PACKET LOSS MINIMIZATION IN ASYNCHRONOUS TRANSFER MODE (ATM) IN WIRELESS COMMUNICATION NETWORKS

Udeh Ikemefuna James1, Lois Onyejere Nwobodo2
1Department of Electrical and Electronics Engineering, Enugu State
2Department of Computer Engineering, Enugu State

Correspondence should be addressed to Udeh Ikemefuna James

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ABSTRACT

Asynchronous Transfer Mode (ATM) is a multiplexing-switching protocol for broadband services where information flow on logical connections are organized in fixed size cells called packets. The fundamental problem of this wide area switched networks is packet losses due to congestion, bit errors or deliberate discards. This paper focused on the reduction of packet losses to ensure optimal performance of the ATM network. Analysis of the distribution of consecutive cell losses in ATM switch and loss process analysis of the knockout switch using stochastic activity networks are proposed. Ultras AN, a SAN based performance modeling and analysis tool were used to automatically generate and construct the needed Markov processes of the underlying stochastic activities of the switch and workload. Packet losses and loss rate were determined using active probe utilities. Results showed that a percentage of 0.01 to 10 percent reduction in packet losses were achieved by the combination of high activity fractions and low loads.

KEYWORDS: Asynchronous Transfer Mode, Packet Loses ATM Switch, Active Probe Activities, Low Load.

INTRODUCTION

The conception and birth of Broadband Integrated Services Digital Networks (B-ISDNs) was the result of the advancement in fiber optic communication and the increasing demand for high bandwidth and high speed information transfers. Now because he B-BISDNs are expected to handle various services, the underlying switching technique is expected to be flexible and fast. These demands led to the option of the Asynchronous Transfer Mode (ATM) as the key switching and multiplexing technology to be used in B-ISDNs (Olives 2012).

In ATM, the switching technology organizes digital data into 53 byte cell units and transmits these over a physical medium using digital signal technology. Individual, a packet is processed asynchronously relative to other related packets and is queued before being multiplexed over transmission path. (William 2007), Because ATM is designed to be easily implemented by hardware (rather than software), faster processing and switch speeds are possible. Speeds on ATM networks can be about 10Gbps. Research in ATM switching has resulted in a variety of FPS designs. The high switching and routing speeds of the FPS have provided a strong impetus in the proposed deployment of ATM-based B-ISDNs, which facilitate integration of diverse services like voice, data, and multimedia on a single transport network. The diversity of input traffic implies widely differing quality of service (QoS) demands from the underlying network. Real-time services like voice and video require very low delays but
are more resilient to loss, while data applications demand the exact reverse (Prakash 2006).

The associated switches therefore need to provide high throughput together with low latency and cell loss. The approaches to designing high-speed switching fabrics thus involve a high degree of parallelism with routing performed at the hardware level. The vast amount of research in Fast Packet Switch architectures in the past decade has led to a variety of designs (Ahamadi 1998, Oie 1990, Tobagi 1990). Further, the advancements in fiber optic technology have motivated photonic fast packet switching. The choice of a particular FPS architecture, however, is not simple, since there exist tradeoffs in the cost and performance of different FBS designs (Decina 1990) and as pointed out by Tobaji, F.A, a unique classification is difficult to obtain. In research work, consideration was given to switches with the following characteristics; (a) a fully interconnected structure to avoid internal blocking, (b) separate output ports to render exact analysis of large switch dimension feasible, and (c) synchronous input/output ports to avoid internal speed-ups (Ortiz 2012).

PROBLEM FORMULATION

Switch Model

The switch considered for analysis as seen in figure 2.1 is characterized by a fully inter-connected structure, with synchronous input/output port and separate output buffering (Gilbert 2002).

Figure 1: Switch Model

![Switch Model Diagram](image)

The behavior of the FPS is modeled by examining the precise sequence of (Matsumoto 2003) events that occur upon cell service. The synchronous input/output ports together with deterministic service time permit one to view the operation of the switch in a time-slotted fashion as shown in figure 2.2.

Figure 2: Timing Diagram of Switch Operation

![Timing Diagram](image)

<table>
<thead>
<tr>
<th>SI</th>
<th>SC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SERVICE INTERNAL</td>
<td>SERVICE COMPLETION</td>
</tr>
</tbody>
</table>

A slot corresponds to the time taken to serve an ATM cell and is denoted by SI (service interval) in fig 2.2. The end of the slot is marked by SC (service completion) (Held 2002).
STATE DESCRIPTOR AND PERFORMANCE MEASURES

For an N x N switch with characteristics as in figure 2.1 and a burst workload model as discussed in Subsection 3.3.1.2 the functions f(.), g(.), and h(.) for $A_n$, $D_n$, and $Q_n$ may be represented as follows.

$$A_n = C_r^{n_{ai}} \times (P_{cell})^{r} \times (1 - P_{cell})^{n_{ai} - r} \quad 0 \leq r \leq n_{ai}$$

Where $n_{ai}$ is the number of active inputs at the beginning of the nth Service Interval (SI), and $P_{cell}$ denotes the probability of a cell emission when the workload is active. To calculate $n_{ai}$, the relation of equation 3.2 is used.

$$n_{ai} = a_0 + a_1$$

Where $a_0$ represents inputs that are idle in the (n-1)th SI but becomes active in the nth SI, and $a_1$ represents inputs that remain active in the nth SI. The expressions for $a_0$ and $a_1$ are:

$$a_0 = C_k^{ni} \times (P_i - a)^k \times (1 - P_i - a)^{ni - k} \quad 0 \leq k \leq ni$$

$$a_1 = C_i^{N_{ai}} \times (P_{as})^i \times (1 - P_{as})^{N_{ai} - i} \quad 0 \leq i \leq (N - ni)$$

where $ni$ represent the number of idle sources in the (n-1)th SI, $P_i - a$ denotes the probability that the workload transitions from idle to active states ($p_{01}$); and $p_{as}$ represents the probability that it remains active ($p_{11}$) in the nth SI.

Since the FPS is fully interconnected with no discarding within the interconnection fabric, the expression for $D_n$ becomes:

$$D_n = A_n - (Q_{max} - (Q_{n-1} - 1)). \quad A_n > (Q_{max} - Q_{n-1} - 1)$$

Otherwise $D_n = 0$

The number of cells at the output queue depends on the number enqueued in the (n-1)th SI less one (to denote the cell that completed its service) and the number of arriving and discarded cells.

$$Q_n = Q_{n-1} + A_n - D_n$$

This completes the state descriptor $X_n$

Next, since the system is viewed at fixed time slots and state $X_{n+1}$ depends only on $X_n$, the process $(N_n | n \in N)$ is a discrete-time Markov chain (DTMC).

Regarding the performance variables, we proceed as follows. To calculate CLP, define $CLP_n$, the cell-loss probability at time $n$, as the fraction of number of arriving cells discarded. We have

$$CLP_n = \frac{E(D_n)}{E(A_n)}$$

Where $E(D_n, A_n)$ denotes the expectation. The expectations are obtained by solving for the state occupancy probabilities $\pi_{i,j,k}^{(n)}$ where $\pi_{i,j,k}^{(n)}$ represents the probability that the system is in state $X_n = (i,j,k)$ at time $n$. As the DTMC under consideration is finite state, irreducible, a periodic, and time homogenous, the limiting probabilities exist and are independent of the initial state. Thus, $\pi_{i,j,k} = \lim_{n \rightarrow \infty} \pi_{i,j,k}^{(n)}$ and equation (3.8) becomes

$$CLP = \sum_{i,j,k} \pi_{i,j,k}$$

Since the denominator in 3.2 is the traffic intensity $p$. Equation 3.9 gives $CLP$ as seen at the switch. To calculate the loss seen at a particular port, a refinement of the state-space is needed to tag the distinguished port. Using superscript to deonte the tagged port, the state of the system in the nth SI has $A_n'$ and $D_n'$ in addition to $A_n$, $D_n$, and $M_n$ in its state description and is represented by $X_n'$. Similar to equation (3.8),

$$CLP_{n}^{p} = \frac{E(D'_n)}{E(A'_n)}$$
Since the limiting probabilities exist, the limiting CLP as seen by the tagged port, $CLP_t$, is calculated similar to equation (3.9) with the denominator being $p_t$ instead and the numerator being only those cells discarded from the tagged stream.

### Table 1: Statistical Summary for Canonical Path

<table>
<thead>
<tr>
<th>Data set</th>
<th>10H₂</th>
<th>20H₂</th>
<th>100H₂</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>μ</strong></td>
<td><strong>σ</strong></td>
<td><strong>μ</strong></td>
<td><strong>σ</strong></td>
</tr>
<tr>
<td>Loss Rate (Raw)</td>
<td>ZING</td>
<td>5.9x10⁻⁵</td>
<td>3.5x10⁻³</td>
</tr>
<tr>
<td>Loss Rate (Filtered)</td>
<td>ZING</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Loss free periods (Raw) (Seconds)</td>
<td>ZING</td>
<td>5.0x10⁻²</td>
<td>6.4x10⁻⁵</td>
</tr>
<tr>
<td>Loss Periods (Raw)</td>
<td>ZING</td>
<td>2.8x10⁻²</td>
<td>5.3x10⁻³</td>
</tr>
<tr>
<td>Change-free period Duration (Raw) (Seconds)</td>
<td>ZING</td>
<td>1.2x10⁶</td>
<td>0</td>
</tr>
<tr>
<td>Number of change free periods (Raw)</td>
<td>ZING</td>
<td>1</td>
<td>511</td>
</tr>
</tbody>
</table>

**Effect of Traffic Bursts and AF on CLP**

Table 2: below show the relationship between steady & bursty traffic on cell loss probability (CLP) with AF being 0.5 and BS = 9

<table>
<thead>
<tr>
<th>Bursty Input</th>
<th>Traffic CLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>1.0e-19</td>
</tr>
<tr>
<td>0.5</td>
<td>1.0E-18</td>
</tr>
<tr>
<td>0.6</td>
<td>1.0E-13</td>
</tr>
<tr>
<td>0.7</td>
<td>1.0E-11</td>
</tr>
<tr>
<td>0.8</td>
<td>1.0e-07</td>
</tr>
<tr>
<td>0.9</td>
<td>1.0e-04</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Steady Input</th>
<th>Traffic CLP</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.4</td>
<td>1.0e-11</td>
</tr>
<tr>
<td>0.5</td>
<td>1.0e-085</td>
</tr>
<tr>
<td>0.6</td>
<td>1.0e-05</td>
</tr>
<tr>
<td>0.67</td>
<td>1.0e-045</td>
</tr>
<tr>
<td>0.76</td>
<td>1.0e-03</td>
</tr>
<tr>
<td>0.86</td>
<td>1.0e-02</td>
</tr>
</tbody>
</table>

**PRESENTATION AND DISCUSSION OF RESULTS FOR HOMOGENOUS AND HETEROGENEOUS TRAFFIC**

Result presentation is made in two subtitles. The first is made with respect to performance with homogenous traffic, while the second is made with respect to the behavior with heterogeneous traffic, both for an 8x8 switch unit with uniform loading across the output ports. Since loss behaviors is very significant, attention is given to the distribution of consecutive cell losses, but some results on the average CLP as well presented, whenever pertinent. While studying distribution of consecutive cell losses, loss burst is looked at and results presented for the fraction of the number of occurrences of loss bursts of lengths m, with m as a parameter. For example, a probability of 0.2 for a consecutive loss length 4 means that when the system is observed at some random time in steady state, 20% of the losses observed have occurred over 4 successive slots.

The choice of realistic values for the burst parameters of the workload is difficult. This is because the AFs for a
given average load may range from very low (peaked) to large (smooth) values based on the relative mix of the number and type of application and the port speed. The work by (Khalib, K.M et al) also addressed a similar problem of workload characterization in LANs. The results indicated the smoothening effect due to aggregation at high loads on the overall LAN traffic parameters, with the burst nature prevailing more strongly at low loads.

While the issue of “appropriate” parameters with burst workload is very much debatable, it is apparent that these parameters will very significantly depending on the relative mix of the various traffic types. Therefore, to capture such a mix, imply varying the burst parameters over a wide range in the analysis, and both homogenous as well as heterogeneous input is used. Regarding the cell drop mechanism, observe that both the consecutive cell-loss behavior and its effect in terms of the reconstructed signal will be influenced by the particular cell drop mechanism. However, since the focus of this work is not on comparing the various cell drop mechanism (e.g, push-out, head, tail, stardom), or, coding techniques (which also influence signal recovery), use is made of a tail-dropping mechanism that, can be implemented fairly easily and without any overheads in fast packet switches. Further, no particular encoding structure is assumed. This result thus provide useful insights into the trends that occur and the FPS robustness with varying burstiness and mixes of input traffic, rather than absolute measures of performance.

Figure 3: Effect of Bursty traffic on CLP

![Figure 3: Effect of Bursty traffic on CLP](image)

Figure 4: Effect of AF with heterogeneous inputs on distribution of consecutive cell losses for a tagged port

![Figure 4: Effect of AF with heterogeneous inputs on distribution of consecutive cell losses for a tagged port](image)
CONCLUSION

In this work, minimization of packet losses in ATM network is presented. This research was based on the analysis of the distribution of consecutive cell losses in ATM switch, loss processes analysis of the knockout switch and active measurement of packet losses in a wide areas within two weeks using a surveyor infrastructure and a network backbone. Considering appropriate performance measures of the switch with correlated input it was concluded that large BSs or low AFs alone do not necessarily imply poor performance rather the combination of low AFs and large loads. While the average CLP with homogeneous traffic for the switch and tagged input are same, the fraction of loss bursts of particular lengths for the two vary considerably despite homogeneity. However as the values seen at the switch are averaged over all sources the higher loss bunching at the switch does not imply poor QoS from the switch with the tagged stream exhibiting a much lower loss bunching.

The effect of a very Bursty input on the smoothened inputs demonstrated using heterogeneous inputs was found to be detrimental. The gain in performance of a bursty source at the expense of the smoother sources increased as his disparity in their burstiness increased. This provides useful clues into problems while providing adequate QoS across heterogeneous inputs hence requesting for efficient policing and traffic control systems.

REFERENCES