The University of Kansas

Information and Telecommunication Technology Center

Technical Report

AAL2 UPC Parameter Study

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ITTC-FY99-TR-15664-01

February, 1999

Project Sponsor:
Sprint Corporation

1 Introduction

The objective of this study is to obtain UPC (usage parameter control) parameter estimates for a given VBR (variable bit rate) traffic stream. The basic traffic descriptors for a VBR service class are SCR (sustainable cell rate), BT (burst tolerance), PCR (peak cell rate) and CDVT (cell delay variation tolerance). This study attempts to estimate all possible "critical sets" (defined later) of VBR traffic descriptors, using simulation techniques. Selection of a particular set of parameters can then be made based on factors such as Quality of Service (QOS) requirements and bandwidth usage. A virtual buffer measurement (see figure 1) is done to determine the UPC parameters. The techniques used for mapping the virtual buffer measurements to the traffic descriptors are analytically derived in Section 2. These techniques are then used to find the traffic descriptors for AAL2 traffic. AAL2, a new encapsulation scheme for variable size packets, can use the VBR (variable bit rate) service class. Auxillary results of AAL2 and AAL2+ATM efficiencies and AAL2 and AAL2+ATM percent padding are also obtained from the study.

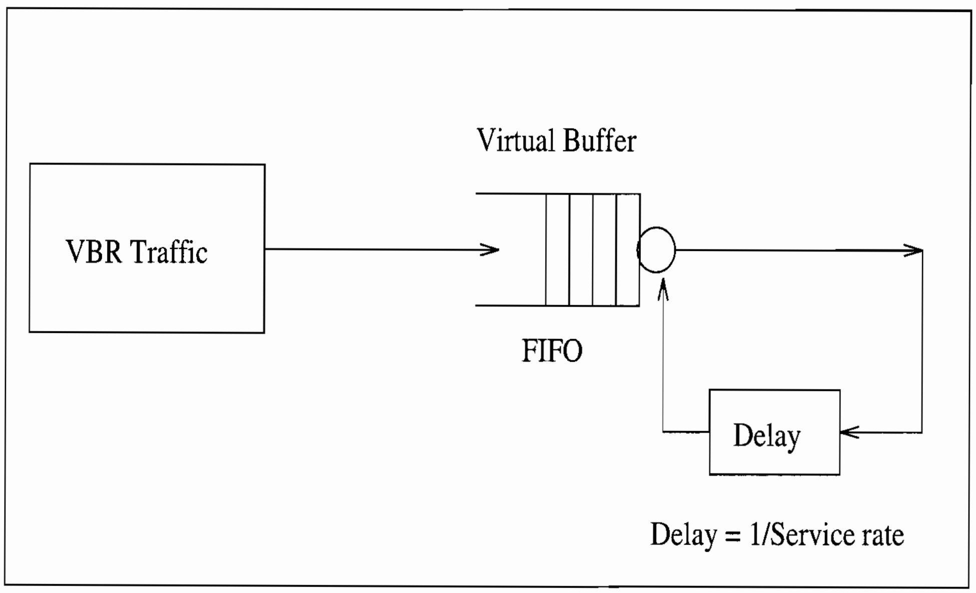


Figure 1: Virtual Buffer Model

2 Obtaining UPC Parameters via Virtual Buffer Measurement

2.1 Overview

Network Resources are allocated for a particular traffic stream depending on the traffic descriptors. The traffic can be monitored by using one or more traffic policers, each implemented as a Generic Cell Rate Algorithm (GCRA)[5]. We attempt to find all "critical sets" of the UPC parameters PCR, CDVT, SCR, BT for a particular traffic stream, where a critical set is defined as follows.

1) The traffic stream will be completely compliant (all cells complaint) when policed by a GCRA(T_0, T_0)

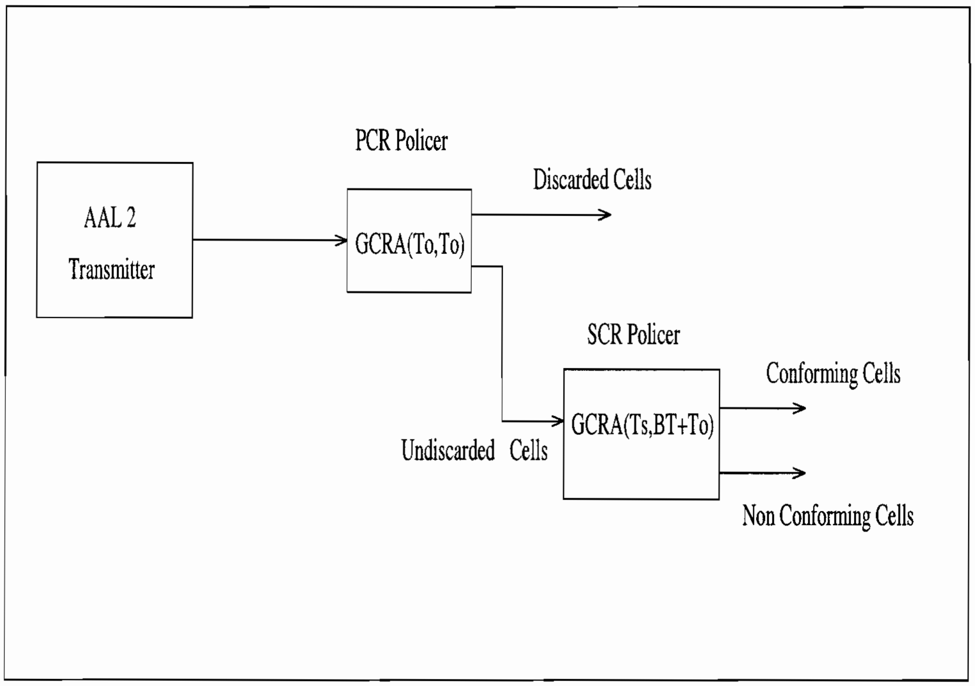


Fig.2 Dual Policer Configuration

policer (see figure 2) followed by a GCRA($T_s, \tau + T_0$) policer where,

PCR $= 1/T_0$

CDVT $= T_0$

SCR $= 1/T_s$

BT $= \tau$

The restriction of CDVT = 1/PCR is in accordance with standards recommendations [5].

2) Any reduction in any one of the values PCR, CDVT, SCR, BT will result in some nonconformance when using the above dual policer configuration on the given traffic stream. We find a unique value for the PCR (and hence CDVT), the curve of BT vs SCR and the curve of Maximum Burst Size (MBS) vs SCR for the given traffic stream. The value of BT is first calculated, from which MBS is calculated.

The traffic descriptors can be found from the virtual buffer in the following steps.

1) PCR and CDVT (see section 2.2) : The FIFO is served at a variable rate and the maximum buffer fill of the FIFO is noted. A curve between the service rate and the maximum buffer fill (MBF) is thus obtained. The minimum service rate of the FIFO that gives a maximum buffer fill of 1 corresponds to the PCR of the critical UPC parameter set.

2) SCR and MBS (see section 2.3): The curve between service rate and maximum buffer fill can be converted to SCR and MBS respectively. The service rate corresponds to the SCR, BT and MBS can be found from MBF, SCR and PCR by using the relations,

$$BT = MBF * T_s - T_0 \tag{1}$$

$$MBS = \lfloor (MBF * T_s - T_0)/(T_s - T_0) \rfloor + 1 \tag{2}$$

where $\lfloor\rfloor$ represents the integer part.

2.2 Analytical PCR derivation

Consider the two systems shown in figure 3. Refer also to figure 4 for details of the GCRA algorithm. We wish to show that the Maximum Buffer Fill (MBF) of the FIFO is 1 cell at a service rate PCR($= 1/T_0$ cells/sec) if and only if every cell of the input cell stream is GCRA(T_0,T_0) compliant. This can be established by proving,

1) $MBF = 1 \Rightarrow GCRA(T_0, T_0)$ compliant.

2) $GCRA(T_0, T_0)$ compliant $\Rightarrow MBF = 1$.

Without loss of generality let t=0 be the instant of the first cell arrival. For a FIFO, note that as long as

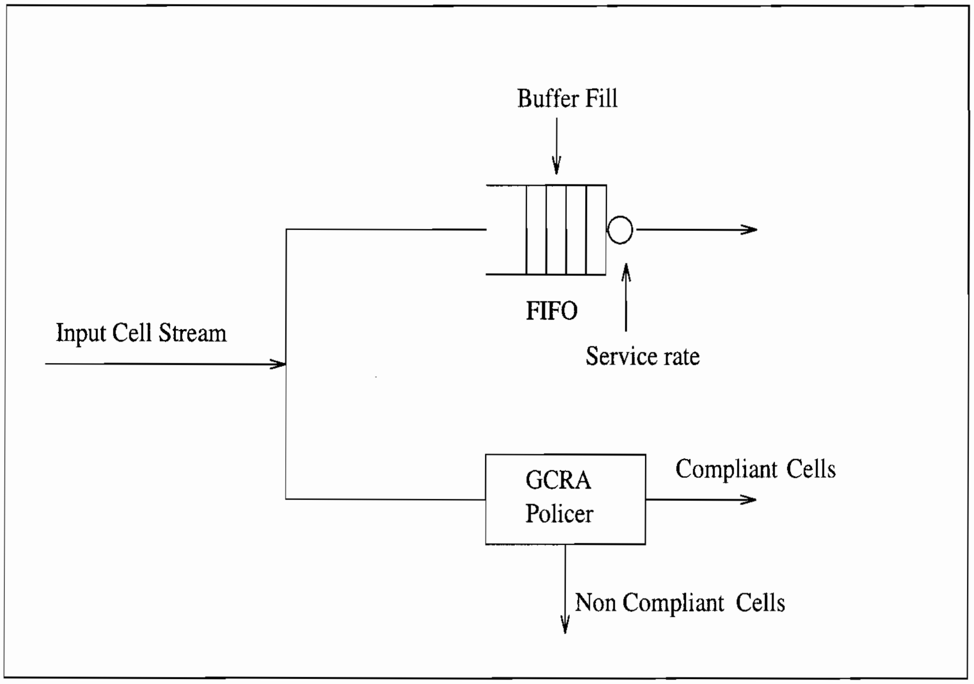


Figure 3: Comparision of the two Systems

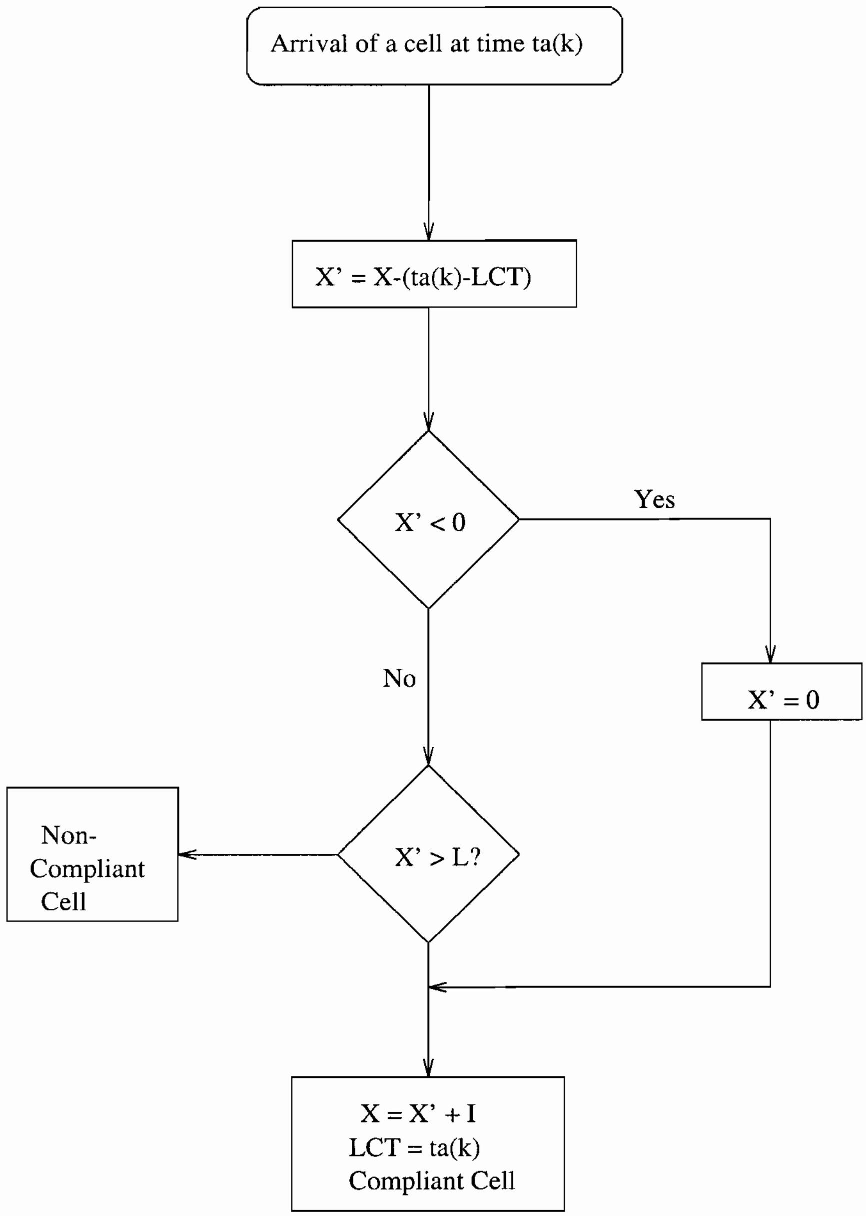
the server remains busy, service completion instants will be t=kT, where k is an integer and 1/T is service rate. Further the server will be busy until time NT if for every k $\in \{1, 2, ..N-1\}$ the number of arrivals (besides the first) in [0,kT) is at least k. If there are two or more arrivals in any interval [(k-1)T , kT), the MBF will be greater than 1. So, MBF = 1 in a busy period is equivalent to exactly one arrival in any interval [(k-1)T,kT). When the server is idle, X' in the GCRA becomes negative. The arrival of the next cell resets the value of X' to 0. Thus we need to analyse only busy periods, and we can reset t=0 at the arrival of the first cell of each busy period.

When the server is busy we need to prove,

1) Exactly 1 arrival in FIFO in any interval $[(k-1)T_0, kT_0) \Rightarrow$ GCRA(T_0, T_0) compliant

2) GCRA(T_0, T_0) compliant $\Rightarrow$ exactly 1 arrival in FIFO in any interval $[(k-1)T_0, kT_0)$.

1) During a busy period, MBF = 1 implies that there is exactly one cell arrival in each servicing interval. Consider the cell arrival pattern shown in figure 5. Let T1 , T2 , T3 have arbitrary positive values. Consider the GCRA(T_0, T_0) leaky bucket algorithm at the arrival of each cell (refer to figure 4), in which we would have I = L = T_0.



I = Increment

L = Limit

ta(k) = Time of arrival of a cell

X = Value of the leaky bucket counter

X' = Auxiliary variable

LCT = Last compliance time

Figure 4: The GCRA leaky bucket policer

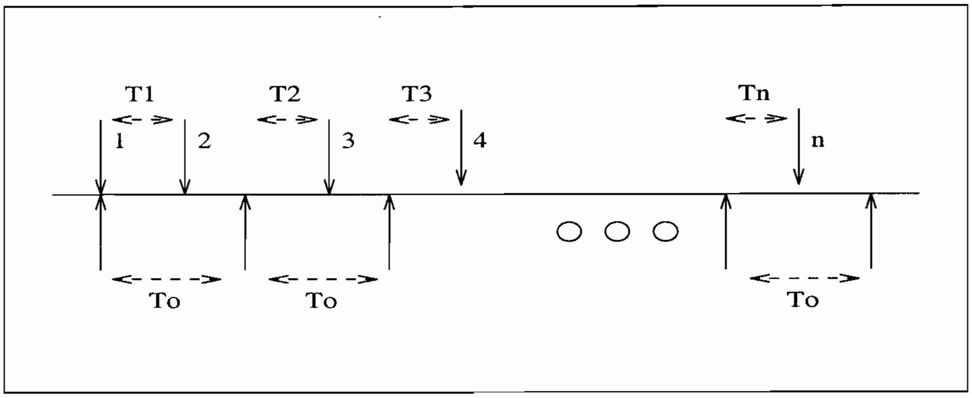


Figure 5: Proof Part 1

Arrival 1 at time 0

$X' = 0 \Rightarrow$ first cell compliant

X = T_0

LCT = 0

Arrival 2 at time T_1

$X' = T_0 - T_1$

$T_1 \geq 0$, $X' \leq T_0 \Rightarrow$ second cell compliant.

$X = 2T_0 - T_1$

$LCT = T_1$

Arrival 3 at time $T_0 + T_2$

$X' = 2T_0 - T_1 - (T_0 + T_2 - T_1) = T_0 - T_2,$

$T2 \geq 0$, $X' \leq T_0 \Rightarrow$ third cell compliant.

$X = 2T_0 - T_2$

$LCT = T_0 - T_2$

Arrival 4 at time $2T_0 + T_3$

$X' = 2T_0 - T_2 - (T_0 - T_2 + T_3) = T_0 - T_3$

$T_3 \geq 0$, $X' \leq T_0 \Rightarrow$ fourth cell compliant.

$X = 2T_0 - T_3$

$LCT = 2T_0 + T_3$

Following the pattern, the nth cell will be compliant and result in

$X = 2T_0 - T_{n-1}$

$LCT = (n-2)T_0 + T_{n-1}$

Then at the arrival of the (n+1)th cell at time $(n-1)T_0 + T_n$ *results in*

$X' = 2T_0 - T_{(n-1)} - (T_0 - T_{(n-1)} + T_n) = T_0 - T_n$

$T_n \geq 0$, $X' \leq T_0 \Rightarrow$ nth cell compliant.

Thus it is proved that if the MBF = 1 when the FIFO is served at a rate $1/T_0$, then the input cell stream is GCRA(T_0, T_0) compliant.

2) Assume the cell arrivals are GCRA(T_0, T_0) compliant. Consider the cell arrival pattern that is shown in figure 6.

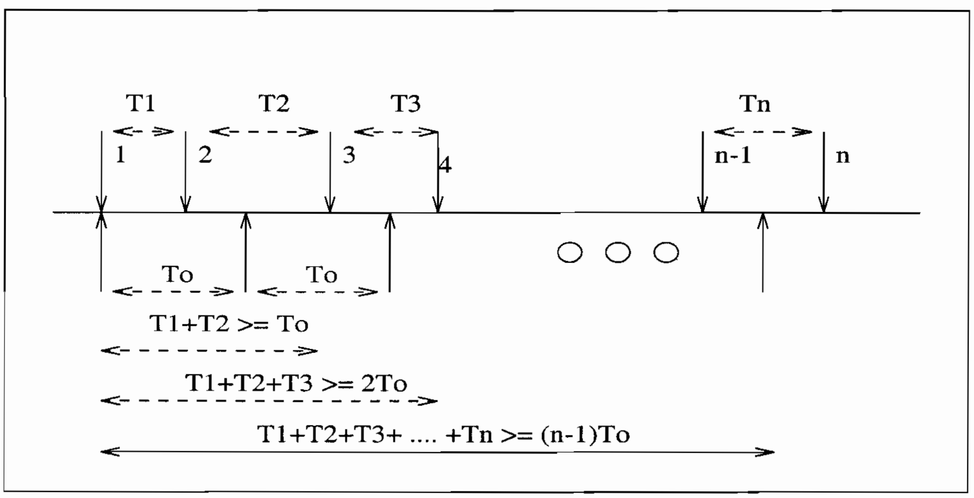


Figure 6: Proof part2

Consider the GCRA algorithm at each cell arrival.

Arrival 1 at time 0

$X' = 0$

The only cell that arrived is being serviced, hence the buffer fill is 0.

$X = T_0$

$LCT = 0$

Arrival 2 at time T_1

$X' = T_0 - T_1$

Cell compliance $\Rightarrow T_1 \geq 0$

At this point 2 cells came in and one of them is being serviced, hence the buffer fill is 1.

$X = 2T_0 - T_1$

$LCT = T_1$

Arrival 3 at time $T_1 + T_2$

$X' = 2T_0 - T_1 - T_2$

Cell compliance $\Rightarrow T_1 + T_2 \geq T_0$

Hence the arrival of the third cell occurs after time $t = T_0$, and there is exactly one arrival (number 2) (besides the first) in the interval $[0,T_0)$. This implies that MBF=1 in the interval $[0,T_0)$.

$X = 3T_0 - T_1 - T_2$

$LCT = T_1 + T_2$

Arrival 4 at time $T_1 + T_2 + T_3$

$X' = 3T_0 - T_1 - T_2 - T_3$

Cell compliance $\Rightarrow T_1 + T_2 + T_3 \geq 2T_0$

Hence the arrival of the fourth cell occurs after time $t = 2T_0$, and there is exactly one arrival (number 3) in the interval $[T_0, 2T_0)$. This implies that MBF=1 in the interval $[0,2T_0)$.

Arrival n at time $T_1 + T_2 + T_3 + ... + T_{n-1}$

$X' = (n-1)T_0 - T_1 - T_2 - T_3 - .... - T_{(n-1)}$

Cell compliance $\Rightarrow T_1 + T_2 + T_3 + ... + T_{(n-1)} \geq (n-2)T_0$

Hence the arrival of the nth cell occurs after time $t = (n-2)T_0$, and there is exactly one arrival (number (n-1)) in the interval $[(n-3)T_0, (n-2)T_0)$. Together with single arrivals in all previous service intervals, this implies that MBF=1 in the interval $[0,(n-2)T_0)$. Hence it is proved that when a cell stream is GCRA(T_0, T_0) compliant, MBF in the FIFO is 1 cell.

2.3 Calculation of BT and MBS

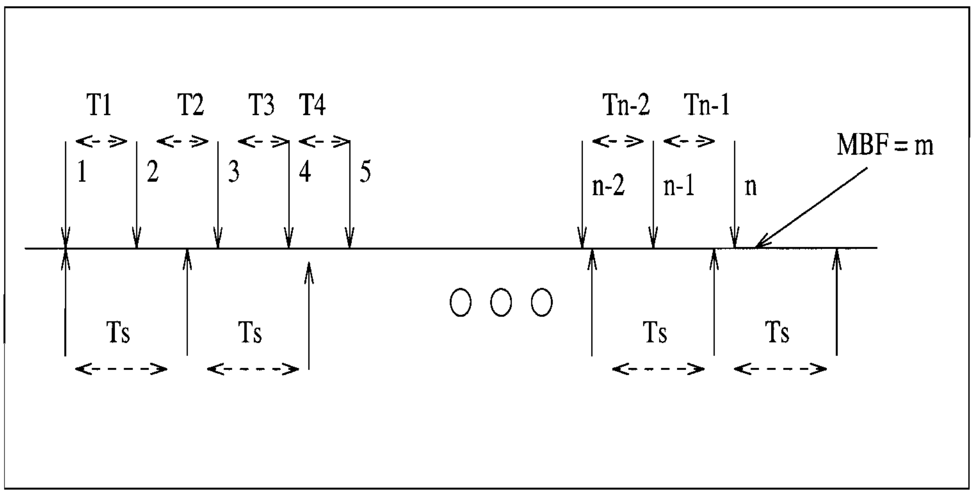


Figure 7: MBF to BT conversion

We calculate BT from MBF and the service rate. The service rate is interpreted as SCR. MBS can then be found from SCR, BT and PCR. Assume that t=0 be the instant of arrival of the first cell. Let the burst be of length 'n' cells. Let the time since the previous arrival be $T_1, T_2 ... T_{n-1}$ for the cells $2, 3, ..., n$ respectively (see figure 7). Let this arrival of cells give an MBF of 'm'. This means that there have been exactly 'n-m-1' service completions between time t=0 and the arrival of the nth cell. This yields

$(n-m-1)T_s \leq T_1 + T_2 + T_3 + ... + T_{(n-1)} \leq (n-m)T_s$

Now follow the GCRA(I,L) algorithm with $I = T_s$ and $L = BT + T_0$ at the arrival of each cell, assuming compliance:

Arrival 1 at time 0

$X' = 0 \leq BT + T_0$ (for compliance)

$X = T_s$

$LCT = 0$

Arrival 2 at time T_1

$X' = T_s - T_1 \leq BT + T_0$ (for compliance)

$LCT = T_1$

Arrival 3 at time $T_1 + T_2$

$X' = 2T_s - T_1 - T_2 \leq BT + T_0$ (for compliance)

$LCT = T_1 + T_2$

Arrival n at time $T_1 + T_2 + T_3 + ... + T_{n-1}$

$X' = (n-1)T_s - (T_1 + T_2 + T_3 + ... + T_{n-1}) \leq BT + T_0$ (for compliance)

$LCT = T_1 + T_2 + T_3 + ... + T_{n-1}$

using the inequality for $T_1 + T_2 + T_3 + ... + T_{(n-1)}$ above,

we conclude that $(m-1) * T_s \leq X' \leq m * T_s$

As noted, for all of the above cell arrivals to be compliant the limit parameter ($L = BT + T_0$) should be greater or equal to X' after the arrival of each cell. Combined with the previous inequality with $m = MBF$: we conclude that a safe value for BT satisfies

$BT + T_0 = L = m * I = MBF * T_s$

That is $BT = MBF * T_s - T_0$, where $1/T_s = SCR$ and $1/T_0 = PCR$. We see that the analytical PCR derivation done in section 2.2 is in agreement with the above equation and is a special case of it for $L = T_0$, $I = T_0$ and MBF=1.

Thus we obtain the value of BT from MBF, SCR and PCR. We can also obtain an expression for MBS as:

$$MBS = 1 + \lfloor BT/(T_s - T_0) \rfloor = 1 + \lfloor (MBF * T_s - T_0)/(T_s - T_0) \rfloor$$

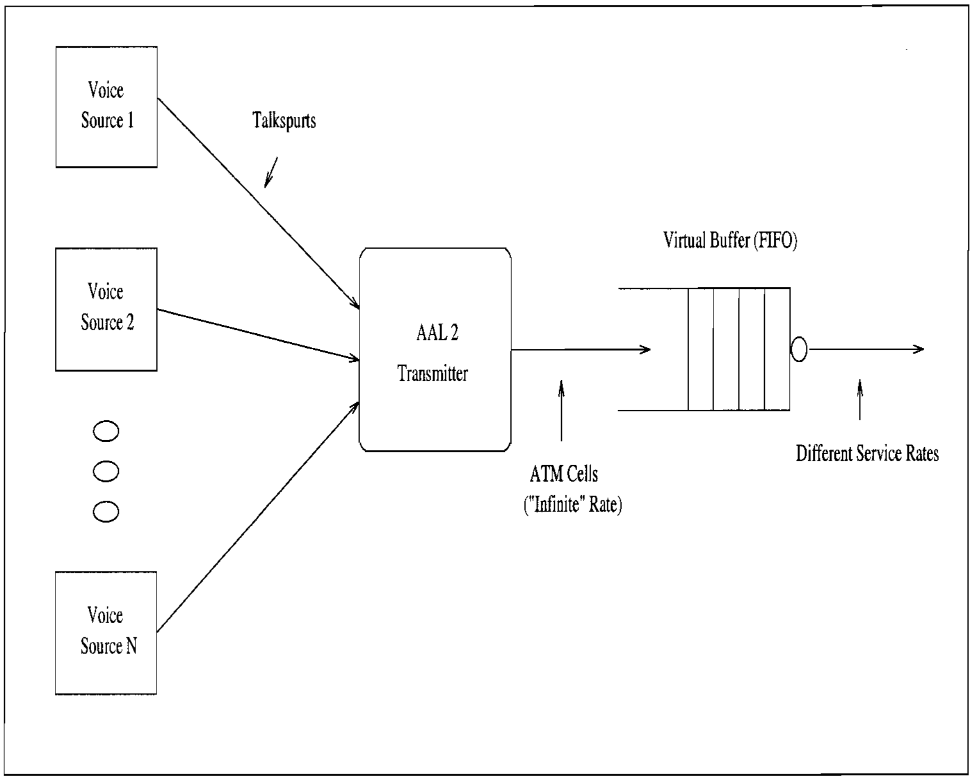


Figure 8: Simulation Model

3 Description of Simulation

All modeling and simulation was done with the BONes Designer simulation package. The results obtained in section 2 are used to obtain the traffic descriptors for AAL2 traffic. A previously designed AAL2 transmitter [2] is used as a source for generating AAL2 traffic. The AAL2 output is fed to a number of parallel FIFOs. The output rate of the transmitter is given a practically infinite value (10 Mbps) for the traffic. The FIFOs are served at different rates corresponding to various SCR or PCR values and the MBF is measured in all FIFOs.

3.1 Simulation Models

3.1.1 Sources

Each individual voice source is modeled as an on-off source. The on and off times of the sources are assumed to be exponentially distributed. The sources have a constant rate when they are ON. This model for the on-off sources is derived from [3]; it has been verified by analyzing additional recordings of telephone conversations (another technical report covering this analysis is under preparation). From the analysis of the recordings, it is found that the distribution of ON and OFF times is not a pure exponential distribution. The values of on and off times estimated from these recent recordings are reasonably close to but different from the values from [3].

3.1.2 AAL2 Transmitter

A previously designed AAL2 transmitter is used for generating AAL2 traffic. This has been designed on the basis of the ITU-T draft specification I.362.3. It is fully debugged and has been used in previous studies like the AAL2 performance characterization [2] and finding the maximum number of users subject to a 95th percentile delay constraint [4].

3.2 Parameters Used in Simulation

3.2.1 Fixed Simulation Parameters

- Mean ON time (1.230s)
- Mean OFF time (1.373s)
- CPS packet size (20 bytes).
- Voice coding rate (32 kbps).
- CU Timer (5.1 ms).

The combination of CPS packet size and voice coding rate results in a packetization time of 5 ms. The CU timer is selected as 5.1 ms to make sure that the cells are packed fully, ensuring high AAL2 efficiency.

The padding is very small, as 2 packets are packed in a cell even for a single user. The maximum time delay for a packet is 10.1 ms (5 ms of packetization delay and 5.1 ms CU Timer). The mean On and mean Off times are taken as 1.23 and 1.373 s as found from the analysis of speech files. A total of 60,000 CPS packets are simulated for each parameter set.

3.2.2 Variable Simulation Parameters

- Number of voice sources: The simulation is done for 1 through 12 users in steps of 1 and from 12 through 48 users in steps of 6.
- Virtual Buffer Service Rate:

The service rate has been varied from a value slightly larger than effective mean rate given by,

$$effective\ \ mean\ \ rate = n * 0.473 * 32 * (23/20) * (53/47) kbps \tag{3}$$

to a value more than twice effective peak rate.

$$effective\ \ peak\ \ rate = n * 32 * (23/20) * (53/47) kbps \tag{4}$$

Twenty rates in this range are taken to obtain the curves.

4 Results and Discussion

4.1 UPC Parameter Results

We obtain a curve between MBF and the service rate (see figure 9). From this curve we obtain

- PCR and CDVT : The service rate that corresponds to MBF=1 is taken as the PCR and CDVT is taken to be $1/PCR = T_0$. From the results of section 2, this ensures that the traffic is GCRA(T_0, T_0) compliant.
- Curves BT vs SCR and MBS vs SCR (see Figures 10 and 11): The maximum buffer fill (MBF) is converted to the burst tolerance (BT) using equation 1 and the FIFO service rate corresponds to the

SCR. We thus obtain figure 10. From Figure 10 we find infinite number of SCR, BT pairs that describe the given traffic. We can also obtain figure 11 which shows the curve MBS vs SCR using equation 2.

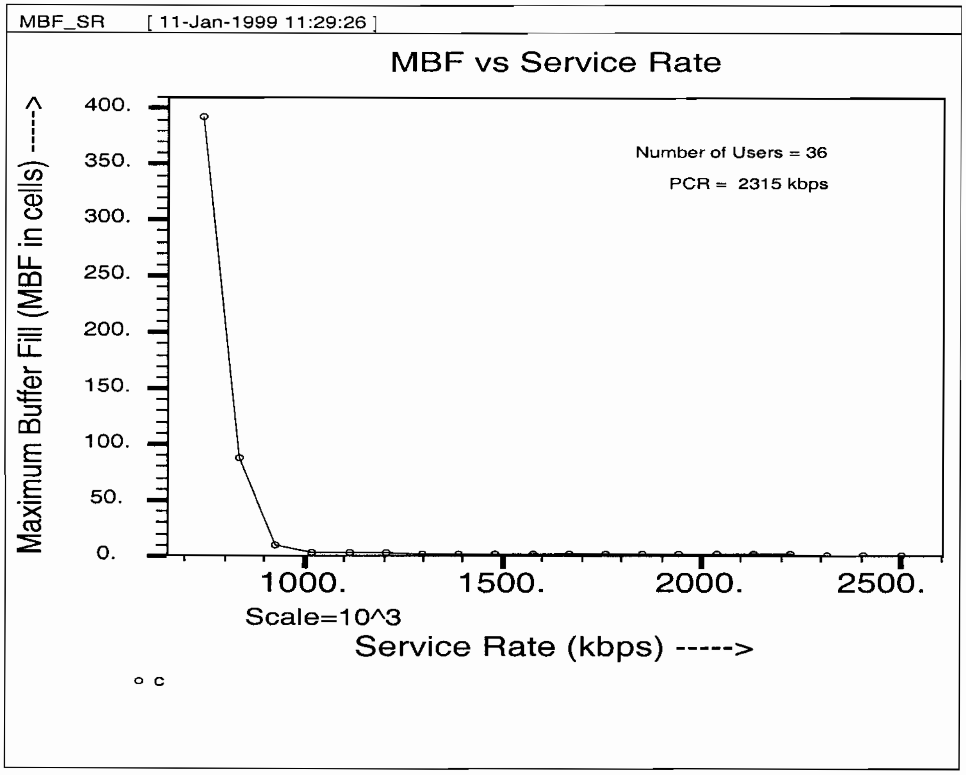


Figure 9: MBF vs Service rate for 36 users

The values of PCR, CDVT, SCR and BT found above are verified with a dual policer configuration as shown in figure 2, and the cells are found to be compliant. The compliance test has been done in 3 stages after selecting a point from the SCR, BT curve for a fixed PCR (see figure 10). These tests have been done to verify that the traffic descriptor set (PCR, SCR and BT) found is a minimal set that would give complete conformance when used with the dual policer configuration shown in figure 2. The point PCR = 2315 kbps, SCR = 835 kbps and BT = 0.044502 secs has been selected for verification.

1) Compliance test with variation in PCR: The values of SCR and BT are kept constant and the value of PCR is varied. PCR is decreased in steps of the servicing rates used in the simulation [see section 3.2.2]. The traffic stream is tested for compliance with a PCR policer and an SCR policer as shown in figure 2. Table 1 shows the number of non-compliant cells in the PCR and SCR policers in relation

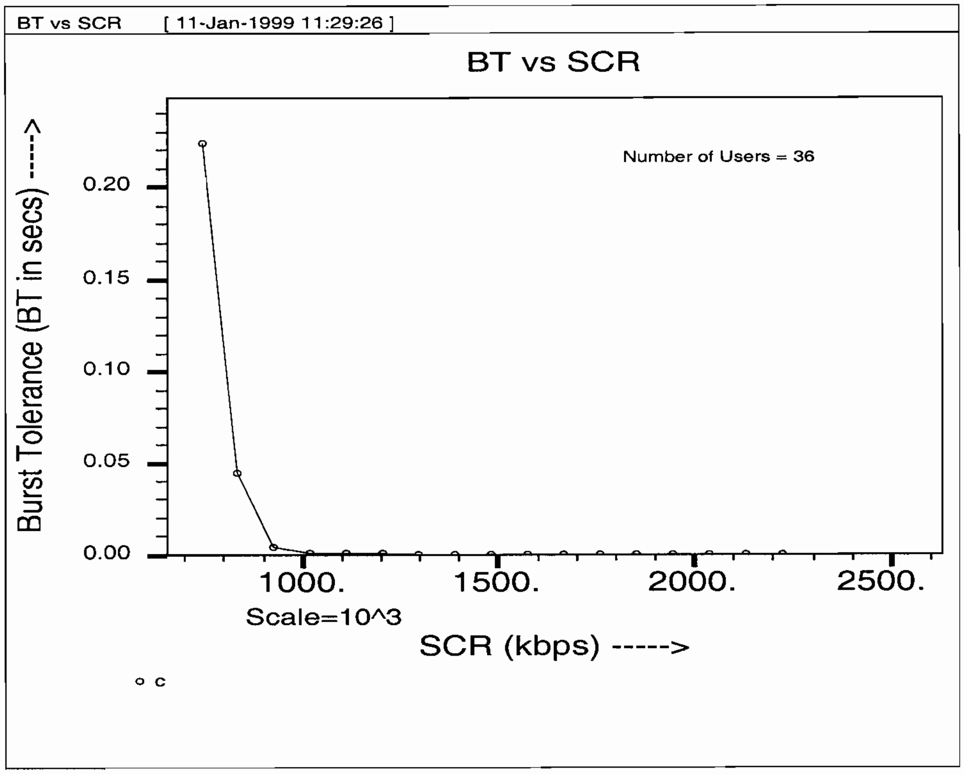


Figure 10: BT vs SCR for 36 users

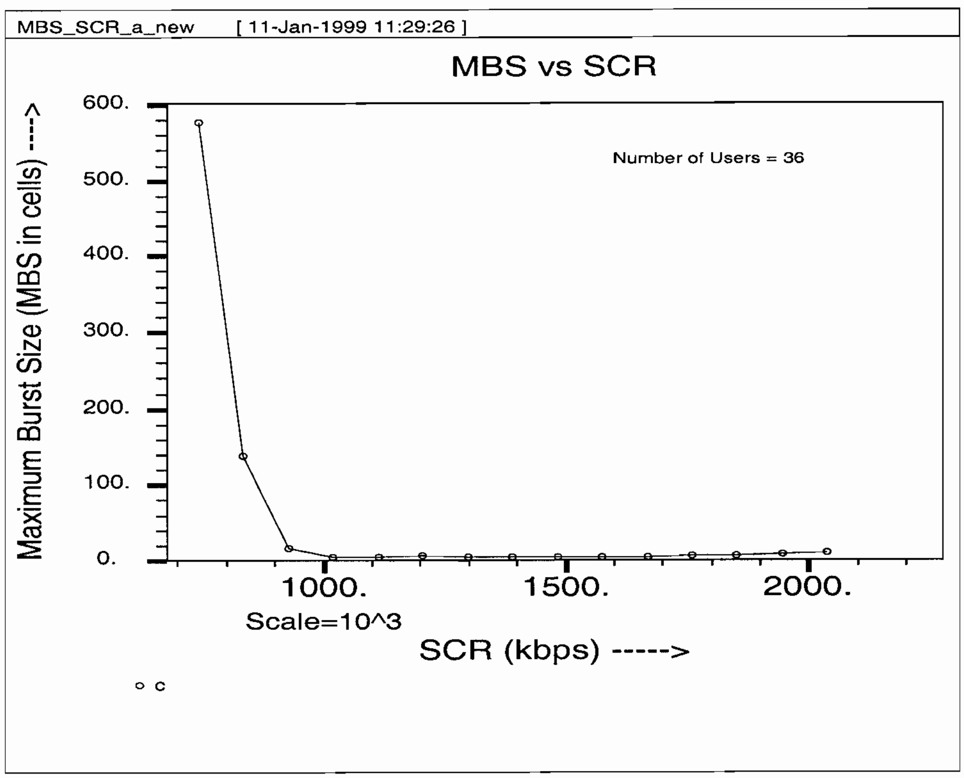


Fig.11 MBS vs SCR Estimates for 36 users

with the values of PCR. It has been found that even a slight decrease in PCR gives violations in the PCR policer.

PCR (kbps)	Number of violating cells with PCR policer	Number of violating cells with SCR policer
2315.0	0	0
2222.5	1	0
2130.0	1	0
2037.5	1	0
1945.0	21	0
1852.5	75	0

Table 1: PCR violation

2) Compliance test with variation in SCR: The values of PCR and BT are kept constant and the value of SCR is varied. SCR is decreased in steps of 50 kbps (smaller than the FIFO service rate increment). Table 2 shows the number of non-compliant cells in the PCR and SCR policers in relation with the values of SCR. It has been found that slight decrease in SCR gives violations in the SCR policer.

SCR(kbps)	Number of violating cells with PCR policer	Number of violating cells with SCR policer
835	0	0
785	0	74
735	0	332
685	0	1056
635	0	2105

Table 2: SCR violation

3) Compliance test with variation in BT: The values of SCR and PCR are kept constant and the value of BT is varied. BT is decreased in steps of T_s first and by larger values later. Table 3 shows the number of non-compliant cells in the PCR and SCR policers in relation with the values of BT. It is found that even slight decrease in BT gives violations with the SCR policer.

BT(secs)	Number of violating cells with PCR policer	Number of violating cells with SCR policer
0.044685	0	0
0.044085	0	1
0.043485	0	2
0.042885	0	3
0.030	0	20
0.025	0	31

Table 3: BT violation

From the above tests it has been verified that the traffic descriptors (PCR, SCR, BT) found are a minimal set for the given traffic. Any point on the curve of Figure 11 will result in zero non-conformance. The selection of this can be done by different methods.

Method 1: Choose the SCR and MBS set so as to minimize the effective bandwidth requirement. The effective bandwidth might be maximum at larger values of MBS and correspondingly smaller values of SCR. This may not sometimes be an ideal choice.

Method 2: Limit MBS to a reasonable value and select the corresponding SCR value. The SCR values for MBS of 50 cells are given in Table 4 . The incremental SCR for each additional user is also given. It is found that the additional SCR required to support each additional user tends to a constant value as the number of users increases. It is clear that this incremental SCR must be lower bounded by the effective mean rate per source of 19.6 kbps (from equation (2) with n = 1).

Figure 11 shows the estimated PCR vs the number of users. The value "calculated PCR" corresponds to the FIFO service rate for MBF of 1 cell. Twice the maximum equivalent cell bit rate (equation 3) is shown as "estimated PCR" in Figure 11. We see that it may be possible to use twice the maximum equivalent cell bit rate (see equation 3) to estimate the required PCR without resorting to simulation.

Number of Users	SCR (kbps) at MBS = 50 cells	SCR (kbps) per User
1	40.5	40.5
2	78.5	39.25
3	113	37.67
4	150.5	37.625
5	191	38.2
6	215	35.83
12	358	29.8
18	535	29.7
24	699	29.125
30	832	27.7
36	900	25
42	1060	25.2
48	1158	24.125

Table 4: Incremental SCR values

4.2 Auxiliary Results

- AAL2 and AAL2+ATM efficiency (Figure 12)

Percent AAL2 efficiency is defined as ,

$$AAL2 \quad efficiency = (mean \quad speech \quad sample \quad bytes \quad per \quad cell)/48 \tag{5}$$

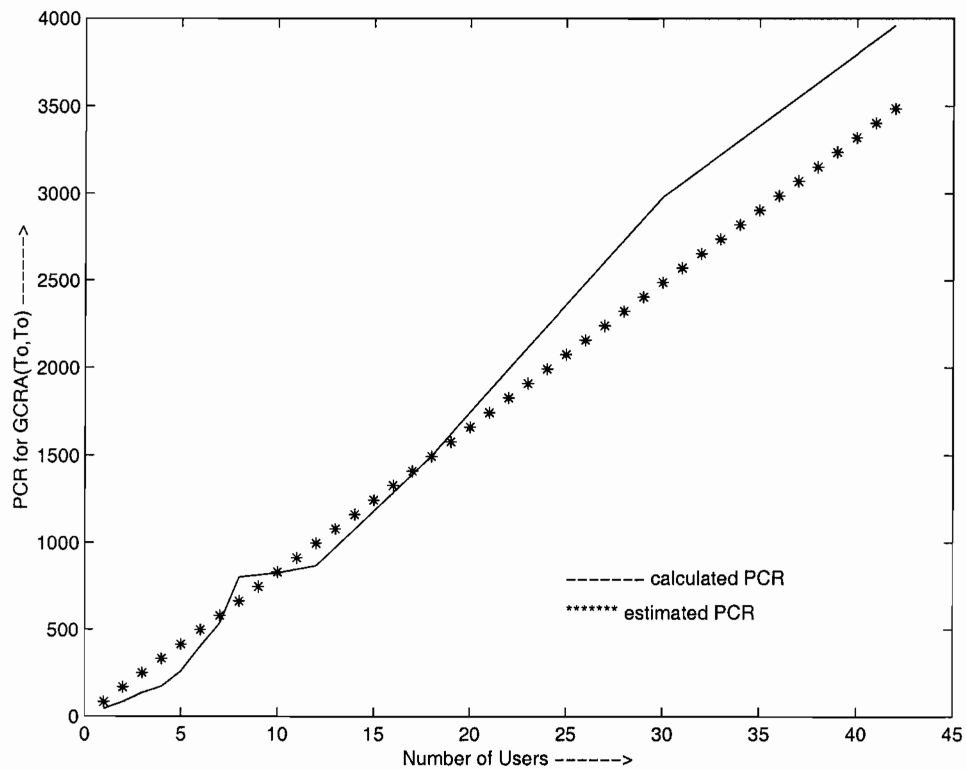


Fig.11 PCR estimate vs no. of users

Percent AAL2+ATM efficiency is defined as

$$AAL2 + ATM \quad efficiency = (mean \quad speech \quad sample \quad bytes \quad per \quad cell)/53 \tag{6}$$

High efficiencies are observed because of the choice of the parameters given in Section 3. The choice of CU Timer (5.1 ms) for a packetization time of 5 ms results in almost all cells being packed with a minimum of 2 CPS packets, which results in high AAL2 efficiency. The efficiency would go down for a decreased value of CU Timer.

- AAL2 and AAL2+ATM Percent Padding

When the CU Timer expires before the cell is completely filled, the cell is filled up with zero padding and sent. This is done to avoid delay of more than a given maximum value. This padding is a wastage in

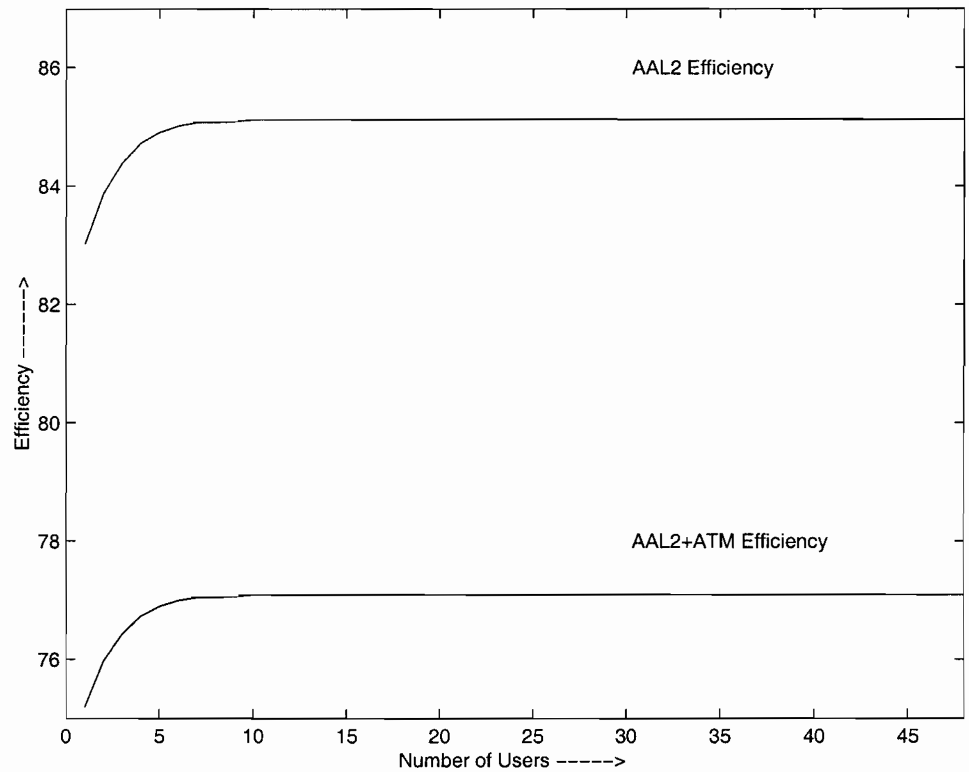


Fig.12 Percentage AAL2 efficiency

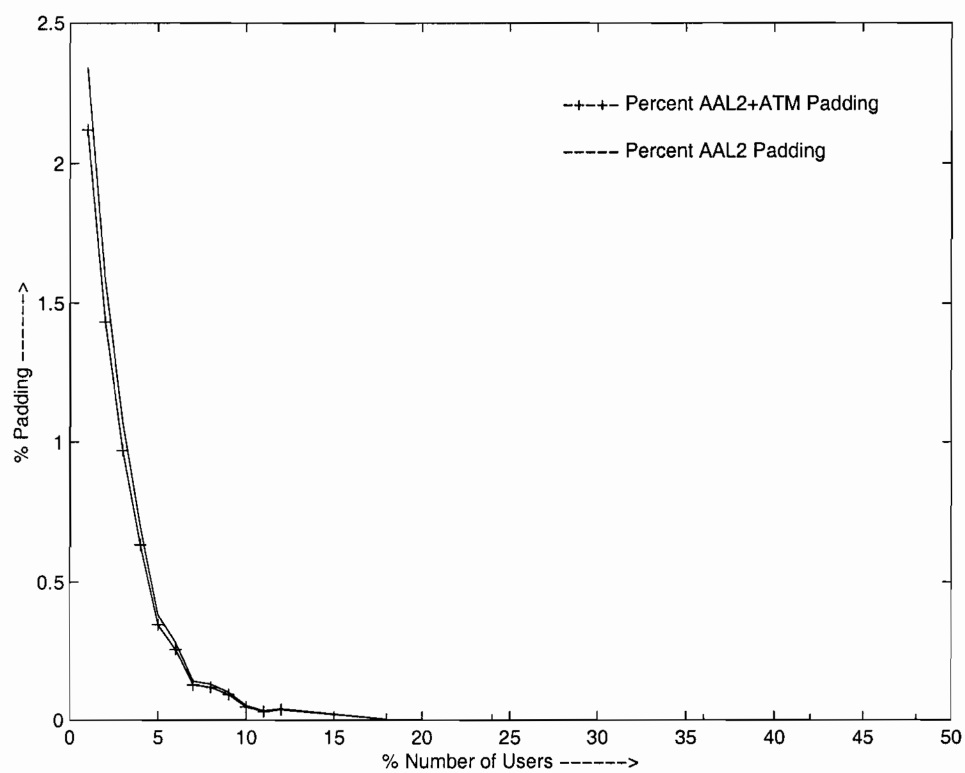


Fig.13 Percentage AAL2 Padding

bandwith. Padding is done to maintain the fixed size of the cell. Percent AAL2 padding is given by,

$$Percent \quad AAL2 \quad padding = (mean \quad zero \quad padding \quad bytes \quad per \quad cell)/48 \tag{7}$$

Percent AAL2+ATM padding is defined as

$$Percent \quad AAL2 + ATM \quad padding = (mean \quad zero \quad padding \quad bytes \quad per \quad cell)/53 \tag{8}$$

Percent AAL2 padding is observed to be very small also because of the choice of the parameters in Section 2. With the CPS packet size of 20 bytes there is very little padding required with at least 2 CPS packets in each cell.

5 Conclusions

In this paper, we develop a virtual buffer measurement method for finding the UPC parameters of a given traffic stream. The methods used have been analytically derived and verified with simulation. As an example, this measurement method is used for finding the UPC parameters for AAL2 traffic.

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