POINT COORDINATION FUNCTION WLAN TRAFFIC LOADINGS

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ABSTRACT

The current proliferation of Internet and the advancements in its technology contributed significantly in the gradual shift from wired LANs to wireless LANs (WLANs). WLAN's ability to provide high capacity links, mobility and low acquisition cost played considerable positive role in its popularity. The operation of WLAN in Nigeria is associated with excessive traffic loading that adversely influence its performance since bandwidth is usually very limited. Achievement of satisfactory performance standard under this condition requires thorough analysis of traffic loadings on WLAN. Therefore, in this work, WLAN performance analysis under traffic loadings is presented. Influence of traffic loadings on WLAN quality of service (QoS) parameters was analyzed using computer simulation modeling technique. It was shown that the operation of WLAN is highly influenced by the intensity of traffic that it supports. The relationships between the network quality of service (QoS) parameters and traffic loading for specified values of resources were determined. A useful control tool was derived from the relationships for the determination of the optimum traffic loadings in a point coordination function (PCF) WLAN.

Key words: *WLAN, PCF-WLAN, traffic loading, network resources, QoS parameters.*

INTRODUCTION

The last decade has witnessed rapid growth in the deployment of wireless LANs (WLANs) that are based on the IEEE 802.11.x standards. This growth was fuelled by WLAN's high capacity links, mobility and relative low acquisition cost [1]. Equally, the advancements in the internet technology played an immense role. The universality in the application of WLAN's access protocol in connecting users may have resulted in excessive traffic loadings under very limited bandwidth in the network in Nigeria. In the more developed environments the bandwidth is increased with increasing traffic intensity. This situation made it necessary to engage in detailed WLAN traffic loading analysis using the approach in [2].

The MAC protocol defines the coordination functions that specify the WLAN channel access method – how and when a workstation is permitted to transmit or receive packet over the common channel (wireless medium). There are two main coordination functions – distribution coordination function (DCF) and point coordination function (PCF) [3, 4, 5].

PCF WLAN is very popular in Nigeria which is the main reason why it is the object of study in the ETF Centre of Excellence. PCF function is realized by the point coordinator (PC) in the WLAN access point (AP). Its function supports connection-oriented time-bounded packet transmission across the wireless medium. It operates with contention free aware workstations. It may be pertinent to note that it can coexist with DCF that based its operation with contention aware workstations. PCF therefore, supports the switching from contention free period to contention period and back at a specified contention free period repetition interval. Basically, operation within the contention free period requires the WLAN-AP to control network access in such a way as to avoid channel contention through polling.

DCF function is contention based and is supported by carrier sense multiple access with collision avoidance (CSMA/CA) protocol [7, 8]. The CSMA/CA media access control (MAC) protocol of IEEE WLAN is a unique way of avoiding the collision of the user packets when the traffic sources transmit bursty packets [3, 4, 5, 6].

The determination of the influence of homogenous traffic loadings on WLAN's QoS parameters for specific resource values was the aim of this study. Though data networks are sensitive to loss, it may not imply that delay should be completely neglected in data networks performance analysis. Therefore, while data loss rate was analyzed in this work, attention was also given to the corresponding delay, specifically, access delay.

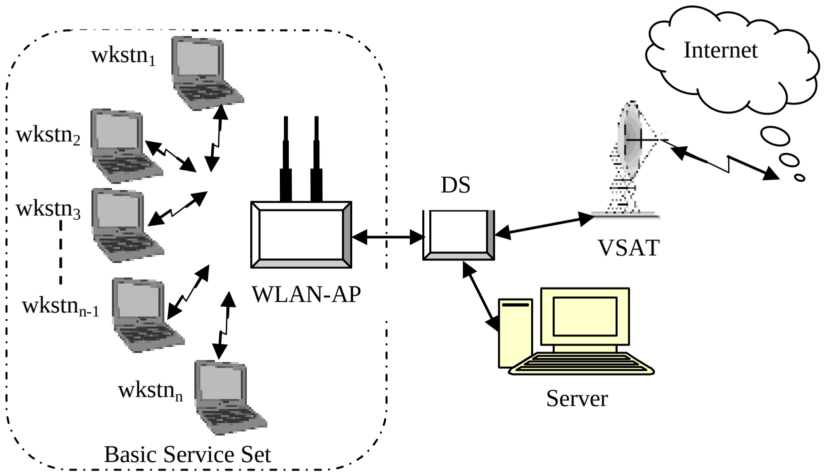
Therefore, WLAN network model was developed and converted into a computer simulation model using MATLAB computer simulation environment. The IEEE 802.11 PCF MAC protocol was the basis for the development of the WLAN model. The model was simulated to determine the influence of traffic loadings on QoS parameters - packet loss rate and delay. Network traffic loadings were simulated by varying the number of workstations linked to the network. Since QoS parameters are influenced by network resources the model was simulated for varying resources – transmission rate and buffer capacity. The simulation results were intended to serve as network loading control tool for network designers and service providers.

WLAN ARCHITECTURE

Figure 1 illustrates the adopted WLAN architecture. The architecture is comprised of workstations (wkstns), the WLAN access point (WLAN-AP), distribution system (DS), server and very small aperture terminal (VSAT). WLAN infrastructure network is comprised of basic service set (BSS), DS and portals. BSS and the DS are usually referred to as extended service set (ESS). The user terminals (workstations) were linked to the WLAN-AP via the atmosphere wirelessly [5]. The BSS is comprised of the workstations and the WLAN-AP. The geographical extent covered by BSS is referred to as basic service area (BSA). All stations within the BSA can also communicate directly with each other wirelessly. The BSS links the server or the VSAT via the DS while the ESS links the internet via the VSAT [9].

The MAC protocol for the architecture was based on PCF which is usually implemented on infrastructure networks [7, 8]. In PCF mechanism, the stations were under the control of a PC where stations polled for transmission were permitted to deliver and receive MAC service data unit (MSDU). Though PCF and DCF can be implemented in the same MAC, this work was dedicated to only the PCF [4].

The packet generation pattern of the workstations is typically that of bursty ON-OFF. The packet generated during the ON period is random and is assumed to have been distributed following Poisson distribution law [10]. The ON and OFF intervals distribution follow the exponential service distribution [10].



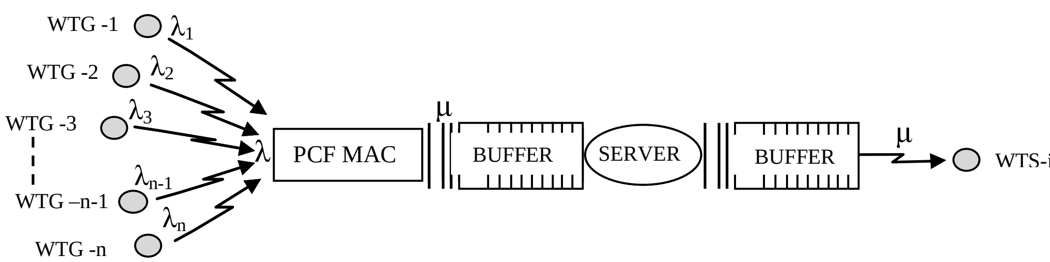
wkstn – Workstation;
WLAN- AP - Wireless LAN Access Point
VSAT - Very Small Aperture Terminal
DS – Distribution System

Figure 1: WLAN Infrastructure network

WLAN MODEL

The performance of a WLAN may be defined by the QoS parameters. The QoS parameters considered in the modeling of the WLAN are packet delay, and loss. The two parameters influence the operation of the network and specifically the resource assignment to the traffic load.

The network model was based on an isolated IEEE 802.11 PCF MAC protocol of the network architecture shown in Figure 1 [9]. Figure 2, therefore, represents the network model.



WTG – Workstation traffic generator
WTS – Workstation traffic sink

Figure 2. Model of PCF WLAN

The WLAN simulation model consists of workstations (source generators and sinks), PCF MAC communication protocol, single server and buffer system. The source generators were intended to generate bursty packets with varied length randomly. The source generators were developed on the basis that packet arrival process is randomly distributed and Poisson in nature with intensity, λ. Also, random exponentially distributed packet lengths were implemented. The server utilization was enhanced by the application of buffering system that controls packet arrivals from the sources and to the sinks. A source transmits packets in bursts when permitted to transmit packets. The rate of packet transmission (transmission rate) through the wireless medium was represented by μ [bps].

Probes were implemented in the model to gather the necessary data on the desired QoS parameters – packet delay and loss rate. Network packet (pkt) delay was considered as being comprised of packet access delay, propagation and processing delays. The average delay was processed as expressed in equation (1) [2, 11, 12]. Network packet loss was considered to consist of packet loss due to access blockage, collision, packet unacknowledgment and buffer overflow. The network packet loss rate is defined as the ratio of the number of packets lost to total number of packets offered for transmission during the simulation period (observation time), see equation (2) [2, 11, 12].

$$Mean\ pkt\ delay = \frac{\sum_{i=1}^{n}\left(value\ of\ delay\ recorded\ for\ each\ packet\right)_i}{Number\ of\ packets,\ n,\ transmitted} \quad (1)$$

$$Packet\ loss\ rate = \frac{Number\ of\ packets\ lost}{Number\ of\ packets\ offered\ for\ transmission} \quad (2)$$

SIMULATION

Figure 2 was converted into a computer simulation model using MATLAB Simulink SimEvent block oriented environment. Insight into the system's performance was provided by the probes strategically positioned to collect data for the calculation of the mean packet delay and packet loss rate as expressed in equations (1) and (2) [13, 14].

The simulation was run for 3600 seconds in other to achieve the required stability during which packet loss rate and delay were computed for varying number of workstations and network resources (buffer storage space and medium transmission rate - bandwidth).

The workstations generate packets with exponential time distribution; the exponential parameter has 0.15 mean value. Network loading was varied from 5 to 100 workstations. The buffer capacity was varied from 5 to 90 while the transmission rate was varied from 1Mbps to 11Mbps.

Figure 3. Bursty Packet Events (Traffic) vs Simulation Time (sec.).

Figure 3 presents the pattern of traffic generation that was employed for the simulation. The pattern was from a single source and depicts a typical bursty ON-OFF packet generation.

RESULTS

The relationships between QoS and number of workstations for varied values of network resources were obtained and illustrated graphically in Figures 4, 5, 8 and 9.

Figures 4 and 5 show the relationship between QoS parameters and varying number of workstations for constant transmission rate and buffer capacity values. Results were obtained for four different transmission rates - 1Mbps, 2Mbps, 5.5Mbps and 11Mbps while buffer capacity remained constant at 50 packets.

In the same way, figures 8 and 9 show the relationship between QoS parameters and varying number of workstations for a given buffer capacity and transmission rate values. Results were also obtained for several buffer capacity values when transmission rate remained constant at 1Mbps. The buffer capacity values were chosen between 1 and 100.

The graphs in figure 4 show that increase in the network traffic loadings results in a sharp rise in packet loss rate from zero value. The number of workstations that may be allowed into the BSA at zero packet loss rate increases with increase in the data transmission rate. For instance, maximum of 30, 40 and 50 workstations may be allowed at 1Mbps, 2Mbps, 5.5Mbps transmission rates respectively. Increases in the transmission rate values beyond 5.5Mbps could not result in further creation of more number of workstations within the BSA at zero packet loss rates. The reason being that at 5.5Mbps transmission rate and above, buffer occupancy remained almost the same for the 80% of the traffic loadings. Generally, the above recorded maximum number of workstations for given transmission rate values may be exceeded if packet loss rate greater than zero is permitted in the network. In the case of 1Mbps transmission rate, more than 30 workstations may therefore be permitted into the BSA if the zero loss rate QoS standard is lowered.

Figure 5 shows that for a given transmission rate increase in traffic loadings resulted in a corresponding increase in the mean network packet delay for 50 packets buffer capacity. The increase was sharp when the number of workstations was below 10 and gradually levels off with continuously increase in the number of workstations. This pattern was illustrates the behavior of buffer occupancy which mostly influences the mean delay. If the network were operated at a 1ms network delay, maximum of 10, 17, 35 and 60 workstations may be permitted at 1Mbps, 2Mbps, 5.5Mbps and 11Mbps transmission rates respectively.

It was clear, from the above, that both packet loss rate and delay need to be considered together while determining the maximum traffic loading on the network for a given buffer capacity and transmission rate. Therefore, harmonization of the different restrictions placed on traffic loadings by packet loss rate and delay requires the combination of the relationships in Figures 4 and Figure 5 as shown in Figure 6. Network maximum traffic loadings were, defined for both packet delay and loss rate values in Figure 6. It is shown in Figure 6 that packet loss standard requirements on network resources would intersect with those for packet delay at a point. The intersection defines the area within which optimum resources would be assigned for given QoS parameter values.

Figure 7 shows the extraction of the relationship between packet loss rate and delay against traffic loadings for 1Mbps transmission rate. The extraction was intended to illustrate the application of Figure 6 in the determination of network traffic loading under a specified network resource capacity. The possible number of workstations permitted in a given BSA for given values of packet loss rate and delay and for fixed quantities of network resources could be determined from Figure 7. The shaded area in the plot represents the area within which WLAN may operate at zero packet loss rates and delay not more than 1ms. Therefore, at 1Mbps transmission rate and 50 packets buffer capacity the maximum number of workstations permitted is 40. In the case where higher packet loss rate and delay are allowed the number of workstations may be consequently increased. If the need arises for lower delay values to be required at zero loss rates, the optimum number of workstations would definitely be less than 40 and could be read from Figure 6 or 7.

Figure 6 shows that, at 2Mbps transmission rate and 50 packets buffer capacity the maximum number of workstations is 48. In the same manner, at 5.5Mbps transmission rate and 50 packets buffer capacity the maximum number of workstations permitted is 62.

Figure 8 presents the graphs that show the relationship between packet loss rate and varying number of workstations for given buffer capacity. The relationship shows that increase in buffer capacity reduces packet loss. The reduction in packet loss rate ceases at a point where buffer occupancy starts to be less than the buffer capacity. Figure 9 shows the graphs that illustrate the relationship between packet delay and varying number of workstations for given buffer capacity. Figure 9 shows that increase in buffer capacity increases the value of packet delay. Figures 8 and 9 could be combined to produce a platform identical to that in Figures 6 and 7 that could be employed for the determination of the optimum number of workstations for a given packet delay, packet loss rate and buffer capacity values.

CONCLUSION

In this paper, computer simulation model for IEEE 802.11 PCF MAC was developed. The model implemented user terminals with bursty packet generation. Traffic loadings were simulated by varying the number of workstations within a BSA.

The relationships between traffic loadings and QoS parameters for specified network resource values were determined. The approach through which optimum number of workstations permitted within a BSA may be determined for given values of QoS and resources was presented. The number of workstations that may be allowed into the BSA at zero packet loss rate increases with increase in the data transmission rate. Therefore, number of workstations may be increased at the expense of QoS standard and network resources.

Figure 6 constitutes the example tool with which optimum network loadings is determined. A more comprehensive tool (loading template) can be determined following the same approach.

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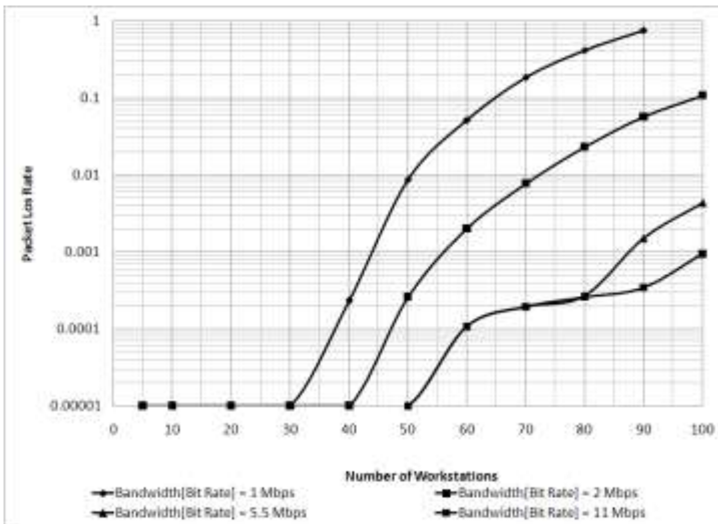

Figure 4. Packet loss rate vs Number of workstations (Buffer capacity = 50 [packets])

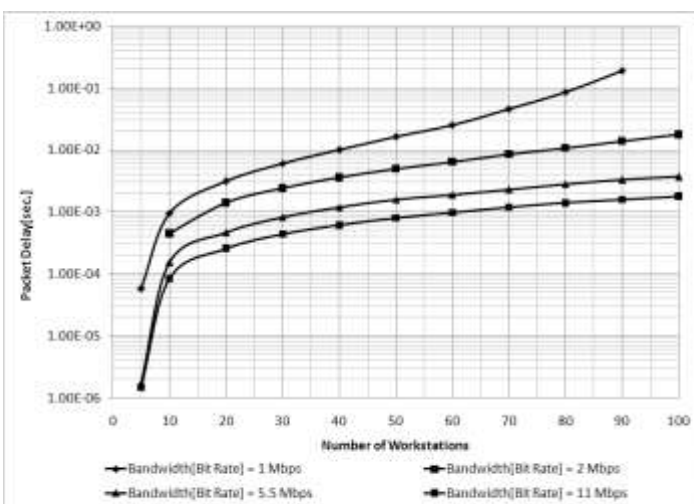

Figure 5. Packet delay vs Number of workstations (Buffer capacity = 50[packets])

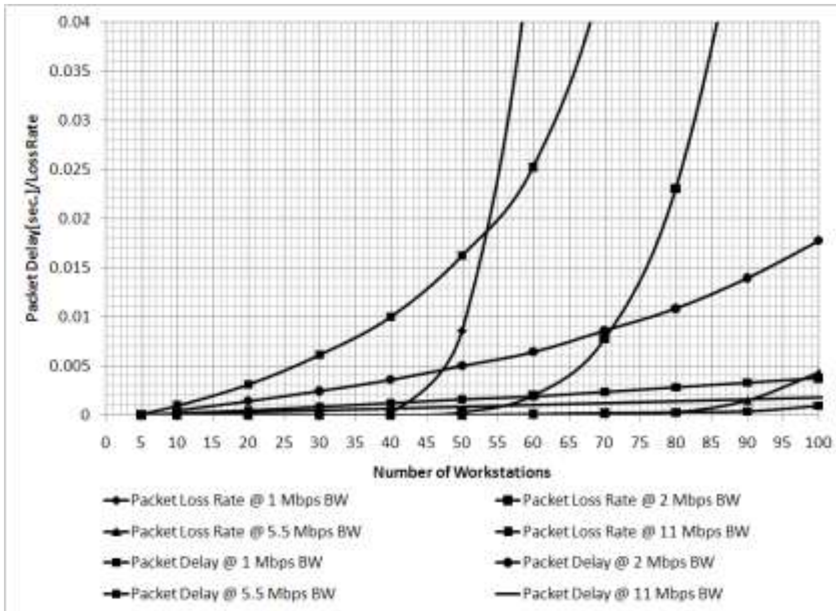

Figure 6. Packet delay/loss rate vs Number of workstations

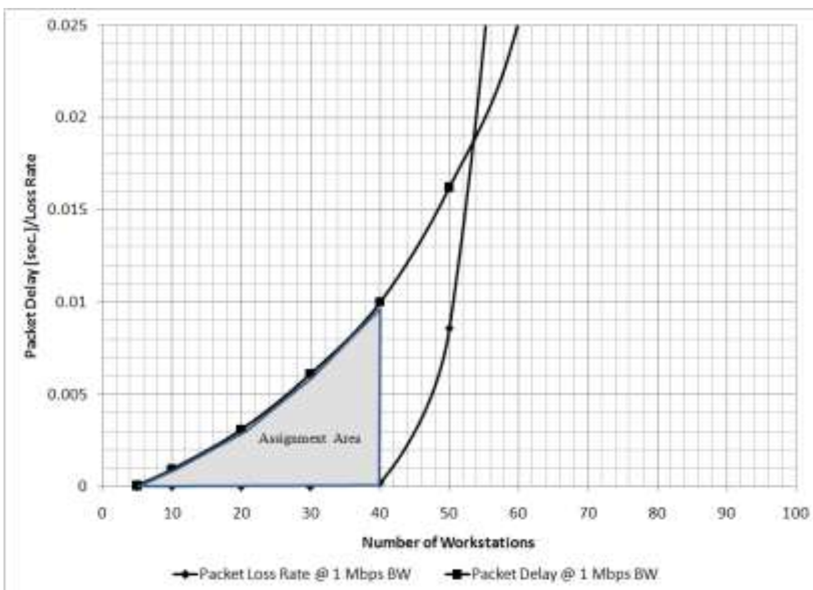

Figure 7. Packet delay/loss rate vs Number of workstations

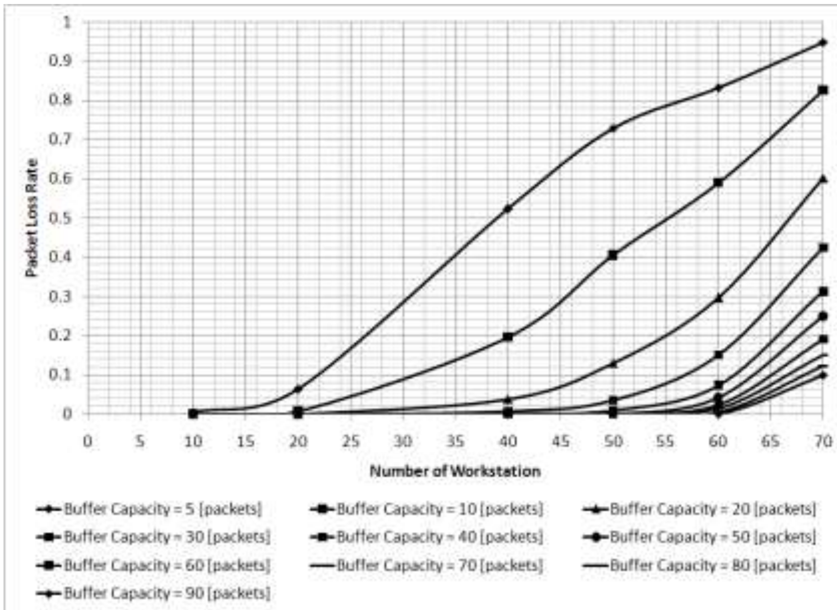

Figure 8. Packet loss rate vs Number of workstations (Transmission rate = 1Mbps)

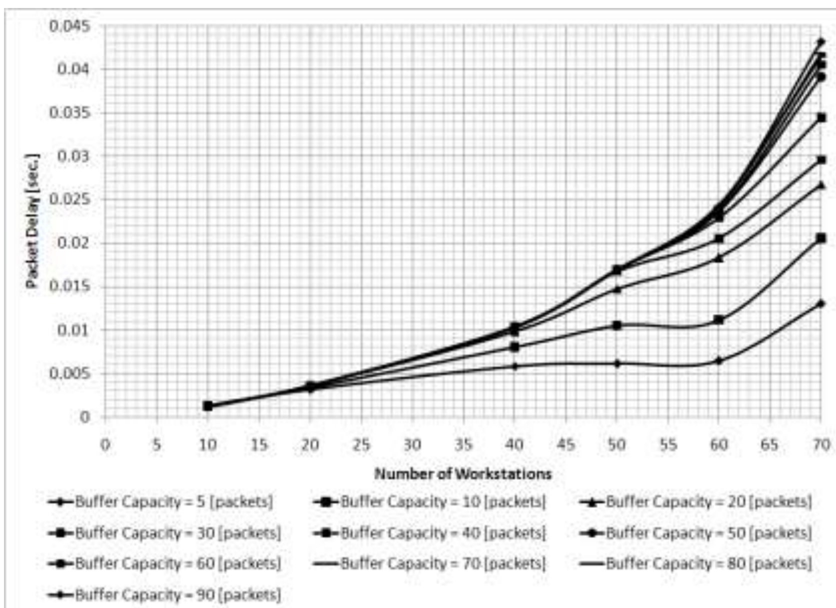

Figure 9. Delay vs Number of workstations (Transmission rate = 1Mbps)