# CALL-BLOCKING PROBABILITY OF ATM-CENTRIC ADSL SYSTEM DUE TO CROSSTALK AND CABLE LENGTH EFFECTS

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**Abstract:** A new option on the applications of asynchronous transfer mode (ATM) refers to provisioning of service offerings enabled by ATM into the home and small offices. Known as ATM-centric ADSL, relevant strategy essentially considers the palette of ATM services offered by a provider over a digital subscriber line (DSL). The specific research tasks performed refer to provisioning permanent virtual channels for ATM specific calls on the ADSL access lines. Relevant call-blocking probabilities are ascertained. Simulation results based on Poisson arrival of different classes (QoS specified) traffics, are obtained pertinent to the algorithms derived. The procedure allows a quick evaluation of blocking probabilities due to crosstalk and cable length effects.

**Keywords:** Call-Blocking Probability, ATM over ADSL, and Crosstalk

## 1 Introduction

Asymmetric digital subscriber line (ADSL) is a promising, upcoming DSL technology. It was originally conceived for video-on-demand (VOD) services, but now is considered more for Internet access service. ADSL uses only one twisted-pair line and can deliver data rate from 1.5 to 9 Mbps in downstream direction and 16 to 640 kbps in upstream direction depending on the distance of the line. ADSL has many versions. Rate adaptive DSL is a smart version of ADSL that can automatically change the data rate depending on the condition of the twisted-pair line so as to optimize the transmission quality. Since ADSL/RADSL uses splitters to separate telephone signals from the line and telephone companies (telcos) have to install such splitters at customer's premises. This splitter-based system is known as Customer DSL or G. ADSL lite. Alternately, ADSL lite that uses no splitters has been the cost. However, such CDSL/G. lite system has a low-speed data rate, namely, 96-256 kbps in downstream and 32-128 kbps in upstream directions. Higher data rate, 1.5-2.0 Mbps of downstream direction, has been indicated by in the International Telecommunication Union-Telecommunication Standardization Sector (ITU-T) for ADSL applications.

## 2 ATM-centric ADSL: Upstream and downstream connections

ADSL subscribers connect to the upstream services and gateways via a Permanent virtual channel (PVC) centric model, where the service provider preprovisions the required ATM connections. (In future deployment of user specified Switched virtual channels (SVCs) across ADSL is also contemplated).

The ADSL service provider is assumed to deploy necessary hardware and software to allow user connectivity to upstream ISPs. An end-user may connect to the ADSL provider via point-to-point protocol (PPP/ATM) across the ADSL local loop. At the provider's PoP, the user's domain (ISP) is authenticated (within the scope of authentication, authorization, and accounting (AAA) functions) and the user's PPP session is tunneled via L2TP to the user's native ISP. Here, the user undergoes full authentication and assigned an IP address belonging to the ISP.

The traffic mix consists of ADSL bytes encapsulated in ATM cells. There are a variable number of ABR AAL5 PVCs as well as AAL1 and AAL2 CBR and VBR PVCs associated with the ATM over ADSL support and the relevant traffic consists of various mixes constituted by:

- 1.5 Mbps downstream by 25 kbps upstream "best-effort delivery" data (ABR); here, the bit rate may not drop below an average of 256 kbps over an hour
- 384 kbps by 384 kbps CBR data on up- and downstreams
- 1.5 Mbps by 1.5 Mbps VBR video on up- and downstreams.

## 3 Crosstalk: NEXT and FEXT

Considering two pairs of wires ($x_1, x_2$) as depicted in Figure 1 a signal $v_s(t)$ at the entry-end of the $x_1^{th}$ pair, as it propagates through the loop can generate two types of crosstalk in the $x_2^{th}$ pair. The crosstalk $v_{cn}(t)$ that appears at or near the entry-end is called the near-end crosstalk or NEXT the crosstalk $v_{cf}(t)$ that may be perceived at the far-end of the $x_2^{th}$ pair is known as the far-end crosstalk or FEXT.

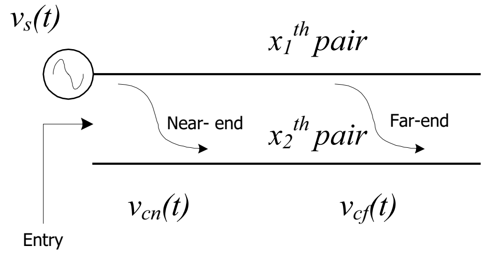


Figure 1 NEXT and FEXT.

In the presence of NEXT, the SNR of $j^{th}$ pair can be defined as the ratio between the power spectral density (psd) of the signal level in the $j^{th}$ pair to the psd of the additive interference $v_{cn}(t)$. In reference to the entry-end, the signal-to-interfering near-end crosstalk noise ration $SNR_n$ is given by [1]

$$SNR_n(d, f) = \exp[-2d\alpha(f)]/xf^{3/2} \tag{1}$$

Where d is the small distance from the entry-end at which the NEXT is measured, α(f) is the frequency-dependent attenuation factor, f is the frequency and $x$ is a random variable, which is the function of the distributed $j^{th}$ pair under consideration. Typically, for a 24 gauge cable, the value of $x \approx 1.4\text{x}10^{-9}$. Similar considerations on FEXT leads to an SNR parameter given by [1].

$$SNR_F(d,f) = \frac{1}{\psi f^2 d} \tag{2}$$

Where ψ is another random variable, which is a function of the distributed part under consideration: Typically, $\psi \approx 10^{-10}$ [1].

The ADSL provides essentially a simple operation (at 1.5 Mbps) from a CO to the subscriber location. In this context, FEXT may become the dominant crosstalk inasmuch as, the received signal strength at the subscriber end could be low as result of attenuation if suffered along the loop; (and hence is prone to FEXT). Therefore, the potential interference in ADSL is assumed to stem from the FEXT plus other additive gaussian noise (AWGN) of the system. By including these background noise power density considerations, the total interference component at the $j^{th}$ subchannel can, therefore, be written as [1]:

$$SNR_{j,Total}\,(\text{in Db}) = SNR_{F,j}\,(\text{in Db}) + SNR_{AWGN}\,(\text{in Db}) \tag{3a}$$

$$SNR_{j,Total} = \frac{1}{\psi(j\times BW_j)^2 \times d + \frac{\sigma^2}{P} e^{2\alpha(f)d}} \tag{3b}$$

where ψ is a random variable. Typically, $\psi \approx 10^{-10}$ [2]. P and $\sigma^2$ are input signal power and AWGN power respectively. α(f) is an attenuation function of twisted-pair cable.

## 4 Twisted-Pair Channel Modeling

The twisted-pair telephone loop transmission channel modeling plays an important role in evaluating the subchannel allocation performance of the ADSL system. In the relevant channel modeling, a copper loop can be assumed to be perfectly terminated with its characteristic impedance. The corresponding transfer function of the loop for a signal at a frequency f over a line length d is given by [1]:

$$H(d,f) = e^{-d(k_1\sqrt{f}+k_2 f)} e^{-jdk_3 f} \tag{4}$$

Here, d, namely, the length of the loop is specified in units of mile, and f is in Hz. Further, $k_1$, $k_2$, and $k_3$ are constant parameters depending on the gauge of cable. Table 2.8 shows typical values of $k_1$, $k_2$, and $k_3$ for different gauge of twisted pairs. [1]

Table 1. Parameters for a Twisted Pair Cable Model.

| Gauge | **$k_1$** (x$10^{-3}$) | **$k_2$** (x$10^{-8}$) | **$k_3$** (x$10^{-5}$) |
|---|---|---|---|
| 22 | 3.0 | 0.035 | 4.865 |
| 24 | 3.8 | -0.541 | 4.883 |
| 26 | 4.8 | -1.709 | 4.907 |

The channel attenuation or loss (expressed in units of dB) is obtained from Eqn.(4) and is given by:

$$L_{dB}(d, f) = -20\log_{10}|H(d, f)| = \frac{20}{\ln 10} d\alpha(f) \approx 8.686\, d\alpha(f) \tag{5a}$$

$$\alpha(f) \equiv \zeta\sqrt{f} \tag{5b}$$

Where ζ parameter depends on gauge of cable. For example, a #26 gauge loop cable has $\zeta = 9\text{ x}10^{-7}$ with d expressed in the unit of feet.

## 5 The "Best-effort" Loading Algorithm to Allocate the PVC [3]

The ATU-R can be regarded as smart regulator that performs provisioning of PVC to the upstream cell flow. That is, it assigns VPI/VCI to the cells consistent with the rate class of the bits of a given cell; and, this assigned VPI/VCI should match the resource, namely, the subchannel capacity of the DSL.

This PVC allocation (based on appropriate subchannel loading) can be done on a probabilistic, best-effort QoS guarantee, say, the cell-loss probability not exceeding L, a small number. And, provisioning PVC is done on the basis of an observed statistics of the traffic over a period of time.

The PVC refers to a static route defined in advance. It is also possible to support the growing user population with PVCs. Suppose there are i = 1, 2, ..., I service types being supported and Type-i call is assumed to have a QoS metric, $Q_i$. The PVC call arrival process of Type-i can be assumed to follow the Poisson statistics with a rate $\lambda_i$. Further, all call arrival processes are independent of each other. The call duration of service Type-i, has hence, an exponential distribution with a parameter, $\mu_i$. Again, all call duration are presumed to be independent of each other. Let $\{N_1, N_2, \ldots N_i\}$ be a set with the random variable $N_i$ denoting the number of Type-i calls.

Let the call-types, {i} be of three categories denoting respectively, i=1, for the "best-effort delivery" ABR data (256 kbps on upstream), i = 2 for the 384 kbps CBR data (on upstream) and i = 3 for the 1.5 Mbps VBR data (on upstream).

The ABR service refers to the category of call in which the network delivers limited cell-loss, if the end-user responds to flow control feedback. Further, the ABR service is not concerned about cell-transfer delay (CTD) nor does it control the cell-delay variation (CDV). It is essentially specified for data bits (such as text file transfers), where the semantic attributes are more critical than any delay sensitive issues. It is intended to be supported on AAL#5 in the ATM adaptation. As mentioned earlier, the service-category of call-type-i = 1 refers to this ABR profile. In addition, the traffics to be supported on the ADSL upstream are the constant bit rate (CBR) call-type-2 and a variable bit rate (VBR) call-type-3.

In reference to this scenario, as above, the end-to-end protocol architecture consists of facilitating PVCs for the call-type-1 and SVCs for the call-types-2 and 3.

The bandwidth reservation policy is concerned with the call-type-2 and 3. That is, the allocator upon receiving relevant BW requests (for call-type-2 or 3), it must seek out the contention and assign the VCs vis-à-vis the DMT spectrum subchannel, not already occupied by the PVC on static basis, Figure 2 illustrates the relevant concept.

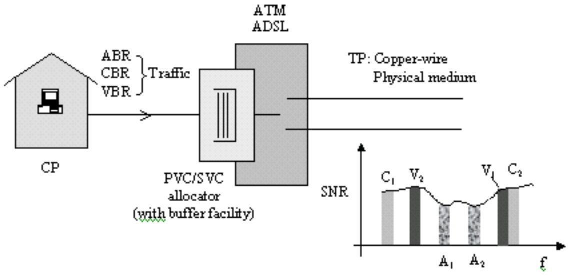


Figure 2 PVC/SVC allocations.
($A_1$, $A_2$ etc: Low SNR subchannel ⇒ PVCs for ABR traffic
$C_1$, $C_2$ etc: SVCs for CBR traffic
$V_1$, $V_2$ etc: SVs for VBR traffic.
The SVC allocations are based on bandwidth reservation policy)

## 6 Allocation Policy

Consistent with the details indicated above, the VC allocation policy can be summarized as follows:

- The ABR traffic is statically given PVCs and the subchannels are identified on the basis of "the best" available SNR conditions. The ABR traffic can be retained at a preallocator buffer until these PVCs are available. That is, ABR traffic "can wait" since CTD/CDV is of no concern; and, "the best" efforts PVC allocation facilitated (seeking the "the best" available SNR conditions) will satisfy the QoS constraint on the cell-loss (or BER) imposed.
- The second policy governs the BW reservation. For the other two traffics namely, call-type-2 (CBR) and call-type-3 (VBR), there are two possibilities of SVC allocation: First, the VBR traffic (call-type-3) can be considered as a higher priority transmission compared to call-type-1 in terms of CTD/CDV considerations. Therefore, the remaining subchannels (namely, those left over after the PVCs are statically assigned for the ABR (call-type-1) traffic) are shared between call-type-2 and call-type-3 contention basis.

## 7 Simulations and Results

Suppose the ABR traffic (call-type 1) rate corresponds to $(\lambda_{1j})_k$ where the index, k specifies the k$^{th}$ duration over which the PVCs are kept static and j is the rate-class of the call and j = 1, 2, ..., J are random values as dictated by the source.

Let $C_\ell$ be the channel capacity of a subchannel with a bandwidth equal to $BW_\ell$ and a signal-to-noise ratio, $SNR_\ell$. It is presumed that $(\lambda_{1j})_k$ matches $C_\ell$ in reference to its $QoS_j$ objectives met by $SNR_\ell$. Hence, by Hartley-Shannon's law the following relation can be stipulated [4]:

$$C_\ell = BW_\ell \log_2(1+SNR_\ell) \geqq (\lambda_{ij})_k \qquad (6)$$

If the above identity is satisfied the j$^{th}$ rate-class is assigned a permanent VC designated as $PVC_j$. Suppose, $\ell = 1, 2, \ldots, L$ with L > J. The matching condition stipulated above will select a maximum of J out of L subchannels to assign J static PVCs. The remaining (L − J) subchannels are now available for SVC allocations.

Let the call-type 2 (CBR version) be a single-rate class specified by, $(\lambda_{2m})_k$ where m = 1. Likewise, the call-type 3 (VBR version) belongs a set of rate classes specified by $(\lambda_{3n})_k$ where n = 1, 2, ..., N with a burstiness limited to a maximum value of 1.5 Mbps.

Over the specified k traffic-flow durations, the subchannel allocation is specified by the following rules:

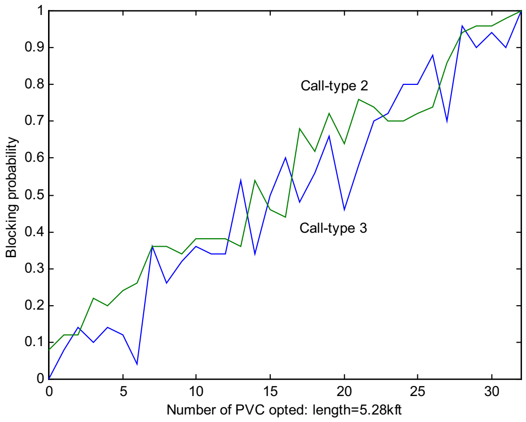
- Number of PVCs statically assigned is ${}^{J}C_L < L$
- The remaining ($L$ - ${}^{J}C_L$) SVCs can be dynamically assigned for call-types 2 and 3 on FIFO basis, if there is no contention
- When there is a contention, call-type-3 gets the priority over call-type-2

Suppose the duration k is assumed as $10^6$ cell units. The number of subchannel $L = 32$ where L is identically equal to the total of PVCs and SVCs. Assuming $J < L$ as a random variable, and simulating a randomly varying profile of SNR on L-subchannels, the ${}^{J}C_L$ number of PVCs are identified with the corresponding subchnnels via Eqn. (2).

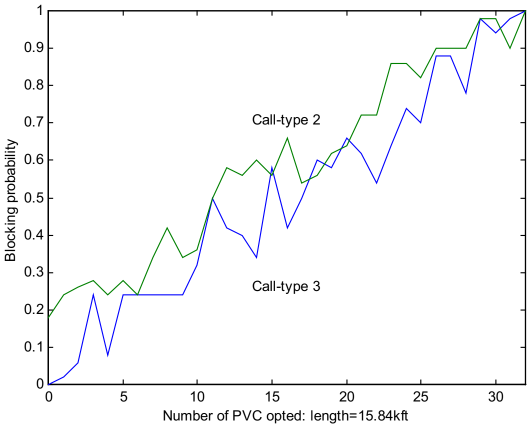
Next, the call-types 2 and 3 are simulated independently as Poisson arrivals and for each arrival segment, the high priority traffic (namely, call-type 3) of the rate-class $\lambda_{3n}$ is accommodated on to a corresponding subchannel, if available (and not already occupied by the PVC-specified call-type 1 rate class traffic) and the rate-class $\lambda_{3n}$ is given a SVC identification otherwise that call is blocked. Should there be a contention between $\lambda_{3n}$ class-rate traffic considered above and a $\lambda_{2m}$ class-rate CBR traffic for the same subchannel, the allocation criterion as indicated earlier would not let the $\lambda_{2m}$ class-rate traffic (of low priority) be assigned a SVC (That is, it will be blocked.). The 5.28kft and 15.84kft 26-gauge twisted-pair loops are chosen in this study.

When there is no contention, the traffics of rate classes $\lambda_{3n}$ and $\lambda_{2m}$ are assigned to their corresponding subchannels as ascertained via Hartley-Shannon's information theoretics.

These blocking probabilities $P_{B2}$ and $P_{B3}$ [2] for the call-types 2 and 3 respectively can be plotted as function of PVCs facilitated (namely, j) as depicted in Figure 3 (a)-(b).



(a)



(b)

Figure 3 Blocking probabilities of SVC-specified traffics versus PVCs assigned
(a) Cable length = 5.28kft
(b) Cable length = 15.84kft

## 8 Concluding Remarks

The specific research tasks performed refer to provisioning permanent virtual channels for ATM specific calls on the ADSL access lines. The blocking probabilities involved in implementing the proposed scheme are explicitly derived. Simulation results based on Poisson arrival of different classes (QoS specified) traffics, are obtained pertinent to the algorithms derived. The trend in increase of blocking probabilities and decrease of bandwidth utilization with increased deployment of PVCs is consistent with practical motions on the ATM-centric ADSL systems.

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