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Evaluation of an ADSL Established Link Using Traffic Generators

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Abstract. Asymmetric Digital Subscriber Line (ADSL) technology transforms the existing classic telephone infrastructure into access means for high-speed data communications. The data rates depend on a number of factors, including the length of the copper line, its wire gauge, presence of bridged taps, and cross-coupled interference. Line attenuation increases with line length and frequency, and decreases as wire diameter increases. For these reasons we need mechanisms to simply evaluate how "good" is a link between Central Office and the user's ATU-R modem. This paper propose a cost effective solution for rapid evaluation of the quality of an ADSL established link. The developed modules enhance the functionality of the DSLAM and of the ATU-R modem.

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1. Introduction

ADSL technology plays an important role as telephone companies, and other service providers, enter new markets for delivering high-speed data communications. New broadband cabling will take decades to reach all prospective subscribers. An ADSL circuit connects an ADSL modem on each end of a twisted-pair telephone line, creating three information channels: a high speed downstream channel, a medium speed duplex channel, depending on the implementation of the ADSL architecture, and a POTS (Plain Old Telephone Service) or an ISDN channel. The POTS/ISDN channel is split off from the digital modem by filters, thus guaranteeing uninterrupted POTS/ISDN, even if ADSL fails. An ADSL communication system is illustrated in figure 1.

The parts implied in the ADSL communication are two different ADSL Transceiver Units (ATUs), one of them situated in Central Offices at the Telecom operators' premises (ATU-C), and the other situated at the user location - ATU-R (ATU Remote-end). The connection between ATU-C modems and the broadband networks as well as the multiplexing of data flows are performed by DSLAM (DSL Access Multiplexer). The most of the DSLAMs are implemented as chassis which contain ATU-C linecards.

2. Solution deployment

The effective ADSL communication begins after the link was established between ATU-C and ATU-R modems, which assumes that initialization stage is ended. The task of the initialization process is to maximize the throughput and reliability of the link. This process is also transparent to the vendors choice of the method of separating upstream and downstream signals (either FDM or echo cancelation). The channel

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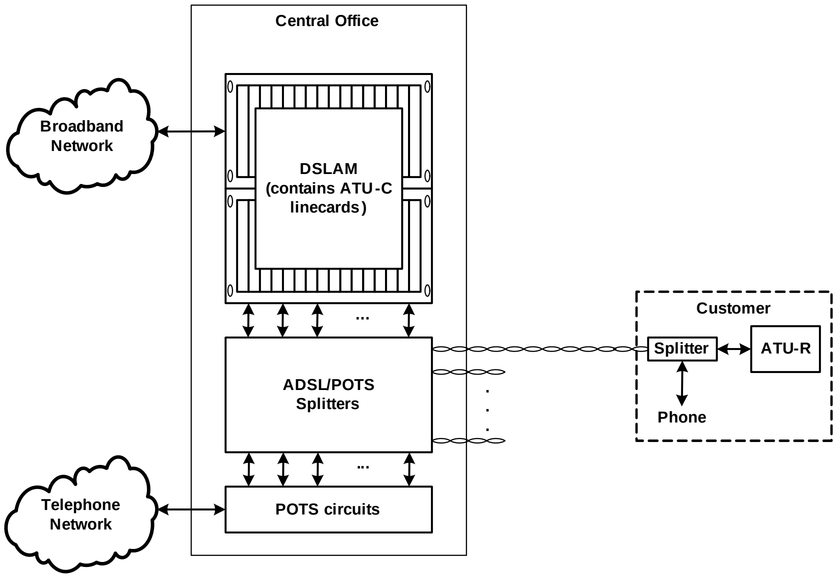

FIGURE 1. ADSL Communication System

attribute values determined by the initialization procedure include the number of bits and relative power levels to be used on each DMT (discrete multitone) sub-carrier, as well as any messages and final data rates information.

The result of the initialization process consists of a complex parameter set, which configures in fact the ADSL equipments. The meaning of these parameters are unknown for the almost all users, but in the same time all users want to be aware about the quality of their established ADSL link. In conclusion, it is important to have a mechanism to provide such information about the communication channel and the result of initialization stage, using an interface which don't impose to the users any knowledge about ADSL technology.

The deployment diagram of the proposed solution is depicted in figure 2. The ATU-C modem includes a traffic generator "**TGc**" and the corresponding, ATU-R modem contains an evaluation module "**EVr**". Basically, the traffic generator TGc send packets according to considered traffic model and parameters (average rate, average packet size, etc.). The corresponding evaluation module EVr will receive generated traffic and will determine its average rate. Based on that, the EVr block will be able to provide a rough positioning of the computed throughput value against the theoretical range. This position could be easily shown using a simple interface (e.g. a LED bar).

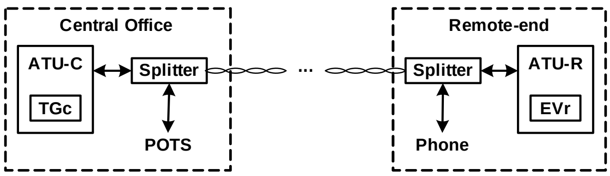

FIGURE 2. Deployment diagram

2.1. Traffic Model. Traffic models are at the essence of evaluation of telecommunications networks. The quality of broadband networks is strictly dependent of the accurate estimation of network performance. Such networks need to guarantee an acceptable quality of service (QoS) level to the users. Therefore, traffic models need to be accurate and able to capture the statistical characteristics of the actual traffic. In [2] are examined traffic models that are currently used in the literature. Traditional short-range and non-traditional long-range dependent traffic models are presented together with the number of parameters needed, parameter estimation, and ability of traffic models to capture marginal distribution and auto-correlation structure of the actual traffic. Good results are obtained, in terms of queuing behavior and number of states, using a parameter fitting procedure using Markov Modulated Poisson Processes (MMPPs), proposed in [7]. The method leads to accurate estimates of queuing behavior for network traffic exhibiting long-range dependence behavior. The procedure matches both the autocovariance and marginal distribution of the counting process. A major feature is that the number of states is not fixed a priori, and can be adapted to the particular trace being modeled. The article [6] provides an overview of computer simulation modeling for communication networks, as well as some important related modeling issues. It gives an overview of discrete event simulation and singles out two important modeling issues: traffic modeling and rare event simulation. Monte Carlo computer simulation is used as a performance prediction tool and Markov models are considered. The problem of rare event simulation is analyzed also in [13] where is provided an overview of sampling techniques and how they can be used to provide orders of magnitude speedup for many network problems, having in mind that using simulation to obtain rare event probabilities such as cell/packet loss or delay in networks still requires prohibitively long execution times.

Other approaches was focused on network-responsive traffic generator which automatically extracts distributions for user, application, and network behavior and then generates live traffic, corresponding to the underlying models in a network emulation environment running commodity network protocol stacks [14]. One of the main result of the mentioned paper is burstiness reproduction in traffic across a range of timescales, using a model applicable to a variety of network settings.

In our solution we use a traffic generator TGc based on "4IPP" traffic model which is capable to generate accurate, self-similar traffic found in both Ethernet and Internet [4]. For the stated purpose this model is the best choice, because of simplicity and low-computation requirements. The model generates traffic only in one direction of flow, but a two-way traffic flow can be easily obtained by a summation of two independent one-way models. The model is based on an Interrupted Poisson Process (IPP) and to generate the self-similar traffic, a superposition of four IPPs has been found in [4] to be a good model to use. Each interrupted Poisson process generates traffic between the DSLAM and the ATU-R modem.

The interrupted Poisson process is in fact a special case of the Markov-modulated Poisson process (MMPP). It can be defined as a two-state MMPP model where one state is an "ON" state with an associated positive Poisson rate, and the other is an "OFF" state with associated rate zero. During the ON state the IPP generates λ packets/unit-of-time (uot), and does not generate packets during the OFF state. The transition probability rate, α, is the number of transitions from the ON state to the OFF state per unit-of-time and the transition probability rate, β, is the number of transitions from the OFF state to the ON state per unit-of-time. The transition diagram of the described IPP is presented in figure 3.

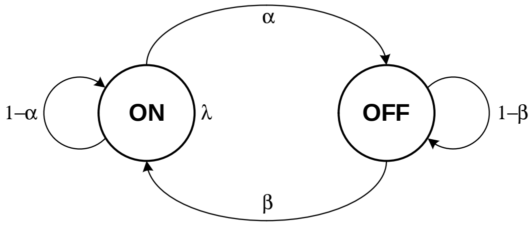

FIGURE 3. Interrupted Poisson Process

The transition matrix of the considered Markov chain is:

$$P = \begin{bmatrix} 1-\alpha & \alpha \\ \beta & 1-\beta \end{bmatrix} \tag{1}$$

and accordingly, the Markov chain generator,

$$Q = \begin{bmatrix} -\alpha & \alpha \\ \beta & -\beta \end{bmatrix} \tag{2}$$

The steady-state vector of the Markov chain is $\pi = (\pi_1, \pi_2)$ such that

$$\pi Q = \mathbf{0}, \qquad \pi_1 + \pi_2 = 1 \tag{3}$$

where π_1 represent the long-term mean probability of being in the ON state and π_2 represent the long-term mean probability of being in the OFF state. After solving (3) we obtain:

$$\pi = (\pi_1, \pi_2) = \left(\frac{\beta}{\alpha+\beta}, \frac{\alpha}{\alpha+\beta} \right) \tag{4}$$

To model the self-similar traffic found in Ethernet and Internet traffic samples, four IPPs are superimposed. Each of the four processed has different α, β and λ parameters to represent four different time scales found in the self-similar traffic. The parameters in the table 1 define the basic 4IPP considered model. These parameters are chosen to match self-similar traffic that has a Hurst parameter of 0.9. The Hurst parameter is the measure of correlation of the present packet with the previous packet. The Hurst parameter of 0.9 matches the traffic measure at both Telcordia Technologies and at the Lawrence Berkeley Labs. The parameters were derived from reference [3].

Source i	λ_i [pkts/uot]	α_i [trns./uot]	β_i [trns./uot]	Averaged over both ON and OFF states [pkts/uot]
IPP1	2.679	4.571E-01	3.429E-01	1.1480
IPP2	1.698	1.445E-02	1.084E-02	0.7278
IPP3	1.388	4.571E-04	3.429E-04	0.5949
IPP4	1.234	4.571E-06	3.429E-06	0.5289

TABLE 1. Basic 4IPP Model

The normalized 4IPP model must be scaled to obtain the appropriate data rate for the cases considered in ADSL-link evaluation process. We illustrate scaling process, taking into account ADSL transport of synchronous data (STM) case. According to [1] the STM data rate must be an integer multiple of 32000 bits/sec. The maximum rate 6144 kbits/sec, on downstream channel AS0, corresponds to the integer multiple

192. From the Telcordia and Lawrence Berkeley Labs data, the average packet size is 192 bytes = 1536 bits. Thus, the number of packet per seconds for considered data rate is 6144000/1536= 4000 pkts/sec. The average packet rate of the whole 4IPP normalized model is the sum of the average packet rates of all four sources (i.e. 3 pkts/uot). It arise that we must scale all the parameters of the base model with 4000/3 = 1334 uot/sec. The scaled 4IPP model for the 6144 kbits/sec data rate is presented in table 2.

Source i	λ_i [pkts/sec]	α_i [trns./sec]	β_i [trns./sec]	Averaged over both ON and OFF states [pkts/sec]
IPP1	3574	6.10E+02	4.57E+02	1531.43
IPP2	2265	1.93E+01	1.45E+01	970.89
IPP3	1852	6.10E-01	4.57E-01	793.60
IPP4	1646	6.10E-03	4.57E-03	705.55

TABLE 2. Scaled 4IPP Model: data rate = 6144 kbits/sec, average packet size = 192 bytes

2.2. Experimental results. The proposed solution was tested using various traffic parameters. Thus, according to [1], the maximum rate in STM case, 6144 kbits/sec., corresponds to the integer multiple 192 and the minimum value, 640 kbits/sec., to the integer multiple 20. Figure 4 illustrates a sample of Internet traffic generated with 640 kbits/sec. data rate and 192 kbytes average packet size.

For the characterization of established ADSL link, we consider more three intermediate integer multiples, as follows 144, 96, and 48. These stated five rates allow link throughput characterization roughly, using five grades, which can be displayed by a 5 LEDs bar interface. The number of light on LEDs will indicate the grade corresponding to the measured rate and thus the user will have a very intuitive information about his ADSL link.

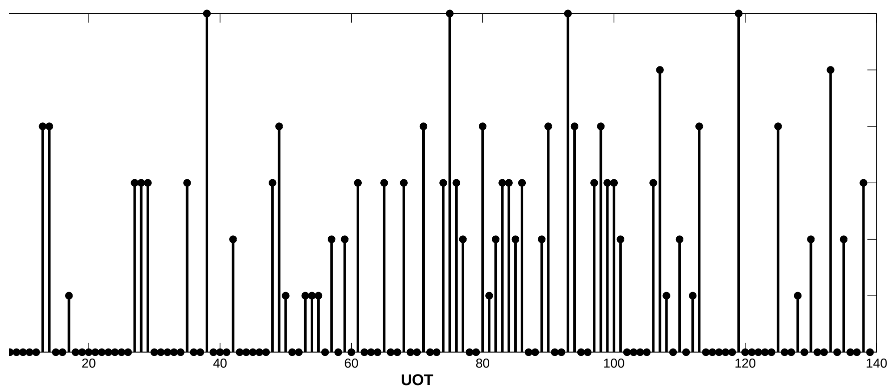

FIGURE 4. Generated IPP traffic sample (integer multiple = 20, data rate = 640 kbits/sec., average packet size = 1536 bits

3. Conclusions

The paper proposes an efficient solution for rapid evaluation of an established ADSL link. The quality of the communication channel and the result of the initialization process could be easily observed by the users, which don't need to have any specific knowledge about ADSL technology. The traffic model used for evaluation of the established ADSL link is based on 4IPP traffic model which has the ability to generate self-similar traffic found in Ethernet/Internet networks. Also the used model represent a very good choice for the traffic generator due to its simplicity and low-computation resources requirements.

References

[1] ⋆⋆⋆ - *Digital Transmission System for Asymmetrical Digital Subscriber Line (ADSL) Transmission on Metallic Local Lines, with Provisions for Operation in Conjunction with Other Services*, ITU (International Telecommunication Union) Draft G.992.1

[2] A. Adas - *Traffic Models in Broadband Networks*, IEEE Communications Magazine, Volume 35, Issue 7, 1997, p82-89

[3] A.T. Andersen, B.F. Nielsen - *A Markovian Approach for Modeling Packet Traffic with Long-Range Dependence*, IEEE Journal on Selected Areas in Communications, Volume 16, No. 5, 1998, p719-732

[4] C.R. Baugh - *4IPP Traffic Model for IEEE 802.16.3*, IEEE 802.16 Broadband Wireless Access Working Group, Contribution IEEE802.16.3c-00/51, October 2000, 11 pages, http://ieee802.org/16

[5] W. Fisher, K.S. Meier-Hellstern - *The Markov-modulated Poisson process (MMPP) cookbook*, Elsevier Performance Evaluation Journal, Vol. 18, No. 2, 1992, p149-171

[6] V. Frost, B. Melamed - *Traffic Modeling for Telecommunications Networks*, IEEE Communications Magazine, Vol. 32, No. 3, 1994, p70-80

[7] P. Salvador, R. Valadas, A. Pacheco - *Multiscale Fitting Procedure Using Markov Modulated Poisson Processes*, Springer Telecommunication Systems, Volume 23, Numbers 1-2, 2003, p123-148

[8] T. Starr, M. Sorbarra, J. Cioffi, P. Silverman - *DSL Advances*, Prentice Hall, 2002

[9] W.R. Stevens - *TCP/IP Illustrated (Vol.1). The Protocols*, Addison-Wesley, 2000

[10] G. Stoian, M. Preda - *DSLAM Design for Modern ASDL Networks*, Proceedings of 9^{th} International Symposium on Automatic Control and Computer Science Iasi, Paper 48-FM-AC03-1, pages 6, ISSN1843-665-x, November 16-18, 2007

[11] G. Stoian, M. Preda - *Multi-traffic capable DSLAM Design*, The 5th WSEAS International Conference on Applied Electromagnetics, Wireless and Optical Communications, p106-111, Tenerife, Canary Islands, Spain, December 14-16, 2007

[12] A. Tanenbaum - *Reţele de calculatoare*, Ed. a 4-a, Editura Byblos, 2003

[13] J.K. Townsend, et al. - *Simulation of rare events in communications networks*, IEEE Communications Magazine, Volume 36, Issue 8, 1998, p36-41

[14] K.V. Vishwanath, A. Vahdat - *Realistic and responsive network traffic generation*, Proceedings of the 2006 conference on Applications, technologies, architectures, and protocols for computer communications, Pisa, Italy, 2006, p111-122

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