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Formulation of WLAN/Cellular Radio Resource Management Protocol

***OTAVBORUO, E. E.*[1,*]**

[1]*Department of Electrical and Electronic Engineering, Federal University of Petroleum Resources, Effurun, Delta State*

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ABSTRACT

Traditional cellular and legacy data networks were designed with dissimilar resource formats and allocation strategies with each separately and individually aiming at improving network performance goals. Such network-centric design approaches are based on different technological perspectives without the support for one another. Such conventional design technique is marred by mismatches among the radio access configurations. There are a few mechanisms that could solve coexisting related problems such as guaranteed QoS, fair sharing of radio resources, interference management, throughput, spectral efficiency, spectral deviation, delay, cycle duration. Thus, the need to formulate a radio resource management protocol from analytical expressions of the WLAN/cellular and modelling with MATLAB's script editor and workspace environment. The result of the simulation model shows that: (i) throughputs for the 6 Mps, to 54 Mps WLAN, increased with an increase in packet length with corresponding improvements from 8% to 20.37%. (ii) This study achieved a maximum spectral efficiency of 90.80. (iii) The lowest spectral deviation occurred at 6 Mps, at 3.23 % while the highest deviation occurred at 54 Mps with a value of 54 % when the packet length is 1600 bytes. (iv) The queue delay with data rates of 6 and 12 Mps increased slowly from 0.88 and 0.292 µs and sharply to 0.46 µs, and 91.7 respectively at 0.01 and 0.9. In the case of 24 and 54 Mps data rates, the increase in queue delay is almost steady, ranging from 0.01 to 0.2 µs, and 0.020 to 0.10 µs, as the traffic density is increased from 0.1 to 0.9, respectively. Thus, the WLAN/cellular access with data rate 6 Mps produced the highest cycle delay, while the 54Mps RRM protocol had the lowest cycle duration. The lowest cyclic delays occur 4 Mps, 6.44 10-5 to 5.80 10-4 per meter square.

1. INTRODUCTION

Traditional cellular and legacy data networks were designed with dissimilar resource format and allocation strategies with each separately and individually aiming at improving network performance goals. Such network-centric design approaches are based on the different technology without supports from the other. Such conventional approaches are gradually fizzling out. Traditional networks also referred to conventional networks lack the ability to manage interference from current smart devices. The problem associated with the earlier approaches is non consideration of the mismatches between the quality of service (QoS) and the actual QoS experienced offered by smart devices that was not perceived by the radio accesses of these networks. they do not incorporate mechanisms that could solve coexistence-problems such as

*Corresponding author, e-mail: otavboruo.ericsson@fupre.edu.ng
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guaranteed QoS, fair sharing of radio resources, interference management, low delay profile, high throughput, speed and bandwidth, seamless operation (Anabalagan, 2017). This study is motivated by the need to develop an improved resource allocation management protocol that could solve the problem of congestion caused by the voice and data packets pair in an infrastructure WLAN radio interface. To strike a balance between the conflicting goals affecting the cellular and data networks as well as maximising network performance constitute a huge problem (Sadek, *et al.*, 1995). An effective, well-defined radio resource management is required for load-balancing. The explosive user demands, increasing numbers of new applications, huge and diverse traffic loads etc., create additional challenges bugging the network-centric approach Anabalagan, 2017). Lu *et al.*, (2017) had already predicted an expected compound average growth rate of 45 percent for mobile data between 2013 and 2019 as a support for the explosive demands. The number of Internet of things and cellular network devices will likely be more than the population while mobile data traffic is expected to reach 36.9 exabytes per month by 2020 (Sun, 2017). These data growths emanate from smart devices utilizing dissimilar technologies. Therefore, the application of homogeneous network design concepts needs to be adjusted to meet the current trend. Further increase in wireless devices, as forecasted in Feng and Feng (2017) could soar to 28 billion thereby expanding users' demands of data usage on wireless broadband access to the Internet beyond 500-folds in 2020 Abinader, *et al.*, (2014). The exponential increase of wireless data is not expected to stop beyond 2030 as the Internet of things (IoS) continues to swell the wireless network. Escalating growth resulting purportedly from cellular and non-cellular wireless data applications/traffics has prompted academic scholars, industries, research bodies and other organizations to seek ways of solving the future network problems. Finally, a shift to a newly technological paradigm that supports the coexistence of non-cellular and cellular wireless networks in the unlicensed bound was embraced, and state-of-the art network models are proposed in this regard. Performance degradation is one of the consequences of network integration sharing the same frequency spectrum (Cavalcante, 2013). Workstations originally connected to the wireless local area network (WLAN) access point (AP) require the services of a particular intelligently evolved-base station (e-BS) connecting mobile stations, vice versa. For the WLAN and the cellular network to coexist, there are agreed preconditions that should be established to achieve or maintain acceptable quality of services (QoS). These conditions, though designed in favour of the primary users, must be kept by the secondary users. It is based on this approach that the heterogeneous cognitive radio resource allocation and dynamics were developed (Awoyemi, 2017) and (Aryafar *et al.*, 2019). For example, the precondition for WLAN users to be allocated resources in a cellular base station could be the delay tolerance parameter. Why in the case of cellular users accessing the WLAN AP, the precondition to be maintained is the loss tolerance parameter. Effective coexistence requires resource management of the traffic demands of wireless data in the licensed and unlicensed bounds. This is to ensure the proper radio resource management takes into account the interworking and access channel selection criteria. WLAN presents more prospects for industrial deployment. One of the achieved prospects is the transferring of load from the licensed spectrum to the unlicensed spectrum. Load transfer to the unlicensed spectrum is known as offloading. Coexisting radio management of multi-rate radio access technologies such as 5G radio, LTE and WLAN IEEE 802.11x is supported by the 3GPP standard.

2. RADIO RESOURCE MANAGEMENT

Radio Resource Management is a feature of both homogeneous and heterogeneous wireless mobile networks located at the base station sub-system (BSS) of a single cell. A homogeneous network serves packets from the same tier of networks only; an example is the cellular network. An ongoing call established in a target cell, as a result of the user's mobility, can cross into a neighbouring cell which is under the control of a different BSS. Such a call is sustained by the collaboration, coordination and the cooperation of the radio resources of the target and the neighbouring BSS. The procedure for ongoing call sustenance which involves the APs making decisions and consequently taking actions that optimised wireless mobile networks is referred to as Radio Resource Management (RRM) (Huan, *et al.*, 2019). APs and BS are used interchangeably in this study. The purpose of RRM in wireless networks includes increasing the number of services supported, the system capacity and the performance enhancement of the individual users (Del, 2011). Some procedures for developing the RRM include establishing, maintaining and releasing radio connections by establishing connection, allocating time slots to arriving calls. In the absence of resources, calls may be rejected or blocked from utilizing the network. Call maintenance is the process of continually sustaining an already established connection, re-assigning of resources and controlling of transmission power as the user approaches a neighbouring cell (Xu *et al.* 2016). The IEEE 802.11 initially did not include QoS in their standard, but later version such as the IEEE 80.11e and IEEE 80.11k groups amended the IEEE WLAN standard by adding the load metric which is an equivalent of radio resource management (RRM) in cellular system (Nguyen and Sato, 2016). Multiple access points (APs) of an extended infrastructure WLAN coordinated by a distributive system were also stated in the IEE 802.11 standards. Ethernet is used as an example of a distributive system in the standard. The RRM could be deployed by linking the access points (APs) of the individual corresponding mobile terminals to an intelligent switch. Information is gathered and sent back and forth between the switch and the APs, respectively. In this way, the switch controls the operating RRM parameters of the APs. These parameters comprise the radio channels and transmit power. The switch, among other things, instructs the APs on what channels to operate on, the transmit power control and load sharing. Besides these functions, it determines the denial of acceptance of request association of user terminals (Hills and Friday, 2004). Furthermore, an RRM coordination of APs in the 2.4 and 5 GHz radio frequencies making use of intelligent and smart arrays-of-antenna covering a wide area was described in by Wang *et al.*, (2004). A rapid technological growth that expands the versatility of users' devices in respect to different radio access technology is deployed in Gustafsson and Jonsson (2003). Instances are the Internet connectivity of the cellular global system for mobile communication (GSM), universal mobile telecommunications systems (UMTS), and the code-division multiple access (CDMA 2000), and enhanced by general packet radio services (GPRS) are made possible by the RRM. The implementation of the RRM between a WLAN and wireless cellular networks, and between a WLAN and universal mobile telecommunication system (UMTS) are tiers referred to as heterogeneous wireless networks as opined in Hisham (2006). The access point of such tiers is represented by the proposed RRM access protocol in Figure 1. The main aim of this research is to specifically develop a formalized approach that would efficiently manage the WLAN and cellular radio resources. To obtain this, the study seeks to determine the QoS such as the: (i) throughput, (ii) spectral efficiency, (iii) spectral deviation; and (iv) delay (time taken for packets to traverse the

queue of the radio resource and the medium). The purpose of this work is to present the state-of-the-art WLAN/cellular access protocol that could assist communication researchers, network operators, and service providers in upgrading wireless networks to match up with the explosion of smart devices.

3. MODEL OF RADIO RESOURCE MANAGEMENT

This study adopted and modified one of the methods and conceptual modelling mechanisms available in the literatures. Heuristic approach is employed in developing the analytical theories, queuing technique (stations polling) to model the WLAN radio resources management protocol. As will be seen later in the study, the protocol of the WLAN RRM access is modelled, and analysed so as to improve its performance. Exploitation of the IEEE standards, the Markov analytical method of modelling as well as the performance evaluation of results obtained are presented. An RRM of the infrastructure WLAN presented in this study comprises source stations also known as workstations or multiple queues given access by a single server AP in a cyclic order. The workstations are smart devices that access both the wireless cellular and the WLAN networks. The WLAN is a multiple queue model that dates back to 1950s (Hideaki, 1988), and its application to the infrastructure WLAN/cellular RRM still fits into the current 5G and 6G networks, the concern of this research. Thus, this research applies the multiple queue (multi-queue) model to the IEEE infrastructure WLAN/cellular RRM utilized in the current generation wireless network. Modification of the RRM function is specified using both heuristic and embedded Markov model approaches. Figure 1 is a proposed RRM protocol in the AP deployed to manage the access of a WLAN/cellular AP receiving traffic from smart devices. It is configured to rearrange traffic of the real and non-real time traffic before dispatching the same to the necessary resources responsible for the onward transmission of packets. Workstations are polled for the presence of packets when the network resources are empty. If no workstation has packets to deliver, the process returns to idle state. Request command is transferred to workstations to transmit packets. The RRM herein is a polling scheme that polls stations in a fixed order until a message is transmitted and then it continues in that order. It is called static priority arbitration because each station is assigned a priority or urgency based on the order in which it is polled. Polling stations in a cyclic order and then permitting stations on the AP's list to transmit in that order is the emphasis of this work. Once message transmission is initiated it may not be interrupted. Packets from the workstations are served from the real time or non-real time queues as depicted in Figure 3. The simplified figure comprises five workstations works, workstation 3 successfully transmitted packets and the system return to idle state. Consequently, two packets from workstations 1 and 2 are scheduled to the non-real time service, while work stations 4 and 5 are scheduled to cellular real time server.

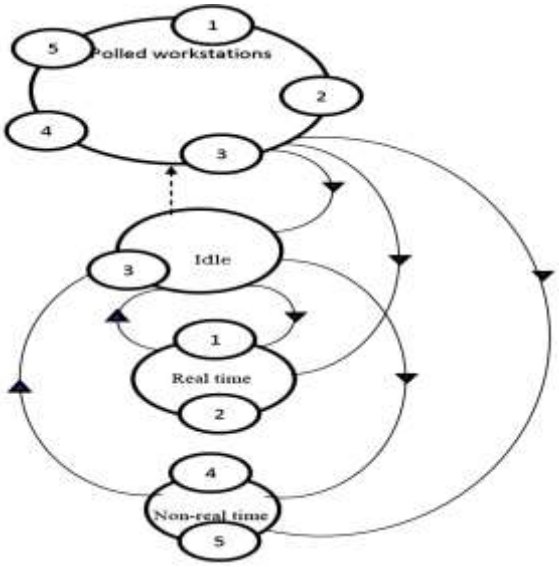


Figure 1: Model of WLAN/cellular RRM access protocol for real and non-real time packets

3.1 Mathematical Modelling of WLAN/cellular RRM

Mathematical model is developed for the proposed RRM depicted in Figure 1. The conversion of the figure into analytics is written and simplified as depicted in Equations (1 & 2) when $T_{i\,pd} = T_{pd}$, $T_{i\,ACK} = T_{ACK}$, $T_{i\,sw} = T_{sw}$, $\frac{\lambda_i}{A_i} = \frac{\lambda}{A}$.

$$T_C = \frac{\sum_{i=1}^{N} T_{poll} + 3\sum_{i=1}^{N} T_{i\,pd} + \sum_{i=1}^{N} T_{i\,ACK} + \sum_{i=1}^{N} T_{i\,sw}}{1 - \sum_{i=1}^{N} \frac{\lambda_i}{A_i} b} \quad (1)$$

$$T_C = \frac{N\left(T_{poll} + 3T_{pd} + T_{ACK} + T_{sw}\right)}{1 - N \times \rho_A} \quad (2)$$

Thus, throughput is expressed as the number of visits multiplied by data packet per period of the cycle as presented in Equations (3). Substitution of Equation (2) into Equation (3) produces Equation (4). Equation (4) includes the overhead, preamble time of the physical layer convergence procedure (PLCP) time and short inter-frame spaces, block request acknowledgement and block response acknowledgement (Osama, 2007) presented in Equation (3.5).

$$S = \frac{V}{T_C} \times data\ packet \quad (3)$$

$$S = \frac{V \times data\ packet}{T_C} = \frac{V\left(1 - N \times \rho_A\right) \times data\ packet}{N\left(T_{poll} + 3T_{pd} + T_{ACK} + T_{sw}\right)} \quad (4)$$

where,

V= Number of times a source station is visited

After some mathematical manipulations, the new expression for the cyclic period T_C becomes Equation (6), which agrees with the model presented in (Khun, 1978) and Hideaki, (1988). For N= V_i = data packet = 1 and with a very low channel utilization ($\rho_{AT} << 1$), the throughput is approximated as shown in Equation (7).

$$R = T_{poll} + 3T_{pd} + T_{ACK} + T_{sw} \quad (5)$$

$$T_C = \frac{R}{1 - \rho_A} \quad (6)$$

necessary for quantification and analysis. When the number of stations (N) having packets are transmitting data packets, the cycle duration is

$$S \approx \frac{1}{T_C} \approx \frac{1}{T_{poll} + 3T_{pd} + T_{ACK} + T_{sw}} \quad (7)$$

Recall that Equation (8) is defined as the arrival rate (λ). By substituting Equation (8) into Equation (7) the new equation arrived at is produced in Equation (9). Where T_{idle} is equivalent to the SIFS of IEEE 8.11a/b/g/n WLAN and T_r is equivalent to T_C.

$$\lambda = \frac{1}{T_r + T_{idle}} \quad (8)$$

$$T_r = \frac{T_{poll} + 3T_{pd} + T_{ACK} + T_{sw} - \lambda T_{idle}}{\lambda} \quad (9)$$

The traffic density in an area defined densification of the N randomized packet in an i^{th} workstation (N_i) the product of the arrival rate per area and the service rate is expressed in Equations (10 & 11). The expressions for throughput as a function of densification are shown in Equations (12 to 14)

$$\rho_{T\,A} = b\left(\frac{\sum_{i=1}^{N}\frac{\lambda}{A}}{N} + \frac{\sum_{i=1}^{N}\frac{\lambda}{A}}{N} + \frac{\sum_{i=1}^{N}\frac{\lambda}{A}}{N} \ldots + \frac{\sum_{i=1}^{N}\frac{\lambda}{A}}{N}\right) \quad (10)$$

where,

$$N_1 = N_2 = \ldots = N_p;$$

$$A_{1i} = A_{2i} = \ldots = A;$$

$$\lambda_{1i} = \lambda_{2i} = \ldots = \lambda$$

$$\rho_{TA} = N_p \times \frac{\lambda}{A} \times b \quad (11)$$

$$S = \frac{V \times data\ packet}{Tc} \quad (12)$$

$$S = \frac{V \times data\ packet}{T_{poll} + Nb \times T_{data} + T_{ACK} + T_{sw} + T_{sifs}\left(Nb + 2\right)} \quad (13)$$

$$S = \frac{8 \times V \times data\ packet}{T_{poll} + Nb \times T_{data} + T_{ACK} + T_{sw} + T_{sifs}\left(Nb + 2\right)} \quad (14)$$

where,

N_p = number of randomized packets or packet length

N = Number of workstations

Recall that the maximum throughput occurs in a WLAN with a very low traffic density (ρ_{AT} «1) (that is, one AP visitation (V=1), in which one data packet is served from a station (N=1) in a cycle. The maximum throughput is given by:

$$S_m \approx \frac{1}{T_C} = \frac{1}{T_{poll} + Nb \times T_{data} + T_{ACK} + T_{sw} + T_{sifs}(Nb+2)} \quad (15)$$

When the packet size is as large as one hundred (100) and the probability of an AP successfully transmitting packets in a specified area is very low, then the pmf of the binomial is approximated by the Poisson probability mass function (pmf) Oladugba A. V. (2014). That is, if $\frac{\lambda}{A} = \frac{lp}{A}$ where(l=N) is the number of trials and p is the probability of success, the throughput with respect to Equation (12) becomes the formula depicted as Equation (16). If there only a trial (N=1) as implied in Bernoulli pmf, which is equivalent to one station accessing the admission control protocol, the expression for throughput changes to Equation (3.17). Bandwidth efficiency or spectral efficiency is the ratio of maximum throughput to data rate (channel bandwidth) expressed as given in Equation (18):

$$S = \frac{8 \times V \times data\ packet \times p}{T_{poll} + Nb \times T_{data} + T_{ACK} + T_{sw} + T_{sifs}(Nb+2)} \quad (16)$$

$$S = \frac{8 \times V \times data\ packet \times \lambda}{T_{poll} + Nb \times T_{data} + T_{ACK} + T_{sw} + T_{sifs}(Nb+2)} \quad (17)$$

When $\lambda = p = 1$

$$S = \frac{8 \times V \times data\ packet}{(T_{poll} + Nb \times T_{data} + T_{ACK} + T_{sw} + T_{sifs}(Nb+2)) \times R} \quad (3.18)$$

It has been shown in part one of this study that the average queue waiting delay expressed as:

$$E[W_i] = \frac{E[N_i]}{\lambda} = \frac{2A\rho_A - (A\rho_A)^2 + \lambda^2 C_B^2}{2\lambda(1 - A\rho_A)} = \frac{2\rho - \rho^2 + \lambda^2 C_B^2}{2\lambda(1-\rho)} \quad (19)$$

Where,

$$Var(T) = (E[T])^2 C_B^2 = \lambda^2 C_B^2$$

C_B^2 = square of the coefficient of variation of the service distribution.

4. ANALYSIS OF PCF WLAN RESOURCES

Graphical illustrations of the results of the analytical model were carried out by varying the parameters of the WLAN/cellular protocol RRM access protocol to determine the QoS, and plotted using MATLAB and Microsoft Excel templates. The author only presents the MATLAB editor and workspace environment. This is because is the preferred choice for the model. Please refer to the parameters displayed in the MATLAB's workspace and editor in Appendices A and B.

4.1 Analysis of throughput against packet length

The packet length was increased from 0 to 1600 bytes and the results of the throughput were obtained as depicted Figure 1. The exponential increase of throughput (S) against the linear increase in packet length is presented in the figure. The throughputs for the 6 Mps, 12 Mps, 18 Mps, 24 Mps, 48 Mps, 54 Mps WLAN, increased from 0.00 to 5.48×10^6 (91.33%), 0.00 to 8.03×10^6 (89.22%), 0.00 to 10.5×10^6 (87.75%), 0.00 to 15.00×10^6 (83.33%), 0.00 to 19.20×10^6 (80.00%), 0.00 to 33.10×10^6 (68.96%), 0.00 to 36.00×10^6 (66.67%) bytes, respectively. The highest throughput was recorded at the data rate of 54 Mps, while the least was recoded at 6 Mps. The research study of DCF WLAN. Xiao and Rosdah (2002) achieved a maximum throughput of 24.70Mps (45.7% of 54Mps) for 54 Mps at packet length 1000 bytes while in this study the throughput is 30 Mps (55.5% of 54 Mps) at the specification. The value of throughput is 5.30Mps (9.8%) higher than that in Xiao and Rosdah (2002). The maximum throughput in this dissertation is 36.00 Mps (66.70%) for the 54 Mps at a packet length of 1500 bytes. When compared to the study in Xiao and Rosdah (2002)., there is 20% increment in the value of throughput in this dissertation. Further comparison confirmed that the optimal throughput of DCF MAC occurs at

packet length 1500 byte Ilic *et al.* (2005). This justifies the result of this dissertation. The graphical analyses of DCF WLAN throughput against packet length using OFDM presented in (Jun, 2003) are very similar to the results presented in this study with the exception that the values of the maximum throughput are recorded up to a packet length of 4500 bytes. Values of throughput shown in (Jun, 2003) when the packet length is 1500 bytes are approximately: 5 Mps (83.33%), 9.5 Mps (79.17%), 16 Mps (66.67%), and 25 Mps (46.30%) in the case of a DCF WLAN with data rates 6 Mps, 12 Mps, 24 Mps, 54 Mps. Analysis of the results recorded in this study shows that with a packet length of 1500 bytes, the throughput values are: 5.48 Mps (91.33%), 10.50 Mps (87.75%), 19.20 Mps (80.00%), and 36.00 Mps (66.67%) for the WLAN PCF with data rates 6 Mps, 12 Mps, 24 Mps, 54 Mps. Throughput improvements recorded by the analyses against the study Jun I. P and Ssichitu M. (2003) are: 8%, 8.85%, 13.33%, 20.37% at data rates 6 Mps, 12 Mps, 24 Mps, 54 Mps.

Figure 2b illustrates the throughput against the number of workstations with a packet length of 1500 bytes at specified data rates of 6 Mps, 12 Mps, 18 Mps, 24 Mps 36 Mps, 48 Mps and 54 Mps. The WLAN/cellular RRM access protocol maximum transmission rates are: 5.77 Mps (96.17%), 8.57 Mps (74.10%), 11.30 Mps (94.17%), 16.70 Mps (92.78%) 21.90 Mps (91.25%), 40.90 Mps (85.21%) and 45.2 Mps (83.70 %).

Figure 2c represents the graph of spectral efficiency against packets. It is observed that the increase in spectral efficiency is very steep for the ranges between 6Mps to 24 Mps with the linear increase in packet length from 0 to 24 400 bytes. From 400 to 1600 bytes, the increase of spectral efficiency is slow. In the case of 48 and 54 Mps, the spectral efficiency possessed a uniformly curvilinear line as the packet length is increased from 0 to 1600 bytes. The spectral efficiencies of the DCF WLAN obtained in (Jun, 2003) are approximately: 90%, 85%, 75%, 59% for 6 Mps, 12 Mps, 24 Mps and 54 Mps, respectively. This study achieved spectral efficiencies of 90.80%, 86.56%, 79.16% and 65.22% for the range of data rates. Therefore, improving spectral efficiency by 0.80%, 1.56%, 4.16%, and 6.22% at 6Mps, 12 Mps, 24 Mps, 24 Mps, and 54 Mps, respectively. The spectral efficiency when the packet length is 1000 bytes is 55.56 % as against 45.80 % obtained in Ani and Otavboruo (2010). Thus, an improvement of 9.76 % was recorded in this study.

The graph of spectral deviation against packet length is shown in Figure 3. Spectral deviation increased with increase in the packet length. The lowest spectral deviation occurred at 6 Mps, it ranges from 0 to 3.23 %. Spectral deviation at 9 Mps, 12 Mps, 18 Mps, 24Mps 36 Mps and 54 Mps are 0 to 3.44 %, 0 to 11.5 %, 0 to 17.8 %, 0 to 24 % 0 to 45.40 % and 0 to 54 % while the highest deviation occurred at 54 Mps with a value of 54 % when the packet length is 1600 bytes. No comparison was made with other publications because the method by which the deviation was obtained is quite different. This will be resolved in the addendum works

Figure 4 is the graph of queue delay against traffic density. The Queue delay increased exponentially with the increase in traffic density. The queue delay with data rates of 6 and 12 Mps increased slowly from 0.88 to 0.15 µs, 0.176 µs to 0.292 µs from 0.1 to 0.6 per area and then increased sharply from there to 0.46 µs, 91.7 µs, at 0.9, respectively. In the case of 24 and 54 Mps data rates, the increase in queue delay is almost steady, ranging from 0.01 to 0.2 µs, 0.020 to 0.10 µs, as the traffic density increased from 0.1 to 0.9, respectively, as depicted in the figure. The values of the queue delay obtained in this dissertation is lower than those obtained in Ani & Otavboruo, 201; even though the

parameters used in the PCF simulation of that work were different from what is applied in this work. Optimal packet delay that determines the number of workstations of the WLAN wireless network was one of the focal objectives of Ani & Otavboruo, 2010.

Figure 5 depicts the graph of cycle duration against the traffic density of a workstation source. The expected values of the cyclic delay of a single workstation showed the minimum delay observed by the PCF WLAN access protocol. The figure shows that as the traffic density increases linearly from 0.1 to 0.9 per square meter, the cycle duration increases exponentially. Thus, the PCF WLAN with the data rate 6 Mps produced the highest cycle delay while the 54Mps PCF protocol had the lowest cycle duration. The cyclic delays of the 6 Mps, 12 Mps, 24 Mps, and 54 Mps, increased from 1.7×10^{-4} to 1.5×10^{-3}, 1.36×10^{-4} to 1.2×10^{-3}, 7.78×10^{-5} to 7.00×10^{-4}, 6.44×10^{-5} to 5.80×10^{-4} per meter square, respectively. The cycle delay increase was very slow from 0.1 to 0.5 and thereafter, it rose sharply from 0.6 to 0.9.

Figure 6 displays the graph of exponential increase in the cycle durations when the data packet is increased. The graph reveals that the cycle duration is 15.40 ms, 0.98 µs, 0.70 µs, 0.58 µs, 0.58 µs at 6 Mps, 12 Mps, 24 Mps, 36 Mps, and 54 Mps, respectively even when the number of data packets is zero. This duration represents the overhead, prior to the transmission of data packets. These overhead cyclic durations are added to the transmission duration which resulted to the depreciation of data packets transmitted over the PCF infrastructure WLAN access protocol. The maximum cycle delays are: 1.5 ms, 0.98 ms, 0.70 ms, 0.59 ms, and 0.59 ms at 6 Mps, 12 Mps, 24 Mps, 36 Mps, and 54 Mps, with the linear increase in data packets from 0 to 9000 bytes

The findings of this study demonstrated that an exponential increase in throughput and spectral efficiency is associated with an increase in packet lengths of the workstations. Throughput improvements compared with the literature, Jun, et al, 2013 increased from 8%, to 20.37% when the data rates increased from 6 Mps, to 54 Mps which justifies the result of the study, herein. The PCF WLAN maximum transmission rates are: 5.77 Mps (96.17%), 8.57 Mps (74.10%), 11.30 Mps (94.17%), 16.70 Mps (92.78%) 21.90 Mps (91.25%), 40.90 Mps (85.21%) and 45.2 Mps (83.70 %). Packet data loss is less than 10% except in the last two cases where they are about 14.79 % and 17.30%.

5. CONCLUSIONS

This work presented the analytical scheme for PCF infrastructure WLAN radio resource, useful for improving the QoS of the access protocol for a wireless network in a particular area. It computed and modelled the QoS parameters such as throughput, spectral efficiency, spectral deviation, queue delay, and cycle delay.

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Appendix A: Graphs of WLAN/cellular models

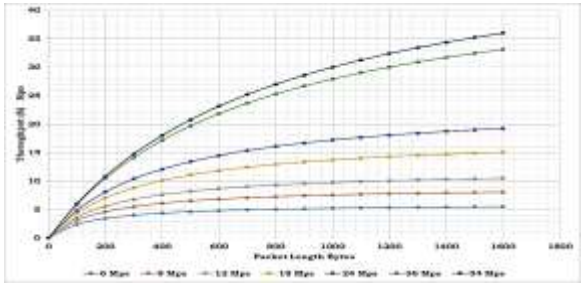


Figure 2a: Graph of throughput against packet length

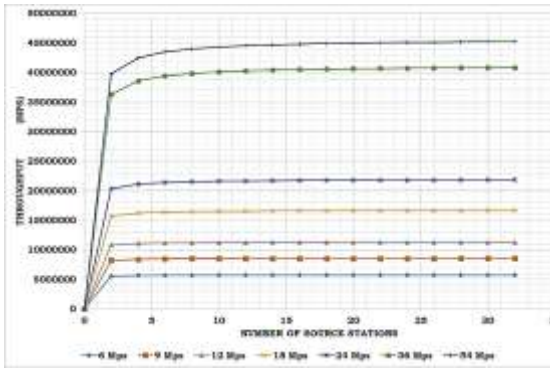


Figure 2b: Throughput against number of stations

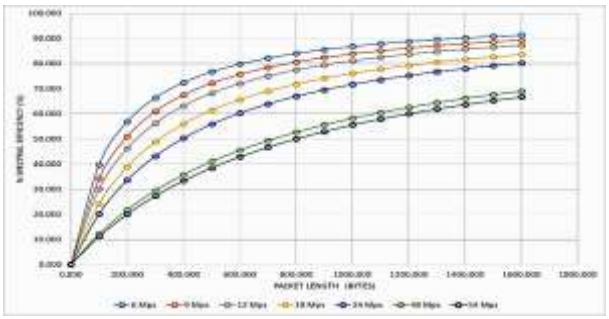


Figure 2c: Graph of spectral efficiency against packets length

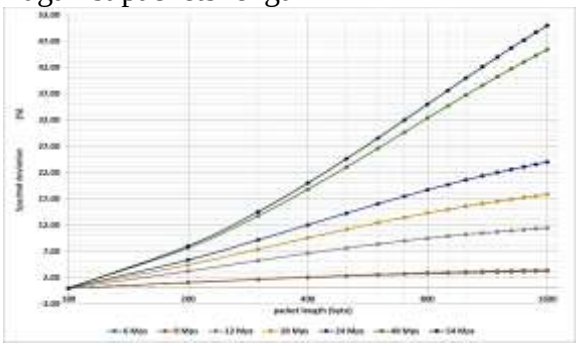


Figure 3: Graph of maximum spectral deviation against packet length

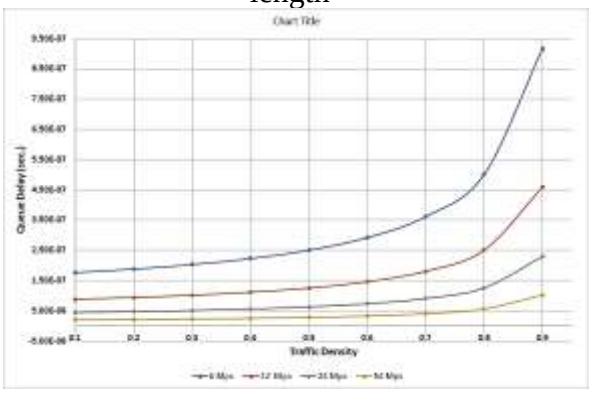


Figure 4: Graph of queue delay against traffic density

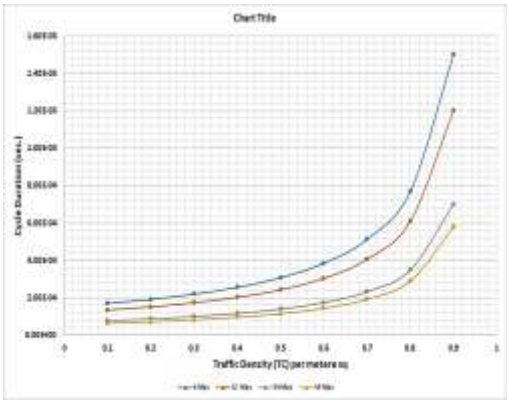


Figure 5: Graph of cycle duration against traffic density

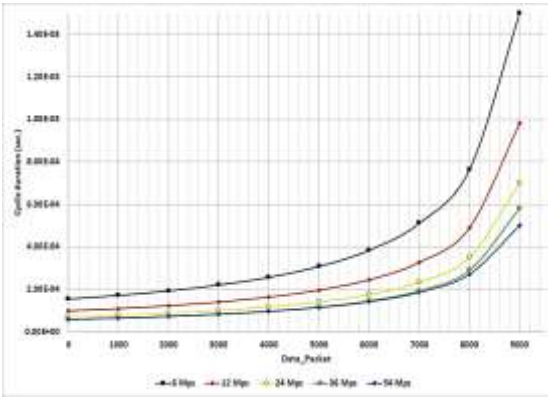


Figure 6: Graph of cycle duration against data packet size

Appendix B: MATLAB script and workspace

