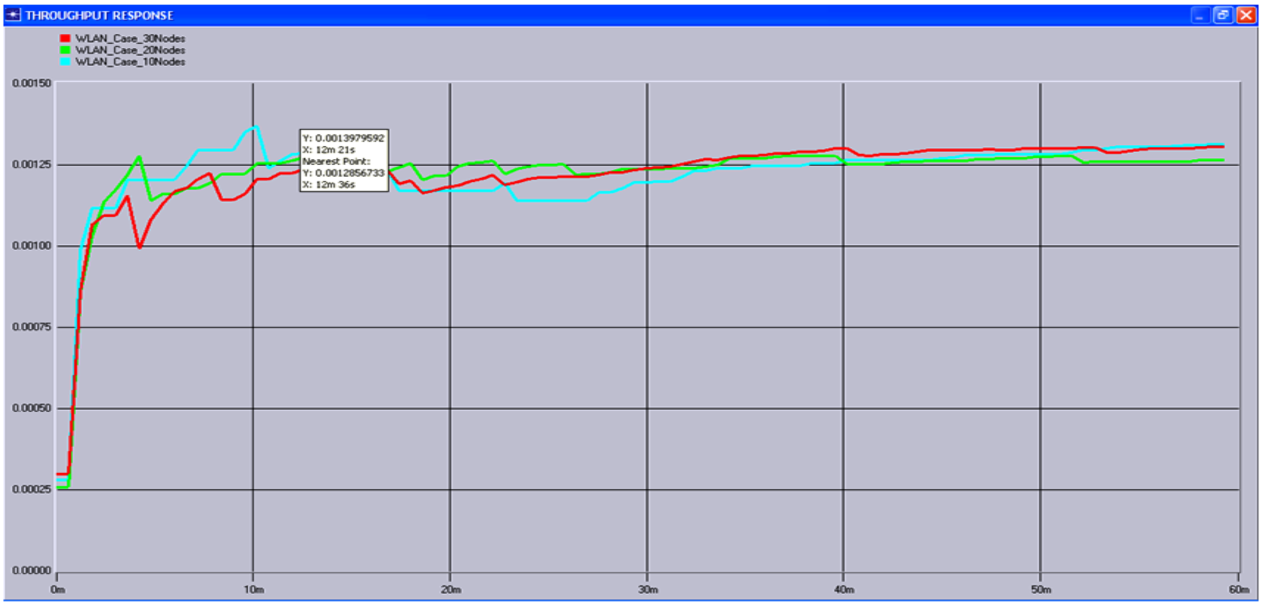

Figure 5 : BSS throughput response

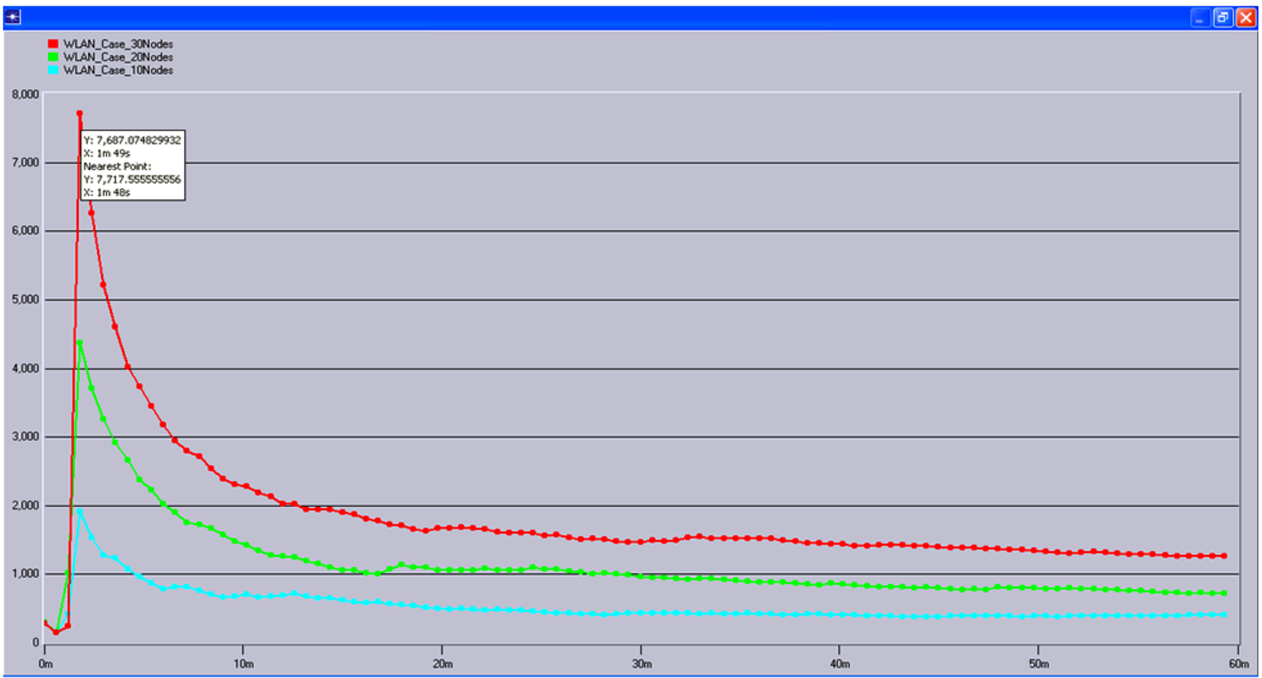

Figure 6: BSS Delay Response

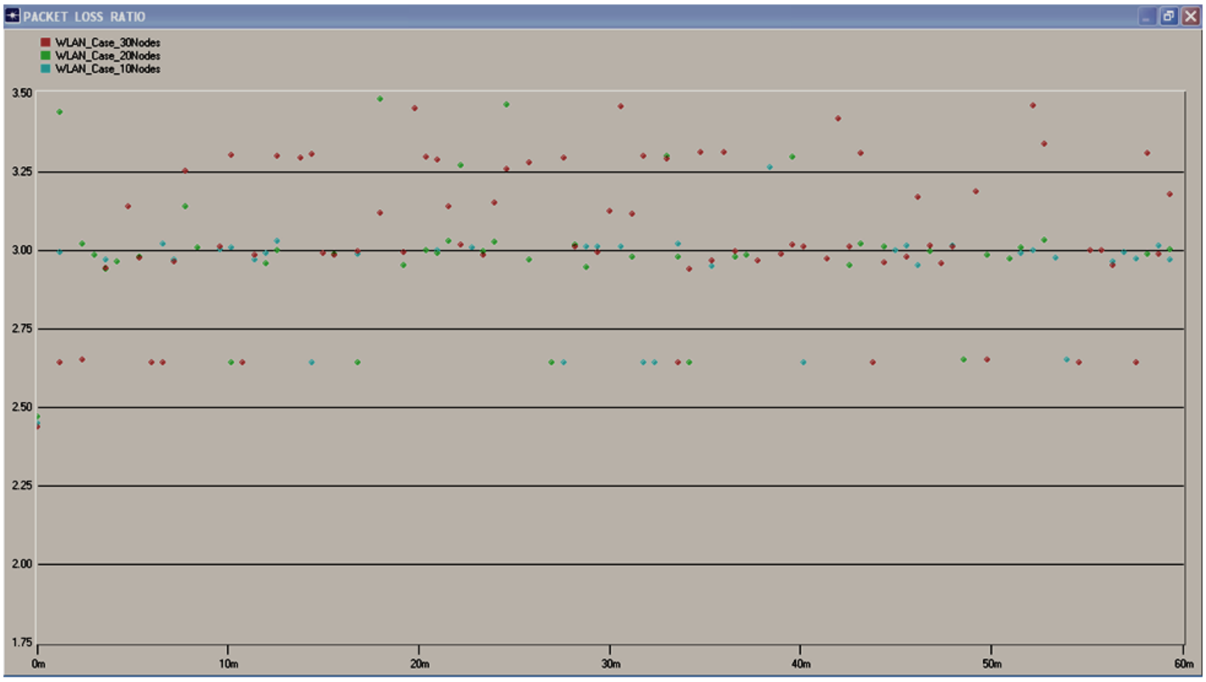

Figure 7: BSS Test-bed Packet Loss Ratio Response on Low traffic

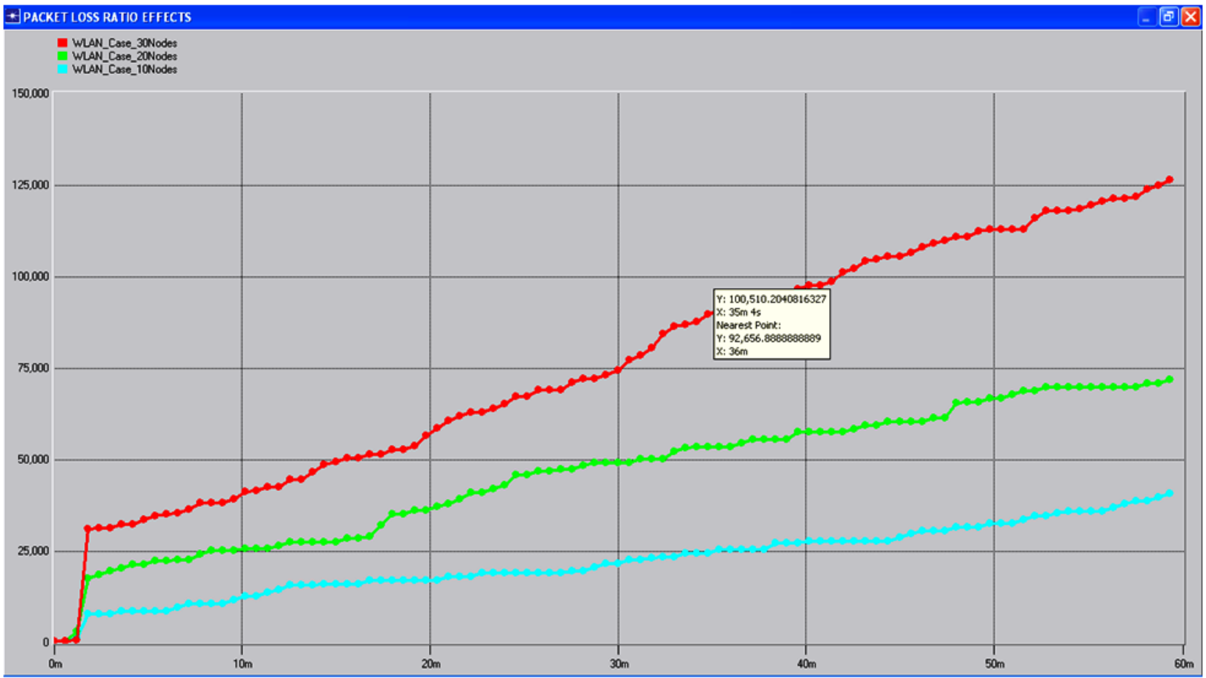

Figure 8: A plot of Packet loss ratio against Load Values Under High traffic Condition

5. Conclusion

A Simulation test-bed of a BSS baseline WLAN is developed in this research work and used to evaluate 802.11 WLAN performances. The work focused on analyzing and evaluating the influence of throughput, SNR, packet loss ratio, and delay on the performance of WLANs. The results presented in this work indicate that careful placement of AP nodes in BSS topology regardless of channel conditions will enhance the performance of the WLAN design. The simulation results obtained using the BSS baseline test-bed is based on the intrinsic properties of the respective BSS devices.
The OPNET environment used in the simulations considered both the MAC and PHY layers of the IEEE 802.11standard. The MAC layer emulates supported 802.11a/b/g data rate, correct medium access, transmission timing relationships, and the optional RTS/CTS mechanism. In any WLAN architecture, trade-offs exist between performance responsiveness and rate vacillation and between providing the best possible AP node placement and ensuring the robustness of the link.

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