Full paper

A CHARGING SCHEME FOR A VBR MULTI-SERVICE NETWORK

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ABSTRACT

In this paper, the authors present the result of a study carried out on the individual impact of the three important parameters of Variable Bit Rate traffic of ATM transmission on the total volume of data transmitted. The simulation of the behavior of the VBR traffic in response to different values of, and combination VBR traffic descriptors is as presented. The measurement of the average cell rate determined from the total cell transmitted was examined for different combination of the values of the three parameters: Peak Cell Rate (PCR), Sustainable Cell Rate (SCR) and Maximum Burst Size (MBS). From the result, we concluded that the dominant factor in determining the volume of cells transmitted is the SCR.

KEYWORDS: Average Cell Rate, SCR, PCR, MBS.

1. INTRODUCTION

Charging, pricing and billing is crucial and a prerequisite in the setup of broadband networks. The importance of these threefold component of accounting management is underscored both by the need to recovering costs and make profit. The failure of the flat rate pricing scheme in controlling congestion in the "best effort" traffic networks necessitate the need for usage-based charging schemes. Mackie-Mason and Varian (1995) argued that in the natural market, price is used as regulator of both demand and supply; this principle should be allowed to influence the distribution of network resources in such a way that will reduce congestion. Although Anania and Solomon (1997) and Odlyzko (2001) disagreed with the necessity of usage-based charging, Courcoubetis et al, (2000a), Courcoubetis et al, (2000b) and Koutsopoulou et al (2004), along with many other researchers, agreed with this position.

Some of the methods propounded for implementing this usage-based charging scheme can be found in (Courcoubetis et al, 2003, Kelly, 1997and Siris et al, 1999). Some of these are quite simple while others involve complex schemes to accomplish an efficient congestion control using pricing. One common deficiency of some of the proposed usage-based mechanism is that it failed to consider simplicity as an important characteristic of policies. According to Siris et al, (1999) , "tariff must be attractive to customers"; in fact the basis for the rejection of usage-based charging by Odlyzko (2001) is customer preference for the simplest possible schemes and arguing that most of the present usage-based schemes will be too technical for ordinary users. Nevertheless, a charging scheme that allows cost recovery, fairness in billing and congestion control is a necessity in today's Broadband Integrated Service Digital Networks (B-ISDN) that relies on the Asynchronous Transfer Mode for switching and transfer of traffic. Cushine and Hutchison (2001) described several charging models including Metered charging, Usage based pricing, Fixed Price, Paris-Metro, Packet charging and Edge pricing that are appropriate for Internet charging. The important question is how will resources consumption be measured in such a way that is fair and understandable to users?

The collection of relevant data for accounting measurement is described in (EURESCOM, 1999. In ATM VBR-RT transmission, the user and the network operator negotiate a traffic contract(Halsall, (1996). The user agrees that his traffic will conform to the following traffic descriptors: Peak Cell Rate; Sustainable Cell Rate and Maximum Burst Size, while the operator guarantees such measures of quality of service like peak-to-peak Cell Delay Variation, Maximum Cell Transfer Delay and Cell Loss Ratio.

This paper presents findings on the impact of the usage descriptors on the traffic so that they can be used as metrics that are fair and enables cost recovery, and at same time simple to understand. As such, we are interested in determining relevant measures of usage in the ATM Variable Bit Rate real-time traffic (VBR-RT) environment. The remainder of the paper is structured as follows. Section 2 discussed related works in the area of measurement of network resource usage and simulation of network traffic. In Section 3, the network traffic model to be used for the simulation was presented while the simulation was carried out in section 4. The result of the simulation was analyzed in section 5 and Section 6 concludes the paper.

2. RELATED WORKS

The work of White and Brownlee (1998), described the various patterns generated by different traffic types while Costamagma et al, (1998) showed that VBR video traffic could be sufficiently modeled using the processes known as chaos. It also showed that the model based on these chaotic maps required less tuning in comparison to Markov chain process and the output of the model is comparable to real stream generated by video clips like the ASTERIX, TERMINATOR and RACE when autocorrelation was used. Garret and Willinger, (1994) further found that VBR sources have evidence of Long Range Dependence (LRD) that is unaccounted for by the statistic process models of VBR video sources. The authors noted that although there are different models for generating VBR traffics, they concluded that the fractal nature of the source traffic could not be adequately characterized by models developed from simple stochastic processes. It was also noted that although Fractional Brownian motion exhibits LRD, it tends to wander from origin and as such, it is not a good tool for modeling VBR traffic source. According to Kode et al, (2001), Poisson and other stochastic models do not give an accurate characterization of the dynamics of such traffic streams like the HTTP, TELNET, SNMP,FTP and NNTP, since these present day traffic are self-similar in nature. Zaborovski et al (1999) modeled an ATM source traffic using Petri nets with provision for specification of the ATM traffic parameter descriptors for each connection. The models made provisions for "send" and "silent" periods of cell activity. However, this model still required that firing subsystem be designed to determine the timing of the "silent" and the "sending" activities. Research efforts also abound on charging, pricing and billing in communication networks. Courcoubetis et al, (2000b) investigated the use of simple parameters like the time-taken and volume of traffic for computing charges when these have been shaped to give a measure of effective bandwidth. The Deliverable 1 of P708 (EURESCOM, 1999) also specified the use of effective bandwidth in its charging proposal. Liu and Petr (1996) in proposing a measurement-based Connection Admission Control (CAC) strategy also mentioned that measurement of real-time traffic showed that using the parameters of the traffic contract in conjunction with dynamic renegotiation is useful in determining actual usage.

3. Modeling and Simulation of RT-VBR Traffic Pattern

Our model is made up of three nodes connected by a directed graph that indicated the direction of flow of traffic at any given point. The three nodes correspond to two Data Terminating Equipments (End User terminals) as endpoints and an ATM switch as transit point. The links on the directed graph correspond to communication channel. This is a simplified model as it assumed that the bandwidth on the communication channel is sufficient for any amount of bandwidth and does not provide a constraint at CAC negotiation. Secondly, the number of ATM switches in the path has been reduced to one for simplicity. This model is shown in Figure 1.

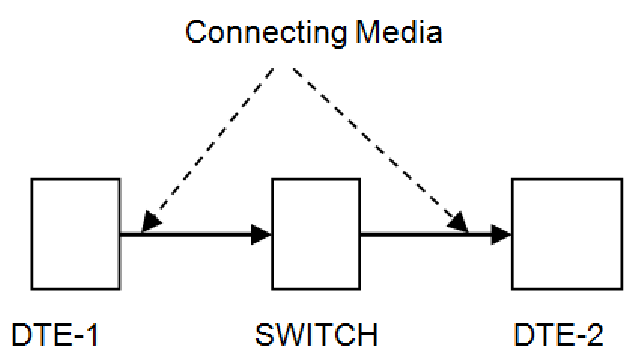

Figure 1: Simplified ATM Network Model for V

The source traffic was constructed from chaotic maps, and a timed Petri net developed by Zaborovski et al (1999) was used to develop a sending pattern of the RT VBR source based on traffic descriptors PCR, SCR and MBS. The Petri net is as presented in Figure 2 BR traffic.

Arcs (S_1,t_1) and (t_1,S_2) both have weight u while (S_2,t_2)and (t_2,S_1)both weight v. U number of tokens are removed from S_1 and put in S_2 when transition t_1 fires. This imitates the behavior of leaky bucket that have L tokens added when a cell that met the policing function criteria arrives at interface. S_2 represent another bucket where the leak goes into and is recycled

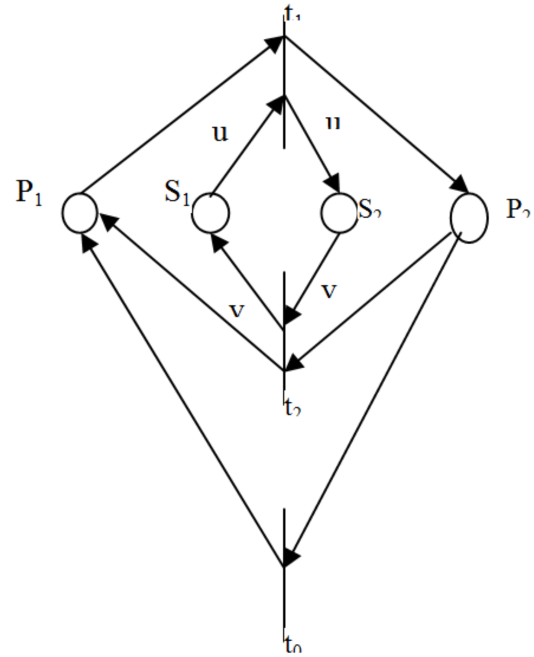

Figure 2: The Petri net model of the leaky bucket and parameters interaction

back into the system. V number of tokens are removed from S_2 and added to S_1 when transition t_2 fires. The place P_1 and P_2 represent an internal clocking system of the source and transition t_0 fires within an interval T_0 where T_0 represents the minimum emission interval.

Initial marking of this conservation timed Petri net is

$M_0 = M(P_1) = 1$
$M(S_1) = z : z > u+v-1$
$M(S_2) = 0$
$M(P_1) = 0$
$M(P_2) = 0$

While the value of $M(S_1)$, u, v and t_o is determined by service parameters PCR, SCR and MBS. The firing of t_1 represent sending of a cell while that of t_2 represent silent period constraint on Petri net are: t_1 cannot fire when token in S_1 is less that u, t_2 cannot be enable if token in S_2 is less than V, and t_1 and t_2 cannot fire simultaneously.

$M(P_1) + M(P_2) = 1$
$M(S_1) = z\text{-}q \Rightarrow MBS*(PCR\text{-}SCR)/w$
(w is the greatest common divisor of PCR-SCR and SCR)
$M(S_2) = q$
$u = M(S_1)/MBS$
$v = (M(S_1)*SCR/(MBS*(PCR\text{-}SCR))$
$T_0 = 1/PCR$

The firing sequence correspond to a VBR traffic pattern PCR=1/To

$SCR=1/T_0 * v*(u+v)$
$MBS= M(S_1)/u$

The actual selection of the transition that will fire out of the t_1 and t_2 is done by a separate sub mode constructed from the chaos function below

$$f(x) = a \times x(x-1) \ \forall \alpha \in \Re: \ 3.7 < a < 4$$

$$x_{n+1} = \begin{cases} f_1(x_n) & \forall x, d \in \Re : 0 < x < d \\ f_2(x_n) & \forall x, d \in \Re : d < x < 1 \end{cases}$$

d = 0.5

The simplicity of the model is that the same function was used for both f1 and f2 but differentiated with different starting points of 0.100 and 0.109 respectively.It was noted through empirical study of Erramilli et al, (1994) and Kode et al, (2001) that network traffic have heavy inter-arrival time density ,so a Gaussian random function was use to compare with value of xn+1 to determine the value of variable yn :

$$y_n = \begin{cases} 0 : x_n > G(n) \\ 1 : x_n \leq G(n) \end{cases}$$

Where G(n) is the Gaussian random variable generated simultaneously with x_n .When y_n=0, t_1 fires and when y_n=1, t_2 fires. This two tool; the Petri net and chaos map functions were translated to a java program to perform simulation.

4. Simulation Result

For any particular parameter K: $K \in S$: S= {MBS, PCR and SCR}, two out of the three traffic descriptor parameters will be held constant while the remaining varies. The simulation program was run ten times per value and an average value of cell rate was taken for it.

The reason for this is to get a value that will be representative of the parameter at that point since video and audio streams have a pattern of behavior that is dynamic. Furthermore, some of the simulation runs were done more than once to make sure that the result is independent of the state of the simulation platform. The result for simulation of the average cell rate was analyzed against the varying values of PCR, MBS, and SCR. The parameter of interest in the simulation in this work was the average rate of bandwidth consumption (this is output of the simulation) while the variables: the specified sustainable cell rate (SCR); the specified peak cell rate (PCR) and the specified maximum burst size (MBS) are varied one.

The behavior of the average rate of bandwidth consumption against the other specified parameters was investigated using the output of the simulation program.

The result is as presented in Tables 1, 2, and 3.

Table 1: Variation of Average Utilization Rate with Peak Cell Rate

PCR (cell/s)	Average Util. Rate (AUR) (cell/s)	RATE as percentage of PCR	SCR as percentage of PCR
25000	22080.5	88.322	90
30000	22062.6	73.542	75
40000	22742.7	56.856	56.25
55000	22488	40.887	40.909
60000	22511.1	37.519	37.5
75000	22262.4	29.683	30
90000	22088.5	24.543	25

Table 2: Variation of Average Utilization Rate with Sustainable Cell Rate

SCR (cells/sec)	AUR (cells/sec)	AUR as percentage of PCR	SCR as percentage of PCR
10000	9694.88	13.85	14.2857
15000	14654	20.93	21.4285
20000	19753	28.22	28.5714
25000	24791.25	34.42	34.7142
30000	30082	42.98	42.8571
35000	35590	50.84	50

Table 3: Variation of Average Utilization Rate with Maximum Burst Size

MBS (cells)	AUR (cells/sec)
130	35384.50
140	35490.50
150	35487.17
160	35399.90
170	35452.33
200	35420.33
500	35566.00
1000	35443.00

5. Result and Discussion

5.1 Effect of Peak Cell Rate on Average Utilization Rate

The Table 4.1 above showed the effect of changes in Peak Cell Rate (PCR) on the behavior of average utilization rate (AUR) when the SCR is held constant. This is shown in Appendix1, which showed the behavior against a global view that although the AUR showed some variation with changes in PCR, those variations are minute compared to the magnitude of change in PCR. The percentage relationship is shown in columns 3 and 4 for AUR and SCR respectively. This is shown graphically in Appendix 1. Both the table 1 and Appendix 2 showed that the ratio of AUR as a percentage of PCR and SCR as a percentage of PCR is almost the same. In effect, it might be deduced that PCR has minimal effect on the AUR. The regression analysis for the relationship of AUR to PCR is as given below:

A linear model constructed using linear regression model is shown equation 1

$$AUR = 23130.717 + 0.004(PCR) \quad (1)$$

The PCR has a statistical significance of p > 0.5085 while the constant parameter has the value of p >3.1030E-7. The interpretation of these values of p is that the contribution of PCR in the model is most likely due to chance while it is almost certain that the constant parameter contributed the given value to the determination of AUR.

The R^2 value of 0.11617with a Standard Error Estimated to be 282.716 from the model fit statistics indicated that the variation in the value of AUR that might be due to PCR is 11.617%. The conclusion therefore is that the effect of PCR on the determination of AUR is likely to be small.

5.2 Effect of Sustainable Cell Rate on Average Utilization Rate

Table 2 shows the variation in the average utilization rate AUR to the change in Sustainable Cell Rate (SCR) (for PCR at 70000 cells/sec and the MBS at 153 cells.) From the Table 2, we deduced that AUR varied almost linearly with changes in SCR. As can be seen from Table 2, changes in values of SCR were matched with equivalent or proportionately equivalent change in the value of AUR. As SCR increased, AUR also increased. Appendix 3 showed the linear relationship and equivalence between the values of AUR and SCR pictorially. The conclusion is that AUR is linearly dependent on SCR and almost totally independent of the value of PCR.. The regression analysis for the relationship of AUR to SCR is as given below:

A linear model was constructed using linear regression model is shown equation 2:

$$AUR = -817.916 + 1.0331(SCR) \quad (2)$$

The SCR has a statistical significance of $p > 4.4269E\text{-}8$ while the constant parameter has the value of $p > 0.0238$. The interpretation of these values of p is almost certain that the SCR contributed the given value to the determination of AUR while the contribution of the constant parameter in the model is not likely due to chance.

The R^2 value of 0.9996 with a Standard Error Estimated to be 200.306 from the model fit statistics indicated that the variation in the value of AUR due to SCR is 99.96%. Nevertheless, it is important to note that the data set for each dependent - independent variables considered was actually computed from the average of ten values. The conclusion therefore is that the SCR is the overriding determinant of AUR.

5.3 Effect of Maximum Burst Size on Average Utilization Rate

Table 3 present the result of the simulation for the values of the Average Utilization Rate in response to changes in Maximum Burst Size (MBS) (for PCR at 65000 cells/sec and SCR at 35000 cells/sec). Appendix 4 showed that the values of the AUR do not have a distinct relationship with changes in MBS as it oscillated randomly. The same graph shown on a different scale indicated that AUR remained constant. The regression analysis for the relationship of AUR to PCR is as given below in equation 3:

$$AUR = 35464.2316 - 0.15859(MBS) \quad (3)$$

The MBS has a statistical significance of $p > 0.8682$ while the constant parameter has the value of $p > 1.6059E\text{-}9$. The interpretation of these values of p is that the contribution of MBS in the model is likely due to chance while it is almost certain that the constant parameter contributed the stated value to the determination of AUR.. The R^2 value of 0.007756 from the model fit statistics indicated that the variation in the value of AUR due to MBS is 0.776%. The conclusion therefore is that the effect of MBS on the determination of AUR is negligible.

6. Conclusion

In this paper, the authors present relative significance of the contribution of each of the traffic descriptors for a real-time VBR traffic within an ATM network. The conclusion is based on the result of the simulation obtained in section 4. The result of the simulation showed that SCR contributed up to 99% in the determination of the volume of cells transmitted in an ATM VBR connection. PCR contributed about 1% while the value of MBS does not have a definite pattern of contribution. It was therefore concluded that SCR is sufficient as a parameter in determining the volume of cells transmitted in an ATM connection. This is in agreement with Liu and Petr (1996).

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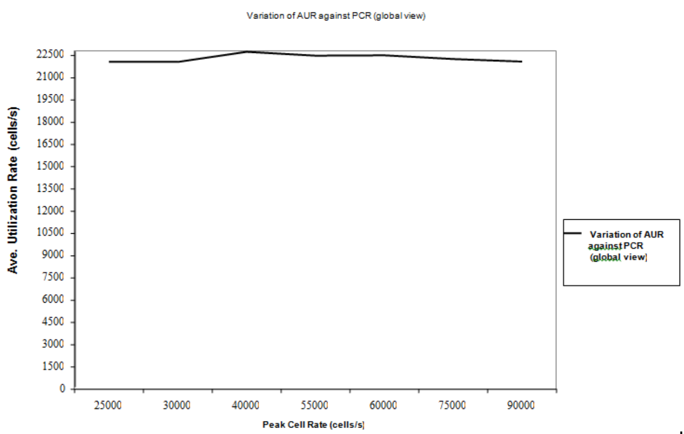
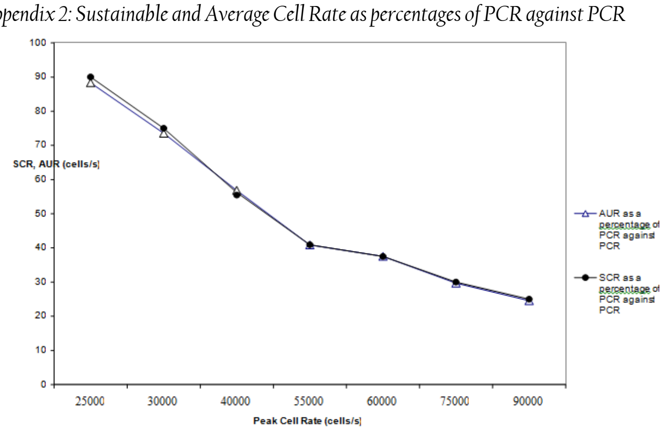
APPENDICES

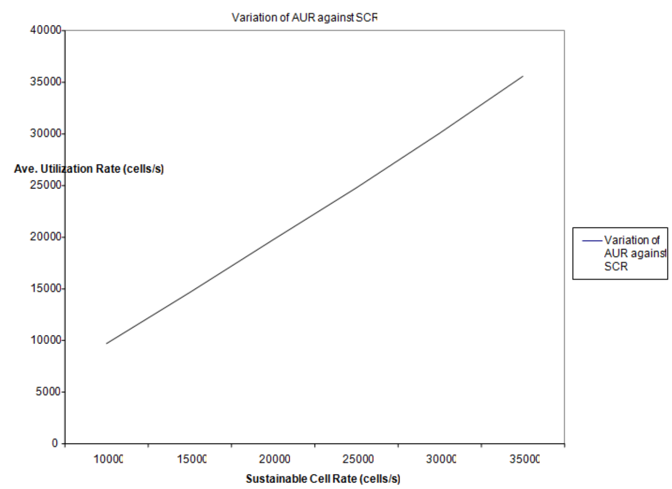
Appendix 1: Extended view of Average Cell Rate against changes in Peak Cell Rate



Appendix 2: Sustainable and Average Cell Rate as percentages of PCR against PCR



Appendix 3: Average Cell Rate against changes in Sustainable Cell Rate



Appendix 4: Average Cell Rate against changes in Maximum Burst Size