Queuing Theory use in the Optical Line Terminal with MATLAB

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ABSTRACT: *We have used the queuing theory to explain the optical lime terminal. This passive optical access framework has the elements which are characterized by the mathematical modelling in this paper. We have presented the OLT process and the reliance of traffic characteristics from many input streams with flow parameters which help to use the mathematical design with MATLAB.*

Keywords: Traffic Modelling, PON, Pareto Distribution, OLT

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1. Introduction

With the development of many advanced multimedia applications, there is a massive increase in bandwidth demand. Passive optical network (PON) technology is emerging as the key access technology, as it has a scalable and cost-effective architecture to satisfy the ever-growing bandwidth requirements generated by advanced applications.[1] To meet the requirements of users and for obtaining acceptable precise predictions of performance of the system, system models must be developed taking into account the characteristics of the actual network load. The integrated nature of the multi-service networks with a wide range services determines the diversity of traffic, which greatly changes it parameters and the mathematical model. The most performance studies, dealt with simulation without mathematical approaches, or used the queuing model traffic models, without considering self similarity and long range dependence of the traffic. In our paper we present analytical model using Bounded Pareto Distribution for network traffic modeling.

An important task in building a modern network is to provide an appropriate quality of service for all types of traffic. The main reason for the degradation of the quality of service in multiservice networks, and subsequently access networks of next generation, is the packet delay caused by queues in the buffers of network devices. This is why we utilize a queuing model for process modeling in Optical Line Terminal (OLT) equipment, integrating switching and routing function in PON systems. The model will be used in the future state for system analysis and prediction of the QoS characteristics, like packet transfer delay and packet delay variation on network planning stage.

2. Traffic Modeling

2.1. Traffic flow

An important task in the description of a queuing system is to describe the flow of arrival and service requests. As arrival requests, in the study of our OLT model we considered the beginning of Ethernet frames entering the system. Intervals between incoming requests, one after another, create random input streams that can be described by the distribution of the time between receipts of the neighboring requests.

The mathematical model of traffic is a probability distribution function of random number of requests for mean service time.

There is an extensive study showing that most network traffic flows in today's multiservice networks can be characterized by self-similarity and long-range dependence (LRD). [2-5] The measure of self-similarity is the Hurst parameter (H). For Short Range Dependence (SRD):

$0 < H < 0{,}5$, for Long Range Dependence (LRD):

$0{,}5 < H < 1$. [4]

An analytical description of network traffic does not exist, because we cannot predict the size and arrival time of the next packets. Therefore, we can only describe network traffic as a stochastic process. Hence, we can describe two stochastic processes - arrival time and packet size; with the use of Hurst parameter and probability distributions. [6]

All processes are usually described by probability distributions. Self-similar process can be described by heavy tailed distributions. [4-5]. The main task for modeling the stochastic process with probability distribution is to choose the right distribution, which would be a fair representation of our network traffic stochastic process. In case of high speed networks with unexpected demand on packet transfers, Pareto based traffic models are excellent candidates since the model takes into the consideration the long-term correlation in packet arrival times [7]. The main property of heavy-tailed distributions is that they decay hyperbolically, which is opposite to the light-tailed distributions, which decay exponentially. The probability density function of Pareto distribution is given by [8] where parameter a represents the shape parameter, and k represents the minimum possible positive value of the random variable x. The mean value - M, variance - σ^2 and coefficient of variation - v of the Pareto distribution are:

$$M = \frac{\alpha k}{\alpha - 1} \quad (1)$$

$$\sigma^2 = D = \frac{\alpha k}{(\alpha - 1)^2 (\alpha - 2)} \quad (2)$$

$$v^2 = \frac{\sqrt{D}}{M} = \frac{1}{\alpha(\alpha - 2)} \quad (3)$$

The relationship between the Hurst parameter H and the shape parameter a is $H = (3 - \alpha)/2$ [9]. Thus if for LRD $0{,}7 \le H \le 0{,}9$, it should result in $1{,}6 \ge \alpha \ge 1{,}2$, but Pareto distribution has a finite mean and an infinite variance for $1 \le \alpha \le 2$.

For real systems, the values of random variables are limited. For a description of self-similar processes, limited (bounded) distribution can be introduced. This limited distribution allows, without changing the shape of the tail of the distribution, to set the maximum value of the random variable. Limited distribution differs from the normal in that there is not one, but two boundaries [10]. The bounded (or truncated) Pareto distribution has three parameters α, L and k As in the standard Pareto distribution a determines the shape. k denotes the minimal value, and L denotes the maximal value. [8]

$$M = \frac{\alpha\left(k\,L^{\alpha} - L\,k^{\alpha}\right)}{(\alpha - 1)\left(L^{\alpha} - k^{\alpha}\right)} \qquad \alpha \neq 1 \tag{4}$$

$$\sigma^2 = \frac{\alpha}{(\alpha - 2)}\left(\frac{k^2 L^{\alpha} - k^{\alpha} L^2}{\left(L^{\alpha} - k^{\alpha}\right)}\right) \tag{5}$$

$$v^2 = \frac{(\alpha - 1)^2\left(L^{\alpha} - k^{\alpha}\right)\left(k^2 L^{\alpha} - k^{\alpha} L^2\right)}{\alpha(\alpha - 2)\left(k\,L^{\alpha} - L\,k^{\alpha}\right)} \tag{6}$$

2.2. PON Systems

The PONs are designed to deliver multiple services and applications, such as voice communications, standard and high-definition video (STV and HDTV), video conferencing (interactive video), real-time and near-real-time transactions, and data traffic. A PON is a point-to-multipoint (PtMP) optical network with no active elements in the signals' path from source to destination. The only interior elements used in a PON are passive optical components, such as optical fiber, splices, and splitters. All transmissions in a PON are performed between an optical line terminal (OLT) and optical network units (ONUs) (Fig.1). The OLT resides in the telecom central office (CO) and connects the optical access network to the metropolitan-area network (MAN) or widearea network (WAN). The ONU is located either at the enduser location fiber-to-the-home (FTTH) and fiber-to thebusiness (FTTB) configurations, or at the curb, resulting in fiber-to-the-curb (FTTC) architecture. In the downstream direction, PON is a broadcasting media; Ethernet packets transmitted by the OLT pass through a 1:N passive splitter and reach each ONU. OLT provides dynamic bandwidth allocation and prioritization between services using a MAC (Media Access Control) protocol. Packets are broadcasted by the OLT and extracted by their destination ONU based on their media-access control (MAC) address [11]. The main functions on a PON OLT line card can be divided into four categories: physical layer, MAC layer, packet processing, and traffic management. The MAC layer functions mainly include framing, media access control, operations, administration and maintenance (OAM), dynamic bandwidth allocation (DBA), forward error correction (FEC), and security. In terms of framing, GEPON (Gigabit Ethernet PON) standards are based on Ethernet. In GEPON, Ethernet frames are carried in their native format on the PON system. Services are all mapped over Ethernet (either directly or via Internet Protocol) (fig.2).

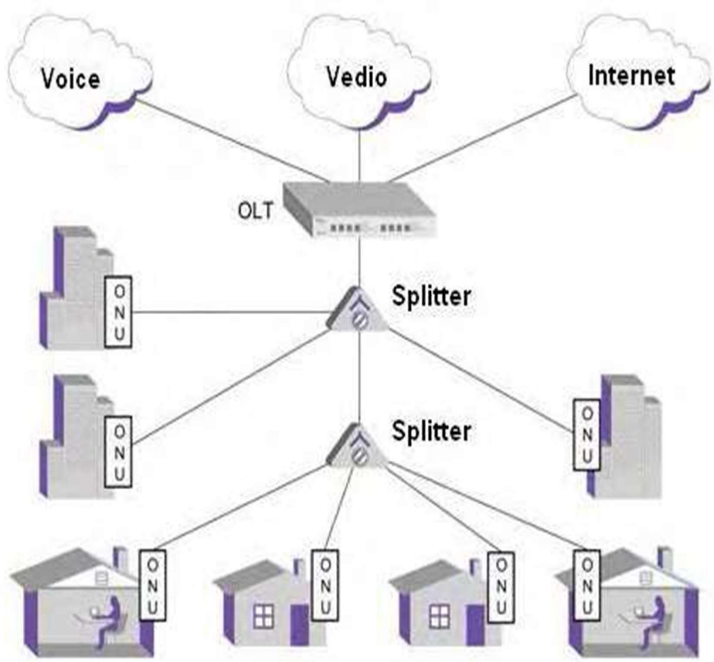

Figure 1. GEPON System Network

3. Mathematical Modeling and Results

We consider OLT device that is part of PON network. In the input on the system we have three types of traffic flows VoIP, Data and IPTV.

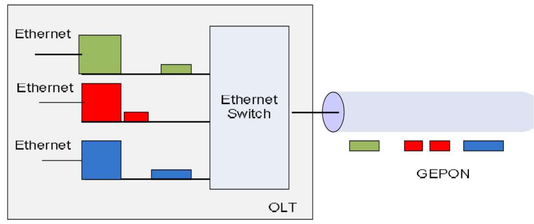

Figure 2. Framing in GEPON [13]

A separate queue for each subscriber and for each traffic flow in the system is created (figure 3). The queue for video flow is one for all subscribers. We consider each traffic flow as a G/G/1 queuing system with Pareto arrival process and Pareto service times, one server, full accessibility, and an infinite number of waiting positions. We have three priority classes and service discipline is FIFO (First In – First Out). Voice traffic flow has highest priority and means arrival rate $\lambda_{v1}\ldots\ \lambda_{v32}$,, Data traffic flow has lowest priority and mean arrival rate $\lambda_{D1}\ldots\ldots\lambda_{D32}$. Number of subscribers in the network is $N = 32$. We assume that the system is in steady state. All streams are composed of Ethernet frames with variable length from 64 bytes to1580 bytes. Their speed depends on the type of traffic. We assume that *k* is the minimal time interval between two adjacent Ethernet frames with a minimum duration and *L* is the interval between two Ethernet frames one of which is in the final in the packet burst and another is first in the next packet burst.

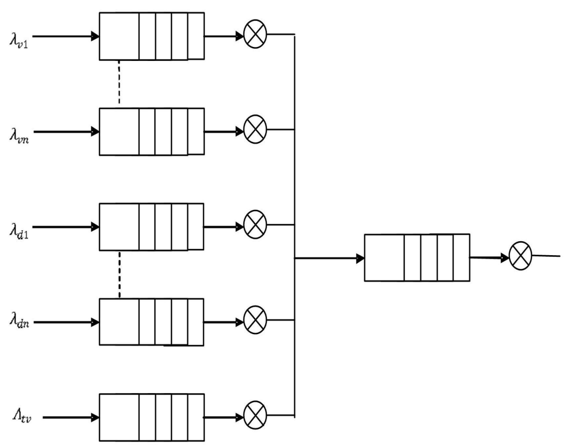

Figure 3. Multiple -priority queues at an OLT

For arrival and service process modeling we use bounded Pareto distribution. Calculations were done for different values for α: $\alpha = 1.1$; a = 1,3; a = 1,6. Coefficient of variation ν were calculated for each type of traffic

L_{aHi} – Maximum value of interval time between incoming requests

k_{aHi} - Minimum value of interval time between incoming requests

L_{bHi} - Maximum value of interval time between service requests

k_{aHi} - Minimum value of interval time between service requests

$$i = (0,1,2,...N)$$

$$H = (0,1,2,... j)$$

In the input buffers of the OLT enters 3 classes traffic flow (H = 0, 1, 2), each with a minimum length n_{minHi} and a maximum speed R_{maxHi}. The minimum transmission interval can be presented:

$$k_{Hi} = \frac{n_{\min Hi}}{R_{\max Hi}} \qquad i = (1,2,...N)\ ; \quad H = (0,1,2)$$

$$\lambda_{Hi} = M_{aHi}^{-1} \qquad i = (1,2,...N)\ .; \quad H = (0,1,2)$$

$$\mu_{Hi} = M_{bHi}^{-1}$$

$$\rho_{HN} = \frac{\lambda_{HN}}{\mu_{HN}}$$

Where, λ is mean arrival rate,

μ -mean rate of service time and

ρ - the traffic intensity parameter.

Figure 4, shows the IPTV traffic intensity as a function of maximum value of interval time between incoming requests (upper Pareto boundary) for: α =1.1; α =1,3; α = 1,6. Figure 5, shows coefficient of variation of intervals in the output streams as a function of the upper limit of the Pareto distribution for VoIP traffic flow, calculated in accordance (2.6), for: α = 1.1; α = 1,3; α = 1, 6. Figure 6, shows coefficient of variation of intervals in the output streams as a function of the upper limit of the Pareto distribution for Data traffic flow. Figure 7, shows coefficient of variation of intervals in the output stream as a function of the upper limit of the Pareto distribution for IPTV traffic flow.

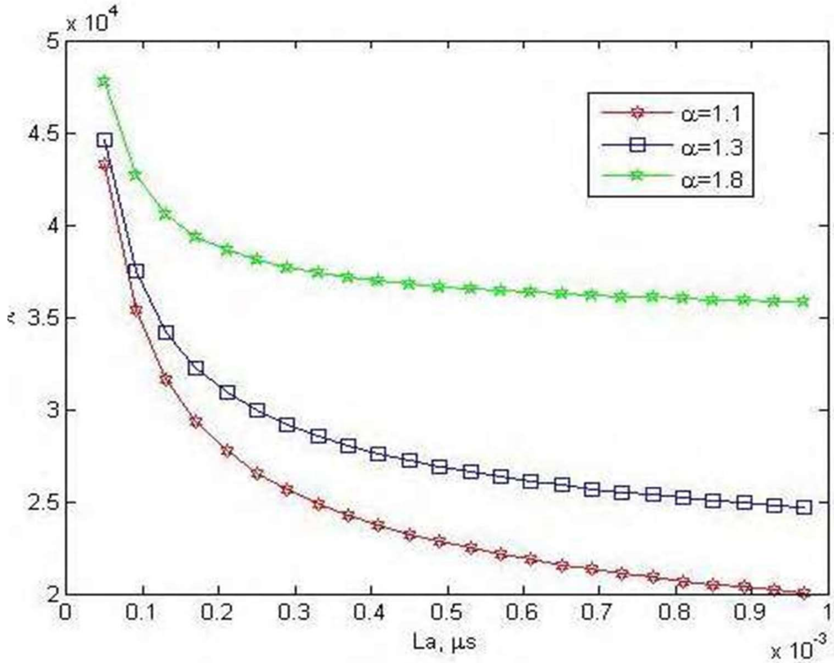

Figure 4. IPTV traffic intensity parameter as a function of upper Pareto boundary

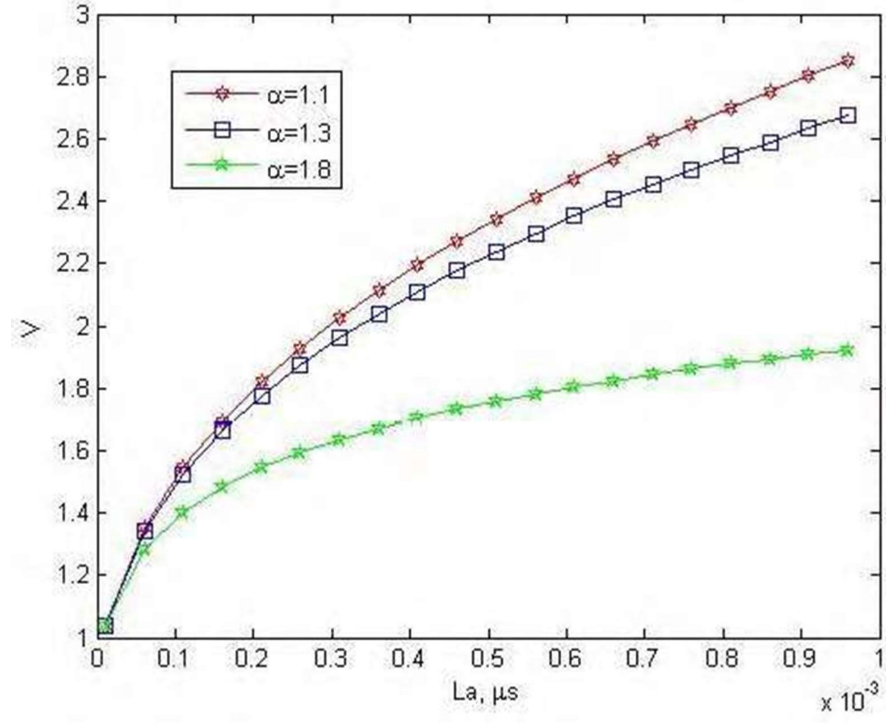

Figure 5. Coefficient of variation of intervals in the output stream as a function of the upper limit of the Pareto distribution for VoIP traffic flow

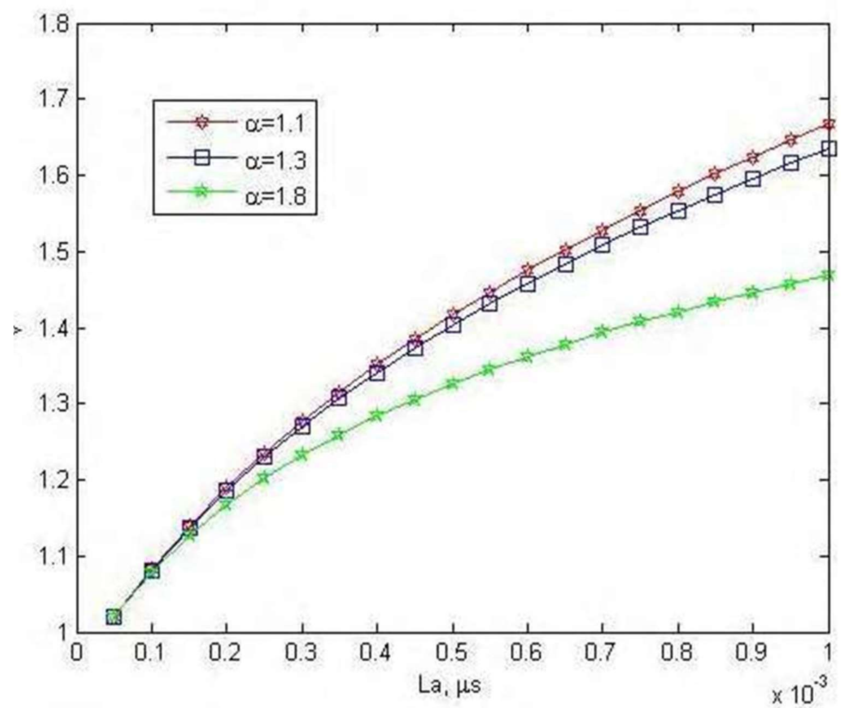

Figure 6. Coefficient of variation of intervals in the output stream as a function of the upper limit of the Pareto distribution for Data traffic flow

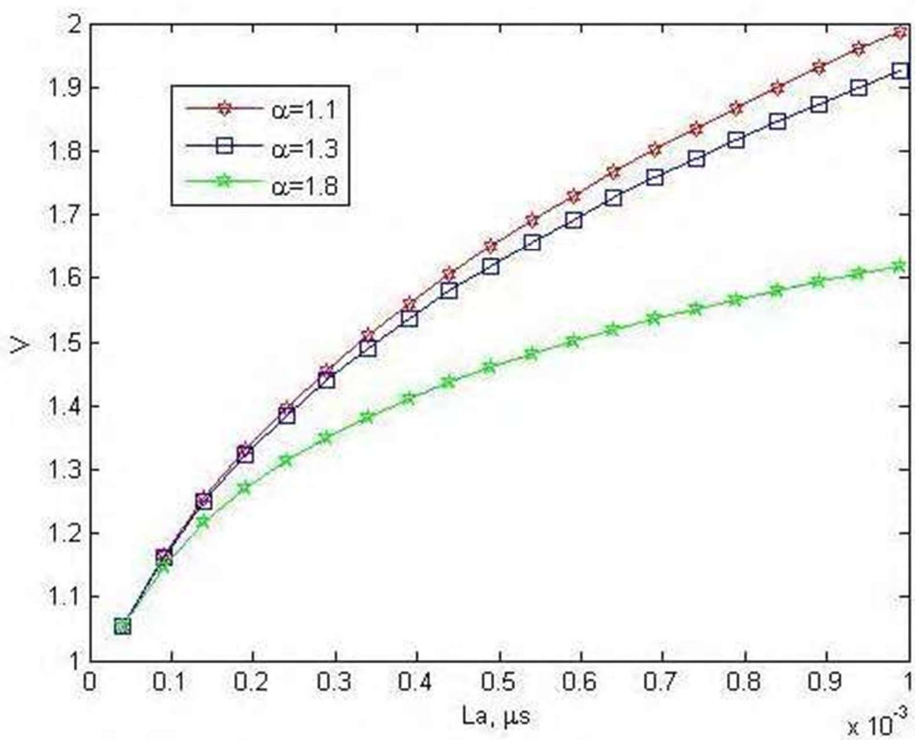

Figure 7. Coefficient of variation of intervals in the output stream as a function of the upper limit of the Pareto distribution for IPTV traffic flow

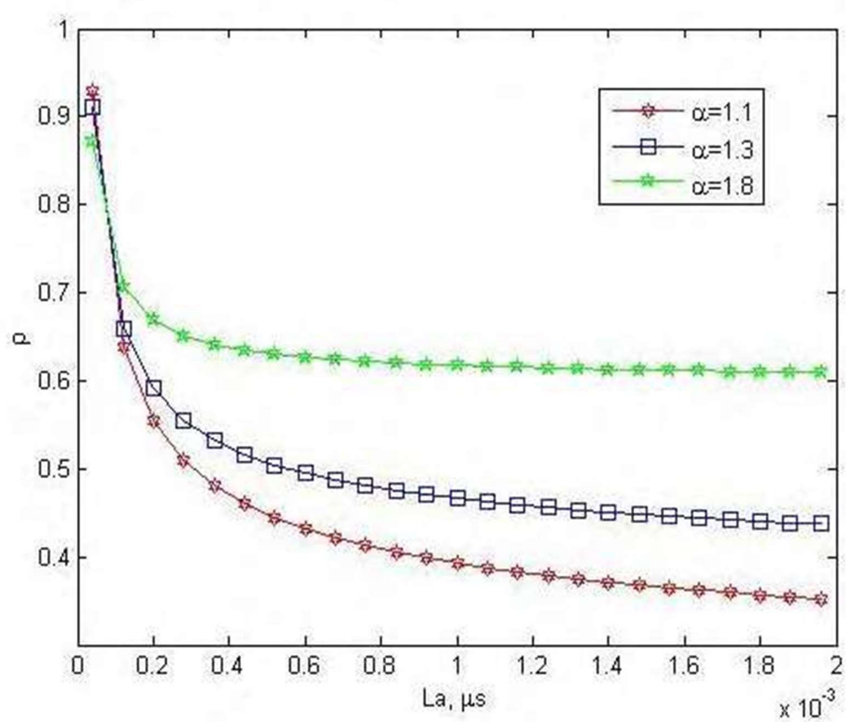

Figure 8. Traffic intensity parameter as a function of maximum value of interval time between incoming requests for IPTV traffic flow

4. Conclusion

The scope of this paper focused on the creation of an analytical model which describes traffic flow processes in a part of PON network, like OLT. Bounded Pareto Distribution was chosen and substantiated for representation of network traffic stochastic process modeling. General queuing model G/G/1 was chosen for presentation of the mathematical model. All calculations were carried out utilizing MATLAB. The results present coefficient of intervals variation in the output streams as a function of the upper limit of the Pareto distribution for different traffic flow. Traffic intensity parameter has been received as a function of maximum value of interval time between incoming requests for IPTV traffic flow and for different shape parameters.

The preliminary obtained results can be used for prediction of OLT processes on depends of traffic flow parameters.

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