Two-Level Flow Control for ABR Traffic in ATM Networks*

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November 1994

Abstract

In this paper, a new two-level flow control scheme using VP credit-based control and stop-and-go rate control for best effort traffic in Asynchronous Transfer Mode (ATM) networks is presented. The proposed flow control scheme can efficiently use the leftover bandwidth after the guaranteed traffic has been satisfied, thus achieving high bandwidth utilization. Further, cell loss can also be completely avoided. It is found that the average end-to-end delay of our proposed scheme is better than that of the original VCFC scheme [1]. In addition, there is also a tremendous saving in the memory requirement when compared with the VCFC scheme.

Keywords

Asynchronous Transfer Mode (ATM), Flow Control, LAN Interconnection, ABR Traffic.

1 Introduction

High speed data communication networks are becoming more important nowadays. The networks can serve as a backbone to interconnect sources at different geographical areas. The characteristics of these sources are usually very bursty and bandwidth demanding (e.g., for those applications such as large file transfer, scientific data visualization, etc.). Since Asynchronous Transfer Mode (ATM) has been adopted by CCITT as the target mode for Broadband Integrated Services Digital Network (B-ISDN), it must provide the capability for the interconnection of these remote high-speed sources.

One of the challenges in developing ATM is the support of connectionless traffic, particularly LAN traffic, as ATM is defined to be connection-oriented. Basically, connection-oriented ATM networks have to establish a connection before data can be transferred. By doing so, bandwidth negotiation is necessary such that appropriate resources can be allocated to the traffic to satisfy the user declared Quality of Service (QOS). However, lacking prior knowledge of the characteristics of the connectionless traffic makes it very difficult to decide when and how much resources should be allocated.

Several solutions have been proposed for the interconnection of LANs and MANs through ATM networks. In [2, 3, 4] the idea is to allocate a certain amount of bandwidth initially to the traffic and to adjust the allocated resources depending on the queue length observed at the switching nodes. Unfortunately, the main drawback is the possibility of stressing the network call processors due to the high frequency of call setups and tear downs [2, 4]. Worst still, cell loss cannot be avoided during congestion. This in turns creates a “snow-ball” effect since the retransmission of packet as a result of cell loss would make the situation worse because a single cell loss requires the retransmission of the entire packet. Another method has been proposed to use a Connectionless Virtual Overlay Network on top of the ATM network for supporting connectionless traffic [5]. The Connectionless Servers (CLS) may be installed at all, or only a subset of the ATM nodes. The CLS reads the destination address from the first cell of the incoming datagram and then determines the proper outgoing VP to the next CLS. Cells from the same datagram are forwarded from one CLS to the next CLS without assembly. The bandwidth utilization of this approach is better that the above mentioned bandwidth reservation approach because the connectionless traffic are handled together. However, the processing overhead at the CLSs limits the suitability of this approach for traffic of low bit rate only [14]. Nevertheless, the issues of when or how much bandwidth should be allocated still remain unresolved.

Due to the fundamental difference between the connection-oriented ATM and connectionless traffic, it has been suggested that connectionless traffic should be transferred in a best effort manner and can be supported by the Available Bit Rate (ABR) Service. Typically, the best-effort traffic is used to fill in the bandwidth slack left by the scheduled traffic that has guaranteed bandwidth and latency [1]. The ABR service thus eliminates the need of contract negotiation between the connectionless traffic sources and the network.

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*Supported by Hongkong Telecom Institute of Information Technology grant HKTIT93/94.E001
Two flow control schemes for ABR traffic were recently under active discussion in ATM Forum [6]. The two are VCFC [1] and ECN [7, 8]. The VCFC requires a lot of memories and each switch has to provide the credit-based flow control capability on a per-VC basis to avoid cell loss. On the other hand, the ECN requires a much less complicated switch architecture; however, it cannot avoid cell loss unless a very large buffer is provided at every switching node. To overcome their shortcomings, we propose a new two-level flow control scheme which is based on both the ideas of credit-based flow control and the ECN rate control for ABR traffic. We have found that the proposed scheme has a significant saving in switch memory requirement and also improves the average end-to-end delay.

The organization of the paper is as follows. In Section 2, previously proposed flow control schemes (i.e., VCFC and ECN) for ABR traffic are reviewed. In Section 3, a detailed description of the proposed two-level flow control scheme for single VP connections is given. Section 4 explains the case of multiple-VP connections. Section 5 discusses the saving in switch memory requirement when compared with the VCFC scheme. Simulation results of average end-to-end delay are given in Section 6. Section 7 concludes the paper.

2 Previously Proposed Flow Control Schemes for ABR Traffic

2.1 Virtual Channels Flow Control (VCFC)

The VCFC scheme [1] is a credit-based flow control scheme per VC on each flow-controlled VC link. Before sending any cell to its downstream node, the transmitter needs to know buffer is available at the receiver. This can be done by the use of credit cells. After sending \( N \) data cells, the downstream node sends a credit cell to its upstream node to indicate the availability of buffer space for receiving data cells for the particular VC. After receiving a credit cell, a node then computes the most up-to-date credit count of the VC by using:

\[
\text{Credit\_Count} = \text{Credit\_Value} \text{ in the Credit\_Cell} - E,
\]

where \( E \) is the number of cells forwarded over the round-trip delay \( R \) between the current and the upstream nodes. This new credit count indicates how many data cells the downstream node can accept. Each time a node forwards a data cell, it decrements its current credit count by one. A data cell can only be sent when the credit count is positive. With this, no data cell is lost as a result of buffer overflow and this is the major advantage of the scheme.

Three different implementations of VCFC have been proposed in [1]. Of the three schemes, the N23 scheme is the most attractive one because it requires the least amount of memory. In this scheme, the buffer for the VC at the current node consists of two zones (N2 zone and N3 zone) and the buffer size is \( N2 + N3 \). The N3 zone is used to prevent data and credit underflow such that the VC can sustain its targeted bandwidth \( B_{VC} \) over time \( R \). It is suggested in [1] that it suffices to choose \( N3 \) to be:

\[
N3 = \left[ R \cdot B_{VC} / \text{Cell\_Size} \right],
\]

where the unit of \( N3 \) is in number of cells, \( B_{VC} \) in bits per second, and \( \text{Cell\_Size} \) denotes the cell size in bits.

It seems that the VCFC scheme is ideal for data traffic because of no buffer overflow and hence no cell loss. However, it is often criticised for the huge buffer requirement because we have to allocate a dedicated buffer of size \( N2 + N3 \) for each VC that passing through the switch. Besides, since all the control, queue length monitoring, buffer management and resources allocation are done on a per VC basis, the VCFC scheme imposes a heavy management burden on each switching node for each VC and hence defeats the original VP concept of trying to simplify the processing overhead per VC at each switching node.

2.2 Explicit Congestion Notification (ECN)

The ECN is a reactive rate control scheme. The two commonly encountered ECN schemes are forward and backward ECN [6, 7, 8]. Under the forward ECN (FECN) scheme, a congested switch sets the congestion bit in the header of the ATM cells that pass through the switch. When the destination receives cells with the congestion bit set, it then sends a congestion notification cell back to the sending source. With the backward ECN (BECN), a congested switch sends a congestion notification cell directly to the sending source. Upon receiving the congestion notification cell, the source can reduce its peak transmission rate. One approach is to reduce the rate by half when congestion occurs [7]. Due to the propagation delay of the congestion notification cell, data cells can still be lost.

Both FECN and BECN have their own advantages and disadvantages. Basically, because of the shorter feedback loop, it is expected that the response time of the BECN is much faster than that of the FECN [6]. On the opposite side of the coin, the switch to implement BECN is more complex than that of FECN as each switch must be capable of detecting congestion and sending the congestion notification cells as well.

3 Proposed Two-level Flow Control Scheme (Single VP Scenario)

After explaining the pros and cons of the VCFC and ECN schemes in Section 2, we now propose a two-level flow control scheme which attempts to eliminate the shortcomings of the two schemes when operated alone. In this section, we assume that each VC passes through only one VP from the source to the destination. The multiple-VP case will be discussed in the next section. The basic idea of the proposed scheme is the notion of virtual path. As the
standard has already adopted the virtual path concept, it is therefore natural to perform the credit-based flow control on a per-VP basis as depicted in Figure 1. This means that after sending \(N_2\) data cells of a VP, the current node then sends to its upstream node a credit cell indicating how much buffer space is available for this particular VP. Similarly, after receiving the credit cell, the upstream node updates its credit count for this particular VP. For each data cell of the VP sent, the credit count is decremented by one. A data cell can only be sent when the credit count is positive. At each switching node, all cells belonging to the same VP share a common buffer and are served in a FIFO manner. Therefore, cells from different VCs are treated equally. Notice in Figure 1 that the credit-based flow control is not implemented between the final switching node and the destinations. The reason for this is to avoid a congested destination to block the flow of cells in the VP and thus to degrade the performance. This credit-based flow control scheme shall be called Virtual Path Flow Control (VPFC) which is similar in spirit as the VCFC scheme. On top of this, an ECN rate control between the destination and the sources is implemented so that the sources can be throttled in the event of congestion at the destination. Without this end-to-end rate control, cell loss can occur as a result of no credit flow control performed between the final switching node and the destinations.

As seen in Figure 1, VPFC is done between every two consecutive switching nodes along the VP. Details of the credit management at the first switching node, the intermediate switching nodes, and the final switching node, will be discussed in Section 3.1. Also as depicted in Figure 1, an end-to-end ECN rate control is implemented between the destination and the source of a VC. When the destination buffer’s queue length exceeds a certain threshold value, the destination immediately sends an ECN message to the source to throttle the input rate. Details of the ECN implementation will be discussed in Section 3.2.

Our proposed scheme has several advantages over the VCFC and ECN schemes. First, because of the statistical multiplexing of VCs over a VP, the amount of memory required is smaller than that required by the VCFC scheme. Second, since all the queue length monitoring, the credit sending and the credit counting are mainly done on a per-VP basis, the processing at the switch should be much simpler. Third, because of the better utilization of the bandwidth, the average end-to-end delay is shorter.

3.1 Credit Management of Virtual Path Flow Control (VPFC)

The credit management of VPFC is very similar to that of the N23 scheme in VCFC as proposed in [1], except at the first and the final switching nodes of the VP.

3.1.1 At the First Switching Node

The credit management between the sources and the first switching node is similar to that of the normal VPFC as described in Section 3 above except that the first switching node would broadcast the credit cells to all its upstream sources (see Figure 1). Since more than one sources may be active at the same time, the buffer management at the first switching node needs to be modified to avoid data overflow. In addition to the existing N2 and N3 zone, an extra zone of buffer N4 is introduced (see Figure 2). This zone of memory is to hold all the inflight data in the access loops when the first switching node is congested. Therefore, this zone is not included in the calculation of credit value to be carried in the credit cells. In order to minimize the size of this zone, the approach of cutoff threshold is proposed. That is, once the buffer’s queue length at the first switching node increases beyond a cutoff value, a credit cell of zero credit value is immediately sent to all the upstream sources. Upon receiving the cutoff signal, all the sources would refrain from transmission. On the other hand, once the buffer’s queue length drops below the same cutoff value, the credit-based flow control then operates as usual. Each switch requires a minimum of \(N_2 + N_3\) buffers to avoid data underflow, while the N4 zone should be large enough to hold the maximum number of cells that could have been forwarded by the sources over the past round trip propagation time over the access loops. As a numerical example, if the access link is \(1\) km long (or the round-trip access loop delay is \(10\mu s\)) and the peak transmission rate of each source is \(100\, \text{Mbps}\), then the size of the N4 zone is

\[
N_4 = \lceil 10\mu s \cdot 100\, \text{Mbps} / \text{Cell Size} \rceil \cdot Q
\]

where the unit of \(N_4\) is in cells, Cell Size is the number of bits in a cell and \(Q\) is the number of VCs connected to the VP (or the number of sources as depicted in Figure 1).

3.1.2 At the Intermediate Switching Node

The functioning of the intermediate nodes in the proposed scheme is exactly the same as those nodes in the VCFC scheme except that the buffer is shared by all VCs belonging to the same VP. The targeted bandwidth of the VP, or \(B_{VP}\), can be calculated by

\[
B_{VP} = \min \{B_{Link}, \sum \limits_{all\ VCs} B_{VC}\}
\]

where \(B_{Link}\) is the link speed and the term \(\sum \limits_{all\ VCs} B_{VC}\) is the sum of \(B_{VC}\) of each VC in the VP. The rationale behind (4) is that the maximum bandwidth that a VP can sustain is the link speed. Therefore, if the sum of all the VCs’ targeted bandwidth is greater than the link speed, we should use the link speed as the targeted bandwidth of the VP. Otherwise the targeted bandwidth of the VP is simply equal to the sum of all the VCs’ targeted bandwidth. Likewise, the size of the N3 zone can be calculated as:

\[
N_{3_{VP}} = \min \{N_{3_{Link}}, \sum \limits_{all\ VCs} N_3\}
\]

where \(N_{3_{VP}}\) is the size of the N3 zone required to sustain \(B_{VP}\), \(N_{3_{Link}}\) is the size of the N3 zone required to sustain the link speed, and \(N_3\) is the size of the N3 zone of each
VC to sustain its own $B_{VC}$ in the VCFC scheme, which is given by (1). The rationale behind (5) is similar to that of (4). $N_{3_{VP}}$ and $N_{3_{Link}}$ can be calculated by using (1) with $B_{VC}$ replaced by $B_{VP}$ and $B_{Link}$, respectively.

### 3.1.3 At the Final Switching Node

There is no credit flow control implemented between the final switching node and the destinations and the final node simply sends all the head of line (HOL) cells to their corresponding destinations. However, it still needs to send credit cells to its upstream node.

### 3.2 Explicit Congestion Notification (ECN) between the Source and the Destination

As there is no credit flow control performed between the final switching node and the destinations, it is necessary to implement a feedback rate control to throttle the sources and to allocate some buffers at the destination to hold all the inflight data after the ECN message is sent. We propose to use a stop-and-go approach to control the transmission at the sources. Similar to the ECN schemes described in Section 2.2, once the queue length in the destination increases beyond a certain cutoff threshold, a special ECN cell is transmitted to the sources which send cells to this destination to stop their transmissions. On the other hand, once the queue length drops below a restart threshold, an ECN cell is sent to inform the sources to resume their transmissions.

To avoid cell loss at the destination, the size of the destination buffer beyond the cutoff threshold must be large enough to accommodate all the inflight cells. Therefore, the minimum size of the buffer beyond the cutoff threshold should be equal to the maximum number of cells in the VP, plus the maximum amount of traffic that can be sent out by the source before the ECN cell is received. The size of the buffer behind the cutoff threshold can be user-determined. Since the memory (RAM or disk storage) in the destination workstations is rather cheap, it is expected that the size of the buffer at the destination can be rather large and thus the frequency of sending ECN cells can be made low.

### 4 Proposed Two-level Flow-Control Scheme (Multiple-VP Scenario)

We now discuss how the proposed scheme can handle the case when the VCs need to pass through more than one VP. In the single VP case, all HOL cells at the final switching node of the VP are sent to their destinations without any credit flow control. However, in the multiple-VP case, we need to introduce an intermediate buffer in between two VPs to hold cells coming out from the upstream VP and waiting to be transmitted into the downstream VP. We propose that the intermediate buffers should be located near the first switching node of the downstream VP. As far as the upstream VP is concerned, the intermediate buffers can be treated as the destination’s buffer in the single VP case and act like the sources in the single VP case as far as the downstream VP is concerned. In addition, ECN mechanism described in Section 3.2 is employed between every pair of intermediate buffers at the two end of each VP. In order to avoid cell loss, the size of the intermediate buffers beyond the cutoff threshold must be large enough to hold all the inflight cells along the upstream VP.

Several VCs may utilise the same VP connection that consists of multiple VPs. In this case, it is sufficient to use one intermediate buffer for the VCs having the same upstream and downstream VPs. It is because when the downstream VP is congested, all its corresponding VCs in the upstream VP should be affected. In the case of $m$ VPs in the first stage and $n$ VPs in the second stage, $m \times n$ intermediate buffers are needed in between the two stages of VPs. Figure 3 indicates the situation when $m=2$ and $n=3$. Therefore, 6 intermediate buffers are required. The intermediate buffer 11 in Figure 3 is responsible for buffering all traffic travelling through VP A and then VP C. When the queue length of the intermediate buffer 11 reaches the cutoff threshold, ECN cells are sent to throttle the sources with traffic going through VP A and VP C.

The N4 zone is not required at the first switching node of all subsequent VPs of a VP connection consisting of multiple VPs because the intermediate buffers are located inside the first switching node of all subsequent VPs and thus the intermediate buffers can receive the cutoff signal as soon as it is generated.

### 5 Comparison of Switch Memory Requirement

In this section, the memory requirement of our proposed scheme is compared to that of the VCFC scheme. The following assumptions are made in the calculation. First, we assume that all VCs have the same $B_{VC}$ value and all access length are 1km long. Second, the size of the destination or intermediate buffer behind the restart threshold for ECN rate control is $N_3$. For simplicity, we assume that the restart threshold is the same as the cutoff threshold. Third, since the buffers at the sources and destinations considered to be outside the network, they are not included in our calculation. Fourth, we also assume that there are $P$ switching nodes in a VP and $Q$ VCs sharing a VP. In addition, we also take $N_3$ as the size of the N3 zone for each VC in the VCFC scheme so as to sustain the same $B_{VC}$. Similarly, $N_{3_{VP}}$ is the size of the N3 zone in our proposed scheme.

In the case of single-VP scenario (Figure 1), the total amount of buffer required for all VCs in the VCFC scheme is $P \cdot Q \cdot (N_2 + N_3)$, where $N_3$ is given by (1). This is because in the VCFC scheme, the amount of buffer required per VC in each node is $N_2 + N_3$. On the other hand, our proposed two-level flow control scheme requires $M_{1_{VP}}$ buffer, where

$$M_{1_{VP}} = 3 \cdot Q + P \cdot (N_2 + N_{3_{VP}}),$$  \(6\)
The first term in (6) is the size of N4 zone at the first switching node as calculated in (3) and the second term is the total amount of buffers required for the N2 and N3 zone in the P nodes with N3vp given by (5).

When we consider a two-VP scenario with m VPs at the upstream and n VPs at the downstream, we have to take into account of the additional intermediate buffers. The size of an intermediate buffer is the maximum number of cells in the VP, plus the maximum amount of traffic that can be sent out by the source before the ECN cell is received. Since cells can only be forwarded if the downstream node has enough buffer, the maximum number of cells in the VP would be equal to the total amount of buffers between the first node and the final node, plus the maximum numbers of cells in the transmission link between the final node and the intermediate buffer. This means the size of the intermediate buffer can be given by:

\[ I = P \cdot (N2 + 3Nvp) + [D\text{final} \cdot B\text{vp}/Cell\_Size] + [D\text{end} \cdot B\text{vp}/Cell\_Size] + N3, \]

where the first term is the maximum number of cells between the first node and the final node, the second term is the maximum number of cells in the link between the intermediate buffer and its upstream final switching node where \( D_{final} \) is the propagation delay from the intermediate buffer and its upstream final switching node, the third term is the maximum number of cells that the final switching node can forward before the source receives the ECN cells where \( D_{end} \) is the one way end-to-end delay (which includes propagation and transmission delays) from the intermediate buffer and the sources, and N3 is the size of the restart threshold. In this case, the amount of buffers required by VCFC scheme is \((m + n) \cdot P \cdot Q \cdot (N2 + N3)\) since there are \( m + n \) different VPs, while the requirement of our scheme is

\[ M_{2-VP} = m \cdot [3 \cdot Q + P \cdot (N2 + N3vp)] + n \cdot [P \cdot (N2 + 3Nvp)] + m \cdot n \cdot I, \]

where the first term is the total amount of buffers required in the first stage VPs as given by (6), the second term is the amount of buffers in the second stage VPs and the last term is the amount of buffer used in the intermediate buffers.

As a numerical example, we consider a single-VP scenario as depicted in Figure 1 and a two-VP scenario with \( m = n = 2 \). The saving in the amount of buffer when compared to the VCFC scheme is shown in Figures 4 and 5 with different values of \( P \) and \( Q \). In our calculation, we take \( N2 = 10 \), \( B_{Link} = 100 \text{Mbps} \) and all the VCs choose this as their targeted bandwidth (i.e., \( B_{VC} = B_{Link} \)). It can be shown that when there are more VCs or more nodes in a VP, there is more saving. Furthermore, the improvement is better in the single VP scenario because the additional intermediate buffers are not required. This is in agreement with the general ATM routing principle which states that single-hop traffic is preferred over multi-hop traffic [5].

## 6 Simulation Results for Delay Performance

The purpose of the simulation is to investigate the delay performance of the proposed scheme when compared with the VCFC scheme. Figure 6 shows the simulation model which is implemented by using the simulation package BONEs [10, 11]. A common set of data generators is used to ensure that traffic for both schemes is the same. All traffic are time-stamped right after their generation and are then placed in the transmitter. Then the traffic go through a 2-node network, subject to different flow-control scheme. The cells are then queued at the destination buffer until it is served. At the time of departing from the destination, the cell delay is computed as the difference between the current time and the original stamped-time. At the end of the simulation, the average delay would be calculated for all cells over all VCs. Furthermore, simulations with the presence of background voice traffic having higher priority and sharing the same VP with the data traffic have also been done. Different number of background voice calls are used and their bandwidth requirement are summarized in Table 1.

In our simulations, the characteristics of the traffic sources are based on [12] and are shown in Table 2. We assume that the access length is 1km while the separation between each pair of nodes is 50km. The link speed of the transmission channel and the access speed of the sources would be 10Mbps.

Figure 7 shows the delay performance for different values of \( B_{VC} \) and different numbers of voice calls used as the background traffic. It can be seen that there is a general reduction of delay. In the VCFC scheme, the maximum amount of bandwidth that a VC can sustain is more or less proportional to \( N3 \). This means there would be a wastage of resources when only one or a few VCs are active if \( B_{VC} \) is less than \( B_{Link} \). For the two-level flow control scheme, the maximum amount of resources that the VP can use is also proportional to \( N3vp \). As there are many VCs in a VP, \( B_{vp} \) would be very likely equal to \( B_{Link} \) as \( \sum B_{VC} \) is normally larger than \( B_{Link} \). This means a VC can grab all the available resources in case the others are idle even though \( B_{VC} \) may not be the same as \( B_{Link} \). That is the reason why the average end-to-end delay is shorter than that of the VCFC scheme.

Initially, the relative improvement seems to increase with \( B_{VC} \). It is because the apparent bandwidth that a VC can use in the proposed method increases at a rate faster than in the VCFC scheme. However, the improvement would be less significant when \( B_{VC} \) increases further. It is because the sources can better utilise the available resource in the VCFC scheme, while in the proposed method, the bandwidth that the sources can use remains \( B_{Link} \). This indicates the improvement would drop as \( B_{VC} \) increases.

## 7 Conclusion

This paper has proposed a two-level flow control scheme for the best effort traffic in ATM networks. In addition
to the ease of management burden, the simulation results presented in this paper indicate two main benefits over the previously proposed VCFC scheme. They include the reduction of buffer required and end-to-end delay. The proposed scheme uses much less buffer when compared to the VCFC scheme, especially when there are many VCs in a VP and a large number of stages in a VP. Each terminal can utilise the bandwidth of the link even though $B_{VC}$ may not be equal to $B_{Link}$. When the network is heavily loaded, transmission of cells is stopped after the detection of congestion at the intermediate buffer.

Simulations study in this paper has been limited to single VP scenario and the stop-and-go end-to-end control. The authors plan to evaluate the performance by using more VPs in concatenation and to study a more effective adaptive rate control for the end-to-end ECN control. We would also like to integrate the concept of congestion avoidance [13] into the proposed two-level flow control Scheme. Fairness will also be investigated in the near future.

References


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Figure 4: Memory saving when compared to the VCFC scheme for single VP cases

Figure 5: Memory saving when compared to the VCFC scheme for two VPs cases

Figure 6: Simulation Model
Figure 7: Improvement in delay when compared to the VCFC scheme

Table 1: Number of Background Voice Calls Used

<table>
<thead>
<tr>
<th>Number of Voice Sources</th>
<th>64</th>
<th>128</th>
<th>150</th>
<th>180</th>
<th>225</th>
<th>250</th>
<th>280</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Rate (Mbps)</td>
<td>1.41</td>
<td>2.82</td>
<td>3.30</td>
<td>3.96</td>
<td>4.95</td>
<td>5.50</td>
<td>6.16</td>
</tr>
<tr>
<td>Leftover Bandwidth (Mbps)</td>
<td>8.59</td>
<td>7.18</td>
<td>6.70</td>
<td>6.04</td>
<td>5.50</td>
<td>4.50</td>
<td>3.84</td>
</tr>
</tbody>
</table>

Table 2: Traffic Characteristics of On-Off Sources

<table>
<thead>
<tr>
<th>Traffic Class</th>
<th>Peak Rate (Mbps)</th>
<th>Mean Rate (Mbps)</th>
<th>Burst Length (Cells)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice</td>
<td>0.064</td>
<td>0.022</td>
<td>58</td>
</tr>
<tr>
<td>Data</td>
<td>10</td>
<td>1</td>
<td>339</td>
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