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Congestion Control in ATM Networks Using Transmission Control Protocol (TCP) Theoretic Model

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Abstract-This research proposes a system solution on congestion control of ATM network by using an improved feedback model. In a complex world, where networking expands very rapidly, the network stability of flow of bandwidth plays a vital role in transmitting packets. Hence, it is imperative to find negative feedback mechanism was added to the network. Feedback was developed using both control and queuing theory. The congested signal was tested for stability using control theory. Kendall notation was used to determine both arrival and service rates with all the queue discipline. Matlab was used to simulate the model. Bode plots and impulse responses were used to analyse the performance of the improved model. The results show 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 minimum packet drops, balanced flow of bandwidth, converges to fairness and minimized amplitude of oscillation.

Keywords*- ATM Network, Packets, Kendall Notation*

I. Introduction

ATM is a technology that provides a single platform for the transmission of voice, video and data at specified quality of service (Qos) at speed varying from fractional Ti (i.e. nx64Kbps), to Gbps. Voice, data and video is currently transported by different networks [3]. Video is transported by the public telephone network and data by a variety of packet-switched networks. Video is transported by networks based on coaxial cables, satellites and radio waves, and a limited extent by packet-switched network. ATM was standardized by ITU.T in 1987. It is based on packet-switching and is connection oriented. An ATM packet, known as a cell is a small fixed-size packet with a payload of 48 bytes and a 5-bytes header. The reason for using small packets was motivated mostly by argument related to the transfer of voice over ATM. ATM networks are used in variety of environments. For instance it is widely used in the backbone of internet service provider (ISP) and in campus networks have also been deployed to provide point-to-point and point-to-multipoint video connections [4]. Also there are on-going project in telecommunication companies aiming at replacing the existing trunks used in the telephone network with an ATM network.

A. Definition of ATM Network Congestion

ATM means Asynchronous Transfer Mode. It is a dedicated connection switching technology that organizes digital data into 53-byte cell units and transmits them over a physical medium using digital signal technology [1].

Individually, a cell is processed asynchronously relative to other related cells and is queued before being multiplexed over the transmission path. Because ATM is designed to be easily implemented by hardware (rather than software), faster processing and switch speeds are possible. The pre specified bit rates are either 155.520 Mbps or 622.080 Mbps. Speeds on ATM networks can reach 10 Gbps.

ATM also stands for automated teller machine, a machine that bank customers use to make transactions without a human teller. This project research work concerns Asynchronous Transfer Mode Congestion. ATM congestion control is concerned with allocating the resources in a network such that it can operate at an acceptable performance level when the demand exceeds or is near the capacity of the network resources [2], (i.e. to prevent it from operating in the Congested region for any significant period of time.

II. RESEARCH AND DESIGN METHODOLOGY

This section outlines the methodology used in the paper. It clearly describes what the researcher did and how he did it so that it would be easier for other researchers, students or the readers to understand, or duplicate if they wished to. Packet switching, feedback mechanism, dynamic systems and MATLAB simulation tool were used for the analysis. ATM technology distinguishes itself from the previous networking protocols in that it has the latest traffic management technology and thus allows guaranteeing delay, throughput, and other performance measures. This in turn allows users to integrate voice, video, and data on the same network. One problem of ATM is congestion. Feedback system will give us concepts for ATM networks congestion control and possible system solutions through dynamic explicit feedback scheme [5], etc. With improved feedback system, ATM can ensure efficient operation to meet different quality of service (QoS) desired by different types of traffic and to ensure that each connection gets the quality of service (QoS) it was promised.

Due to the complexity of the research and modeling process, break down approach was used to gain a deeper insight on the modeling steps and as well have a good understanding of ATM congestion and its control. The research make use of two sources of data, namely, primary and secondary data which was gathered from various sources such as the internet websites, text books, and ATM centers and through questionnaire.

A. Research Method

Primary and secondary data are used for the modeling of congestion control for ATM network using valued information gotten through questionnaire and research. The primary data was obtained from the questionnaires. The sampling was done randomly such that the respondents were from different ATM network in United Bank for Africa Plc., Port Harcourt branches in Rivers. For the sample size, the bank managers, ATM system and network engineers and few individuals were taken into consideration. The sample size comprises these people in other to have different view and option on ATM congestion. The number of questionnaires given was 50, and feedback was received from 30 respondents.

Secondary data were collected from documentary materials such as textbooks, newspaper, journals, magazines, and websites and published research thesis. Google search engine was used during the internet browsing and based on the top information collected from various means; an analysis was carried out and processed to obtain the solution to ATM network congestion. The output results, model and the proposed solutions were derived from the research and observations carried out on the input data. From the analysis, ATM networks has bottleneck or congestion point, i.e., locations where more data may arrive than the network can carry [6]. A common cause for this congestion is a mismatch in speed between networks

B. Research Instrument

Internet, questionnaires, feedback system and Mat lab simulation tool are the research instruments used for this study. The researcher prepared and distributed the questionnaire using face to face distribution method, thus, giving a helping hand where necessary.

Figure 1 represents a block diagram of ATM Network, this block diagram consist of the switches, clients, end systems, DHCP, ATM services, LECS, and interfaces [7]. For ATM switch to lay a connection, a cell is received across a link (UNI or NNI) on a known VPI or VCI value [20]. The switch looks up the connection value in a local translation table to determine the outgoing port (or ports) of the connection and the new VPI/VCI value of the connection on links. The switch then retransmits the cell on the outgoing link with the appropriate connection identifiers [17]. Because all VCIs and VPIs have only local significance across a particular links, the value are remapped as necessary at each switch. PPP is a data link protocol used to establish a direct connection between two nodes [8]. It provides connection authentication, transmission encryption and compression. ARP are used to map higher-layer address to their corresponding ATM address. DHCP is a protocol used by networked computer to obtain IP address automatically, with dynamic addressing a device can have different IP address anytime it connects to the network.

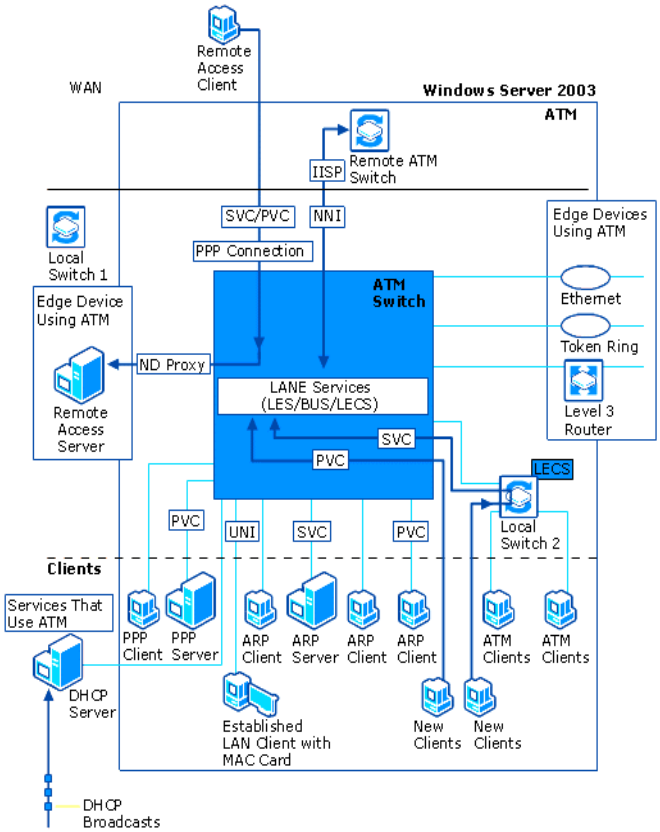

Figure 1. Block diagram of ATM Network

The figure 2 below shows a block diagram of improved feedback model. The message is broken into packets by means of packetization [9]. Packets are transmitted from source to destination(s). A message is transmitted to the first router which acts as a buffer. The message remains in the buffer for a while until there is an available router that packet 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 a packet had been sent to the receivers. If some packet were lost or delayed in a queuing system, the feedback controller passes a message to any of the router that there was congestion somewhere along the link. The router therefore adjusts the speed of transmitting packets. The stability of flow of packet is then regulated [10].

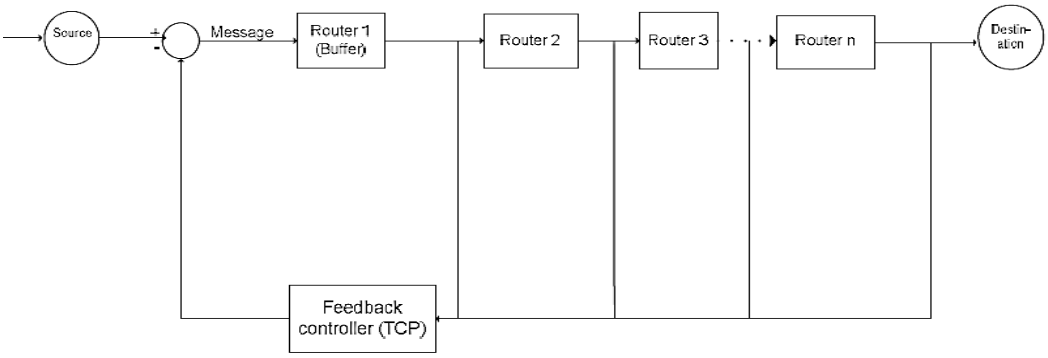

Figure 2. Block Diagram for improved feedback model for congestion control in ATM Network.

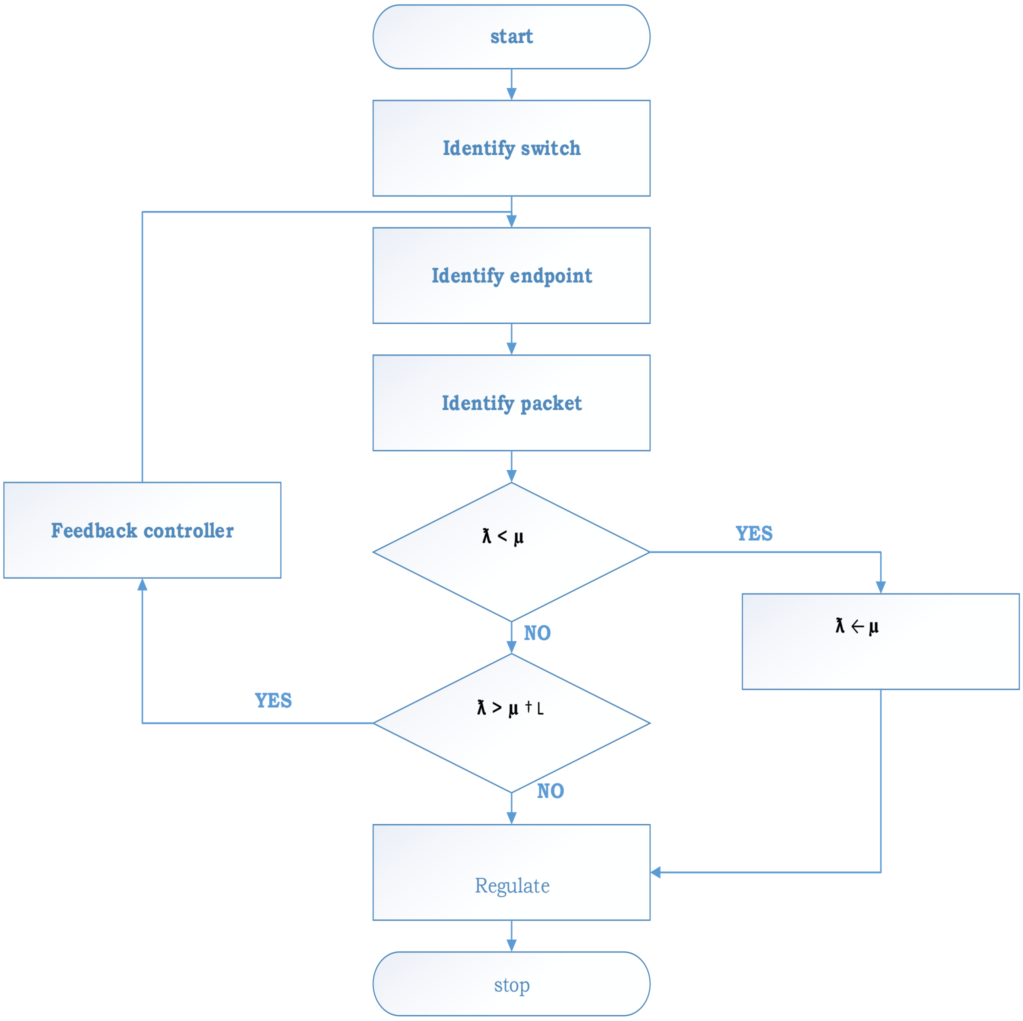

Figure 3. A design flow chart for congestion control

λ = rate of arrival of packets

μ = service rate (rate of transmitting packets)

L= Limit (requested CDVT)

C. Model construction

Queuing model was applied to construct the model. The parameters of the queuing model were modified and applied to the situation of packet switch [11]. The queuing model for packet flow in packet switched 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 for web resource 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 users per time. Under these condition, $\rho < 1$ and $\lambda<\rho$. If arrival rate is higher than the service rate, then the geometric series will not converge and the steady – state probability will not exist [12]. The queue length will continually increase and no steady will be reached in the network.

$$letting\ = \rho = \frac{\gamma}{\mu},$$

The expression for P_n in the generalised model then reduced to

$$P_n = \rho^n P_o\ , n = 0,1,2,3, \dots \dots \dots .. n \tag{2}$$

To determine the value of P_o we use the identity

$$P_o = (1 + \rho + \rho^2 + \cdots \dots \dots \dots \dots \rho^n) = 1 \tag{3}$$

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

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

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

For steady state probability P_n=1

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

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

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

For multiple server models which are the case of interest, there are c parallel servers (routers) [13]. The arrival rate is λ and 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 server in the network. The queue discipline is a rate generalized distribution that satisfies all conditions [14]. The parameters considered were arrival rates (β), 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 $\rho = \frac{\gamma}{\mu}$ and assuming $\frac{\rho}{c} < 1$ the value determine from

$$\sum_{n=0}^{\infty} \rho^n = 1 \tag{7}$$

L_q was determine a MIMO systems

$$if\ \rho = \frac{\gamma}{\mu} \quad (n = 0,1,2,3, \dots \dots \dots \dots \dots \dots \dots .. n)$$

Then

$$P_n = \frac{\gamma^n}{\mu \times 2\mu \times 3\mu \times \dots \dots \dots \dots \dots \times n\mu} \tag{8}$$

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

$$\frac{\gamma^n}{c!c^{n-c}\mu^n} \times P_o \qquad n \gg c$$

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

$$L_s = L_q + \rho = \frac{\rho^{c+1}}{(c-1)!(c-\rho)^2} \times P_o + \rho(c-1)!\,(c-\rho)^2 \tag{10}$$

These are the measurement of performances in a multiple server and multiple queues in ATM networks.

The mathematical models for packet switch network were subjected to fluid flow analysis [15].

For the equation of number of users requesting for web resources,

$$L_q = \frac{\rho^{c+1}}{(c-1)!(c-\rho)^2} \times P_o \tag{10}$$

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

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

Which on further substitution

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

Network utilization

$$\rho = \frac{\gamma}{\mu} \tag{11}$$

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

$$U = P_o \gamma^{n+1} \mu^{1-n}$$

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

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

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

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

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

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

Substituting

$\rho = \frac{\gamma}{\mu}$ in equation (13) gives

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

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

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

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

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

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

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

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

Substituting n = 4 for number of servers in the following equations (17) & (18).

When n = 4 for dL_q

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

When n = 4 for dL_s

$$\frac{dL_s}{d\gamma} = \frac{P_o\gamma^4(3\gamma-20\mu)}{6\mu^3(\gamma-4\mu)^3} + \frac{1}{\mu} \quad (18)$$

The input and output functions of the differentiated equations with respect to the arrival rate of the packets are not linear and could not be used to find the transfer functions, however, one of the prominent for stability analysis in non – linear system is linearization of equation (9). The non – linear equation were made linear by the process of linearization. Linearization accesses the local stability of the equilibrium point of non – linear equations of dynamic systems [16].

When y = o, linearization of dL_s and dL_q for n = 4

y= f(x) + f^1(x)(x-⋏)

substitute f(⋏) = 0 in equation (19)

$$y = \frac{P_o\gamma^4(3\gamma-20\mu)}{6\mu^3(\gamma-4\mu)^3}(x - ⋏) \quad (20)$$

when y=0

x = ⋏ at equilibrium point

y= f(x) + f^1(x)(x-x_o) (21)

when f(x) = 0

y= f^1(x)(x-x_o)

$$y = \frac{P_o\gamma^4(3\gamma-20\mu)}{6\mu^3(\gamma-4\mu)^3}(x) \quad (22)$$

$$y = \frac{P_o\gamma^4(3\gamma-20\mu)}{6\mu^3(\gamma-4\mu)^3}(x - ⋏)$$

which imply that

x = ⋏ at equilibrium point

y= f(x) + f^1(x)(x-x_o)

when f(x) = 0

y= f^1(x)(x-x_o)

when x_o = 0

y= f^1(x)(x)

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

The Laplace's transforms for the differentiated linear equations of the number of network users requesting for web resources and number of users in the system were computed. The transfer function of equation was computed from the two laplace's transforms of number of server n =4.

Laplace transform for $\frac{dL_q}{d\gamma}$ $for\ n = 4$

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

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

sY(s) = $\frac{P_o\gamma^4(3s-20\mu)}{6\mu^3(s-4\mu)^3}$

$\mathcal{L}\frac{dL_q}{d\gamma} = \frac{P_o\gamma^4(3s-20\mu)}{6\mu^3(s-4\mu)^3}$

$Laplace\ transform\ for\ \frac{dL_s}{d\gamma}\ for\ n = 4$

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

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

sY(s) = $\frac{P_o s^5(3s-20\mu)}{6\mu^3(s-4\mu)^3} + \frac{s^2}{u}$

$\mathcal{L}\frac{dL_s}{d\gamma} = \frac{P_o s^5(3s-20\mu)}{6\mu^3(s-4\mu)^3} + \frac{s^2}{u}$

Transfer function for n=4

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

$$= \frac{P_o s^3(3s-20\mu)}{P_o s^3(3s-20\mu) + 6\mu^3 s^2(s-4\mu)^3} \quad (24)$$

D. Data Collection

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 response.

TABLE I. RESULTS FROM BODE PLOTS AND IMPULSE RESPONSES OF THE SERVICE RATE FOR 4 SERVERS WHILE THE PROBABILITY OF THE ROUTER NOT ACCEPTING PACKETS IS CONSTANT AT 0.10

Service rate (Mb/s)	Magnitude (dB)	Cut Off Frequency (Hz)	Phase angle (º)	Amplitude at t =0.0001 (sec)
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 II. RESULT FROM BODE PLOTS AND IMPULSE RESPONSES OF THE PROBABILITY OF NUMBER OF ROUTERS NOT ACCEPTING PACKETS FOR 4 SERVERS AT CONSTANT SERVICE RATE OF 100MB/S

Probability of router not accepting packet	Magnitude (dB)	Cut Off Frequency (Hz)	Phase angle (º)	Amplitude at t =0.0001 (sec)
0.10	2.350	120.00	74.00	-1460.00
0.20	2.420	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

III. RESULT AND ANALYSIS

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 4 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.

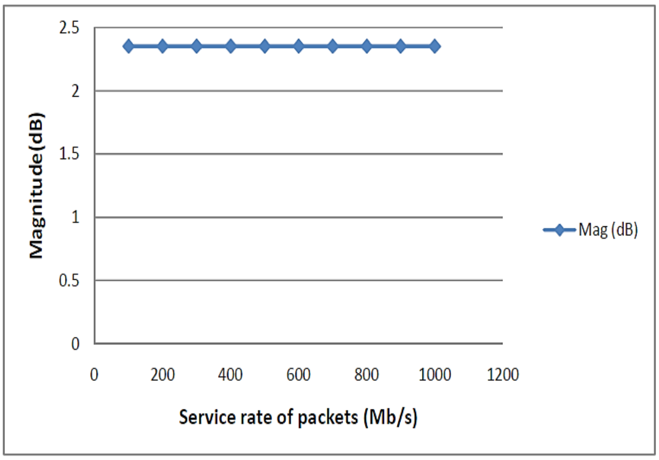

Figure 4. Service rates of packets against magnitude

Figure 5 produced from table 1 shows the graph of cut-off frequency against service rate of packets. The cut off frequency produced a positive slope which raises from 12 Hz to 120 Hz. he 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.

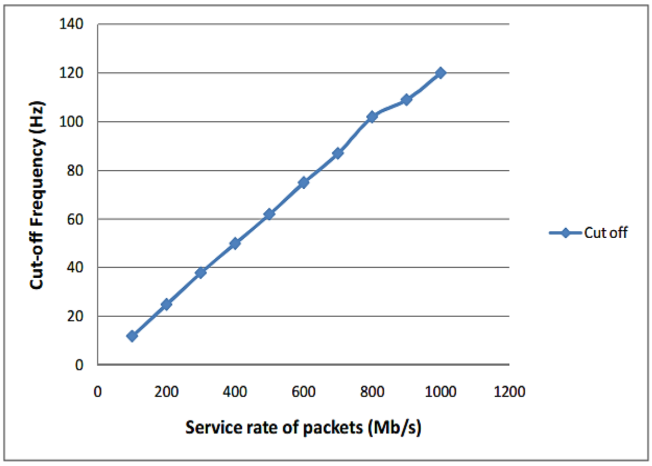

Figure 5. Graph showing service rate of packets against cut-off frequency

Figure 6 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.

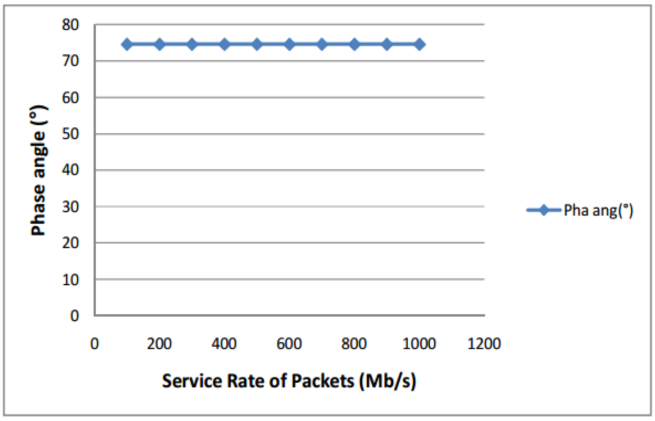

Figure 6. Graph of service rate of packets against phase angle

Figure 7 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.

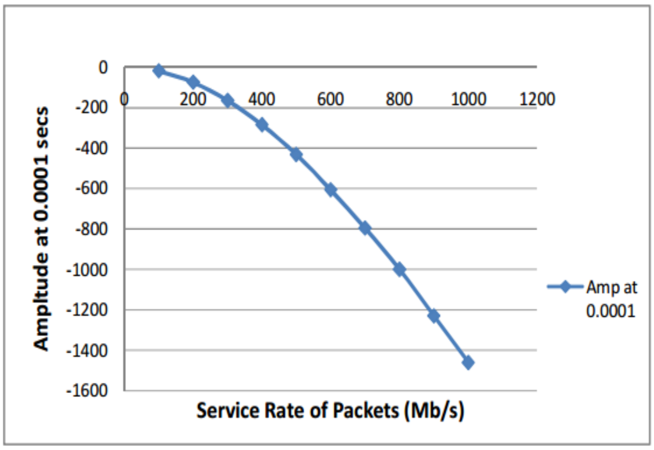

Figure 7. Graph showing service of packets against Amplitude at t = 0.0001 seconds

Figure 8 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. Then the magnitude of the flow of bandwidth is low, the flow of bandwidth is stable and feedback model becomes responsive to the network.

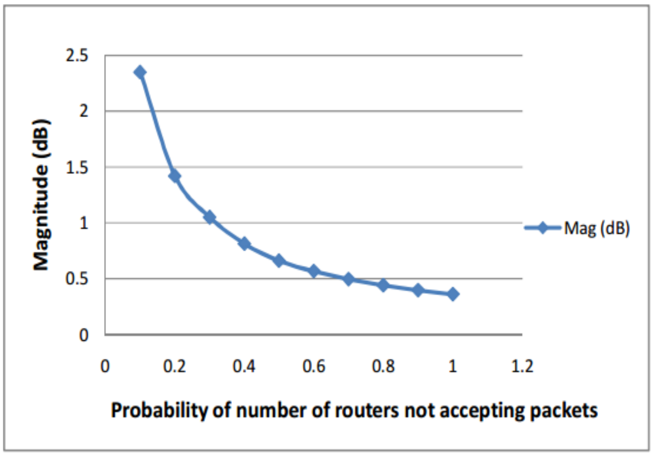

Figure 8. Graph showing probability of routers not accepting packets against magnitude

Figure 9 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.

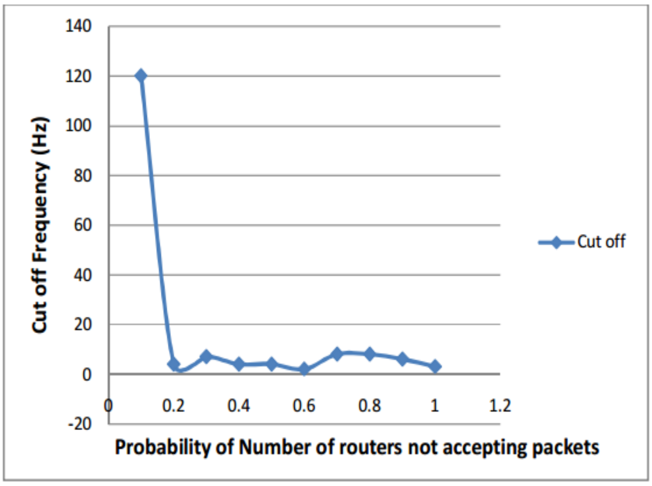

Figure 9. Graph showing probability of routers not accepting packets against cut off frequency

Figure 10 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.

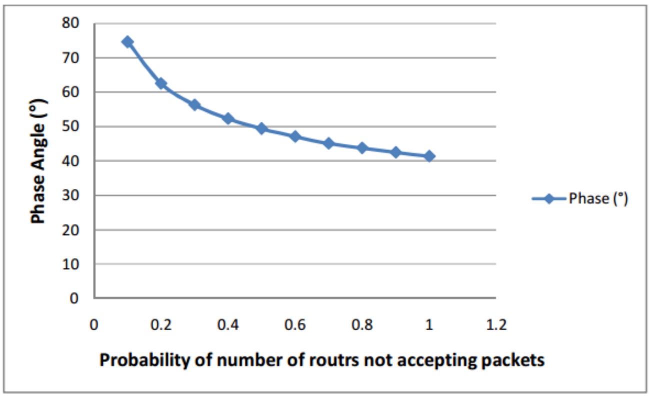

Figure 10. Showing probability of number of routers not accepting packets against phase angle

Figure 11 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.

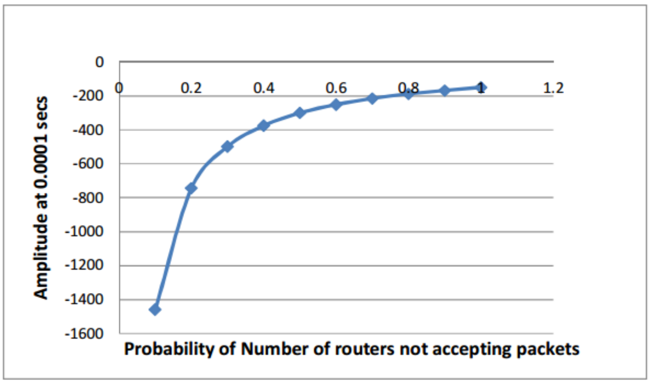

Figure 11. Graph showing probability of number of routers not accepting packets against amplitude at t= 0.0001 seconds

IV. CONCLUSION

In conclusion, congestion control concerned with allocating the resources in a network such that it can operate at an acceptable performance level when the demand exceeds or is near the capacity of the network resources (i.e. to prevent it from operating in the congested region for any significant period of time).Without proper congestion control mechanisms, the throughput (or network) may be reduced considerably under heavy load.

In ATM networks, the information is transmitted using short fixed-length cells, which reduces the delay variance, making it suitable for integrated traffic consisting of voice, video and data.

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