Improvement the Performance of the WLAN Subnetwork With Radio over Fiber Solution for Broadband Multimedia Access

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Abstract
The increasing demand for high-capacity multimedia services in real-time demands wireless broadband access. In order to meet this demand, a fiber based wireless access scheme using radio-over fiber (ROF) technology can be used. Fibre-optic media will do better transmitting high frequency radio signals over a longer distance because fibre-optic cables are immune to EMI and noise, provide excessive bandwidth in the region of THz. WLAN parameters such as delay, throughput, data dropped and load at the AP and mobile nodes are examined and analyzed.OPNET Modeler is used to model a WLAN subnetwork deployed within an enterprise WAN framework. Results from the simulated network models show the effect of replacing copper wiring with fibre-optic cables in the WLAN feeder network infrastructure.
Keywords:*WLAN, Radio-over Fiber (ROF),Wireless Broadband Multimedia*

1 - Introduction

A Wireless Local Area Networks(WLAN) is a versatile data communications system deployed either as an extension, or as an alternative to a conventional wired LAN. Majority of WLAN systems use Radio Frequency (RF) transmission technology with a few commercial installations employing the Infrared (IR) spectrum.RF wireless LANs employ either narrowband or wideband radio technology. Narrowband WLANs requires the user to obtain a licence. On the other hand, wideband WLANs use the ISM frequency bands of 915MHz, 2.4GHz and 5GHz, which do not require licences[1,2,3].

The susceptibility of radio signals transmitted in free space to Electro-Magnetic Interference (EMI) and existing regulatory limits are major drawbacks to improving on the distance that can be covered by current WLAN installations.
An effective and efficient way of increasing the coverage of WLANs is to place one or more access points at a central location and distribute the wireless signals from the access points to various antenna locations. Fiber-optic media will do better transmitting high frequency radio signals over a longer distance because fibre-optic cables are immune to EMI and noise, provide excessive bandwidth in the region of THz, and are more secure.
Broadband wireless communications have gained increased interest during the last years. This has been fueled by a large demand on high-frequency utilization as well as a large number of users requiring simultaneous high-data-rate access for the applications of wireless mobile Internet and ecommerce.
Radio over Fiber (RoF) technology, a means of transferring radio signals using optical fibers without changing radio format, has become a candidate for the common platform for wireless access networks. This technology provides a simplified and cost-effective radio access network and supports high-speed multimedia to satisfy the increasing demand when the radio spectrum is limited. It also helps to increase transmission capacity and distance of wireless communication thank to high capability and low transmission loss of optical fiber [4]. However, the applicability of this solution greatly depends on the availability of fiber cable infrastructure and installation costs.
WLANs have started to become more popular, not only within companies and homes, but also as a public hotspot technology. The reason for the popularity of IEEE802.11-based networks are simple: the technology is cheap; for upper layers and applications it performs just as “wireless Ethernet”; and as unlicensed radio technology it is easy to deploy. It is also the only widely available wireless technology to quickly build broadband wireless networks[5,6].
Commercial wireless LANs employ spread-spectrum technology to achieve reliable and secure transmission in the ISM bands although bandwidth efficiency is compromised for reliability. Newer WLAN technologies such as the IEEE 802.11(a)

and (g) are employing Orthogonal Frequency Division Multiplexing (OFDM) schemes.This modulation technique has been adopted for modern wireless communications because it provides increased robustness against frequency selective fading and narrowband interference, and is efficient in dealing with multi-path delay spread[7,8].

A typical WLAN is connected via the wired LAN as shown in Figure 1 below.

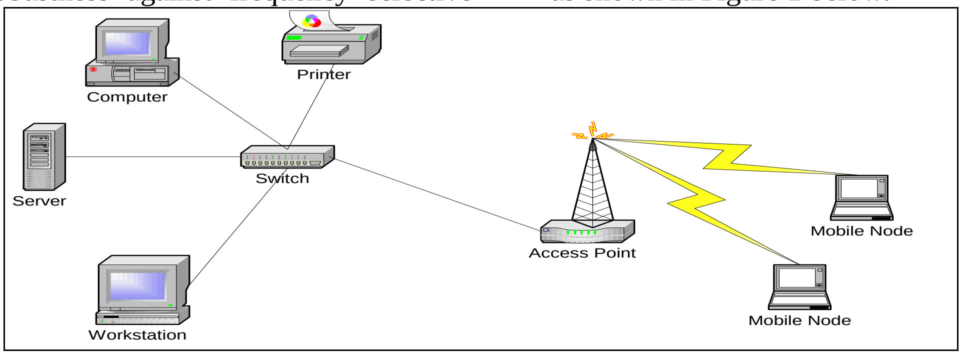

Figure 1: Wireless Local Area Network

2.1- Wireless LAN Standards

Developed as a simple and cost-effective wireless technology for best effort services, IEEE 802.11 has gained popularity at an unprecedented rate. However, due to the lack of built-in quality of service support, IEEE 802.11 experiences serious challenges in meeting the demands of multimedia services and applications[9].

The IEEE 802.11 WLAN standard specifies a Media Access Control (MAC) layer and a physical layer for wireless LANs as shown in fig. 2. The MAC layer provides to its users both contention-based and contention-free access control on a variety of physical layers [10,11].

For wireless networks to go broadband, the capacity of the feeder network must also be increased. The current copper based wired LANs that feed wireless LANs will not be adequate, and they will have to be replaced by high capacity infrastructure – ultimately optical fibre.

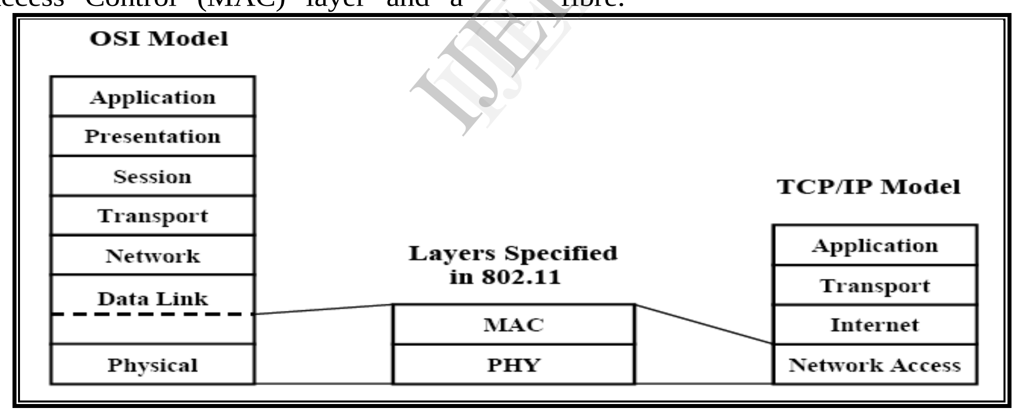

Figure 2: 802.11 and the OSI and TCP/IP Models

2.2 Optical Techniques for Generating and Distributing RF Signals

A system for distributing RF signals over optical fibre consists of a Central Site (CS) and a Remote Site (RS) connected by an optical fibre link or network. For WLANs, the CS would be the head-end while the radio access point would act as the RS. Pioneer Fibre-Radio systems such as the one depicted in Figure 3 were primarily used to transport microwave signals, and to achieve mobility functions in the CS. That is, modulated microwave signals had to be available at the input end of the Fibre-Radio system, which subsequently transported them over a distance to the RS in the form of optical signals [12, 13].

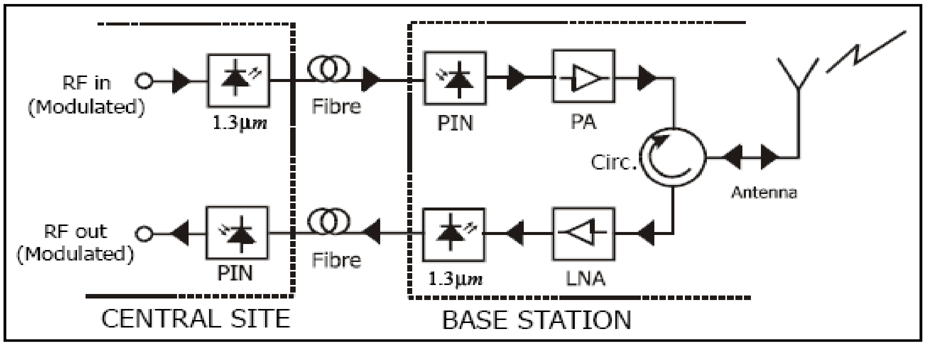

Figure 3: 900MHz Fibre-Radio System [12]

At the RS the microwave signals are re-generated and radiated by antennas. The system shown in Figure 3 was used to distribute GSM 900 network traffic. The added value in using such a system lay in the capability to dynamically allocate capacity based on traffic demands. Fibre-Radio systems of nowadays, are designed to perform added radio-system functionalities besides transportation and mobility functions.

These functions include data modulation, signal processing, and frequency conversion [12,13]. The generated electrical signal must meet the specifications required by the wireless application be it GSM, UMTS, WLAN or other.

By delivering the radio signals directly, the optical fibre link avoids the necessity to generate high frequency radio carriers at the antenna site. However, the main advantage of Fibre-Radio systems is the ability to concentrate most of the expensive, high frequency equipment at a centralized location, thereby making it possible to use simpler remote sites.

2.3 Benefits of Fibre-Radio Convergence

Low Attenuation Loss

Electrical distribution of high frequency microwave signals either in free space or through transmission lines is problematic and costly. In free space, losses due to absorption and reflection increase with frequency. In transmission lines, impedance rises with frequency as well. Therefore, distributing high frequency radio signals electrically over long distances requires expensive regenerating equipment. As for mm-waves, their distribution via the use of transmission lines is not feasible even for short distances. An alternative solution is to use optical fibres, which offer much lower losses.

Increased Bandwidth

Optical fibres offer enormous bandwidth. There are three main transmission windows, which offer low attenuation,namely the 850*nm*, 1310*nm* and 1550*nm* wavelengths. For a single SMF optical fibre, the combined bandwidth of the three windows is in the excess of 50*THz.*

Immunity to Electromagnetic Interference (EMI)

Immunity to EMI is a very attractive property of optical fibre communications, especially for microwave transmission. This is so because signals are transmitted in the form of light through the fibre. Because of this immunity, fibre cables are preferred even for short connections at mm-waves.

Security

Related to EMI immunity is the immunity to eavesdropping, which is an important characteristic of optical fibre communications, as it provides privacy and security.

Ease of Installation and Maintenance

In Fibre-Radio systems, complex and expensive equipment is kept at the CS, thereby making remote base stations simpler. For instance, most Fibre-Radio techniques eliminate the need for a local oscillator and related equipment at the RS. In such cases, a photodetector, an RF amplifier, and an antenna make up the RS equipment. Modulation and switching equipment are kept in the CS at the headend and shared by several RS.

Low Cost

Fibre-Radio architecture results in smaller and lighter RS, effectively reducing system installation and maintenance costs. Easy installation and low maintenance costs of RS are very important requirements for mm-wave systems, because of the large numbers of the required antenna sites.

2.4 Wireless Broadband Multimedia Communication

Present communication systems are primarily designed for one specific application, such as voice on mobile telephone or high-rate data in a WLAN. However, current trends suggest that communication networks will converge into what are referred to as next generation Wireless Broadband Multimedia Communications

Systems (WBMCS) [14]. WBMCS will integrate various functions and applications. As such, they will require capacities beyond that which is currently available as evident in Table 1.

The requirement for high data rates will push carrier frequencies into millimeter (mm) waves (60 GHz) and high carrier frequencies result in smaller radio cells due to increased radio propagation losses.

Table 1: Multimedia Applications and Associated Data Rates [14]

Application	Technique	Required Data Rate
Streaming Video	MPEG - 4	0.005 – 10 Mbps
Broadcast Quality Video	MPEG - 2	2 – 4 Mbps
HDTV	MPEG - 2	25 – 34 Mbps
Streaming Audio	MPEG – 3 (MP3)	0.032 – 0.32 Mbps
Studio Quality Sound	MPEG with FFT	0.384 Mbps
Standard Voice	G.711 PCM	0.064 Mbps
DSL	ADSL	1.5 – 9 Mbps

3- Simulation Network Model

Academic OPNET Modeler is used for all network simulations. OPNET Modeler is a powerful communication system discrete event simulator developed by OPNET Technologies [15]. OPNET Modeler assists with the design and testing of communications protocols and networks, by simulating network performance for wired and/or wireless environments.

The 802.11g baseline model was created using a variation of the OPNET 802.11 standard models *wlan_deployment*scenario.In this scenario, the behaviour of a single infrastructure 802.11g WLAN is examined within the framework of a deployed WAN to better emulate the configuration of an actual network[16].

The WLAN is connected via its AP to an office LAN connected through a central hub using 100BaseT (100Mbps) Ethernet wiring emulating a real life office environment with a standard Fast Ethernet LAN having a WLAN extension to an area of cabling difficulty or requiring aesthetics e.g. a conference or media room. An IP gateway (i.e., an enterprise router) connects the LAN to an IP cloud used to represent the backbone Internet. The gateway connects to the office LAN using 100BaseT Ethernet wiring while the connection between the gateway and the IP cloud is done with a Point-to-Point T1 (1.544Mbps) serial link[17].

The red octagon in Figure 4 titled *location_a*represents the remote branch office comprising an *office_LAN* having many workstations and an 802.11g WLAN BSS subnetwork connected by a 100BaseT link. Within that subnetwork are the mobile nodes and the AP that comprise the WLAN, as seen in Figure 5. A single fixed AP and ten mobile nodes were chosen as the WLAN configuration for the model. All mobile nodes are equidistant from the AP.

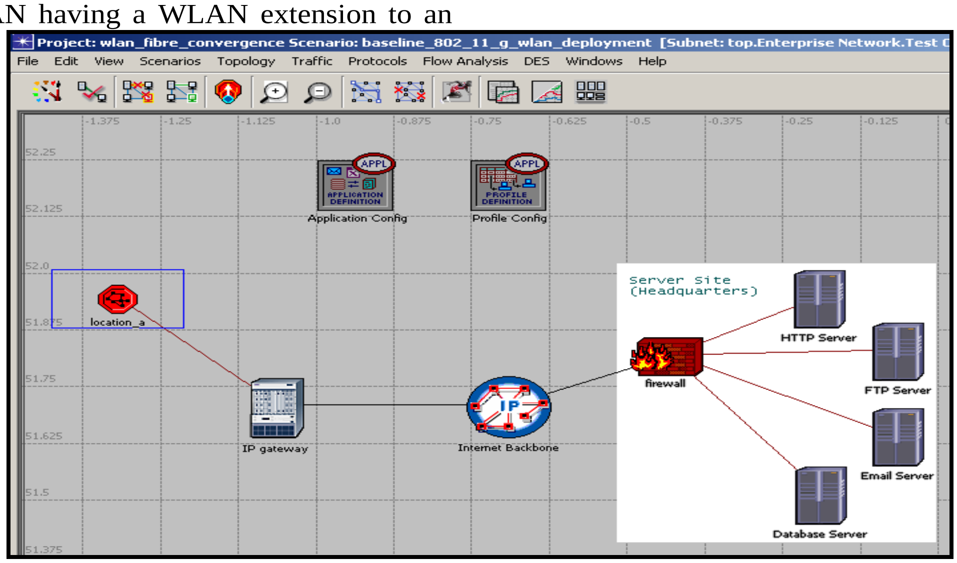

Figure 4: Simulated WAN Framework

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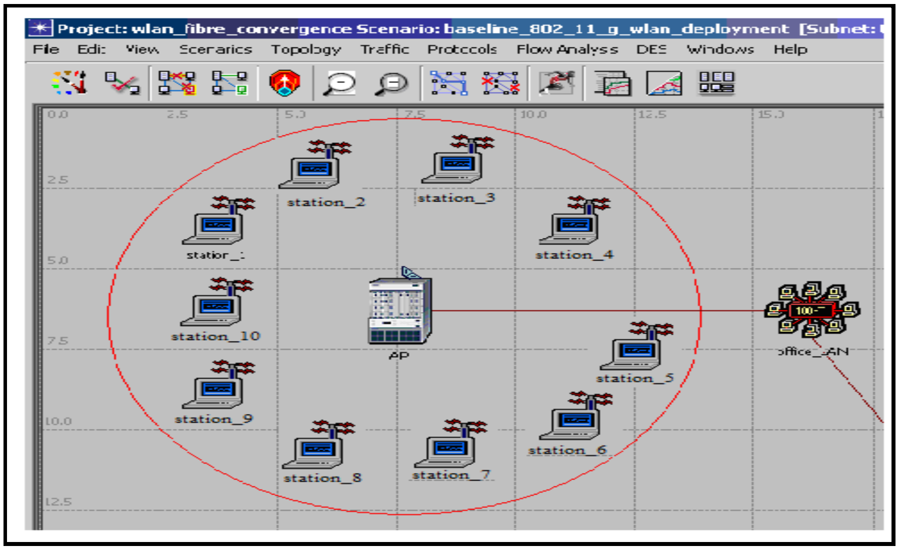

Figure 5: 802.11g WLAN BSS

The traffic load on the network was configured to emulate the type of traffic expected in an enterprise network of a typical corporation. OPNET Modeller uses the profile and application configuration objects to model network traffic. The application configuration object is used to represent a broad class of standard applications such as database access, file transfer, electronic mail, web browsing, video conferencing and voice applications while the profile configuration object is used to create profiles for the network users[18]. The profile is used to describe the activity pattern of a user or a group of users in terms of applications used over a period of time. Therefore, a network user can run the applications included in the user profile.

3.1Radio-Fibre Scenario

The baseline scenario is duplicated and then modified. All Fast Ethernet 100BaseT links are replaced by optical fibre using Fibre Distributed Data Interface (FDDI) links while the serial T1 WAN links remain unchanged.

This modification also necessitates the following changes:

1. At the server site, a fibre switch is introduced to connect the firewall to the servers.
2. The Ethernet-SLIP firewall is changed to a FDDI-SLIP firewall.
3. The Fast Ethernet 100BaseT switched LAN in *location_a* is changed to a FDDI switched LAN with all other configurations unchanged.
4. The Ethernet servers are replaced by FDDI servers.
5. The WLAN-Ethernet router is changed to a WLAN-FDDI router to act as the radio access point for the 802.11g WLAN BSS.

Figure 6 shows the modified high-level network environment appropriately named *radio_fibre_802_11_g_wlan_deployment*.The modified 802.11g WLAN BSS using fibre links and devices is shown in Figure 7.

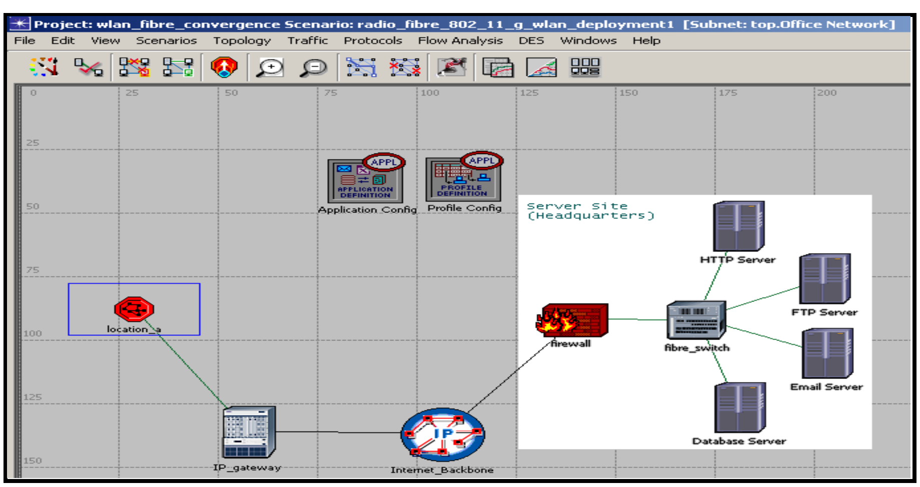

Figure 6: Radio-Fibre WLAN Deployment

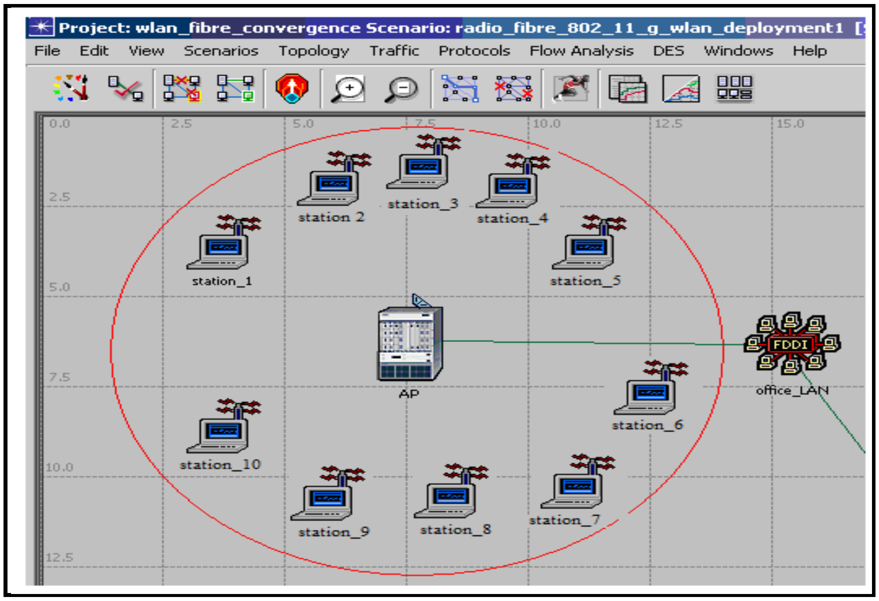

Figure 7: Radio-Fibre 802.11g WLAN

3.2Multimedia Load Scenarios

The main goal is to carry out a performance evaluation of a WLAN in an enterprise WAN with a special focus on the user perceived performance of the WLAN when subjected to varying load patterns. More importantly, considering multimedia traffic across a WLAN as envisaged in the near future. As such, multimedia traffic is introduced into the network in the form of video conferencing. Video conferencing encompasses data, voice and images and adequately represents the ultimate multimedia traffic. A video server is introduced to serve video conferencing applications across the network as shown in Figure 8.

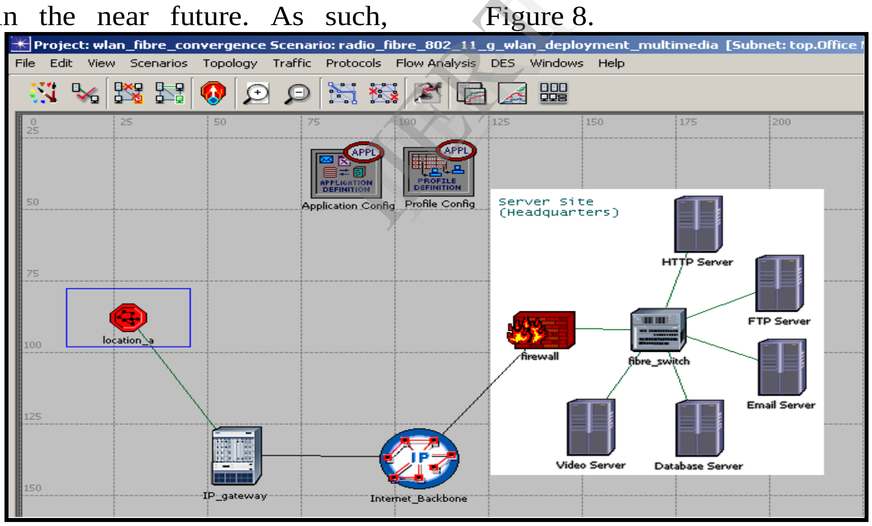

Figure 8: Modified Radio-Fibre WLAN Deployment with Video Conferencing

4- Simulation Results & Analysis

WLAN parameters such as delay, throughput, data dropped and load at the AP and mobile nodes are examined and analysed. More specifically, the response times of applications (HTTP, FTP, Email, Database and Video Conferencing) at the mobile nodes are also analysed to ascertain the user perceived performance of the WLAN.

The 802.11g baseline model was used in an OPNET simulation to test and verify its performance. The goal of the simulation was to confirm proper operation of the model using the analysis of a particular aspect of a protocol's behaviour or examining a specific network performance characteristic.

A simulation time of 10 minutes is set for all scenarios with the Start time Offset for all applications set to 110 seconds.

4.1 Load

An essential parameter that influences the overall performance of the wireless standards is load. The load test is concernedwith the receipt of the payload data without considering overhead of network against load. The load on the WLAN as a function of time as the simulation progressed is one of the more important results.

The overall WLAN load data is displayed in Figure 9 showing an approximate average value of 59Kbps on the 10 minute mark.

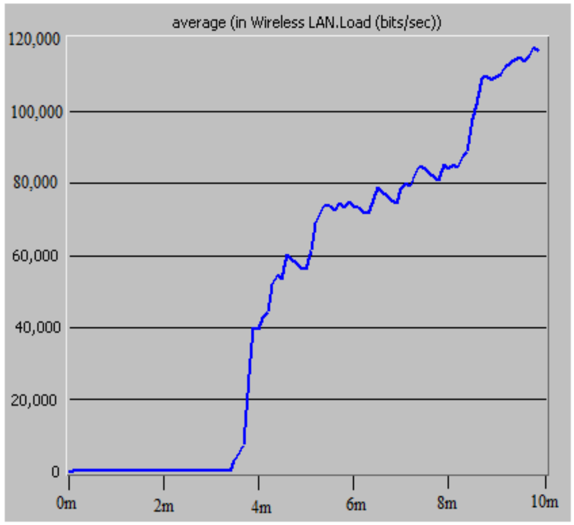

Figure 10 : Total Load on the Simulated WLAN

4.2 Delay

Delay is an essential metric to characterize the QoS of any network, especially for real time Multimedia application. The delay is considered as the time taken by the system for data to reach the destination after it leaves the source. The delay for any network can be measured at three layers, end-to-end delay, wireless LAN delay and MAC (media access control) delay.

It's important factor to determining the successful operation of the MAC layer, its timing operations which are the medium access delay and the statistics of overall packet transmission delay. The results are displayed in Figure 11. Average overall Wireless LAN delay peaks at 6.8ms while the average fiber - WLAN delay peaks at 6.4ms. The delay values increase with the load as we would expect, but of course don't exceed approximately 7ms of overall delay. These values are consider to be typical of an efficient WLAN under normal traffic loads.

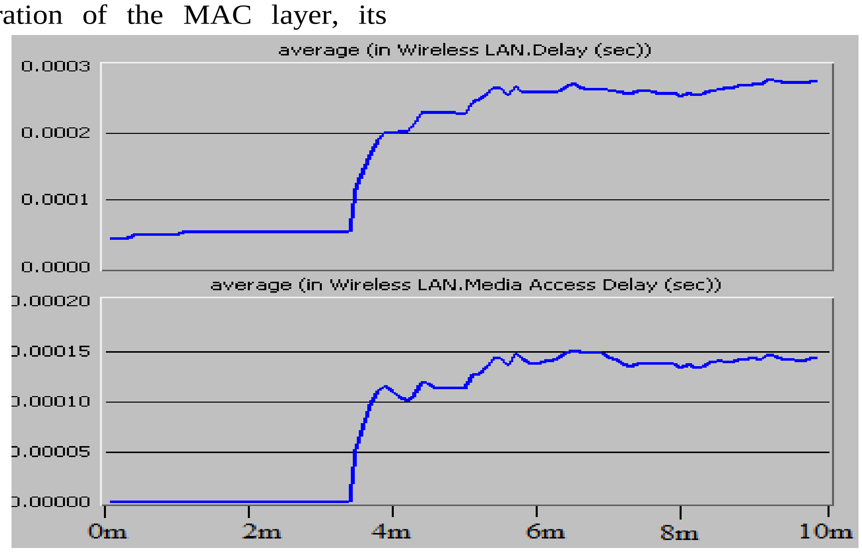

Figure 11: Simulated Packet Delay and Medium Access Delay

4.3 Throughput

Throughput in a network is defined as the number of packets passing through the network in a unit of time. The throughput is reduced as a result of collisions. The total load on the WLAN must be closely matched to the overall throughput of the WLAN which is the case here as is shown in Figure 12.

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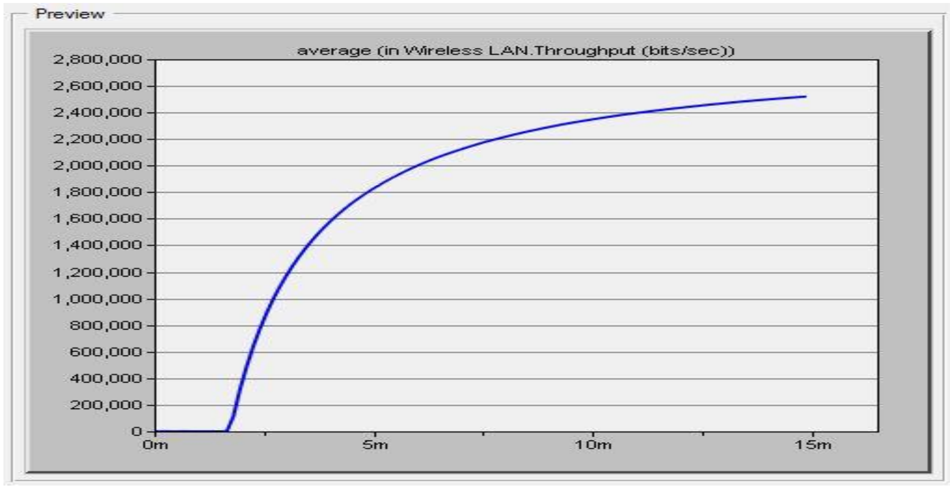

Figure 12 the overall throughput of the WLAN

2.5 IEEE 802.11g WLAN Radio-Fibre Deployment Scenario

All copper based wiring in the form of (100BaseT) Fast Ethernet cabling will be replaced with optical fibre cable in this scenario and implementing a Fibre Distributed Data Interface (FDDI). The change in physical medium requires changes to equipment with interfaces for optical fibre connections which signifying increased cost although the overall architecture remains unchanged. No changes are including traffic and network configurations so as to be able to properly isolate the effect of a change in physical medium only.

5-1 Delay

The first performance statistic to be observed is the WLAN media access delay in this scenario. It is clear that there is a significant increase in the medium access delay of the WLAN in the radio-fibre model with a peak average of 0.175ms when compared with 0.165ms of the baseline model as depicted in Figure 13.This is to allow an early insight into the effect of a change in physical medium.The introduction of optical fibre cabling means increased capacity. As a result, TCP attempts to send more packets than normal.

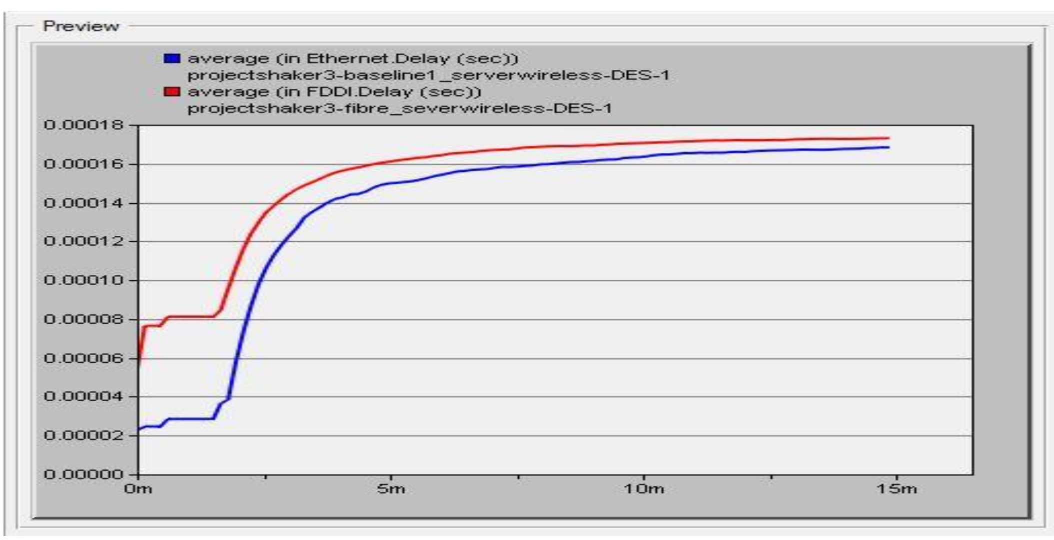

Figure 13: Comparing WLAN media access delay between baseline and radio-fibre models

5-2 Load

The overall WLAN load statistics is compared in Figure 14, with a peak average value of 2500 Kbps. This shows that there is relatively a small difference in the load transmitted in the baseline and the radio-fibre models except for a slight increase in the radio-fibre model which is attributed to the same causes of delay in the model. The load characteristic dispels any thought of attributing the increase in delay to an increase in load.

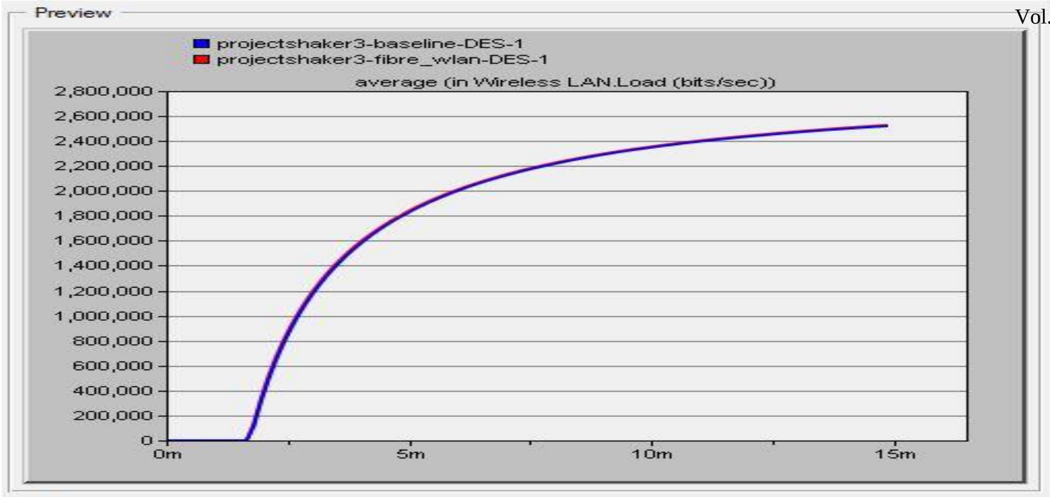

Fig 14: Comparing WLAN load between baseline and radio-fibre models

5-3 Throughput

Comparing the WLAN throughput in both scenarios also shows again that there are no dropped packets and there is still a high level of efficiency in the WLAN sub-network. Figure 15 which compares the throughput between the two models remains identical with the load statistics in Figure 14. A slight increase in the throughput of the radio-fibre model is evidence that there is greater capacity for traffic.

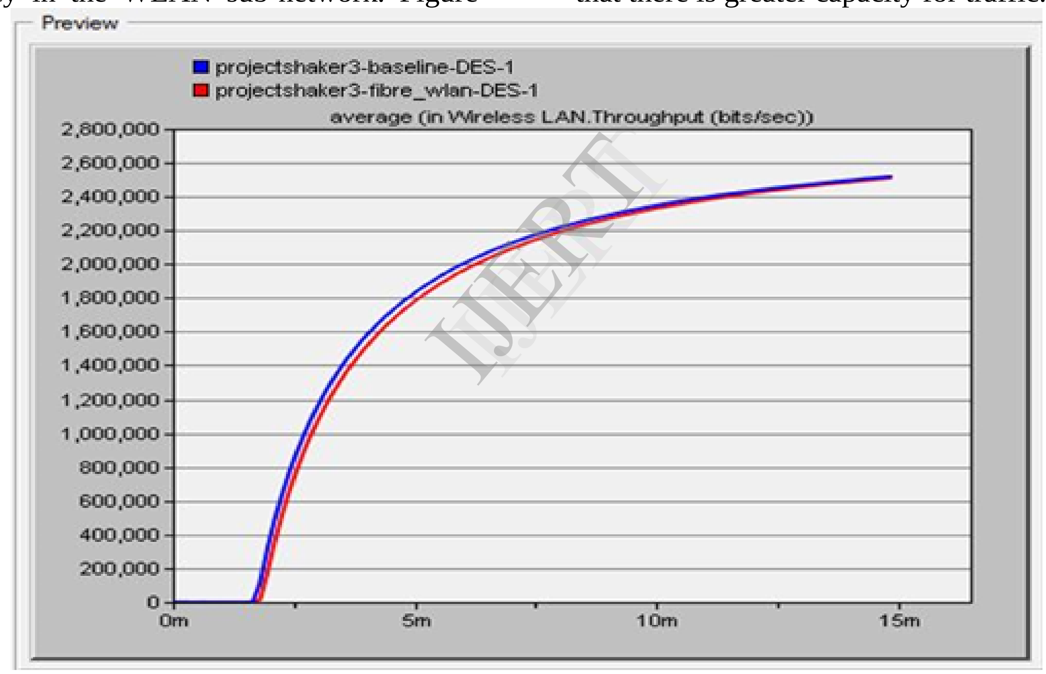

Figure 4.11: Comparing WLAN throughput between baseline and radio-fibre models

5- CONCLUSIONS

The lack of capacity and limited transmission range in WLANs have restricted its usage to applications that expend relatively small bandwidth and in-building coverage. Fibre-optic media will do better transmitting high frequency radio signals over a longer distance because fibre-optic cables are immune to EMI and noise, provide excessive bandwidth in the region of THz, and are more secure. This can be exploited in the form of a Distributed Antenna System increasing the range and capacity of such networks.

The main aim of this paper was to model a WLAN subnetwork deployed within an enterprise network and evaluate, using results from simulated network models, the user perceived performance of the WLAN subnetwork in the baseline network model using copper-based cable WLAN infrastructure with that of a proposed model using fibre-optic cable WLAN infrastructure. The network configuration was built using the OPNET Modeler 14.0.

Altering the baseline model by only replacing the copper Ethernet wiring with fibre-optic cables provided a concise platform to investigate the effect of this modification. This scenario showed that both the overall WLAN delay and the medium access delay increased considerably when compared with the results of the baseline model. A closer inspection revealed that this increase was due mainly to typical TCP protocol behaviour.

A slight increase in both the overall WLAN load and the throughput of the radio-fibre model is evidence that there is greater capacity for traffic. It means that to maximise the increased capacity introduced by the fibre-optic cabling, the TCP parameters have to be reconfigured to complement the media.

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