ATM/Frame Relay망에서 효율적인 ATM 트래픽 변수의 설정과 성능분석에 관한 연구

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Design and Analysis of Efficient ATM Traffic Parameter Mappers for ATM/Frame Relay

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ABSTRACT

In this paper,To interwork Frame Relay networks over the ATM network,special interworking unit(IWU) should be employed.Besides a common frame to cell conversion,the IWU converts the Frame Relay traffic parameters in order to make assure the contact Frame Relay traffic characteristics in the ATM network.Therefore,the development of an effecient conversion scheme for the Frame Relay traffic parameters into the proper ATM traffic parameters in strongly required.In addition,when LAN traffic is transferred to the ATM network,it uses the available bit rate service(ABR) of ATM network.

요 약

본 논문에서는 프레임릴레이 서비스가 ATM망을 경유할 경우 VBR서비스를 이용하게 되는데,이때 프레임 릴레이와 ATM 망간의 연동을 수행하는 네트워크 정합장치(IWU)는 프레임 릴레이의 서비스의 사용자가 계약한 트래픽 특성이 ATM망에서도 보장받도록 적절한 ATM 트래픽변수로 변환시켜 주어야 한다.따라서,사용자와 망 사업자간에 주어진 프레임 릴레이용 트래픽 파라메타를 설정하는 메카니즘을 개발하는 것이 요구된다.만일,LAN 트래픽이 ATM망을 경유할 경우에는 ABR서비스를 이용하게 되는데 LAN은 프레임 릴레이와는 달리 트래픽 제어를 위한 트래픽 변수들이 존재하지 않음으로 LAN과 ATM망을 연동하는 IWU에서 ABR서비스에서 사용되는 적절한 ATM 트래픽 변수를 설정해 주어야 한다.본 논문에서 제시된 트래픽 변수의 설정은 ATM링크 효율 및 셀 손실율을 모두 만족시킴으로써 망 사용자와 망 사업자 모두를 만족시키는 결과를 가져온다.

I. Introduction

Frame Relay has been evolved from the conventional X.25 packet switching technology and handles variable length frames to transport the user traffic across the Frame Relay-terminal equipment(FR-TE)/FR node interface. Like X.25, Frame Relay can multiplex frames from different sending stations via a single line on a statistical bandwidth allocation basis, supporting speeds between 56 Kbps and 45 Mbps(1). A major difference between Frame Relay and X.25 is in the error control mechanism. A Frame Relay network node offers no facility for recovering lost or faulty data frames. That

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is why Frame Relay takes hold so quickly as a transfer technology especially for interconnecting LAN links. Frame Relay brings the short-term commercial advantages such as cost-effectiveness, high availability, more efficient bandwidth allocation, etc.. Therefore, many organizations are concerned with preserving their investment in Frame Relay network while migrating to ATM. The asynchronous transfer mode(ATM) service is based on switching fixed length packets of data which are known as cells. Cell switching is popular for a variety of reasons, one of which is that switch architectures can be optimized to switch cells at much higher speed than variable length packets. But the ATM technology is relatively new and typically more expensive than Frame Relay one. From the perspective of ATM vendors, the ATM Forum specifications, and other supporters of this technology, ATM is currently viewed as the backbone for interconnecting other networks.

An ATM/Frame Relay interworking unit(IWU) is a network device supporting a seamless traffic flow over the interface between Frame Relay and ATM networks. Because several traffic parameters for Frame Relay and ATM networks are different from each other, we must equip the IWU with an efficient traffic parameter mapper for matching the ATM traffic contract to the Frame Relay one, and vice versa. When Frame Relay is interworking with ATM, Frame Relay frames are transmitted on the variable bit rate(VBR) service[2] of ATM network. Frame Relay has some traffic parameters such as committed information rate(*CIR*), excess information rate(*EIR*), committed burst size(*Bc*), excess burst size(*Be*). And ATM has some parameters such as peak cell rate(*PCR*), sustainable cell rate(*SCR*), cell delay variation tolerance(*CDVT*), burst tolerance(*BT*). When frames with the variable length are segmented into a number of fixed length cells of 53 bytes, the segmentation process yields considerable overhead. This segmentation overhead requires additional ATM link bandwidth to the effective bandwidth of Frame Relay. Therefore, we have to find an efficient and simple conversion rule between the Frame Relay traffic parameters with concerning of overhead.

Recently, ITU-T and ATM Forum have provided relatively simple examples for the traffic mapper. Based on these examples, we here consider three cases. As the worst case example, we assume that all Frame Relay frames over an E1 link have 89 byte lengths. One can note that each the frame produces the longest segmentation and reassembly(SAR) overhead. To support these frames over an ATM connection, we found that the required value of PCR is about 3.5 Mbps*. One can see that this value is about two times bandwidth of an E1 Frame Relay link. Since the length of actual Frame Relay frames are variable, it is clear that the actual SAR overhead is smaller than the worst case. If the ATM connection for interworking with Frame Relay is set up under the worst case assumption, Frame Relay users have no problem to guarantee their quality of service(QOS). However, the ATM network providers waste their bandwidth due to the excessive bandwidth assignments. If the ATM network providers decrease the PCR value in order to use their bandwidths efficiently, Frame Relay users may complain about frame losses over their ATM connections. How to determine the ATM traffic parameters to provide common benefits on both sides, Frame Relay network users and ATM network providers? This is the main concern to be investigated in this paper.

In this papar, we suggest and analyze the methods for mapping ATM traffic parameters on VBR from Frame Relay traffic source. After this introduction, in chapter II, we review the traffic parameters of Frame Relay and ATM, and then we derive the numerical formulas for mapping the ATM traffic parameters from the Frame Relay ones. In chapter III, we present several numerical results of the ATM traffic parameters which are derived from our numerical analysis for three cases : worst, best and general cases. To validate our numerical results, we implement a simulator and show the simulation results in chapter IV. In the last chapter, we make conclusions.

II. Traffic Characteristics in Networks

1. Traffic Parameters of ATM

The traffic characteristics of an ATM connection are described by such parameters as peak cell rate, average cell rate, burstiness, peak duration, and source type. These parameters are provided by the user during the connection establishment with the setup message.

▶ **Peak Cell Rate(*PCR*)** : The PCR of the ATM connection is the inverse of the minimum inter-arrival time, *T* which is called the peak emission interval of the ATM connection. Accordingly, *PCR* specifies as upper bound on the traffic that can be submitted on an ATM connection. Enforcement of this bound by the usage parameter control(UPC) allows the network operator to allocate sufficient resources to ensure that the network performance objective (e.g., for *CLR*) can be achieved. In the signalling message, the *PCR* is coded as cells per second.

▶ **Cell Delay Variation Tolerance(*CDVT*)** : The *CDVT* is defined in relation to the *PCR* according to the GCRA. ATM layer functions (e.g., cell multiplexing) may alter the traffic characteristics of ATM connections by introducing cell delay variation. When cells from two or more ATM connections are multiplexed, cells of a given ATM connection may be delayed while cells of another ATM connection are being inserted at the output of the multiplexer. Consequently with reference to the peak emission interval *T*, some randomness may affect the inter arrival time between consecutive virtual path connection(VPC)/virtual channel connection(VCC) cells as monitored at the UNI. Accordingly, *CDVT* is the upper bound on the clumping measurement. The *CDVT* at the public UNI, τ is defined in relation to the *PCR* according to the algorithm GCRA(T,τ), where *T* is the inverse of *PCR*. *CDVT* is specified by the network provider and it is not negotiated between the user and the network during the connection setup time.

▶ **Sustainable Cell Rate(*SCR*)** : The *SCR* is an upper bound on the possible conforming average cell rate of an ATM connection, where average cell rate is the number of cells transmitted divided by the duration of the connection. Where in this case, the duration of the connection is the time from the emission of the first cell until the state of the GCRA for the *SCR* returns to zero after the emission of the last cell of the connection. Enforcement of this bound by the UPC could allow the network operator to allocate sufficient resource, but less than those based on *PCR*, and still ensure that the performance objectives (e.g., for *CLR*) can be achieved.

▶ **Burst Tolerance(*BT*)** : The *BT* together with the *SCR* and the GCRA determine the *MBS* that may be transmitted at the peak rate and still be in conformance with the GCRA(T_s,τ_s). In signalling message, the *BT* is conveyed through the *MBS* which is coded in number of cells. The *SCR* and *BT* traffic parameters are optional traffic parameters a user may choose to declare jointly, if user can upper bound the realized average cell rate of the ATM connection supporting VBR service to a value below the *PCR*. These parameters enable the end-user/terminal to describe the future cell flow of an ATM connection in greater detail than just the *PCR*.

▶ **Maximum Burst Size(*MBS*)** : The *MBS* is the maximum number of cells that can arrive at the switch back to back at the *PCR*. *MBS* is given as follows : $MBS = [\ 1 + BT/\{(1/SCR) - (1/PCR)\}]$, where [x] denotes the integer part of x.

2. Traffic Parameters of Frame Relay

Frame Relay needs some method of enforcing user data rates which ensures the fairness of the network, and offers a service in which one user does not unfairly affect the throughput of other users. But it is so hard to decide which users should be given preference, and what should happen to the traffic of the users who are momentarily flooding the network. So, Frame Relay networks resolve this issues by offering a range of options at subscription time. Within a typical Frame Relay network service there are traffic several parameters(1) that affect the network performance at the access level as follows.

- **Access Rate(R_F)** : The access rate is the maximum speed at which data can be passed into the network, and is defined by the line speed of the link between the user and the network. In other networking methods this represents the maximum rate at which a user is permitted to transmit data onto the network, however for a Frame Relay network this simply represents the speed at which data is forwarded into the network, not the maximum data rate actually permitted by the network.
- **Committed Information Rate(*CIR*)** : The *CIR* is the rate at which the network agrees to accept data from the user, and which the network commits to transfer under normal operating conditions. The *CIR* must always be less than or equal to the access rate. Users choose their *CIR* at subscription time which equal to the exceeds the average rate at which data will be forwarded to the network. Ideally, the network should be sized to accept all the users *CIR*s simultaneously. The *CIR* is expressed in bits per second, but is averaged over a defined time period.
- **Excess Information Rate(*EIR*)** : The EIR is defined as $(Bc+Be)/Tc$. The bits that arrive during the interval Tc in excess of $(Bc+Be)$ are discarded by the Frame Relay node.
- **Committed Burst Size(*Bc*)** : The maximum amount of data (in bits) that the network agrees to transfer, under normal conditions, during the time interval *Tc*.
- **Excess Burst Size(*Be*)** : The maximum amount of uncommitted data (in bits) in excess of *Bc* that a Frame Relay network can attempt to deliver during the time interval *Tc*. This data, *Be* is generally delivered with a lower probability than *Bc*. The network treats Be data as discard eligible.
- **Committed Rate Measurement Interval(*Tc*)** : The time interval during which the user can send only *Bc* committed amount of data and *Be* excess amount of data. In general, the duration of *Tc* is proportional to the burstiness of the traffic. *Tc* is computed (from the subscription parameters of *CIR* and *Bc*) as $Tc = Bc/CIR$. *Tc* is not a periodic time interval. Instead, it is used only to measure incoming data, during which it acts like a sliding window. Incoming data triggers the Tc interval, which continues until it completes its commuted duration.

All of these parameters are negotiated separately at call establishment time for the switched virtual connection(SVC) mode of operation.

III. ATM traffic parameter mapping scheme for Frame Relay

1. ATM/Frame Relay Interworking

A brief ATM and Frame Relay interworking scheme is specified in ITU-T recommendation I.555, the ATM Forum broadband inter carrier interface(B-ICI) specification, and the Frame Relay Forum implementation agreement(FRF-IA)[8],[9]. ATM and Frame Relay interworking can operate in one of two scenarios.Scenario 1 is that Frame Relay networks are interconnected over ATM. The use of the ATM network is not visible to the Frame Relay end users. The IWU provides all mapping and encapsulation functions necessary for the Frame Relay terminal to unaware of the presence of the ATM transport. Scenario 2 is that Frame Relay interworks with an ATM end system. The use of the ATM network by a Frame Relay network terminal and a ATM terminal is not visible to the Frame Relay end user. The ATM terminal has to support the Frame Relay service specific convergence sub-layer(FR-SSCS) in its protocol stack. The IWU provides all functions necessary to ensure that the service provided to the Frame Relay terminal is unchanged by the presence of an ATM transport.

2. Traffic Parameter Mapping Scheme for the ATM/Frame Relay IWU

The ATM Forum Frame Relay-ATM traffic management function, in Appendix A of the ATM Forum B-ICI Specification(10), provides just guidelines for the conversion of Frame Relay traffic conformance parameters (*RF, CIR, EIR,* etc.) to ATM traffic conformance parameters (*PCR, CDVT, SCR, MBS,* etc.) using the GCRA[2]. Noting that the Frame Relay network carries ethernet LAN traffics, we assume that the distribution of the Frame Relay frame length is exponentially distributed. Under this assumption, we will derive the proper ATM traffic parameter values. Here, the proper ATM traffic parameter values are the values providing up to about 100% ATM link efficiency with an insignificant cell loss ratio. We will expand the derivation of traffic parameters based on the ATM Forum' s recommendation. For practical usage of our numerical results, we will pick up practical traffic parameter values of ATM link speed, Frame Relay link speed, *CIR* and *EIR*, etc. And we will develop a simulation package to verify whether the numerically derived ATM traffic parameters satisfy the both ATM link efficiency and cell loss ratio.

In order to find the proper VBR traffic parameters, we consider that the Frame Relay network conveys ethernet LAN frames[11]. Also, we assume that the LAN frame length, X is exponentially distributed with average value of m[13]. Thus, the frame length distribution function, $F(X)$ is given by

$$F(X)=1-e^{(-X/m)} \tag{1}$$

and its probability density function is given by

$$f(X)=\frac{1}{m}e^{(-X/m)} \tag{2}$$

For the practical ethernet analysis, these equations must be modified to have frame lengths shorter than maximum packet size 1,514 bytes and longer than minimum packet size 64 bytes. In addition, we also note that the Frame Relay frame encapsulates each ethernet LAN frame with additional 2 bytes of Q.922 header. Therefore, we can obtain the modified probability density function as

$$P[X=x]=\begin{cases} F(66) & x\le 66 \\ e^{-(X-1)/m}-e^{-X/m} & 67\le x\le 1515 \\ 1-F(1516) & x\ge 1516 \end{cases} \tag{3}$$

$$\Pr[66\le X\le 1516]=\sum_{i=66}^{1516}\Pr[X=i]=1 \tag{4}$$

From (3) and (4), we can obtain the average Frame Relay frame length value of m as

$$E[X]=m=\sum_{i=66}^{1516}\{i\times \Pr[X=i]\} \tag{5}$$

Before transmitting each frame over the ATM network, the IWU converts the frame into a common part convergence sublayer-protocol date unit(CPCS-PDU). The CPCS-PDU has the variable length overhead(OH), which depends on the frame length X as follows.

$$OH = \left\{ \left[\frac{(X+7)}{48} + 1 \right] \times 48 - X \right\} \tag{6}$$

where [X] is an integer which is less than X. Figure 1 shows the variation of overhead for variable frame lengths.

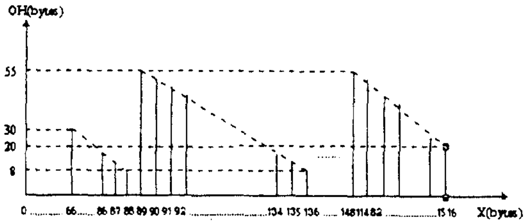


Figure 1. Variation of Overhead for Frame Length.

Therefore, the probability of overhead for frame length, X is given by

$$\Pr[OH=8] = \sum_{n=2}^{31} \Pr[X = 48 \times n - 8], \cdots,$$

$$\Pr[OH=19] = \sum_{n=2}^{31} \Pr[X = 48 \times n - 19],$$

$$\Pr[OH=20] = \sum_{n=2}^{32} \Pr[X = 48 \times n - 20], \cdots,$$

$$\Pr[OH=30] = \sum_{n=2}^{32} \Pr[X = 48 \times n - 30], \tag{7}$$

$$\Pr[OH=31] = \sum_{n=3}^{32} \Pr[X = 48 \times n - 30], \cdots,$$

$$\Pr[OH=55] = \sum_{n=3}^{32} \Pr[X = 48 \times n - 55].$$

We can rewrite the above expression as

$$\Pr[OH=j] = \sum_{n=2+\left\lfloor \frac{j}{31} \right\rfloor}^{32-\left\lceil \frac{(55-j)}{36} \right\rceil} \Pr[X = 48 \times n - j], (8 \le j \le 55) \tag{8}$$

From (8), we can obtain the average overhead length in byte, $E[OH]$ as

$$E[OH] = \sum_{i=8}^{55} \{ i \times \Pr[OH=j] \} \tag{9}$$

The average overhead length, $E[OH]$ is the value for a Frame Relay-service specific convergence sublayer-protocol data unit(FR-SSCS-PDU), so in order to get the total overhead of all frames which are transmitted to ATM network, we can obtain the average number of frames, $E[NF]$ on the Frame Relay link speed as

$$E[N_F] = \frac{R_F}{8 \times E[X]} \tag{10}$$

where, RF and NF are the link speed of Frame Relay and the number of total frames on Frame Relay link per second, respectively.

Considering the value of R_F and the total average overhead, we can derive the PCR, the total number of cells which are transmitted to the ATM network per second, as

$$PCR = \frac{R_F + E[OH] \times E[N_F] \times 8}{48 \times 8} [cells/\sec] \tag{11}$$

But this PCR is the value which is associated with the average length of overhead, so if these overhead excesses the average value temporarily, several cells may be forced to be dropped by the policing mechanism such as GCRA.

CDVT is established in order to transfer the bursty traffic which is happened by segmentation of long frame with ATM link speed, R_A. Considering the longest frame length, we can easily find the maximum number of conforming back-to-back cells, N at the full link speed as 32. When the time δ_A (where, δ_A is the time required to send 53 bytes at the ATM link rate, therefore $\delta_A = 53 \times 8/R_A$) is given, the $CDVT$ which accepts this cell clumping is given by

$$N = \left\lfloor 1 + \frac{\tau}{T - \delta_A} \right\rfloor \qquad (For \quad T \rangle \delta_A) \qquad (12)$$

where T is the inverse of PCR value and τ is greater than or equal to T-δ_A.

We can rewrite this equation as

$$\therefore (N-1) \times (T - \delta_A) \le \tau \langle N \times (T - \delta_A) \qquad (13)$$

Choosing the smallest value of $CDVT(\tau)$ from equation (13), we have

$$\tau = (N-1) \times (T - \delta_A) = 31 \times (T - \delta_A) \qquad (14)$$

$$\therefore \tau = 31 \times \left\{ \left(\frac{1}{PCR} \right) - \delta_A \right\} \qquad (15)$$

The average transfer rate of an ATM connection is equal to the total number of cells transmitted divided by the duration of the connection. Based on this definition, the network can know the average rate of a connection only after terminating the connection. Accordingly, the average transfer rate of a connection cannot be used by the network. The SCR is an upper bound on the average rate of an ATM connection. There are two types of SCR[14] such as SCR_0 and SCR_1. SCR_0 is used when CLP bit is 0 and SCR_1 is used when CLP bit is 1. The CLP bit at the ATM cell header defines two loss priorities : high priority (CLP = 0) and low priority (CLP = 1). We can obtain the SCR_0 and SCR_1 by using the same derivation of PCR, except for substituting R_F with CIR, EIR, respectively, as

$$SCR_0 = \frac{CIR + E[OH] \times E[N_{CIR}] \times 8}{48 \times 8} [cells/\sec] \quad (16)$$

$$SCR_1 = \frac{EIR + E[OH] \times E[N_{EIR}] \times 8}{48 \times 8} [cells/\sec] \quad (17)$$

where $E[N_{CIR}]$ and $E[N_{EIR}]$ are the average number of frames on the CIR and the average number of frames on the EIR, respectively.

Both SCR and BT parameters are less effective on ATM bandwidth than PCR. So, these parameters are considered on the worst case, frame length 89 bytes, which brings largest SAR overhead. A 89 byte FR-SSCS-PDU is transmitted to IWU with the rate of N_{CIR}/sec. Where, N_{CIR} = CIR/(89 8). Accordingly, the SCR_0 which supports this rate can be obtained as follows. In this case, a FR-SSCS-PDU is segmented into 3 cells.

$$SCR_0 = 3 \times N_{CIR} = 3 \times \frac{CIR}{89 \times 8} \qquad (18)$$

Like SCR_0, we can get the SCR_1 as follows.

$$SCR_1 = 3 \times N_{EIR} = 3 \times \frac{EIR}{89 \times 8} \qquad (19)$$

BT can be derived from MBS which represents the maximum number of back-to-back cells at the PCR. It is owing to the segmentation of the longest frame. Like the SCR, this BT has two types, $BT_0(\tau_{S0})$ and $BT_1(\tau_{S1})$. Since, MBS_0 and MBS_1 are given by, respectively,

$$MBS_0 = \left\lfloor 1 + \frac{\tau_{S0}}{T_{S0} - T} \right\rfloor and \quad MBS_1 = \left\lfloor 1 + \frac{\tau_{S1}}{T_{S1} - T} \right\rfloor \qquad (20)$$

where, T_{s0} and T_{s1} are the inverse of SCR_0 and SCR_1, respectively, and T is the inverse of PCR. When the longest frame with 1,516 bytes is segmented, 32 cells are generated. So, both MBS_0 and MBS_1 are set to the same value of 32.

IV. Numerical Results

When all Frame Relay frame lengths are 89 bytes, we found that the ATM adaptation sublayer produces the maximum overhead. And if all frames have the 1,432 byte frame lengths then total overhead has the minimum value. However, the actual frame length is not fixed size as the above two extreme cases, and it is so hard to predict the practical frame length. Accordingly, in this thesis we consider three cases, worst case, best case and general case. The worst case is that all frames have the 89 byte frame lengths which bring the largest overhead. The best case implies all frames lengths of 1,432 bytes, which bring the smallest overhead. And the general case is that all frame have the exponentially distributed frame lengths. To derive appropriate ATM traffic parameters, we use the formulas which have been derived in chapter III. The traffic parameters of PCR and CDVT are useful for VBR services such as Frame Relay. For numerical simplicity, we choose several practical traffic parameters as shown in Table 1.

Table 1. Traffic Parameters for Numerical Examples.

FRAME RELAY NETWORK ENVIRONMENT	ATM NETWORK ENVIRONMENT
□ R_F = 1.984 Mbps (Effective Speed of E1 Link)	□ R_A = 149.760 Mbps (Effective Speed of STS-3C ATM Link)
□ CIR = 128 Kbps	□ δ_A = (53 bytes × 8 bits)/R_A = 2.831 μs
□ $EIR = R_F - CIR$ = 1.856 Mbps	
□ Bc = 4450 bytes	
□ $Tc = Bc/CIR$ = 278.125 ms	
□ $Be = Tc \times EIR$ = 516200 bytes	

1. Worst Case

The worst case occurs when all frame lengths are 89 bytes. Each frame results in the longest overhead of 55 bytes for each the overhead value a FR-SSCS-PDU. In this case, the probability of frame length, 89 bytes, $Pr[X = 89]$ is one and other probabilities of frame length are zero. From the above network environments, we can get the ATM traffic parameters as follows.

Table 2. ATM Traffic Parameters of the Worst Case.

PCR	SCR_0	SCR_1
8359.550 [cells/sec]	539.326 [cells/sec]	7820.225 [cells/sec]
T (1/PCR)	T_{S0} (1/SCR_0)	T_{S1} (1/SCR_1)
119.623 [μs]	1.855 [ms]	127.877 [μs]
$CDVT$ (τ)	BT_0 (τ_{S0})	BT_1 (τ_{S1})
233.572 [μs]	258.615 [ms]	143.716 [ms]

4.2 Best Case

The best case is that all frame lengths are 1,432 bytes. Each frame results in the shortest the overhead of 8 bytes for each FR-SSCS-PDU. Similar to the worst case, the probability of frame length, 1,432 bytes, $Pr[X = 1{,}432]$ is one and other probabilities of frame length are all zero. From the above network environments, we can obtain the ATM traffic parameters as Table 3.

Table 3. ATM Traffic Parameters of the Best Case.

PCR	SCR_0	SCR_1
5195.531 [cells/sec]	335.195 [cells/sec]	4860.335 [cells/sec]
T (1/PCR)	T_{S0} (1/SCR_0)	T_{S1} (1/SCR_1)
192.458 [μs]	2.976 [ms]	205.719 [μs]
$CDVT$ (τ)	BT_0 (τ_{S0})	BT_1 (τ_{S1})
5.499 [μs]	247.752 [ms]	143.230 [ms]

3. General Case

This general case implies that all frame lengths have exponential distribution. We can get the PCR using the formulas, (1) ~ (11). Figure 2 shows these PCR values for the various average frame lengths, $E[X]$.

By using the same method, we also find the SCR_0

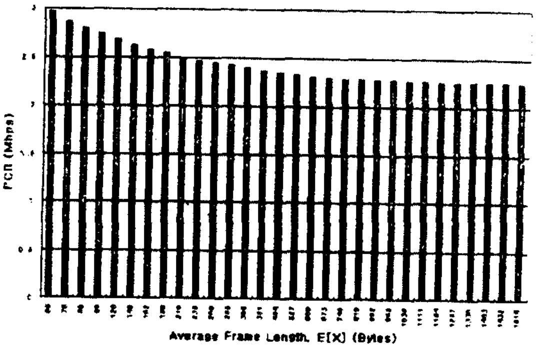


Figure 2. *PCR* for Various Average Frame Lengths.

and SCR_1 from equation (16) and (17) for various average frame lengths, as shown in Figures 3 and 4 respectively.

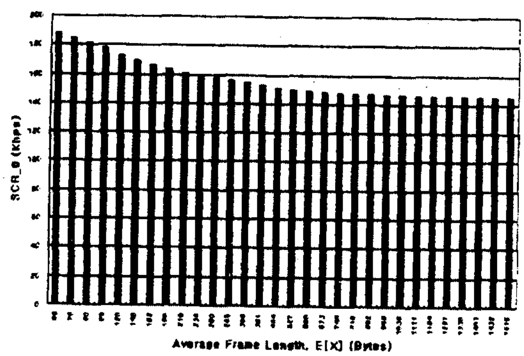


Figure 3. SCR_0 for Various Average Frame Lengths.

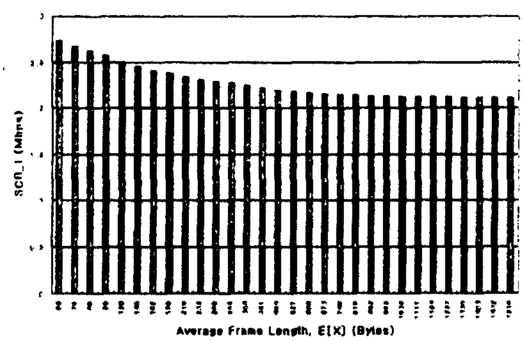


Figure 4. SCR_1 for Various Average Frame Lengths.

IV. Simulation and Discussion

1. Simulation Environment

So far, we have considered the interworking among ATM and Frame Relay. In the case of interworking[18] between ATM and Frame Relay networks, the policing function for Frame Relay traffic is not required in IWU. Because Frame Relay end users traffic is policed by the policer in Frame Relay network. Whereas, in the case of interworking between ATM and Frame Relay end user, the policing function for Frame Relay traffic must be equipped in IWU (broadband terminal adapter for Frame Relay : B-TA/FR) in order to police whether Frame Relay end user conforms the Frame Relay traffic contract or not. Incoming Frame Relay frames are transmitted to the ATM network with the VBR service as shown in Figure 5.

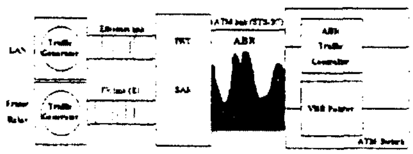


Figure 5. Simulation Model.

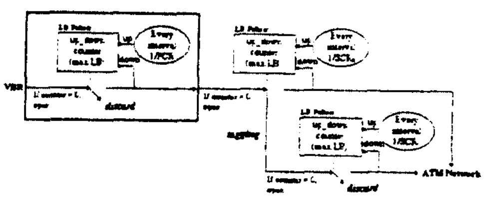


Figure 6. VBR Policer in Simulator.

Nothing that as discussed in chapter II, we can derive SCR_0 from Frame Relay traffic parameter of *CIR* assured by network and SCR_1 from *EIR* without assurance by network. Figure 6 shows the internal operation of the VBR policer. The policer can be implemented by using the three step GCRA algorithm[5] as follows.

For a simplicity, we assume that the Frame Relay traffic always occupies full link capacity. Also, each Frame Relay frame carries a LAN frame in its payload. Accordingly, all frames which are transmitted to IWU from Frame Relay always exist on its link as mush as its link rate. We also assume that each frame length of Frame Relay traffic has the exponential distribution. Also, IWU has the function that converts all frames into cells and transmits them to ATM network. The policer in IWU performs one step GCRA with a leaky bucket using an up-down counter. For the GCRA checking the *PCR* conformance for VBR service, two required parameters are *1/PCR* and *CDVT*, i.e., GCRA(1/*PCR*, *CDVT*). For the *SCR* and *BT*, two required parameters are 1/*SCR* and *BT*, i.e., GCRA (1/*SCR*, *BT*).

We consider the following configuration. The Frame Relay link speed and the ATM link speed are given by 1.984 Mbps and 149.760 Mbps, respectively. We assume that the FR-TE always uses full link speed on its permanent virtual connection(PVC) without idle time, regardless of any frame lengths. Also, the leaky bucket for *PCR* policing at ATM switch is equipped with a counter, rather than a buffer. Each token arrives with interval of $T(=1/PCR)$, and increases the current leaky bucket counter. The maximum value of the counter is set to 32 for handling the maximum frame length which will be segmented into 32 cells. An arriving cell that finds non-zero counter value will be successfully served after decreasing the counter value. If, however, the cell finds the zero counter value, it will be lost. For the above configuration, one can see that there is no buffer in this simulator for simplicity. We implement the simulator with C-language and follows event-driven method.

Now, let us explain how to use this simulator. Since the maximum number of back-to-back cells, *N* is set to 32 cells for the maximum frame length, we do not worry about the cell loss resulting from the cell clumping. The main and sole reason of cell loss is too under-estimated *PCR*. If we increase the *PCR* to the maximum *PCR*, the zero cell loss probability can be obtained. However, the ATM utilization is poor (about 0.7 below). So, we can find that there is a great tradeoff between cell loss probability and ATM utilization.

2. Simulation Results

To verify the numerical analysis, we performed the simulation including ATM policing function of the GCRA with a leaky bucket for *PCR*, and obtained the ATM link efficiency and cell loss ratio(*CLR*) in order to derive the proper values of ATM traffic parameter. Here, the ATM link efficiency, *Util_PCR*, is defined as the ratio of actual cell rate through the ATM network to *PCR*. Thus, *Util_PCR* and *Cell_Loss_Ratio* can be obtained as

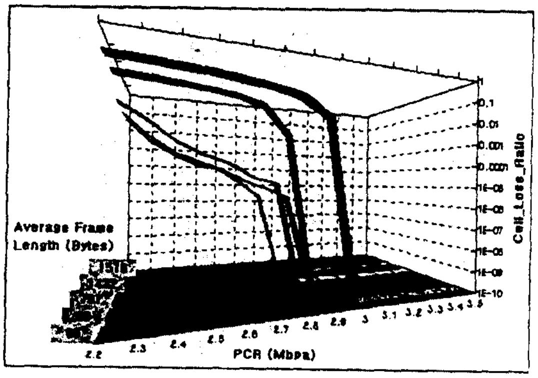
$$\text{Util\_PCR}=\frac{(\text{BTA\_total\_cell\_tx}+\text{BTA\_total\_cell\_loss})}{\text{simulation time}}\times T \quad (21)$$

$$\text{Cell\_Loss\_Ratio}=\frac{\text{BTA\_total\_cell\_LOSS}}{(\text{BTA\_total\_cell\_tx}+\text{BTA\_total\_cell\_loss})} \quad (22)$$

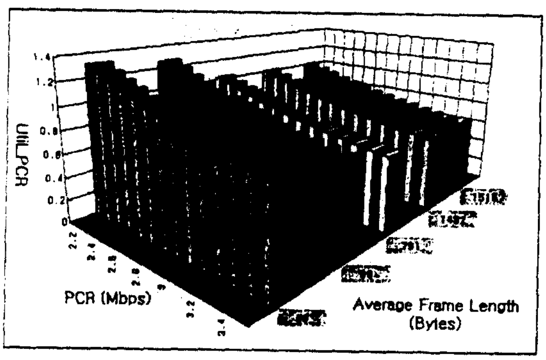
where *BTA_total_cell_tx* and *BTA_total_cell_loss* are the number of transferred cells and the number of lost cells in ATM switch, respectively, and *T* is the inverse of *PCR*.

Figure 7 shows the ATM link efficiency and *CLR* for average frame lengths of 66, 89, 791, 1432, 1516 bytes for various *PCR* value from 2.2 Mbps to 3.5 Mbps. For an example, if the average frame length is 66 bytes in the ethernet network (practically, the length of most ethernet frames is 66 bytes), and allowed *CLR* in this network is below 10^{6} for the

PCR of 2.93 Mbps. From the our simulation result, we can find the proper *PCR* value which satisfying both ATM link efficiency and required *CLR*. There are *PCR* values which exceeds the link efficiency value of 1. In this case, we have to increase the *PCR* value in order to make the ATM link efficiency is less than 1.



(a) Cell Loss Ratio for Various *PCRs*.



(b) ATM Link Efficiency for Various PCRs.

Figure 7. Simulation Results for *CLR* and ATM Link Efficiency.

There are some differences between the *PCR* of simulation result, *Sim_PCR* and the *PCR* of numerical analysis, *Num_PCR*. Table 4 shows these differences.

Table 4. Comparison between Num_PCR and Sim_PCR.

Average Frame Length (Bytes)	*PCR* from Numerical Analysis (*Num_PCR*)			*PCR* from Simulation (*Sim_PCR*)		
	PCR (Mbps)	Simulation Result		*PCR* (Mbps)	Simulation Result	
		CLR	*Util_PCR*		*CLR*	*Util_PCR*
66	2.91	3.59E-03	1.00	2.95	0.00	0.98
89	2.79	4.61E-03	1.00	2.84	0.00	0.98
791	2.28	9.96E-03	1.00	2.81	6.54E-06	0.81
1432	2.25	6.28E-03	1.00	2.77	8.84E-06	0.81
1516	2.25	5.84E-03	1.00	2.73	8.85E-06	0.82

From Table 4, we can find that when we apply the *PCR* value from numerical analysis to the practical network condition which is dependent on the average frame length, we can make the ATM link efficiency up to 100% but for the *CLR*, we can not assure the QOS of the Frame Relay traffic. Especially, the difference between *Num_PCR* and *Sim_PCR* is more serious for the case which average frame length in the network becomes longer. In order to assure the guaranteed *CLR*, we choose a slightly larger *PCR* value than *Num_PCR*. But if we do that, ATM link efficiency becomes worse. Accordingly, we here suggest the good answer to solve this problem. Before the simulation, we set the maximum leaky bucket size of policer in simulator, 32. If we make this value larger than 32, then we could make the difference between the *Num_PCR* and *Sim_PCR* less than the previous results. As we discussed in Chapter 3, the maximum leaky bucket value is associated with *CDVT* value. Accordingly, we can find the proper *PCR* value satisfying both a high ATM link efficiency and a low *CLR*. Table 5 shows the modified results.

Table 5. Modified Proper PCR Values by Increasing the Leaky Bucket Size.

Maximum Leaky Bucket Size	Average Frame Length (Bytes)	*Num_PCR* (Mbps)	*Sim_PCR* (Mbps)	*CLR*	*Util_PCR*
38	66	2.91	2.94	3.42E-06	0.99
36	89	2.79	2.83	3.56E-06	0.99
39	791	2.28	2.32	2.18E-06	0.98
39	1432	2.25	2.27	2.21E-06	0.99
38	1516	2.25	2.27	2.21E-06	0.99

The result of Table 5 shows that the increase of the leaky bucket size can reduce the difference between *Num_PCR* and *Sim_PCR*, and assure of both a high ATM link efficiency and a low cell loss ratio. Also, one can find that long frames are more dependent on the leaky bucket size than short frames.

IV. Conclusions

In this paper, we have designed a translator between the Frame Relay traffic parameters and the ATM traffic ones. Before beginning the traffic parameter mapping, we had some idea that when LAN or Frame Relay frames came into the ATM network with cells, the number of overheads generated through SAR are dependent on their frame lengths. If these ATM overheads were not treated in the IWU, some Frame Relay users may experience unexpected frame losses through the ATM network. In order to make assure the conforming frames have not discarded by an ATM policer, we first try to set large *PCR* values for Frame Relay users. But this trial makes the ATM network providers waste their link bandwidth. To solve this problem, we developed an efficient traffic parameter mapper to find the proper ATM traffic parameters satisfying both the high ATM link efficiency and the low cell loss ratio using the numerical analysis and simulation. The different values of *PCR* between numerical results and simulation results are solved by increasing the maximum leaky bucket size in ATM policer. This result is just for *PCR*, but this method may be applied to find *SCR*.

Finally, it is worthwhile to note that our ATM traffic parameter translation methods from Frame Relay traffic can satisfy both ATM network providers and Frame Relay users with an efficient ATM bandwidth management and the assurance of the conforming Frame Relay contracts, respectively.

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