Enhanced Transmission Efficiency of Multimode Optic Fiber for Long Distance Data Transmission Using Fuzzy Controller

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Abstract: **The high rate of delay in multimode optic fiber transmission efficiency has agitated to introduction of enhanced transmission efficiency of multimode optic fiber for long distance data transmission using fuzzy controller. It is done in this manner, characterizing the network understudy, evaluating the causes of low transmission in multimode optic fiber from the characterized data, designing a multimode optic fiber rule base that will eradicate the causes of low transmission in multimode like congestion and designing a SIMULINK model for enhanced transmission efficiency of multimode optic fiber for long distance data transmission using fuzzy controller. The results obtained after its extensive simulation are the lowest conventional bit error rate occurred in 10seconds and it is 0.000020 while when fuzzy controller is imbibed in the system it is 0.000001913. With these results it shows that when fuzzy controller is introduced in the system the efficacy of multimode transmission enhanced, the lowest conventional congestion is 1.76 while that when fuzzy logic controller is inculcated in the system is 1.683. With these obtained results, it indicates that when fuzzy controller is incorporated in the system the transmission efficiency of multimode optic fiber increased and the highest conventional throughput is 8 while the throughput when fuzzy controller is embedded in the system is 8.748.The higher throughput observed when fuzzy controller is applied in the system increased the transmission efficiency of multimode optic fiber.**

***Keyword*: Enhanced, transmission efficiency, multimode optic fiber, fuzzy controller**

I. INTRODUCTION

It is an axiomatic that Multimode optic fiber is synonymous to transmitting data in a shorter distance, but its transmission of data to a long distance is delayed by interference, congestion, high attenuation, low throughput, low signal to noise ratio [1]. The transmission of data through optical fiber cables over long distances in communication systems usually experience different types of dispersion and other forms of losses that have impact on transmission performance [2]. Nonlinear characteristics of an optical fiber channel are important in determining the transmission capacity and performance of the system [3; 4; 5]. In order to improve transmission range and minimize data transmission losses, optimization configuration of combinations depends on few factors such as dispersion and optical signal power. There are advantages and disadvantages of using nonlinear effects in optical fiber. The advantages of using nonlinear effects in optical fiber is that it identifies when the network are experiencing the following; congestion, low throughput, low signal to noise ratio that cause bad performance of the network, while its disadvantage is that it takes longer time for it to be identified which might cause serious damage to the multimode fiber data network [6; 7; 8]. These disadvantages have leaved great room for improvement as they have results to over poor quality of service in the network. This paper therefore proposes to address the problems using fuzzy logic controller.

II. METHODOLOGY

The methodology used for the study is characterization which involves the analysis of an optic fiber network to determine the quality of transmission energy efficiency over long distance. the data was collected from Glo Nig Limited which is the first communication network in Nigeria to install long haul optical communication network. This was done to measure the quality of service on the network over 10years and over a distance of 120km using data collection as presented in table 1;

Table 1: data collection for characterization

Yearly	Yearly attenuation	File size	Transmission time (s)	Packet transferred data	Packet Re-transmitted
2009	62.8	16	2	30	25
2010	62.8	20	4	28	24
2011	47.8	24	5	26	20
2012	100.5	16	3	26	18
2013	416.2	18	7	24	16
2014	236	26	6	24	14
2015	306.3	28	8	22	12
2016	287.4	18	4	22	11
2017	205.5	30	5	22	11
2018	311.1	16	4	20	12

The table 1 presented the data collected for characterization, the aim was to use the data and measure the quality of service on the optic network each year using packet loss and congestion as key performance indicators as shown in the model of equation 1 according to [9; 10].

$P = 8/ 3C^2$ --1

Where P is packet loss

C is the network congestion

Then, make C the subject formula in equation 1

The mathematical model for congestion in the network is as shown in equation 2 according to [9]

$P = 8/ 3C^2$

$3C^2P = 8$

$C^2 = 8/3P$

$C = \sqrt{8}/3P$--2

The equation 1 and 2 was used to measure the congestion rate and packet loss on the network with respect to the data in table 1 and the result achieved was reported in the table 2;

Table 1: Quality of service in the optical network characterized

Yearly	Packet loss experienced yearly	Congestion experienced yearly
2009	0.833	1.79
2010	0.857	1.76
2011	0.769	1.86
2012	0.692	1.86
2013	0.667	2.00
2014	0.285	3.04
2015	0.545	2.21
2016	0.556	2.20
2017	0.556	2.20
2018	0.636	2.01

The recorded data of table 1 calculations are presented below;

To find the network congestion in 2009 when the packet loss is 0.833

$C1 = \sqrt{8 / 3 \times 0.833}$

$C1 = \sqrt{8 / 2.499}$

$C1 = \sqrt{3.2013}$

$C1 = 1.79$

Congestion in 2010 when packet loss is 0.857

$C2 = \sqrt{8 / 3 \times 0.857}$

$C2 = \sqrt{8 / 2.571}$

$C2 = \sqrt{3.11}$

$C2 = 1.76$

Congestion in 2011 when packet loss is 0.769

$C3 = \sqrt{8 / 3 \times 0.769}$

$C3 = \sqrt{8 / 2.307}$

$C3 = \sqrt{3.47}$

$C3 = 1.86$

Congestion in 2012 when packet loss is 0.692

$C4 = \sqrt{8 / 3 \times 0.769}$

$C4 = \sqrt{8 / 2.307}$

$C4 = \sqrt{3.4677}$

$C4 = 1.86$

Congestion in 2013 when packet loss is 0.667

$C5 = \sqrt{8 / 3 \times 0.667}$

$C5 = \sqrt{8 / 2.001}$

$C5 = \sqrt{3.998}$

$C5 = 1.99$

$C5 = 2.0$

Congestion in 2014 when packet loss is 0.2858

$C6 = \sqrt{8 / 3 \times 0.285}$

$C6 = \sqrt{8 / 0.867}$

$C6 = \sqrt{9.23}$

$C6 = 3.04$

Congestion in 2015 when packet loss is 0.545

$C7 = \sqrt{8 / 3 \times 0.545}$

$C7 = \sqrt{8 / 1.635}$

$C7 = \sqrt{4.893}$

$C7 = 2.21$

Congestion in 2016 when packet loss is 0.55

$C8 = \sqrt{8 / 3 \times 0.55}$

$C8 = \sqrt{8 / 1.65}$

$C8 = \sqrt{4.85}$

$C8 = 2.2$

Congestion in 2017 when packet loss is 0.55

$C9 = \sqrt{8 / 3 \times 0.55}$

$C9 = \sqrt{8 / 1.65}$

$C9 = \sqrt{4.85}$

$C9 = 2.2$

Congestion in 2018 when packet loss is 0.636

$C10 = \sqrt{8 / 3 \times 0.636}$

$C10 = \sqrt{8 / 1.908}$

$C10 = \sqrt{4.193}$

$C10 = 2.01$

Congestion in 2019 when packet loss is 0.6

C11= √ 8 / 3 x 0.6

C11= √ 8 / 1.8

C11 =√ 4.44

C11 = 2.1

Characterization of the Throughput and Bit error rate performance

To measure the throughput which is the amount of data delivered by the optical network over the given period of time, the model in equation 3 was used and also considered to develop the bit error rate model in equation 4 and the calculated results presented in table 3;

Throughput = file size/transmission time ----------3

Throughput1 = 16/2 = 8bps

Throughput2 = 20/4= 5bps

Throughput3 = 24/5 = 4.8bps

Throughput4 =16/3 = 5.33bps

Throughput5 =18/7 = 2.57bps

Throughput6 =26/6 = 4.33bps

Throughput7 = 28/8 = 3.5bps

Throughput8 = 18/4 = 4.5bps

Throughput9 = 30/5 =6bps

Throughput10 = 16/4 = 4bps

To determine an ideal bit error rate convenient for the characterized network

BER1 = PER/8 × MTU × 1.03125 ------------------------4

Where MTU is 12000

BER1 = 0.833/8 x 12000 x1.03125

BER1 = 0.833/9900

BER1 = 0.0000841bits

To find the bit error rate in 2010 when the packet loss is 0.857

BER2 = 0.857/9900

BER2 = 0.0000866bits

To find the bit error rate in 2011 when the packet loss is 0.769

BER3 = 0.769/9900

BER3 = 0.0000777bits

To find the bit error rate in 2012 when the packet loss is 0.692

BER4 = 0.692/9900

BER4 = 0.0000699bits

To find the bit error rate in 2013 when the packet loss is 0.667

BER5 = 0.667/9900

BER5 = 0.0000674 bits

To find the bit error rate in 2014 when the packet loss is 0.2858

BER6 = 0.2858/9900

BER6 = 0.000030 bits

To find the bit error rate in 2015 when the packet loss is 0.545

BER7 = 0.545/9900

BER7 = 0.0000551bits

To find the bit error rate in 2016 when the packet loss is 0.545

BER8 = 0.545/9900

BER8 = 0.0000551bits

To find the bit error rate in 2017 when the packet loss is 0.636

BER9 = 0.636/9900

BER9 = 0.0000642bits

To find the bit error rate in 2018 when the packet loss is 0.636

BER10 = 0.2/9900

= 0.000020bits

To find the bit error rate in 2019 when the packet loss is 0.6

BER11 = 0.6/9900= 0.000061bits

Table 2: The throughput and bit error rate performance of the optical network

Yearly	Throughput (bps)	Bit error rate
2009	8.00	0.0000841
2010	5.00	0.0000866
2011	4.80	0.0000777
2012	5.33	0.0000699
2013	2.57	0.0000674
2014	4.33	0.0000300
2015	3.50	0.0000551
2016	4.50	0.0000551
2017	6.00	0.0000642
2018	4.00	0.0000200

From the table 1 and 2; the qualities of service in the optical network have been evaluated using congestion, packet loss, bits error rate and throughout as key performance indicators (KPI) to measure the quality of service over long distance. From the result it was observed that the behavior of the network is very unstable network still leaves great room for improvement. To achieve this, the research proposed to develop a fuzzy based network controller which ensure optimal performance of the KPI and achieved quality of service.

III. DEVELOPMENT OF THE FUZZY LOGIC CONTROL SYSTEM

To develop the fuzzy logic control system a set of rules was established based on the data collected from the domain expert of the case study optical network and then used to information to establish a rule base information as shown in table 3;

Table 3: Rule base information settings

1	if congestion is observed reduce	and interference is observed reduce	and throughput is low increase	then transmission efficiency is bad
2	if congestion is not observed maintain	and interference is not observed maintain	and throughput is high maintain	then transmission efficiency is good
3	if congestion is observed reduce	and interference is not observed maintain	and throughput is low increase	then transmission efficiency is bad

The table 3 presented the rule established and used to develop the fuzzy based engine used to improve the quality of service in the optical network. The block model of the fuzzy based system is presented in the figure 1;

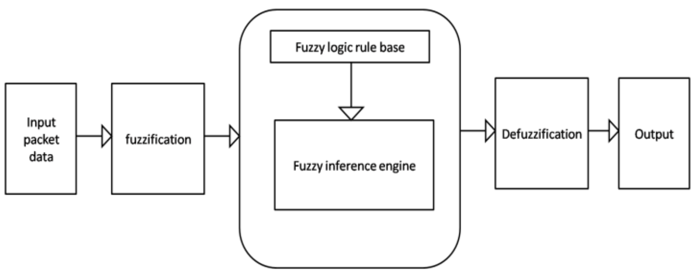

Figure 1: fuzzy logic control system

In the figure 1, the input from the user equipment transmitted by the optical network are first convert the optical packet into fuzzy values and then used the rule base to improve the quality of performance within the inference engine. The output was then converted back to optical packet and then transmits to the receiver end.

IV. SYSTEM IMPLEMENTATION

The system was implemented using fuzzy logic toolbox in Simulink to train the rule based and develop the fuzzy controller as shown in the simulink editor in figure 2;

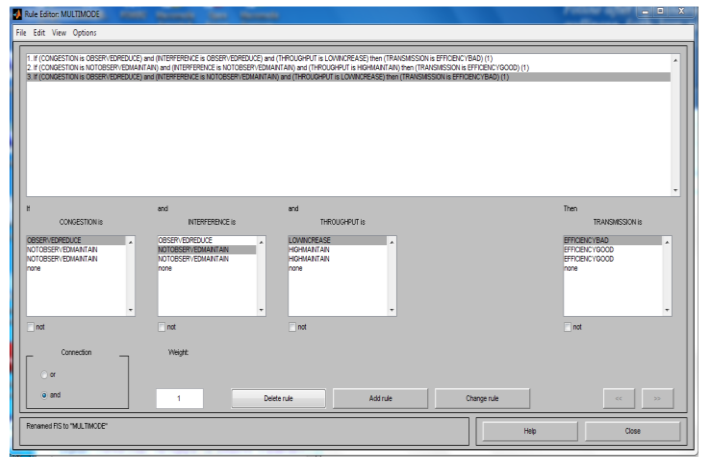

Fig 2: Simulink tool for training the fuzzy logic engine

The figure 2 presented the rule based training tool of simulink using fuzzy logic toolbox and then deployed the fuzzy controller produced on the optical network as shown in the simulink model in figure 3;

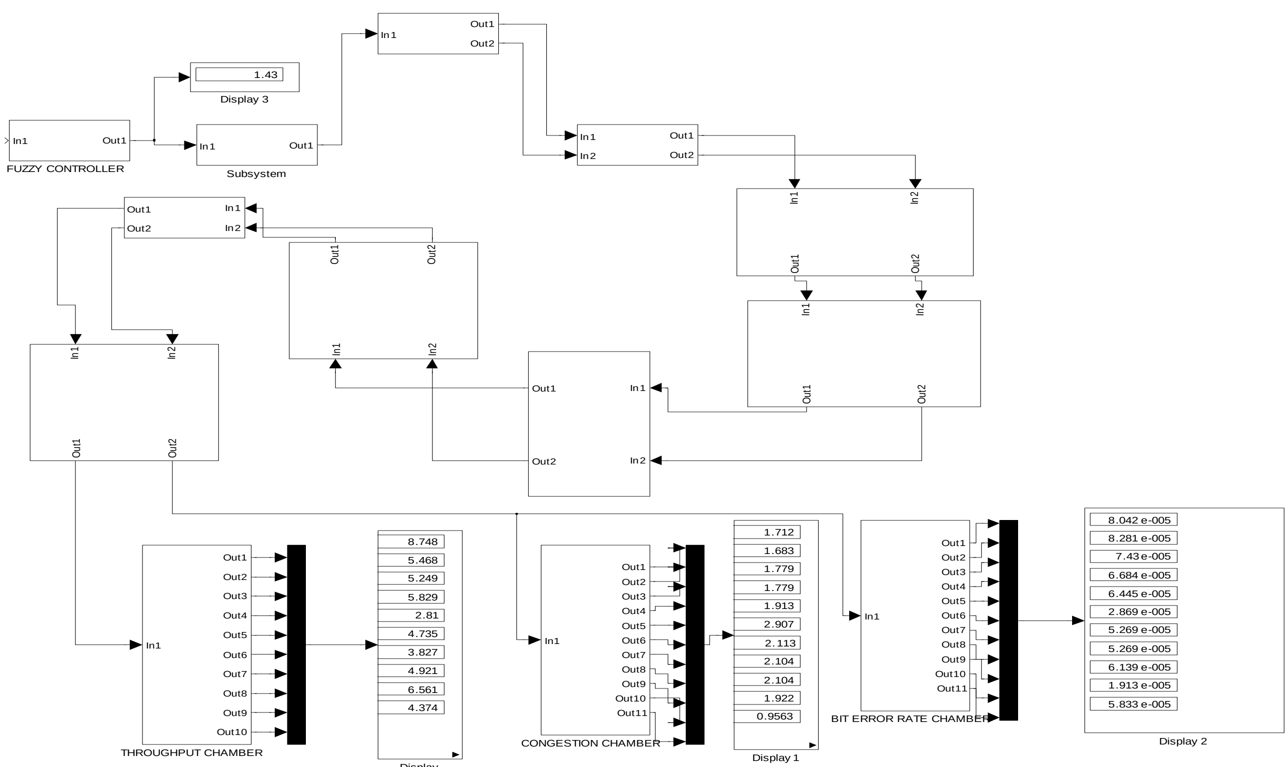

Figure 3: The simulink model of the optical network with fuzzy control system

The figure 3 presented the improved optical network model which was simulated and the result presented in the next section using the bit error model in equation 4.

V. DISCUSSION OF RESULT

The section presented the bit error rate of the optical network simulated and measured with the bit error rate analyzer using the same size of data in the characterized Glo optical network. The result collected was presented in table 4;

Table 4: Bit Error Performance

Time(s)	Bit error performance
1	0.00008042
2	0.00008281
3	0.0000743
4	0.0000684
5	0.00006446
6	0.00002869
7	0.00005269
8	0.00005369
9	0.00006139
10	0.000001913
11	0.00005833

The table 4 presented the bit error performance of the optical network simulated and evaluated. The result achieved was compared with the characterized result to evaluate the performance as shown in table 5;

Table 5: comparing conventional bit error rate and fuzzy controller bit error rate in

Time(s)	Characterized system without fuzzy	Fuzzy controller
1	0.0000841	0.00008042
2	0.0000866	0.00008281
3	0.0000777	0.0000743
4	0.0000699	0.0000684
5	0.0000674	0.00006446
6	0.000030	0.00002869
7	0.0000551	0.00005269
8	0.0000551	0.00005369
9	0.0000642	0.00006139
10	0.000020	0.000001913
11	0.000061	0.00005833

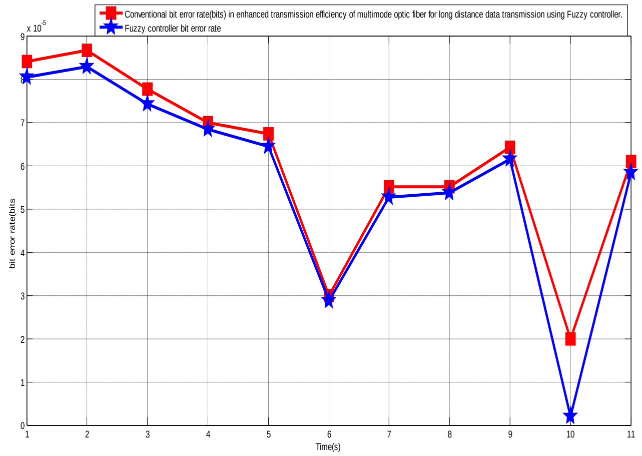

Figure 4: Comparative Bit error result

Figure 4 shows that the lowest conventional bit error rate occurred in 10seconds and it is 0.000020 while when fuzzy controller is imbibed in the system it is 0.000001913. With these results it shows that when fuzzy controller is introduced in the system the efficacy of multimode transmission enhanced. The next result presented the congestion management performance of the system via the analysis if the comparative throughput results as shown in table 6;

Table 6: Comparative throughput performance

Time (s)	Throughput without fuzzy logic(bps)	Throughput with fuzzy controller (bps)
1	8	8.748
2	5	5.468
3	4.8	5.249
4	5.33	5.829
5	2.57	2.81
6	4.33	4.736
7	3.5	3.827
8	4.5	4.921
9	6	6.561
10	4	4.374

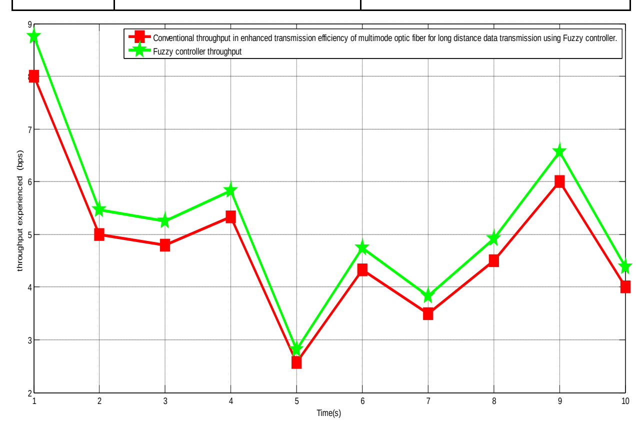

Figure 5: Comparative throughput performance

Figure 5 shows comparing conventional throughput and fuzzy controller throughput in enhanced transmission efficiency of multimode optic fiber for long distance data transmission using fuzzy controller. In figure 5 the highest conventional throughput is 8bps while the throughput when fuzzy controller is embedded in the system is 8.748bps.The higher throughput observed when fuzzy controller is applied in the system increased the transmission efficiency of multimode optic fiber.

VI. CONCLUSION

A lot of delay in the transmission of data in multimode optic fiber has demoralized some of the subscriber to continue subscribing in the network. This calls for introducing enhanced transmission efficiency of multimode optic fiber for long distance data transmission using fuzzy controller to prevent multimode network delay in transmission. To achieve this it is approached and done in this way, characterizing the network understudy, evaluating the causes of low transmission in multimode optic fiber from the characterized data, designing a multimode optic fiber rule base that will eradicate the causes of low transmission in multimode like congestion and designing a SIMULINK model for enhanced transmission efficiency of multimode optic fiber for long distance data transmission using fuzzy controller.

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