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INTELLIGENT SOLUTION TO CONGESTION CONTROL IN 4G WIRELESS NETWORK USING FUZZY LOGIC TECHNIQUE

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ABSTRACT

This paper seeks to address the problem of congestion in 4G Wireless Local Area Network (WLAN) using fuzzy logic technique. To achieve this fuzzy logic controller was developed considering key packet data attributes such as backlog factor, packet arrival factor and the probability factor as he fuzzy membership functions. These were used to model a congestion control system which was implemented in a WLAN using fuzzy logic toolbox and Simulink. The result when evaluated with Http data showed that the average throughput on the network is 89% which is very good based on the Nigerian Communication Commission (NCC) requirement for quality of service in 4G network. The latency was also evaluated and the result showed that average delay recorded in the end to end communication process is 75.3ms which is recommended for improvement in further studies.

Keywords: **WLAN, Congestion, fuzzy logic, 4G Network, NCC, latency, throughput**

1. INTRODUCTION

Every form of digital or analogue communication system has a limited data size and traffic it can carry. In a case where the demand is more than the required capacity, congestion occurs; latency or delay in data transmission operability is experienced (Coutras et al., 2000). The need to prevent this is of great importance to public and private data network entities to facilitate the operation of trade, industries, transport, network, provision and planning.

Over the past decade, congestion control has been a focus in the research community, especially in the field of information and communication technology. The author will say that without proper congestion management, there is chance of inefficient utilization of resources which can pipeline to a collapse of network. Therefore, congestion control and management are processes of adaptation in network performance to changes in the traffic load without adversely affecting users perceive utilities (Ochi et al., 2015).

Today, complex functions are integrated by end users as a result of internet, to keep the core routers of network scalable and simple. Currently, most of the functionalities of the present internet lies within the end user's protocol, especially transmission control protocol (TCP). This strategy has been one of the best in use till date however, due to the increase of traffic volume and evolution of networks; routers need to be involved in the congestion control of traffic (Meng et al., 2019). This process facilitates smooth traffic management and control through differentiated services to various users.

Congestion management of differential mechanism of TCP provides adequate and better throughput via a network. According to Chen and Li (2016) the best result in the wired network tackles congestion challenge where the packet data loss is due to traffic at various routers and nodes. The Control of Congestion and avoidance are the existing solutions that addresses the challenges such as the attributes of poor latency, packet losses etc. In IP, congestion issue occurs when the sender receives three duplicated acknowledgements or when the losses of packet occur, leading to mis management of resources (Tshimangadzo et al., 2020). During the control scheme process, the networks parameter after the realization of traffic queue is reactive while in traffic prevention the scheme manages the network parameters before the occurrence of congestion. This is a proactive process (Mathonsi et al., 2019). The need to manage this network congestion and improve this problem in wireless network has become imperative and is proposed to be addressed in this paper using intelligent system which used fuzzy logic approach to coordinate traffic in WLAN and ensure quality of service.

2. LITERATURE REVIEW

Luigi et al. (2017) presented a study on large-scale network utility maximization (NUM); countering exponential growth. The work was done with the use of exponential gradient technique. The research revealed that the approach applied was able to develop a scalable algorithm tool that was capable of maintaining the same efficiency when the load of the work increases. Furthermore, it provides efficient solutions in time which is magnitude-free.

Ioannis et al (2008) presented a case study on intelligent routing and bandwidth allocation in wireless networks. The work was carried out with the use of swarm-based routing algorithms. The research revealed that the technique depended on the interaction of autonomous agents such as biological agents, who interact with each other all through the environment.

Harris (2017) presented a research on wireless networks with artificial intelligence design, challenges and opportunities. The research discussed the rise of network intelligence and went further to reveal the relationship between artificial intelligence and machine learning to self organization designs. The study provides the need for learners and readers with keen motivation for adoption of artificial intelligence.

Yongmin et al. (2017) presented a research on distributed control and optimization of wireless networks. The research was achieved with the use of Huffman coding and ant colony technique. The author affirmed that various bibliographies relating to wireless network were investigated. Furthermore, the work revealed that for the optimization of wireless network, Huffman coding and ant colony are effective approaches.

3. METHODOLOGY

The methodology used for the development of the new system is based on the IEEE 802.11 for 4G based WLANs. The network under study is made up of the access point, the network nodes, switches, routers as shown in the figure 1.

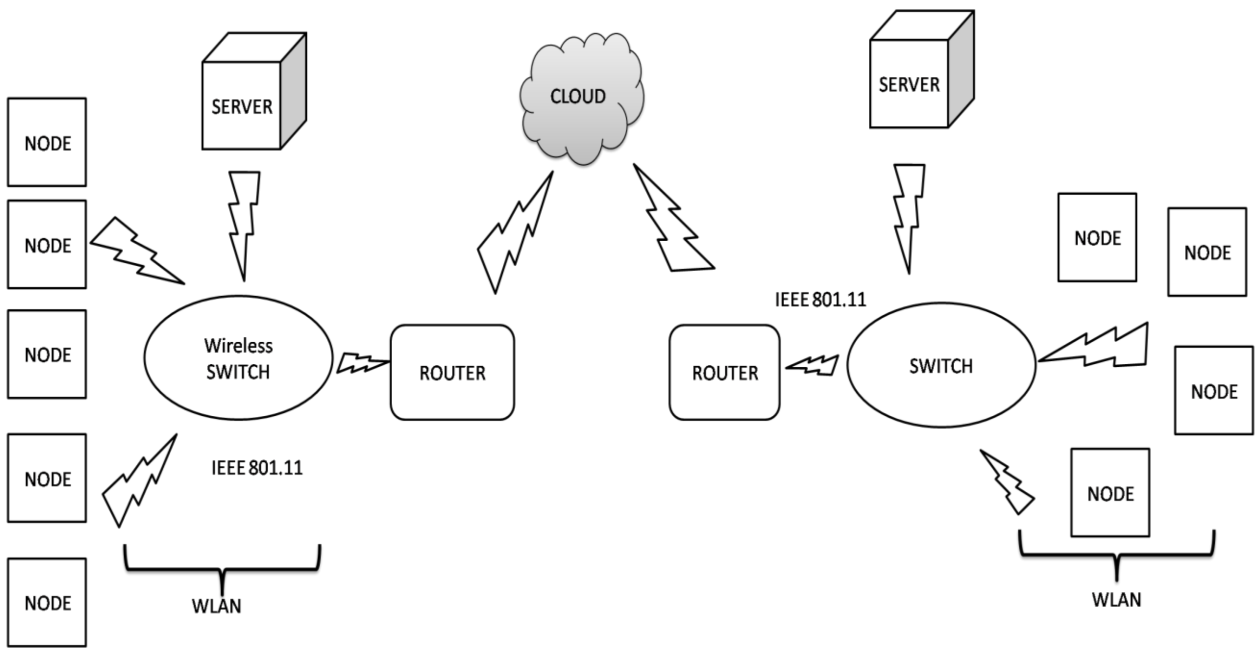

Fig. 1: Wireless Local Area Networks (WLANs) Architecture

The figure 1 showed the network diagram of the case study WLAN which presented the communication setup between various nodes in the area. The network presented the end to end communication between the WLAN showing how the nodes exchange files. However the challenges encountered in the network is due to the size of data been transmitted and then number of nodes interconnected on the network, the congestion control mechanism used to develop the network lack the robustness to control multiple large packets like video calls and http at the same time simultaneous across the network and this results to latency, poor throughput and losses. This has resulted to a major problem which is proposed to be tackled in this research using intelligent congestion control scheme

4. SYSTEM DESIGN AND MODELLING

The intelligent congestion control scheme employed is the fuzzy logic algorithm which employed set of fuzzy rules to control sense the freedom in the carrier channels and control congestion. The fuzzy decision is based on the First in First Out (FIFO) rule which allows only packet information which first enter the carrier channel to transmits while delaying others as shown in the figure 2;.

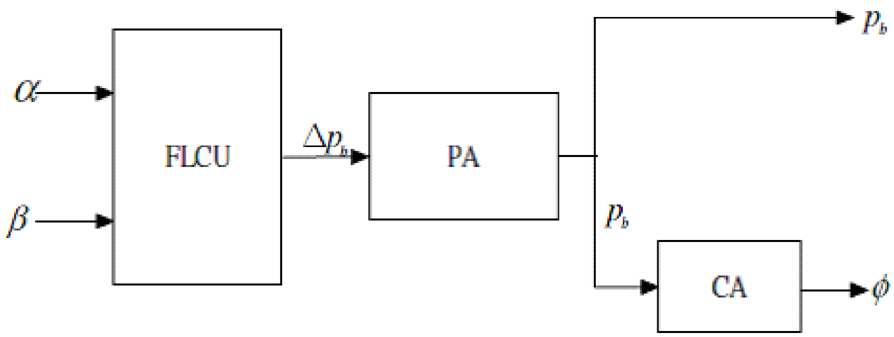

Fig. 2: The fuzzy logic control architecture

A single FIFO in which the packet data equally treated is used. The queue status is also assumed at time of 0.50milliseconds so as to obtain the queue occupation size (blacklog) q(t) and the rate of traffic arrival r(t). The backlog q(t) is translated into the backlog factor α which is the ratio of backlog with respect to the Buffer Size BS where the packet arrival is computed by the actual size of packet that is received at buffer end during the sampling period as;

$$\alpha = q(t) / BS \quad (1)$$

From the equation 2 we assign the number of packets per period to n and measuring weight to ω_1 and $r_m$the maximum packet arrival rate. The weighted mean packet arrival rate r(t) and the packet arrival factor presented in the equations 2 and 3 respectively;

$$\overline{r(t)} = \omega_1 * \overline{r(t-\tau)} + (1-\omega_1) * n \quad (2)$$

$$\beta = \begin{cases} \overline{r(t)/r_m} & \overline{r(t)<r_m} \\ 1.0 & r(t)\geq r_m \end{cases} \quad (3)$$

This determines variation in the data marketing probability fuzzy parameters of α. A rule-based is employed to process the two variables to the output Δp_bbased on the degrees in membership function. Following the rule below such as If α is medium and is medium then b Δp_b is zero. Two functions determine the input variables and a membership is defined for defuzzification of Δp_b. The new packet probability is defined in the equation 4 as

$$P_b(t) = P_b(t-\tau) + \Delta P_b(t) \quad (4)$$

Packet is labeled with a chance probability pb.

Table 1: Fuzzy Rule Settings

S/N	**Backlog Factor A**	**Packet Arrival Factor**	**Change in Dropping Probability**
			ΔP_b
1	Medium	Medium	Normal
2	Low	Medium	Normal
3	High	Medium	High

4	Low	Low	low
5	High	High	High
6	Medium	Low	normal
7	Low	High	High
8	Medium	High	High
9	High	Low	High

The figure 3 presented the flow chart of the intelligent congestion control scheme. The model showed how the fuzzy logic rules was used to control and coordinate packet input to the network based on the packet arrival factor to allow throughput when the packet has a high factor for arrival then the next in the packet arrival priority is scheduled for throughput until the last packet.

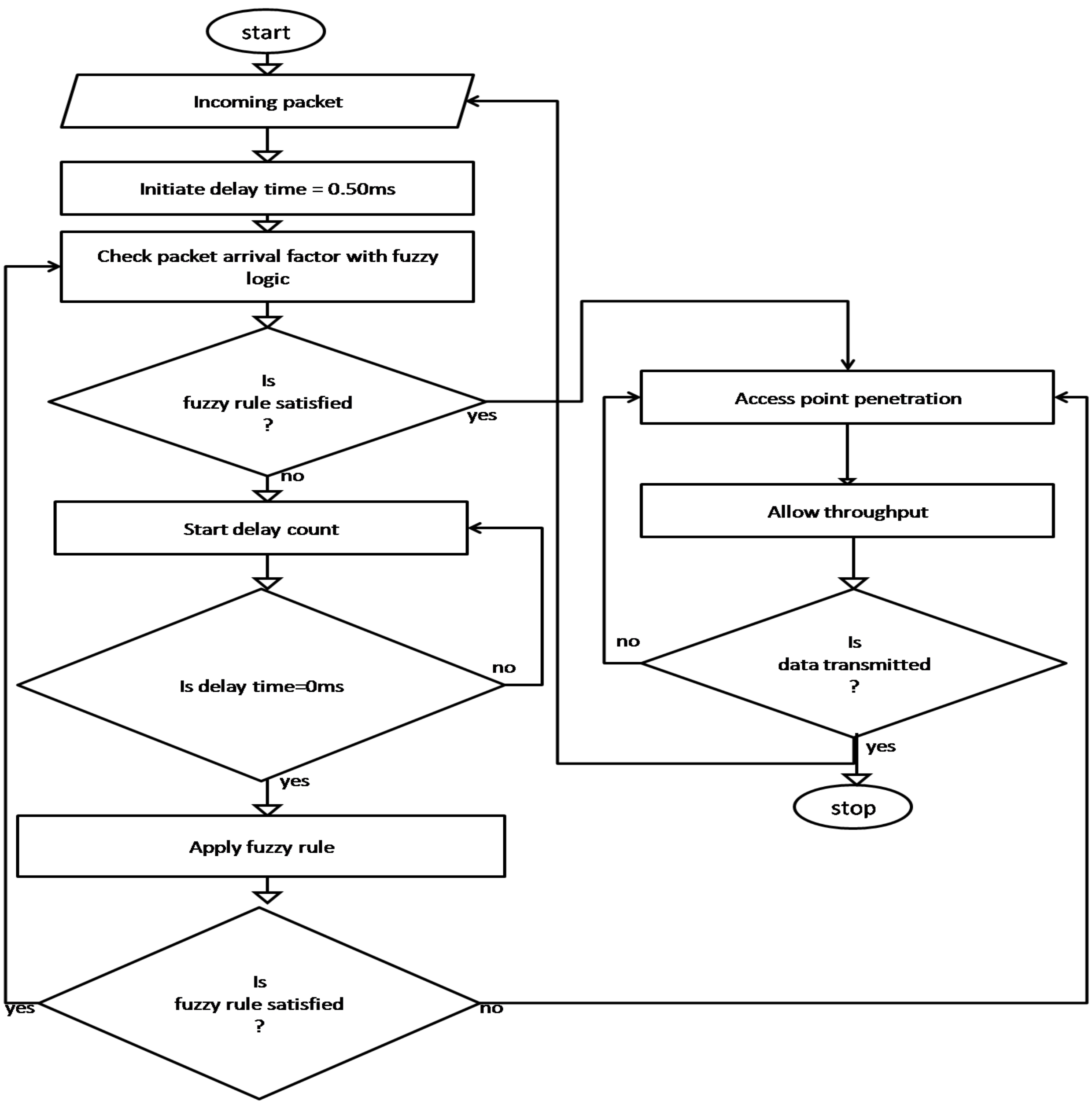

Figure 3: The flow chart of the intelligent congestion control scheme

5. SYSTEM IMPLEMENTATION

The system was implemented with the fuzzy logic toolbox, LTE toolbox, communication toolbox and Simulink. The communication toolbox was used to setup the communication system between the WLAN, the LTE tool was sued to power the communication network with 4G service, while the fuzzy logic tool was configured with the fuzzy rules in table 1 and used to control congestion of incoming packets to the network. The fuzzy logic congestion control is presented in figure 4, while the improved WLAN with the fuzzy logic is in figure 5. The model was simulated with the parameters in table 2.

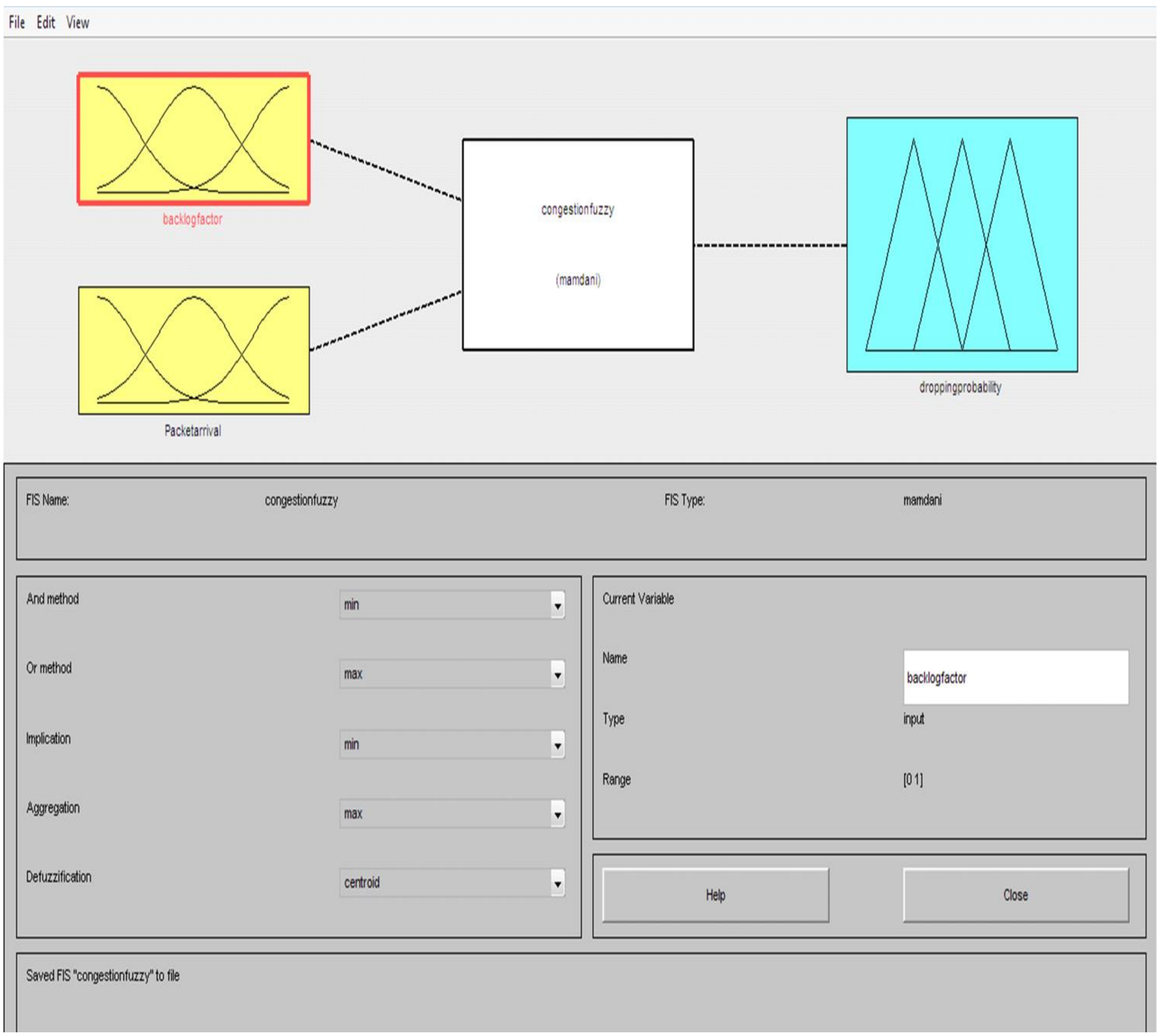

Figure 4: The Simulink model of the fuzzy congestion control system

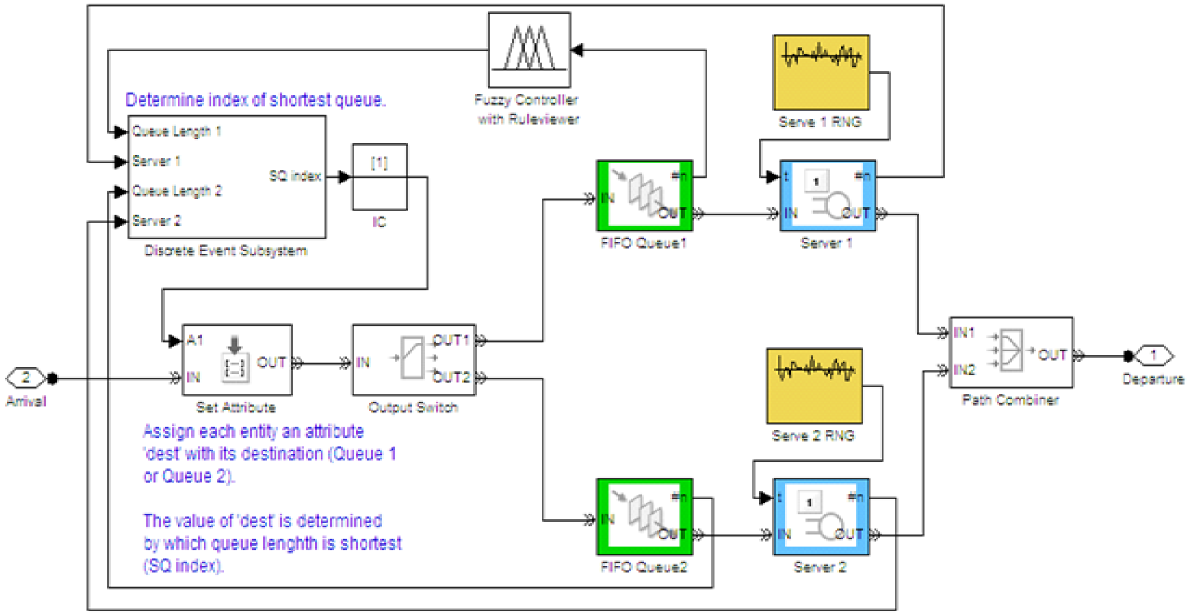

Figure 5: Simulink model of the wireless communication network

Table 2: Simulation parameters of the WLAN

Parameter	Value
Simulation time in seconds	20s
Protocol	IP/UDP/RTP
MACs	CSMA/CA
MAC data rates	11 Mbit/s
Carrier frequencies	2.4 GHz
Transmitting power	2.0 Mw
Thermal noise	-110 dBm
Sensitivities	-85 dBm
SNIR	4 dB
Simulation areas	600 x 400 m
http data rates	http kbit/s

6. RESULTS AND DISCUSSIONS

The result being with the performance of the fuzzy member ship functions used to develop the congestion control system. The membership functions are the key parameters of the packet used to make rules and allow throughput. The figure 6 presented the performance of the backlog factor as modeled in equation 1, packet arrival factor in equation 3 and the probability factor in equation 4;

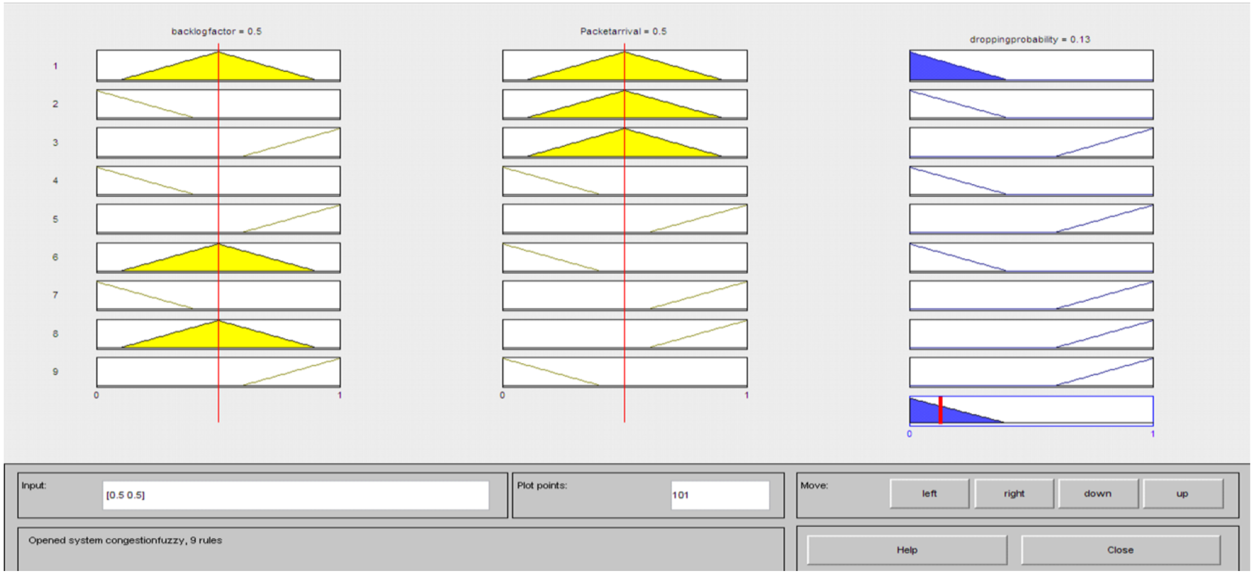

Figure 6: The result of the fuzzy logic

The figure 6 presented the performance of the fuzzy logic congestions control system. From the result the 9 rules in table 1 was used to decide the congestion control performance based the data input which has high level of the backlog factor, packet arrival factor and the probability factor. To measure the throughput performance of the fuzzy logic based congestion control network, the throughput model in Uzochukwu and Onoh (2022) was used and the result was presented as figure 7;

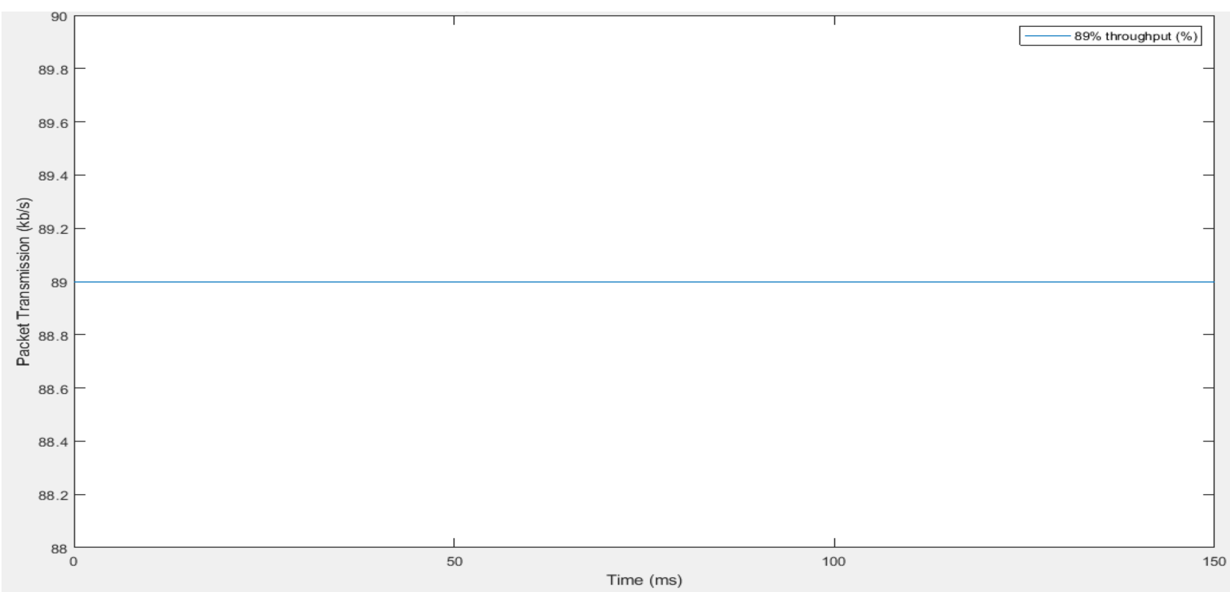

Figure 7: Throughput performance

The figure 7 presented the throughput performance of the network using the congestion control scheme and the result showed that when the packet was transmitted, the average throughput recorded is 89% which is good as it satisfied the Nigerian Communication Commission (NCC) Standard for quality of service. Also the latency model in Uzochukwu and Onoh (2022) was used to measure the time it took for data to be transmitted and delivered in the WLAN and the result was presented in figure 8;

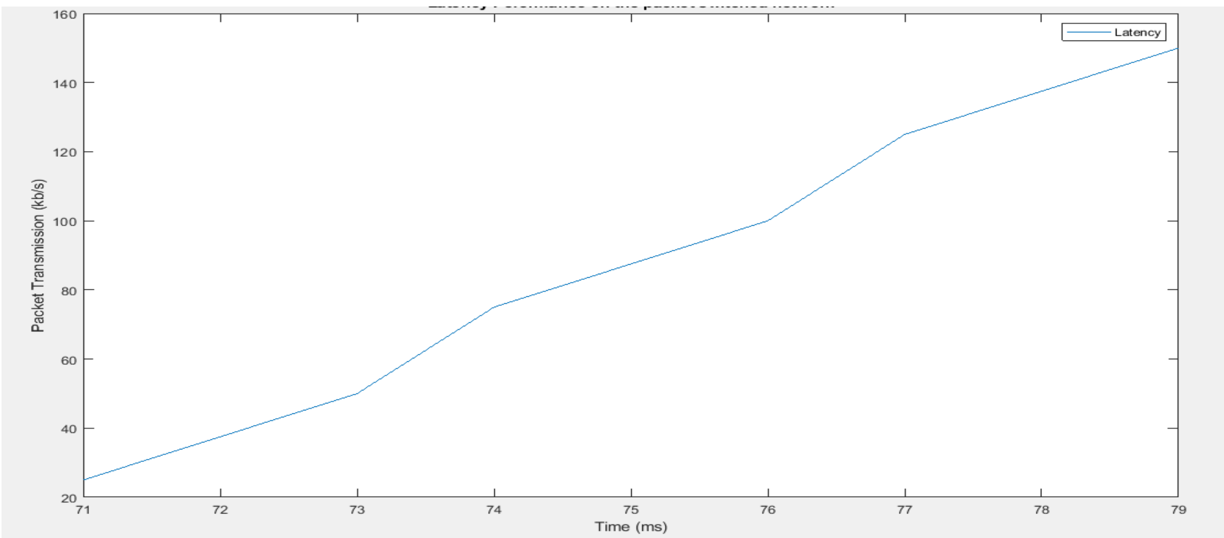

Figure 8: The latency performance

From the result in the figure 8, the performance of data communication in the WLAN was evaluated using latency and the result showed that the average latency is 75.3ms. The implication of the result showed that the training time of the fuzzy logic to prevent congestion on the network induces the delay in the network, but it is tolerable as the packet transmitted is not delay sensitive. However in data like voice of over internet which has considerable small size, the delay time will be drastically reduced.

7. CONCLUSION

Congestion has remained a major problem in WLAN over the years as the number of user and data rate keep increasing. To solve this problem an intelligent solution has been developed which employed fuzzy logic solution considered packet parameters such as backlog factor, packet arrival factor and the probability factor to control congestion and schedule packet for throughput. The result showed that throughput achieved 89% which satisfied the NCC standard. The latency achieved was also recorded as 75.3ms which can be reduced in further studies.

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