Improving The Link Control Mechanism in Data Networks for Enhancing Quality of Service Using Model Predictive Controller

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Abstract- The consistent poor network in our communication network is primarily anchored by not controlling the link mechanism in data network effectively well that constitute low throughput, high bit error rate, congestion and low signal to noise ratio. The poor performance in the communication network is surmounted by introducing improving the link control mechanism in data networks for enhancing quality of service using model predictive controller. To achieve this, it is done in this manner, Characterizing existing link control scheme, evaluating the congestion, interference, bit error rate and attenuation from the characterized network that cause network failure, designing model predictive rule base to eliminate the causes of low performance of link control mechanism in data networks, training ANN in model predictive rule base to eliminate the causes of low performance of link control mechanism in data networks and designing a SIMULINK model for improving the link control mechanism in data networks for enhancing quality of service using model predictive controller The results obtained are the lowest conventional congestion in 1.79bits/s in 2s while that when model predictive controller is imbibed in the system is at the same time is 1.455bits/s, the highest conventional throughput is 15bps This conventional result will reduce the quality of service of improving the link control mechanism in data networks for enhancing quality of service. On the other hand,, when MPC is incorporated in the system, it increased the throughput to 22.69 bps thereby enhancing the quality of service of improving the link control mechanism in data networks for enhancing quality of service and the highest conventional Link control mechanism is 71% thereby reducing the quality of service in the link control mechanism in data networks. Meanwhile, when MPC is imbibed in the system, it increased the link control mechanism to100% which automatically boosted the quality of service of improving the link control mechanism in data networks for an enhanced quality of service

Indexed Terms- Improving, Link, Control, Link, Mechanism, Data, Network, Enhancing, Quality, Service, Model, Predictive, Controller

I. INTRODUCTION

With the proliferation of the use of smart phones, tablets, laptop computers, Point of Sales (POS) devices, Automated Teller Machines (ATMS) etc. in cellular networks, development of algorithms to improve link control to ensure efficiency and quality of service (Qos) would be an important area of research.

Link Control also called Data Link Control (DLC) or Radio Link Control in some wireless Radio Access Technologies like Long Term Evolution (LTE) is the service provided by the Data Link layer of function defined in the Open Systems Interconnection OSI model for network communication (Alluri Sri Amith Varma et. al., 2012). The Data Link layer is responsible for providing reliable data transfer across one physical link (or telecommunications path) within the network.

Telecommunication systems are developed to transmit messages from a sender to a receiver. Besides the task of sending and receiving information over a channel, there are many other tasks a communication system has to do. One important task is to guarantee the correctness of the received information. No existing channel is completely error-free. In order to receive correct information, redundancy is often sent. On the receiver side the redundancy is needed to correct errors which have occurred during transmission.

Link control is very much associated with congestion control. Congestion control is an endless area of research. M. Jain and C. Dovrolis, (2014) talked about the importance of the available bandwidth (avail-bw) in congestion control. Classical and modern control theory have been applied to link control in computer networks. (S. Mascolo, 2001). In this study a Kalman filter based sliding window flow control is proposed for link control.

II. METHODOLOGY

- Characterization of existing link control scheme

The performance of the radio link control protocol in a case study network system can be characterized via base station traffic trace data collected from a live network. The existing link control scheme being characterized is the conventional Sliding Window flow link control algorithm. To characterize the performance of the existing link control scheme in a case study LTE network, network trace data that contains operational parameters relating to the radio link control entity, radio link control buffer memory and parameters relevant to link adaptation are key requirements.

LTE employ the radio link control (RL) protocol for flow control and error recovery based on the hybrid ARQ mechanism. The RLC layer which is found in the data link layer (i.e., layer 2) of the OSI model hides transmission error from upper layers to reduce the chances of mistaken invocation of the upper layers (usually TCP) congestion control mechanism. The LTE RLC is used for data flows and also for signaling flows. Though stop-and-wait is one of the techniques that is implemented in link control, window flow control is the fundamental link control implemented for the link control mechanism in data networks just as in the LTE RLC layer. The link control scheme impacts on the link adaptation process in the LTE system.

Table1 Data collection on packet loss due to congestion and its percentage of link control mechanism in data networks

Time	Packet transmitted	Packet received	File size	Transmission time (s)	Packet loss	Link control mechanism (%)
12.00 AM	30	25	12	2	0.8	50
1.00 AM	28	24	14	3	0.833	61
2.00 AM	26	20	16	2	0.7	65
3.00 AM	26	18	18	4	0.556	71
4.00 AM	24	16	14	3	0.5	52
5.00 AM	24	14	20	5	0.2858	49
6.00 AM	22	12	22	2	0.167	53
7.00 AM	22	11	30	2	0.167	65
8.00 AM	22	11	32	3	0.182	51
9.00 AM	20	12	12	4	0.2	57
10.00 AM	18	13	18	2	0.6154	53

11.00 AM	18	14	26	3	0.7143	54

To evaluate the congestion, interference, bit error rate and attenuation from the characterized network that cause network failure.

The mathematical model for congestion control in improving the link control mechanism in data networks for enhancing quality of service is as shown in equation 2

$$L = \frac{8}{3W^2} \quad (1)$$

Where L is packet loss

W is the network congestion

Then, make W the subject formula in equation 1

The mathematical model for congestion in the network is as shown in equation 2

$$W = \sqrt{\frac{8}{3L}} \quad (2)$$

To find the network congestion in 12.00 AM

W1 = square root 8/ 3 x 0.8

W1 = square root 8 /2.4

W1 =√ 3.33

W1 =1.82

To find the network congestion in 1.00 AM

W2 = square root 8/3 x 0.833

W2 = 8 / 3 x 0.833 = 8/2.499

W2 =√ 3.20

W2 = 1.79

To find the network congestion in 2.00 AM

W3 = Square root of 8/ 3 x 0.7

W3 = square root of 8/ 2.1

W3 = √3.81

W3 = 1.95

To find the network congestion in 3.00 AM

W4 = Square root of 8/ 3 x0.556

W4 = square root of 8/ 1.668

W4 = √4.796

W4 = 2.19

To find the network congestion in 4.00 AM

W5 = square root of 8/3 x 0.5

W5 = Square root of 8/ 1.5

W5 = √5.33

W5 = 2.31

To find the network congestion in 5.00 AM

W6 = Square root 8 / 3 x 0.2858

W6 = Square root 8 / 0.8574

W6 = √9.331

W6 = 3.055

To find the network congestion in 6.00 AM

W7 = Square root 8/ 3 x 0.167

W7 = Square root 8/ 0.501

W7 = √15.968

W7 = 3.996

To find the network congestion in 7.00AM

W8 = 8/ 3 x 0.167

W8 =8/0.501

W8 = √15.968

W8 = 3.996

To find the network congestion in 8.00AM

W9 = 8/ 3 x 0.182

W9 = 8/0.546

W9= √14.65

W9 =3.83

To find the network congestion in 9.00 AM

W10 = 8/3 x 0.2

W10 = 8/0.6

W10 = √13.333

W10 = 3.65

To find the network congestion in 10.00 AM

W11= 8/3 x 0.6154

W11 = 8 /1.8462

W11 =√ 4.333

W11 = 2.08

To find the network congestion in 11.00 AM

W12 = 8/3 x 0.7143

W12 = 8/2.1429

W12 = √3.733

W 12 = 1.93

The collect packet loss data was used to calculate the bit error rate as shown in equation 4. The calculated bit error rate obtained is as shown in table 3 coupled with the calculated congestion.

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

Taking into consideration the worst case scenario, the linear relationship between BER and packet error rate (PER) is expressed as:

$$PER = 8 * BER * MTU * 66/64 \quad (3)$$

Where the MTU is the maximum transmission unit, and using the Ethernet standards it is set to 1500 bytes for the simulations and then the MTU is increased to improve performance. A conversion from 8 bits to 1 byte is shown,

Recall 1 byte = 8bits
1500bytes = 8 x 1500 = 12000bits
MTU = 12000bits

PER is packet loss and BER is bit error rate

To evaluate the bit error rate in 12 A.M when the packet loss is 0.8.

Make BER the subject formula in equation 3.3

$$BER1 = PER/8 * MTU * 1.03125 \quad (4)$$

BER1 = 0.8/8 x 12000 x1.03125
BER1 = 0.8/9900
BER1 = 0.000081bits

To evaluate the bit error rate in 1.00 AM when the packet loss is 0.833.
BER2 = 0.833/9900
BER2 = 0.000084bits

To evaluate the bit error rate in 2.00 AM when the packet loss is 0.7.
BER3 = 0.7/9900
BER3 = 0.000071bits

To evaluate the bit error rate in 3.00 AM when the packet loss is 0.556.
BER4 = 0.556/9900
BER4 = 0.0000562bits

To evaluate the bit error rate in 4.00 AM when the packet loss is 0.5.
BER5 = 0.5/9900
BER5 = 0.000051 bits

To evaluate the bit error rate in 5.00 AM when the packet loss is 0.2858.
BER6 = 0.2858/9900
BER6 = 0.000030 bits

To evaluate the bit error rate in 6.00 AM when the packet loss is 0.167.
BER7 = 0.167/9900
BER7 = 0.000017bits

To evaluate the bit error rate in 7.00 AM when the packet loss is 0.167.
BER8 = 0.167/9900
BER8 = 0.000017bits

To evaluate the bit error rate in 8.00 AM when the packet loss is 0.182.
BER9 = 0.182/9900
= 0.000018bits

To evaluate the bit error rate in 9.00 AM when the packet loss is 0.2.
BER10 = 0.2/9900
= 0.000020bits

To evaluate the bit error rate in 10 AM when the packet loss is 0.6154.

BER11 = 0.6154/9900
= 0.000062bits

To evaluate the bit error rate in 11 AM when the packet loss is 0.7143.
BER12 = 0.7143/9900
= 0.000072bits

The sources of instability is when the network experiences high bit error rate, congestion and interference from the collected packet loss data used for the evaluation of the mentioned core of network failure.

To determine the throughput and signal to noise ratio that reduces the network performance from the characterized network

To evaluate the throughput

$$Throughput1 = File\ size/Transmitted\ Time \quad (5)$$

Throughput 1 = 12/2 = 6bps
Throughput 2 = 14/3 = 4.7bps
Throughput 3 = 16/2 = 8bps
Throughput 4 =18/4 = 4.5bps
Throughput 5 = 14/3 = 4.7bps
Throughput 6 = 20/5 = 4bps
Throughput 7 =22/2 = 11bps
Throughput 8 =30/2 = 15bps
Throughput 9 =33/4 = 8.25bps
Throughput 10 = 12/4 = 3bps
Throughput 11 = 18/2 = 9bps
Throughput 12 = 26/3 =8.7bps

The Signal-to-Noise Ratio (SNR) compares the level of the signal power to the level of background noise.

A ratio of
(1)10-15dB is the accepted minimum to establish an unreliable connection;
(2)16-24dB (decibels) has low signal but usually fast
(3)25-40dB has very good signal and is very fast

(4) 41dB or higher is considered excellent and is lightning fast

Hence 20 dB or greater has good SNR. Greater than 40 dB is even better! Recommended minimum SNR for data is 18 dB and for voice over Wi-Fi is 25 dB. As more interference is introduced, the SNR decreases because it raises the floor noise.

The SNR ratio is usually measured in decibels (dB). If the incoming signal strength in microvolts is V_s, and the noise level, also in microvolts, is V_n, then the Signal-to-Noise Ratio, S/N, in decibels is given by the formula: $S/N = 20 \log_{10}(V_s/V_n)$ If $V_s = V_n$, then S/N = 0.

To determine the Signal to Noise Ratio (SNR) of the analytical congestion obtained from the empirical data

To compute the signal to noise ratio

$$SNR = \mu/\sigma$$

$$\mu = \frac{X1 + X2 + X3 + X4 + X5 + X6 + X7 + X8 + X9 + X10 + X11 + X12}{n}$$

Where μ is mean of the given data

n is the number of occurrences.

σ Standard deviation

$$\mu = \frac{1.82 + 1.79 + 1.95 + 2.19 + 2.31 + 3.055 + 3.996 + 3.996 + 3.83 + 3.65 + 2.08 + 1.93}{12}$$

μ = 29.542/12

μ = 2.46

$$\sigma\sqrt{(X1-\mu)^{\wedge}2}$$

$$\sigma = \sqrt{(1.82-2.46)^2} + (1.79-2.46)^2 + (1.95-2.46)^2 + (2.19-2.46)^2 + (2.31-2.46)^2 + (3.055-2.46)^2 + (3.996-2.46)^2 + (3.996-2.46)^2 + (3.83-2.46)^2 + (3.65-2.46)^2 + (2.08-2.46)^2 + (1.93-2.46)^2$$

$$\sigma = \sqrt{(-0.64)^2} + (-0.67)^2 + (-0.51)^2 + (-0.27)^2 + (-0.15)^2 + (0.595)^2 + (1.536)^2 + (1.536)^2 + (1.8769)^2 + (1.19)^2 + (-0.38)^2 + (-0.53)^2$$

$$\sigma = \sqrt{(0.4096)^2} + (0.4489)^2 + (0.2601)^2 + (0.0729)^2 + (0.0225)^2 + (0.35403)^2 + (2.3593)^2 + (2.3593)^2 + (3.523)^2 + (1.4161)^2 + (0.14444)^2 + (0.2809)^2$$

$$\sigma = \sqrt{11.65}$$

$$\sigma = 3.413$$

To compute SNR

$$SNR = 2.46/3.413$$

SNR = 0.721dB

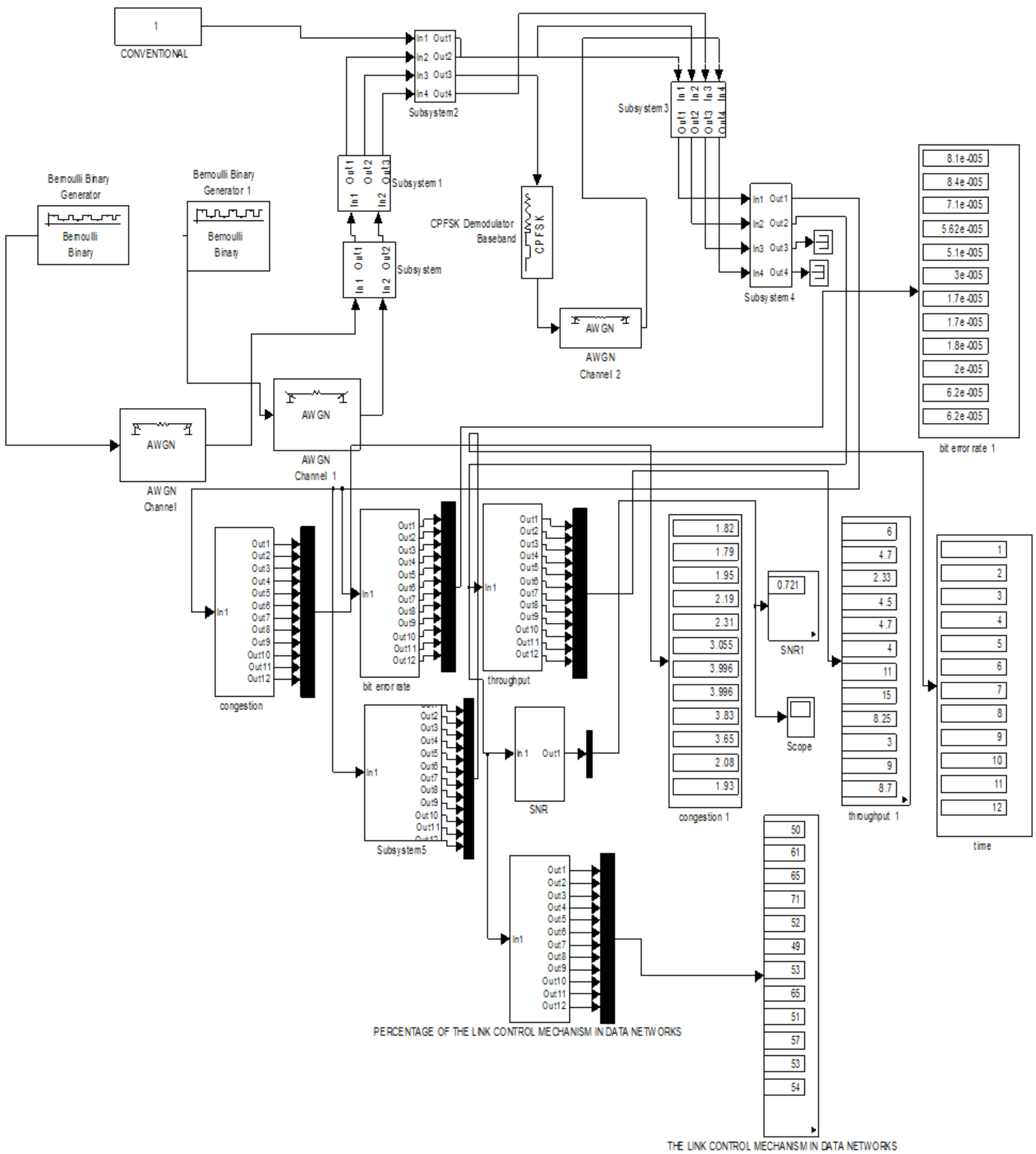

Fig 1 conventional SIMULINK model for improving the link control mechanism in data networks for enhancing quality of service. The results obtained after simulation are as shown in figures 7 through 9.

To design a model predictive rule base to eliminate the causes of low performance of link control mechanism in data networks**.**

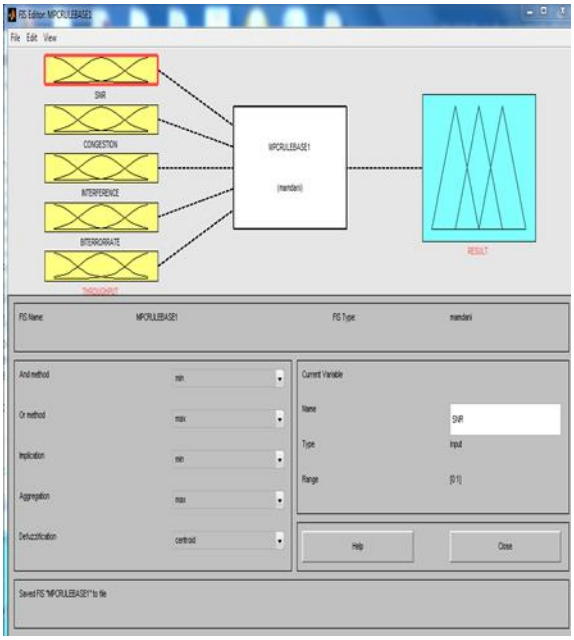

Fig 2 model predictive control fuzzy inference system FIS to eliminate the causes of low performance of link control mechanism in data networks**.** It has five inputs of signal to noise ratio (SNR), congestion, interference, bit error rate and throughput. It also has an output of result.

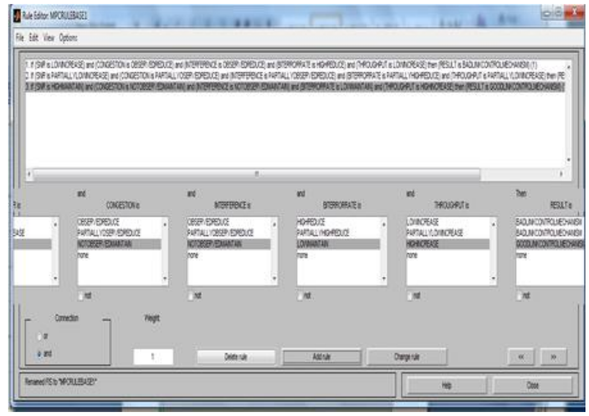

Fig 3 designed model predictive rule base to eliminate the causes of low performance of link control mechanism in data networks**.** Fig 3 shows three rules of model predictive controller that removes the causes of low performance of link control mechanism in data networks**.** Its comprehensive details is as shown in table 2.

Table 2 model predictive rule base to eliminate the causes of low performance of link control mechanism in data networks**.**

1	IF SNR IS LOW INCREASE	AND CONGESTION IS OBSERVED REDUCE	AND INTERFERENCE IS OBSERVED REDUCE	AND BIT ERROR RATE IS HIGH REDUCE	AND THROUGHPUT IS LOW INCREASE	RESULT IS BAD LINK CONTROL MECHANISM
2	IF SNR IS PARTIALLY LOW INCREASE	AND CONGESTION IS PARTIALLY OBSERVED REDUCE	AND INTERFERENCE IS PARTIALLY OBSERVED REDUCE	AND BIT ERROR RATE IS PARTIALLY HIGH REDUCE	AND THROUGHPUT IS PARTIALLY LOW INCREASE	RESULT IS BAD LINK CONTROL MECHANISM
3	IF SNR IS HIGH MAINTAIN	AND CONGESTION IS NOT OBSERVED MAINTAIN	AND INTERFERENCE IS NOT OBSERVED MAINTAIN	AND BIT ERROR RATE IS LOW MAINTAIN	AND THROUGHPUT IS HIGH MAINTAIN	RESULT IS GOOD LINK CONTROL MECHANISM

To train ANN in model predictive rule base to eliminate the causes of low performance of link control mechanism in data networks**.**

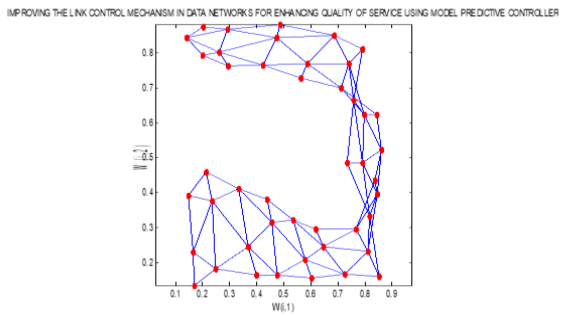

Fig 4 trained ANN in model predictive controller rule base to eliminate the causes of low performance of link control mechanism in data networks**.** The three rules were trained thirty times, 3 x30 =90 neurons that looks like human brain and mimics human intelligence. The result obtained after training is as shown in fig 5.

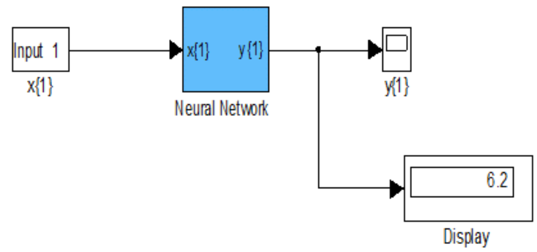

Fig 5 result obtained after the training of ANN in model predictive controller rule base to eliminate the causes of low performance of link control mechanism in data networks**.** This result will be integrated into model predictive controller to boost its efficiency.

To design a SIMULINK model for improving the link control mechanism in data networks for enhancing quality of service using model predictive controller

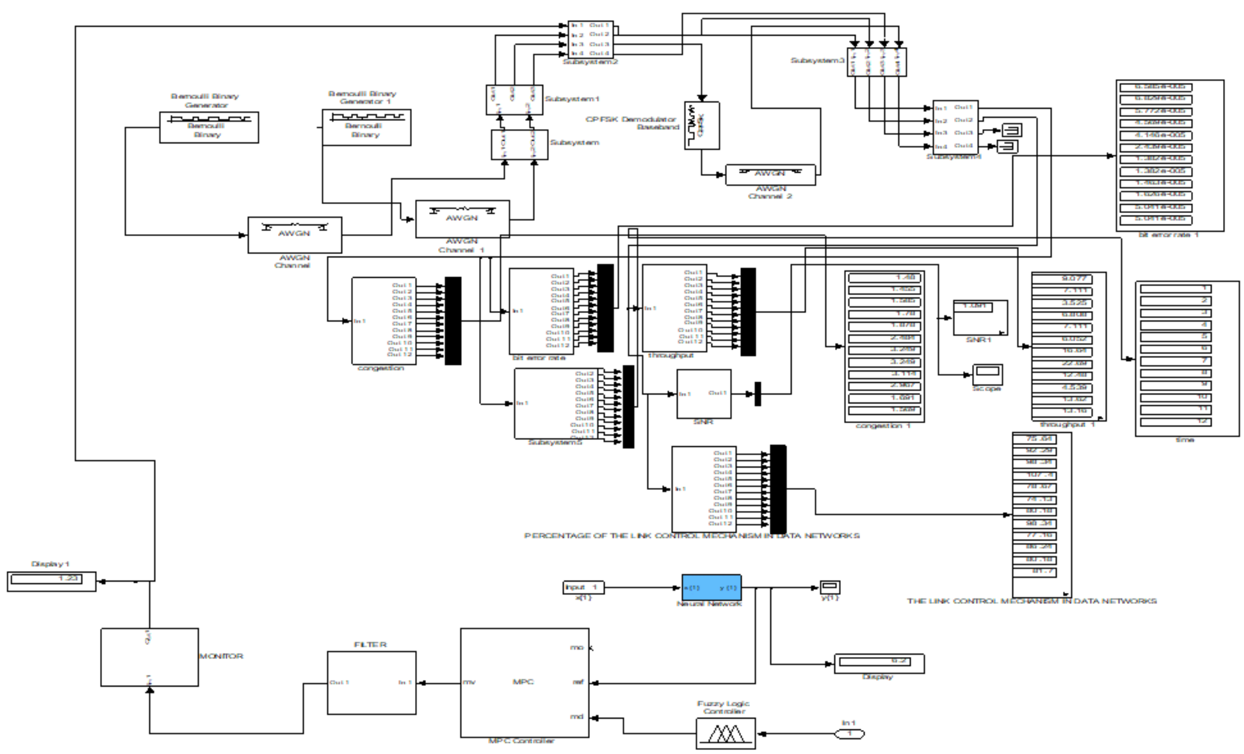

Fig 6 designed SIMULINK model for improving the link control mechanism in data networks for enhancing quality of service using model predictive controller. The results obtained after the simulation are as shown in figures 7, 8 and 9.

III. DISCUSSION OF RESULT

Table 3 compares conventional and MPC congestion in improving the link control mechanism in data networks for enhancing quality of service

Time (s)	Conventional congestion in improving the link control mechanism in data networks for enhancing quality of service (bit/s)	MPC congestion in improving the link control mechanism in data networks for enhancing quality of service (bit/s)
1	1.82	1.48
2	1.79	1.455
3	1.95	1.585
4	2.19	1.78
5	3.055	1.878
6	3.055	1.878
7	3.996	3.249
8	3.996	3.249
9	3.83	3.114
10	3.65	2.965
11	2.08	1.691
12	1.93	1.569

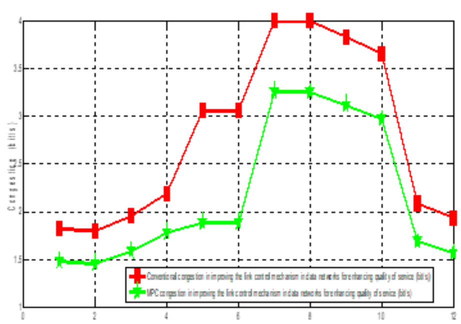

Fig 7 compares conventional and MPC congestion in improving the link control mechanism in data networks for enhancing quality of service. Fig 7 shows that the lowest conventional congestion in 1.79bits/s in 2s while that when model predictive controller is imbibed in the system is at the same time is 1.455bits/s.

Table 4 compares conventional and MPC throughput in improving the link control mechanism in data networks for enhancing quality of service

Time (s)	Conventional throughput in improving the link control mechanism in data networks for enhancing quality of service (bps)	MPC throughput in improving the link control mechanism in data networks for enhancing quality of service (bps)
1	6	9.077
2	4.7	7.111
3	8	12.1
4	4.5	6.808
5	4	7.111
6	11	16.64
7	11	16.64
8	15	22.69
9	8.25	12.48
10	3	4.539
11	9	13.62
12	8.7	13.16

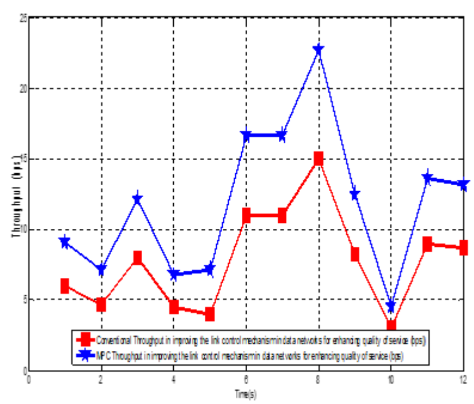

Fig 8 compares conventional and MPC throughput in improving the link control mechanism in data networks for enhancing quality of service. Fig 8 shows that the highest conventional throughput is 15bps This conventional result will reduce the quality of service of improving the link control mechanism in data networks for enhancing quality of service. On the other hand, when MPC is incorporated in the system, it increased the throughput to 22.69 bps thereby enhancing the quality of service of improving the link control mechanism in data networks for enhancing quality of service.

Table 5 compares conventional and MPC Link control mechanism in improving the link control mechanism in data networks for enhancing quality of service

Time (s)	Conventional Link control mechanism in improving the link control mechanism in data networks for enhancing quality of service (%)	MPC Link control mechanism in improving the link control mechanism in data networks for enhancing quality of service (%)
1	50	75.64
2	61	92.29
3	65	98.34
4	71	100
5	52	78.63
6	49	74.13
7	53	80.18
8	65	98.34
9	51	77.16
10	57	86.24
11	53	80.18
12	54	81.7

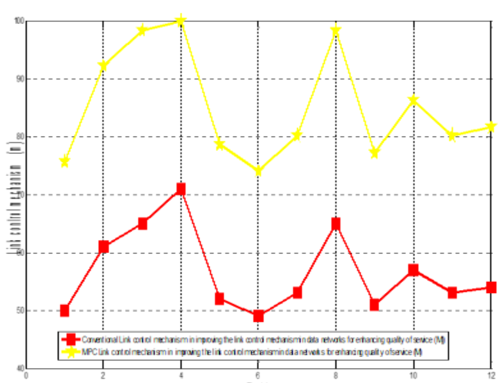

Fig 9 compares conventional and MPC Link control mechanism in improving the link control mechanism in data networks for enhancing quality of service in fig 9 the highest conventional Link control mechanism is 71% thereby reducing the quality of service in the link control mechanism in data networks. Meanwhile, when MPC is imbibed in the system, it increased the link control mechanism to100% which automatically boosted the quality of service of improving the link control mechanism in data networks for an enhanced quality of service.

CONCLUSION

There is late transmitted data in the communication network that has demoralized the moral of subscribers. This is vehemently caused by low percentage of link controlling mechanism., To overcome delay in the transmission of data in communication network there is an introduction of improving the link control mechanism in data networks for enhancing quality of service using model predictive controller. This is achieved in this manner, Characterizing existing link control scheme, evaluating the congestion, interference, bit error rate and attenuation from the characterized network that cause network failure, designing model predictive rule base to eliminate the causes of low performance of link control mechanism in data networks, training ANN in model predictive rule base to eliminate the causes of low performance of link control mechanism in data networks and designing a SIMULINK model for improving the link control mechanism in data networks for enhancing quality of service using model predictive controller The results obtained are the lowest conventional congestion in 1.79bits/s in 2s while that when model predictive controller is imbibed in the system is at the same time is 1.455bits/s, the highest conventional throughput is 15bps This conventional result will reduce the quality of service of improving the link control mechanism in data networks for enhancing quality of service. On the other hand, when MPC is incorporated in the system, it increased the throughput to 22.69 bps thereby enhancing the quality of service of improving the link control mechanism in data networks for enhancing quality of service and the highest conventional Link control mechanism is 71% thereby reducing the quality of service in the link control mechanism in data networks. Meanwhile, when MPC is imbibed in the system, it increased the link control mechanism to100% which automatically boosted the quality of service of improving the link control mechanism in data networks for an enhanced quality of service.

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