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Congestion Control in Packet Switched Wide Area Networks using a Feedback Model

Ogbimi, E.F.[1], A.O. Oluwatope[1], and G.A. Aderounmu[1]

[1]Department of Computer Science and Engineering
Obafemi Awolowo University,
Ile-Ife, Osun State, Nigeria

ABSTRACT

In a complex world, where networking expands very rapidly, the network stability of flow of bandwidth played a vital role in transmitting packets. Hence, it was imperative to find solution to the problem of congestion especially in the follow of bandwidth stability.

Congestion in computer networking is caused by so many factors. Some of the signs are packet loss, queuing delay resulting from overloading the buffer, faulty hardware devices, intermixing of old and new technologies and unstable flow of bandwidth resulting from positive feedback

A negative feedback mechanism was added to the network. Feedback was developed using both control and queuing theory. The congested signalling was tested for stability using control theory. Kendall notation was used to determine both arrival and service rates with all the queue disciplines. Matlab was used to simulate the model. Bode plots and impulse responses were used to analyse the performance of the improved model. The results showed that flow of bandwidth was stable with increase in service rate of packets and decrease in the probability of routers not accepting packets. This shows that adopting dynamic explicit feedback model reduced congestion by minimal packet drops, balanced flow of bandwidth, converges to fairness and minimized amplitude of oscillation.

KEYWORDS

Feedback, Packet-Switched, Wide Area Networks, Bandwidth Stability and Congestion control

1 INTRODUCTION

The rapid growth of WAN in recent years is part of the struggle for network administrators to monitor the network for demand resources such as voice, video and data. Most users continue to add more networking devices of higher capacities to satisfy the needs of network users. Yet, network remains congested and application software continue to run slowly and experience poor performance of networks. New breeds of software applications and information technology drivers like academics, industrialists, and business tycoons contribute to this problem by installing new software which may not be favourable to the networking environment [1]. Technology drivers, demand for bandwidth at the same time leads to the flow of bandwidth instability, where the bandwidth demand for resources is higher than the capacity of the network. In view of the various efforts of the network providers to sustain network performance, congestion and poor performance are still common features of networks. Hence, there is need to continue to conduct research on how to improve the performance of computer networks.

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Congestion is a fundamental communication problem that occurs in shared networks [2]. When the network users collectively demand for more resources than the network is able to offer. In typical packet switched networks, this occurs quite easily when the output links are slower than the input and multiple traffic sources competing for same output link at the same time. Some of the features of congestion are packet loss resulting from overflow of packets from the buffer, faulty hardware devices which may dissatisfy the user and slow down the network; mismatching of different speeds clogging the path with higher and lower speeds of network links and feedback delay in transmitting packets from source to destination. When message is transmitted through a link and passed through the feedback controlled loop, the network is said to be experiencing positive feedback [2]. The output of the positive feedback fails when the input packet transmits faster than the system can handle. The packets eventually get lost due to overcrowding and packet delay. This affects flow of bandwidth stability and have negative implications for routing.

The objective of the paper is to develop a TCP control theoretic model for congestion control in packet switched wide area networks.

2 LITERATURE REVIEW

2.1 Existing schemes for Congestion control in Packet Switched WAN

Several schemes of managing congestion have been used in the past. Among these are three prominent feedback schemes, which are active networking also called active congestion control technique, convention feedback technique and explicit feedback scheme. Active congestion control scheme makes the feedback congestion control more responsive to the network [3]. In active congestion control, congestion is detected at the router which also immediately begins reacting to congestion by changing the traffic that has already entered the network. Active networking with idea of reprogramming routers with data was used to address this shortcoming of feedback control.

Conventional feedback schemes detect congestion when they receive notification from the congested router or when they deduce the existence of congestion due to packet loss or excessive delays. The congestion relief starts from the sender and moves to the congestion node as the sender's rate is reduced. At the congestion nodes, the congestion relief changes in state and sustains that relief that propagates out to the end points[4].

In explicit Binary feedback scheme, a router that is congested sets a congestion indication bit in the network layer header of a data packet that is flowing in a forward direction. When the data reach the head of the acknowledgement packet, the acknowledgement packet is then transmitted from the destination to the source. In this case, users are expected to adjust the window size[5].

2.2 Drawbacks in the Existing Schemes

The drawbacks of Binary Feedback scheme were: the protocol TCP/IP is not efficient enough to transmit data of higher data rate between nodes and propagation delay of the network is very large due to indicated congested data by a bit. The current protocol which is TCP was not effective to handle high sophisticated bandwidth transmission [6]. The current protocol which is TCP was not effective to handle high sophisticated bandwidth transmission. TCP used a binary congestion signal. Oscillation occurred always at the packet level. The dynamics of the network were unstable leading to severe oscillation can only be reduced by accurate estimation of packet loss probability and a stable design of flow dynamics [6]. The drawback of conventional feedback model is that the propagation delay in sending packet was too large and therefore congestion sets in and increases. The drawback for active congestion control was that it was limited to service-time distribution. The model also could not be expanded and it was not robust. The drawback of explicit scheme was that it lacked scalability with respect to network bandwidth and there must always be signals of congestion before the scheme is adopted. It is not flexible to all kinds of traffic conditions. Delay increased in quantity along the congestion site and endpoints. The larger the delay goes from one endpoint to another, the longer it took the packets to be transmitted. Congestion then sets in. The higher the bandwidth, the larger the amount of data, the more congested is the endpoints.

In this paper, a method called Dynamic Explicit Feedback Scheme was adopted to reduce congestion in packet switched WAN.

2.3 The Improved Feedback scheme

The improved feedback scheme being proposed was called dynamic explicit feedback model which kept the bandwidth stable. It reduced packet drops to its barest minimum. It reduced bandwidth delay in packet switched WAN. It balanced the flow of transmission through paths. A feedback mechanism was added to monitor the acknowledgement of packets from receiver to sender.

3 METHODOLOGY

The main concepts adopted in the research were packet switching, feedback mechanism and dynamic systems.

3.1 Model Development

Figure 1 shows the block diagram of the improved feedback model. The message is broken into packets by means of packetization. Packets are transmitted from source to destination(s). A message is transmitted to the first router which acted as a buffer. The message remains in the buffer for a while until there is an available router that packets can be routed on the way to their destinations. The packets are then distributed to the second, third and many other routers. A feedback indicates that the packet had been sent to the receiver. If some of the packets were lost or delayed in the queuing system, the feedback controller passes a feedback message to any of the routers that there was congestion somewhere along the link. The router therefore adjusts the speed of transmitting packets. The stability of flow of packets is then regulated.

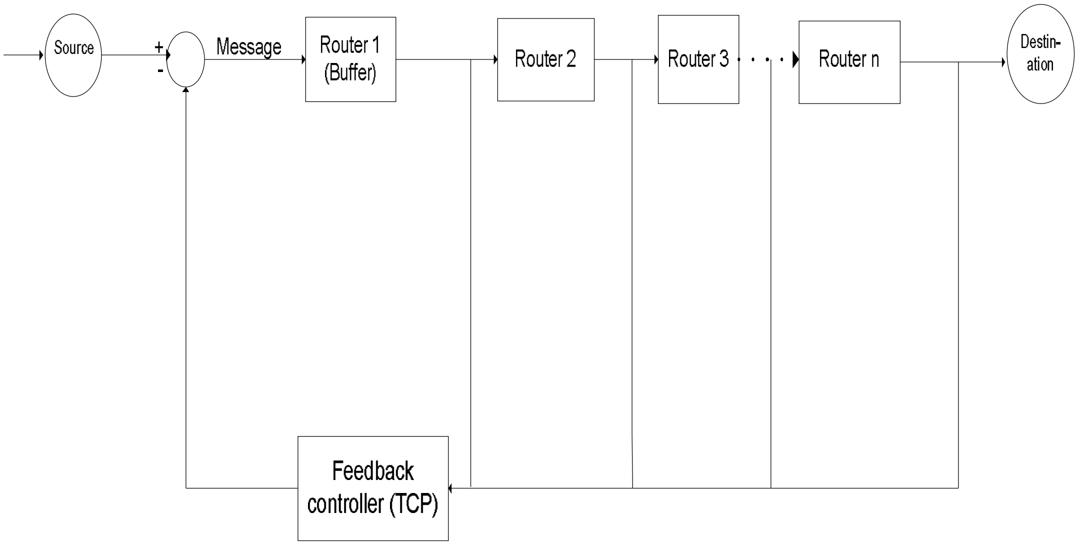

Figure 1:Block Diagram for Improved Feedback Model for Managing congestion in Packet Switched Wide Area Networks

3.2 Model Construction

Queuing model was applied to construct the model [7]. The parameters of the queuing model were modified and applied to the situation of packet switched WAN. The queuing model for packet flow in packet switched WAN was then modelled by the following modified parameters:

λ = rate of arrival of packets
μ = service rate (rate of transmitting packets)
L_s = Average number of users on the network
L_q = Average number of users requesting for web resources from a router in the network (in the queue).
c = number of routers
ρ = network utilization
P_o = Probability of routers that do not accept packets

$$L_s = \sum_{n=1}^{\infty} np_n \tag{1}$$

For a single server model (c =1), there is no limit on the maximum number of users in the network. The model assumes a capacity source. Arrivals occur at rate λ user per unit time. Under these conditions, $\rho < 1$ and $\lambda < \mu$. If arrival rate is higher than the service rate, then the geometric series will not converge and the steady-state probability will not exist. The queue length will continually increase and no steady state will be reached in the network.

Letting $\rho = \frac{\lambda}{\mu}$, the expression for p_n in the generalised model then reduced to

$$P_n = \rho^n p_o \quad , n = 0, 1, 2, \text{-------}, n \tag{2}$$

To determine the value of p_o we use the identity

$$p_o = (1 + \rho + \rho^2 + \text{-----} \rho^n) = 1 \tag{3}$$

Assuming $\rho < 1$, $\left(\frac{1}{1-\rho}\right)$ the Sum to infinity of a series

$$S_n = \frac{a}{1-r} \qquad \text{where } a = 1 \text{ and } r = \rho$$

$$S_n = \frac{1}{1-\rho} \tag{4}$$

For steady state probability $P_n = 1$

$$\left[\sum_{n=0}^{\infty} \rho^n\right] P_0 = 1 \tag{5}$$

$$P_0 = [\sum_{n=0}^{\infty} \rho^n]^{-1}$$

$$P_0 = \left(\frac{1}{1-\rho}\right)^{-1}$$

$$P_0 = (1-\rho) \tag{6}$$

For multiple server models which is the case of interest, there are c parallel servers (routers). The arrival rate is **λ** and the service rate per server is μ. There is no limit on the number of routers in the network. With Kendall's notation (K|M|C):(GD|∞|∞), K is the arrival distribution, M is the service distribution and C is the number of servers in the network. The queue discipline is a generalized distribution that satisfies all conditions [8]. The parameters considered were arrival rate (**λ**), service rate (μ), number of servers (c), probability of number of routers not accepting packets (P_o). L_s and L_q are computed as:

If $\rho = \lambda/\mu$ and assuming $\rho/c < 1$, the value determined from

$$\sum_{n=0}^{\infty} P_n = 1$$

L_q was determined in MIMO systems

If $\rho = \lambda/\mu$ (n = 0, 1, 2....., n)

$$\text{Then } P_n = \frac{\lambda^n}{\mu \times 2\mu \times 3\mu \times \text{---------} \times n\mu} \tag{8}$$

$$P_n = \frac{\lambda^n}{n!\mu^n} * P_0 \qquad n < c$$

$$= \frac{\lambda^n}{c!c^{n-c}\mu^n} * P_o \qquad n \geq c$$

$$L_q = \frac{\rho^{c+1}}{(c-1)!(c-\rho)^2} * P_o \tag{9}$$

$$L_s = L_q + \rho$$

$$L_s = P_0\frac{\rho^{c+1}}{(c-1)!(c-\rho)^2} + \rho$$

$$= P_0\frac{\rho^{c+1}}{(c-1)!(c-\rho)^2} + \rho\,(c-1)!\,(c-\rho)^2 \tag{10}$$

These are the measurements of performances in a multiple server and multiple queue in a packet switched wide area networks.

The mathematical models for packet switched WAN were subjected to fluid flow analysis.
For the equation of number of users requesting for web resources,

$$\mathbf{L_q} = \frac{\mathbf{P_o\rho^{c+1}}}{\mathbf{(c-1)!(c-\rho)^2}} \tag{9}$$

Assuming c = n for many servers to many number of users

$$L_q = \frac{P_o\rho^{n+1}}{(n-1)!\,(n-\rho)^2}$$

Which on further substitution

$$L_q = \frac{P_o\rho^{n+1}}{(n-1)!(n^2 - 2\rho n + \rho^2)} \tag{11}$$

Network utilization = $\rho = \frac{\lambda}{\mu}$; insert $\rho = \lambda/\mu$ in equation (11)

$$L_q = \frac{P_o\lambda^{n+1}\mu^{1-n}}{\mu^2 n^2(n-1)! - 2\lambda\mu n(n-1)! + \lambda^2(n-1)!)} \tag{12}$$

$U = P_o\lambda^{n+1}\mu^{1-n}$ and $V = \mu^2 n^2(n-1)! - 2\lambda\mu n(n-1)! + \lambda^2(n-1)!$

For the equation of the number of users in the network:

$$\mathbf{L_s = P_o} \frac{\rho^{c+1}}{(c-1)!(c-\rho)^2} + \rho\ (c-1)!\ (c-\rho)^2 \qquad (10)$$

For many servers to many users
Assuming c = n

$$L_s = \frac{P_o\rho^{n+1}}{(n-1)!(n-\rho)^2} + \rho$$

$$L_s = \frac{P_o\rho^{n+1}}{(n-1)!(n^2-2n\rho+\rho^2)} + \rho$$

$$= \frac{P_o\rho^{n+1} + \rho(n-1)!(n^2-2n\rho+\rho^2)}{(n-1)!(n^2-2n\rho+\rho^2)} \qquad (13)$$

Substituting $\rho = \lambda/\mu$ in equation (13) gives

$$L_s = \frac{P_o\lambda^{n+1}\mu^{2-n} + \lambda\mu^2 n^2(n-1)! - 2\lambda^2\mu n(n-1)! + \lambda^3(n-1)!}{\mu^3 n^2(n-1)! - 2\lambda\mu^2 n(n-1)! + \lambda^2\mu(n-1)!} \qquad (14)$$

$$U = P_o\lambda^{n+1}\mu^{2-n} + \lambda\mu^2 n^2(n-1)! - 2\lambda^2\mu n(n-1)! + \lambda^3(n-1)!$$

$$V = \mu^3 n^2(n-1)! - 2\lambda^2\mu n(n-1)! + \lambda^2\mu(n-1)!$$

The equations of both the number of network users requesting for web resources (L_q) and number of network users in the system (L_s) were differentiated with respect to the arrival rate of packets (**λ**). Using the quotient rule of differentiation.

$$L_q = \frac{P_o\lambda^{n+1}\mu^{1-n}}{\mu^2 n^2(n-1)! - 2\lambda\mu n(n-1)! + \lambda^2(n-1)!)}$$

$$\frac{dL_q}{d\lambda} = \frac{(n+1)P_o\lambda^n\mu^{1-n}}{(n-1)!(\lambda-n\mu)^2} - \frac{2P_o\lambda^{n+1}\mu^{1-n}}{(n-1)!(\lambda-n\mu)^3} \qquad (15)$$

$$L_s = \frac{P_o\lambda^{n+1}\mu^{2-n} + \lambda\mu^2 n^2(n-1)! - 2\lambda^2\mu n(n-1)! + \lambda^3(n-1)!}{\mu^3 n^2(n-1)! - 2\lambda\mu^2 n(n-1)! + \lambda^2\mu(n-1)!}$$

$$\frac{dL_s}{d\lambda} = \frac{(n+1)P_o\lambda^n\mu^{1-n}}{(n-1)!(\lambda-n\mu)^2} - \frac{2P_o\lambda^{n+1}\mu^{1-n}}{(n-1)!(\lambda-n\mu)^3} + \frac{1}{\mu} \qquad (16)$$

Substitute n = 4 for number of servers in the following equations (17) and (18)

When n = 4 for dL$_q$

$$\frac{dL_q}{d\lambda} = \frac{P_o\lambda^4(3\lambda-20\mu)}{6\mu^3(\lambda-4\mu)^3} \qquad (17)$$

When n = 4 for dL$_s$

$$\frac{dL_s}{d\lambda} = \frac{P_0\lambda^4(3\lambda-20\mu)}{6\mu^3(\lambda-4\mu)^3} + \frac{1}{\mu} \qquad (18)$$

The input and output functions of the differentiated equations with respect to the arrival rate of packets are not linear and could not be used to find transfer functions. However, one of the prominent processes for stability analysis in non-linear systems is linearization of equations [9]. The non linear equations were made linear by the process of linearization. Linearization assesses the local stability of the equilibrium point of non linear equations of dynamic systems .

when y = 0,

Linearization of dL_q and dL_s for n = 4

$$y = f(x) + f'(x)(x - \lambda) \qquad (19)$$

substitute $f(\lambda) = 0$ in equation (19)

$$y = f'(x)(x - \lambda)$$

$$y = \frac{P_0\lambda^4(3\lambda-20\mu)}{6\mu^3(\lambda-4\mu)^3}(x - \lambda) \qquad (20)$$

when y = 0

x = λ, At equilibrium point

$$y = f(x) + f'(x)(x - x_0) \qquad (21)$$

when f(x) = 0

$$y = f'(x)(x - x_0)$$

when $x_0 = 0$

$$y = f'(x)(x)$$

$$y = \frac{P_0x^4(3x-20\mu)}{6\mu^3(x-4\mu)^3}\, x \qquad (22)$$

$y = \frac{P_0\lambda^4(3\lambda-20\mu)}{6\mu^3(\lambda-4\mu)^3} + \frac{1}{\mu}(x - \lambda)$, which implies that

x = λ at equilibrium point

$$\mathbf{y = f(x) + f'(x)(x - x_0)} \qquad \mathbf{(21)}$$

when f(x) = 0

$y = f'(x)(x - x_0)$

when $x_0 = 0$

$y = f'(x)(x)$

$$y = \frac{P_O x^4 (3x-20\mu)}{6\mu^3 (x-4\mu)^3} + \frac{1}{\mu}(x) \tag{23}$$

The Laplace's transforms for the differentiated linear equation of the number of network users requesting for web resources and number of users in the system were computed [10]. The transfer functions of equation was computed from the two Laplace's transforms of number of servers n = 4.

Laplace's transform for $\frac{dL_q}{d\lambda}$ for n = 4

$$\frac{\mathcal{L}dL_q}{d\lambda} = SY(s) - Y(0)$$

$$Y(s) = \frac{P_O s^4 (3s-20\mu)}{6\mu^3 (s-4\mu)^3} S$$

$$SY(s) = \frac{P_O s^6 (3s-20\mu)}{6\mu^3 (s-4\mu)^3}$$

$$\mathcal{L}\frac{dL_q}{d\lambda} = \frac{P_O s^6 (3s-20\mu)}{6\mu^3 (s-4\mu)^3} \tag{24}$$

Laplace's transform for $\frac{dL_s}{d\lambda}$ for n = 4

$$\frac{\mathcal{L}dL_s}{d\lambda} = SY(s) - Y(0)$$

$$Y(s) = \frac{P_O S^4 (3s-20\mu)}{6\mu^3 (s-4\mu)^3} + \frac{s}{\mu}$$

$$SY(s) = \frac{P_O S^5 (3s-20\mu)}{6\mu^3 (s-4\mu)^3} + \frac{s^2}{\mu}$$

$$\mathcal{L}\frac{dL_s}{d\lambda} = \frac{P_O S^5 (3s-20\mu)}{6\mu^3 (s-4\mu)^3} + \frac{s^2}{\mu} \tag{25}$$

Transfer function for n = 4

$$\frac{\mathcal{L}dL_q}{\mathcal{L}dL_s} = \frac{P_O s^5 (3s-20\mu)}{P_O s^5 (3s-20\mu) + 6\mu^2 s^2 (s-4\mu)^3}$$

$$= \frac{P_O s^3 (3s-20\mu)}{P_O s^3 (3s-20\mu) + 6\mu^2 (s-4\mu)^3} \tag{26}$$

3.3 Analytical validation of Bode Plots and Impulse responses using matlab

Two types of graph of Bode plots were produced from the transfer functions; one is the Bode plot and the other is impulse response. Bode plots has graph has two parts, one part measures magnitude in decibels and the other part is the phase angle in degrees which are both y-axis and both have frequency in Hertz as x-axis.
Based on the aforementioned simulations, each flow of bandwidth scenario was simulated twice for consistency. One set used probability of number of routers not accepting packets with 10 variations of service rate of packets. The service rate of packets was varied 10 times per set of data. The service rate of packets were in multiples of 100Mb/s which is from 100 to 1000 Mb/s while the probability of routers not receiving packets were in multiples of 0.10. The simulation set was done using the same set of service rate values and taking value of probability of number of routers not accepting packets of 0.1.

Cut-off frequencies, magnitude, phase angles were produced from the Bode plots while amplitude at 0.0001 seconds was produced from impulse responses.

For n = 4

Table 1: Results from Bode plots and impulse responses of the service rate of packets received with the probability of no of routers not accepting packets (P_o) of 0.10 for 4 servers.

Service rate (Mb/s)	Magnitude (dB)	Cut off Frequency (Hz)	Phase angle (°)	Amplitude at t = 0.0001 secs
100	2.35	12.00	74.60	-19.40
200	2.35	25.00	74.60	-75.70
300	2.35	38.00	74.60	-166.00
400	2.35	50.00	74.60	-286.00
500	2.35	62.00	74.60	-433.00
600	2.35	75.00	74.60	-607.00
700	2.35	87.00	74.60	-796.00
800	2.35	102.00	74.60	-1000.00
900	2.35	109.00	74.60	-1230.00
1000	2.35	120.00	74.60	-1460.00

Table 2: Results from Bode plots and impulse responses of the probability of routers not accepting packets with the service rate of 1000 Mb/s for 4 servers.

Probability of routers not accepting packets	Magnitude (dB)	Cut off Frequency (Hz)	Phase angle (°)	Amplitude at t = 0.0001 secs
0.10	2.350	120.00	74.60	-1460.00
0.20	1.420	4.00	62.50	-744.00
0.30	1.050	7.00	56.30	-498.00
0.40	0.812	4.00	52.30	-375.00

0.50	0.659	4.00	49.40	-300.00
0.60	0.566	2.00	47.10	-251.00
0.70	0.495	8.00	45.10	-215.00
0.80	0.440	8.00	43.80	-188.00
0.90	0.396	6.00	42.50	-168.00
1.00	0.360	3.00	41.40	-150.00

4 RESULTS AND DISCUSSIONS

4.1 Introduction

This section presents the findings from tables 1 and 2 the investigations carried out in to achieve the objectives of the paper. The order of presentation is the experiment, data, graphical analysis and discussion of the results. The software used was Matlab. The purpose of using MatLab 7.0 was to compute transfer functions and plotting Bode plots arising from the Laplace transforms of the equation of both the number of users assessing the web and the number of network users in the system.

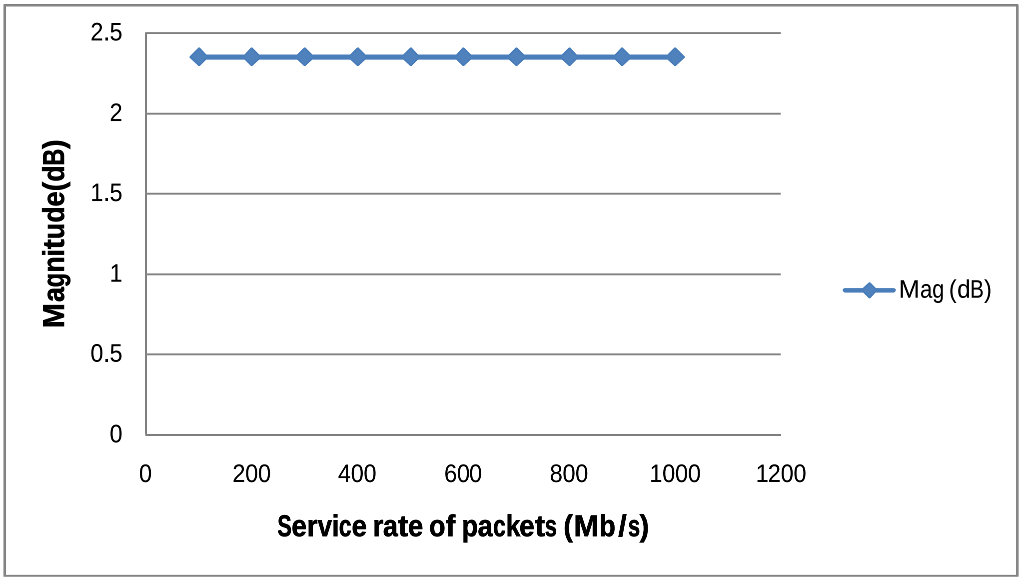

Figure 2: Service rate of packets against Magnitude

Figure 2 produced from table 1 shows the graph of the service rate of packets against magnitude. The graph produced a uniform plot. The magnitude of flow of bandwidth was uniform at 2.35dB with increasing rate of packets from 100 Mb/s to 1000 Mb/s. The higher the service rate of packets, the uniform the magnitude becomes. When the magnitude of the flow of bandwidth is uniform, the flow of bandwidth is stable and the feedback becomes responsive to the network.

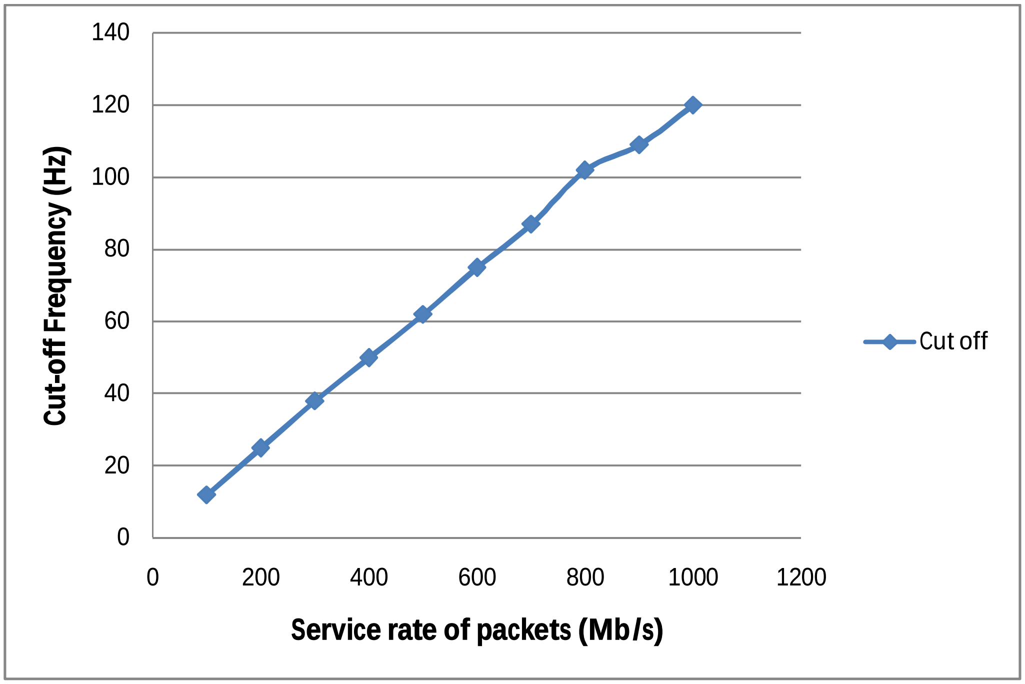

Figure 3: Graph showing service rate of packets against cut-off frequency

Figure 3 produced from table 1 shows the graph of cut-off frequency against cut-off frequency. The cut off frequency produced a positive slope which rose from 12 Hz to 120 Hz. The higher the service rate of packets, the higher the cut off frequency of the flow of bandwidth. When the cut off frequency of flow of bandwidth is high, the flow of bandwidth is stable and the feedback becomes active to the network.

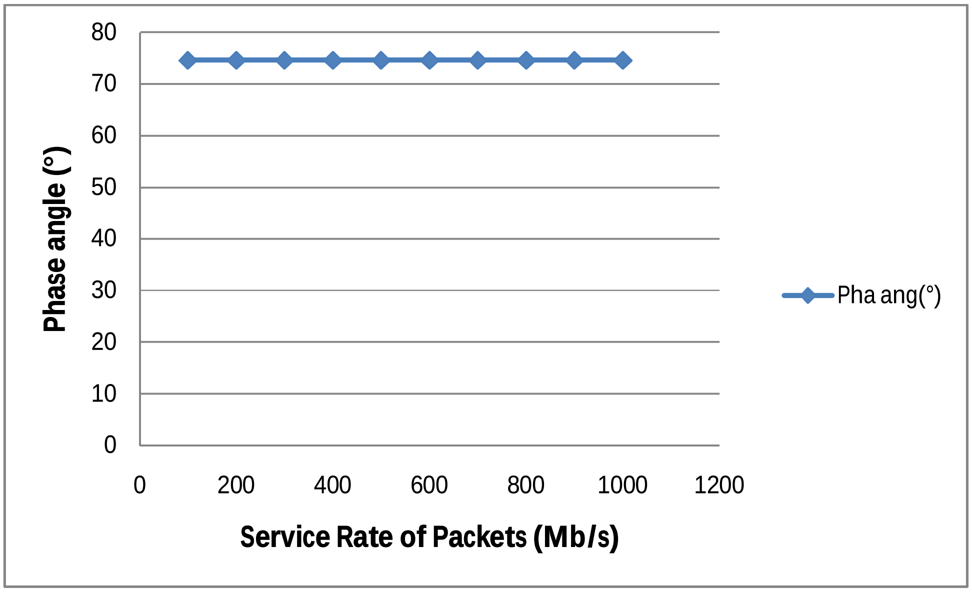

Figure 4: Graph showing service rate of packets against phase angle

Figure 4 produced from table 1 shows the graph of service rate of packets against phase angle. The phase angle was uniform at 74.6° increasing service rate of packets from 100 Mb/s to 1000 Mb/s. The higher the service rate of packets, the uniform the phase angle becomes. When the phase angle of stability is uniform, the flow of bandwidth is stable, the feedback becomes active to the network.

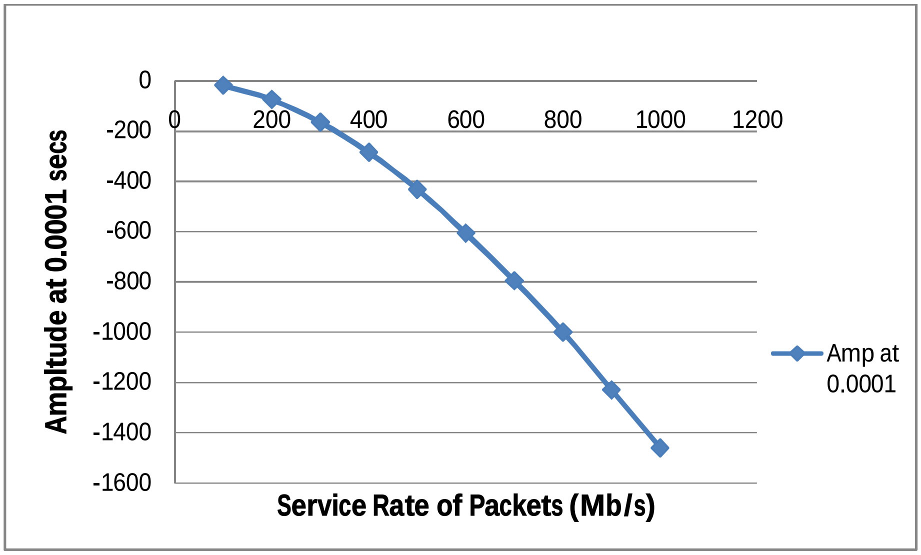

Figure 5: Graph showing service rate of packets against Amplitude at 0.0001 seconds

Figure 5 produced from table 1 shows the graph of service rate of packets against phase angle. The amplitude at 0.0001 seconds produced a negative curve which fell from -14.60 to -1460.00. The higher the service rate of packets, the lower the amplitude at 0.0001 seconds. When the amplitude of the flow of bandwidth is low, the flow of bandwidth is stable and the feedback becomes responsive to the network.

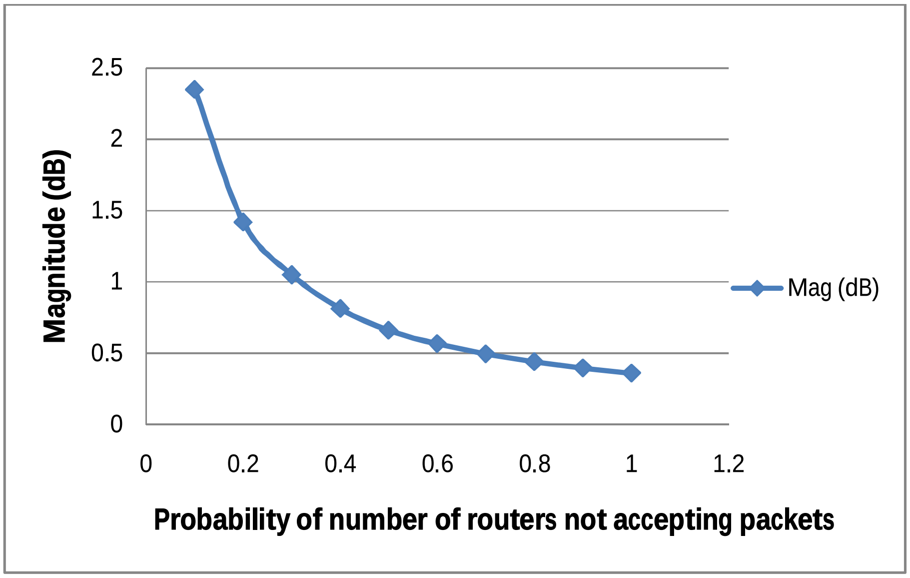

Figure 6: Graph showing the probability of the number of routers not accepting packets against magnitude

Figure 6 produced from table 2 shows the graph of the probability of number of routers not accepting packets against magnitude. The magnitude of the flow of bandwidth produced a negative curve which fell from 2.35 dB to 0.396 dB. The higher the probability of number of routers not accepting packets, the lower the magnitude. When the magnitude of the flow of bandwidth is low, the flow of bandwidth is stable and feedback model becomes responsive to the network.

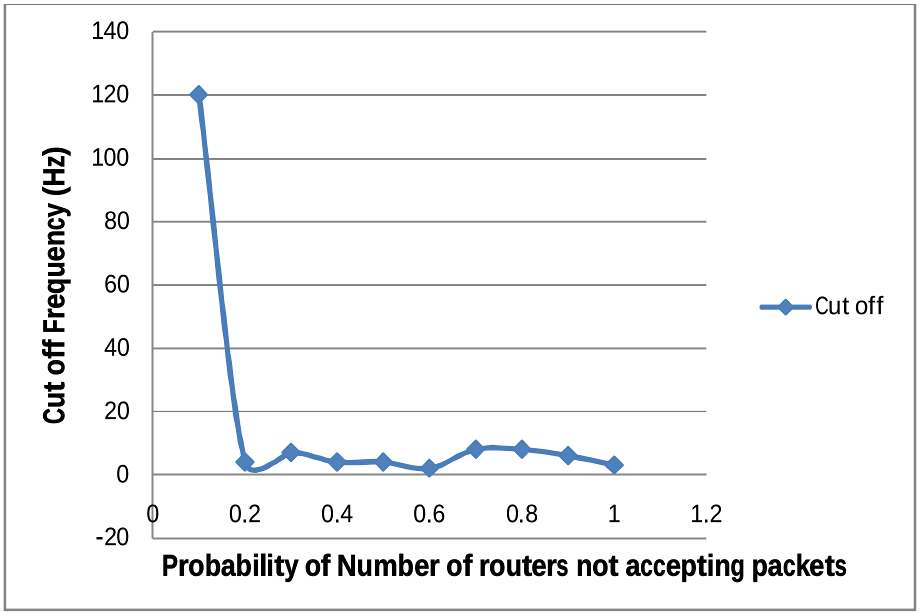

Figure 7: Graph showing the probability of the number of routers not accepting packets against cut-off frequency

Figure 7 produced from table 2 shows the graph of the probability of number of routers not accepting packets against cut-off frequency. The cut off frequency fell from 120 Hz to 4 Hz, rose to 7 Hz, fell to 4 Hz, became uniform and fell further to 2 Hz, rose to 8 Hz and finally fell to 3 Hz. The lower the probability of number of packets, the higher the cut-off frequency of the flow of bandwidth. When the cut off frequency of the flow of bandwidth is high, the flow of bandwidth is stable and the feedback becomes responsive to the network.

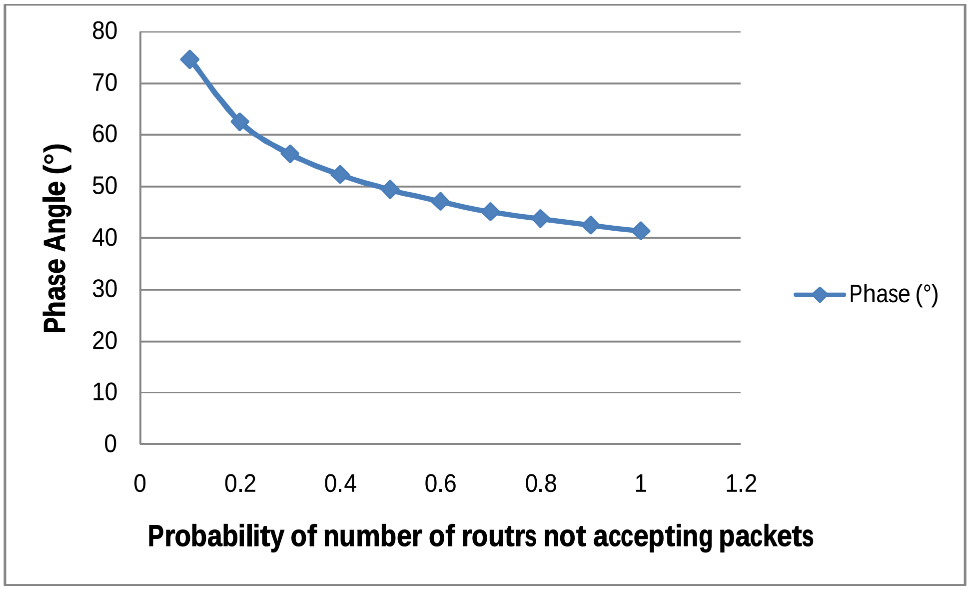

Figure 8: Probability of the number of routers not accepting packets against phase angle

Figure 8 produced from table 2 shows the graph of probability of number of routers not accepting packets against phase angle. The phase angle of the flow of bandwidth produced a negative curve which fell from 74.6° to 41.4°. The higher the probability of the number of routers not accepting packets, the lower the phase angle of stability. When the phase angle of stability is high, the flow of bandwidth is stable and the feedback becomes responsive to the network.

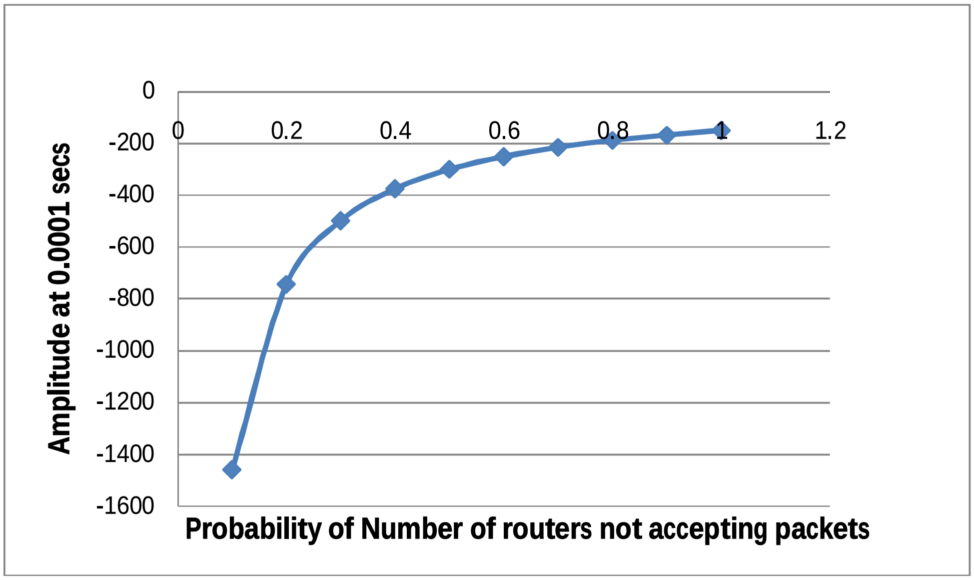

Figure 9: Graph showing the probability of the number of routers not accepting packets against amplitude at 0.0001 seconds

Figure 9 produced from table 2 shows the graph of probability of number of routers not accepting packets against amplitude at 0.0001 seconds. The amplitude of the flow of bandwidth produced a positive curve which rose from -1460 to -150. The higher the probability of number of routers not accepting packets, the higher the amplitude at 0.0001 seconds i.e. the lower the probability of number of routers not accepting packets, the lower the amplitude. When the amplitude of the flow of bandwidth is low, the flow of bandwidth is stable, the feedback becomes responsive to the network.

5 CONCLUSION

In this paper, a scheme was proposed for improved feedback model for reducing congestion using TCP protocols at the network layer. The scheme used variable amount of feedback from the network, with a router to indicate congestion. Each network server that is congested sets the router and sends message to the source by the user. The message goes back to the source from the destination which receives packets. The network was modelled as a negative feedback control system and identified various component in the scheme in the model. The policies that needed to be used in each of these components were studied through analysis and simulation.

The network servers detect their state as being congested and sets the congestion indication router when the time to deliver packets the receiver is longer than expected. The arrival rates and service rate of packets were described. The users receive their packets and determine the flow of bandwidth stability. The probability of routers accepting packets too also determine the stability of flow of bandwidth and it is between 0 and 1.

It was also demonstrated that the scheme is distributed, adapts to any state of the network, converges to fairness, minimizes packet loss and amplitude of oscillation.

The performance of the scheme was addressed under transient changes in the network. The scheme operates the network at a stable point when the network is overloaded even, when the users try to cause bottleneck in the path

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Authors

Ogbimi, E.F. is a staff of the Department of Computer Engineering of The Polytechnic, Ile-Ife. He obtained a Bachelor of Science (B.Sc) degree in Computer Technology from Babcock University, Ilishan Remo. He also obtained a Masters of Science (M.Sc) degree in Computer Science from Obafemi Awolowo University, Ile-Ife. He worked in the area of Computer Communication Systems with exphasis on bandwidth stability.

A.O. Oluwatope is a Senior Lecturer in the Department of Computer science and Engineering of the Obafemi Awolowo University, Ile-Ife. He Obtained a Bachelor of Science (B.Sc) degree, Master of Science (M.Sc) degree and Doctor of Philosophy all in Computr Science and Engineering from Obafemi Awolowo University, Ile-Ife. His area of research includes design, analysis, modelling and simulation of wireless ATM networks with respect to Qos management.

G.A. Aderounmu is a Professor in the Department of Computer Science and Engineering and Director of the Information Technology and Communications Unit of the Obafemi Awolowo University, Ile-Ife. He Obtained a Bachelor of Science (B.Sc) degree, Master of Science (M.Sc) degree and Doctor of Philosophy all in Computer Science and Engineering from Obafemi Awolowo University, Ile-Ife. Aderounmu teaches several courses including digital computer network, digital computer systems, computer graphics and programming language. Area of specialisation is design, analysis and simulation of wireless ATM networks with respect to switching protocol, error control and buffer management.