MODELLING THE PROBABILITY DENSITY FUNCTION OF IPTV TRAFFIC PACKET DELAY VARIATION

Michal HALAS[1], *Stanislav KLUCIK*[1]

[1]Department of Telecommunications, Faculty of Electrical Engineering and Information Technology, Slovak University of Technology, Ilkovicova 3, 812 19 Bratislava, Slovak Republic

halas@ktl.elf.stuba.sk, klucik@ktl.elf.stuba.sk

Abstract. *This article deals with modelling the Probability density function of IPTV traffic packet delay variation. The use of this modelling is in an efficient de-jitter buffer estimation. When an IP packet travels across a network, it experiences delay and its variation. This variation is caused by routing, queueing systems and other influences like the processing delay of the network nodes. When we try to separate these at least three types of delay variation, we need a way to measure these types separately. This work is aimed to the delay variation caused by queueing systems which has the main implications to the form of the Probability density function.*

Keywords

IPTV, packet delay variation, PDF, QoS.

1. Introduction

Quality of Service (QoS) of Internet Protocol Television (IPTV) depends on several factors. One of them is the de-jitter buffer play-out size. When the buffer is too small, IP packets with a bigger delay variation can be lost due to the buffer over or underflow. When the buffer is too long, more time is needed till it is filled. Some IPTV infrastructures use the buffer filling time for streaming a copy of the current received IPTV channel to suppress the waiting time till the moving picture is visible. The bigger the IPTV play-out buffer, the bigger the waiting time or network load.

To separate the packet delay variation (PDV) origins a computer simulator was developed and used. This simulator has been built in MatLab and considers the following network parameters: line speed, queueing system, Ethernet frames and constant signal propagation time, which have no effect on PDV computation. In this way is ensured that only the queueing systems are affecting the PDV. Simulated queueing systems are FIFO (First in First Out), WRR (Weighted Round Robin) and PQ (Priority Queueing). The simulator uses recorded time stamps of H.264 Main profile HD (High Definition) and SD (Standard Definition) video with generated VoIP (Voice over IP) and data traffic. One HD or SD IPTV stream has an average bit rate of 6 $\mathrm{Mbit \cdot s^{-1}}$ or 2,5 $\mathrm{Mbit \cdot s^{-1}}$ respectively. The VoIP generator is driven by the Exponential probability distribution with constant packet sizes. The interarrival times of the data class generator are driven by a Log-normal probability distribution and the packet sizes by an ON/OFF model, which uses the uniform probability distribution. IPTV and VoIP frame sizes are considered to be constant at 1382 B for IPTV and 226 B for VoIP at the Ethernet layer. When 1 $\mathrm{Gbit \cdot s^{-1}}$ Ethernet is used, the minimum packet length of 520 B is considered.

The rest of this paper is organized as follows. The second chapter describes the packet delay variation. The third is aimed at the current state of PDV modeling. Forth chapter describes simulated situations and shows and analyses the results. The last fifth chapter is the conclusion.

2. Packet Delay Variation

RFC 3393 (Request For Comment by IETF) uses the term IP (Internet Protocol) "Packet Delay Variation" (PDV) and also compares it with the term "jitter". These two terms can be considered as equivalent, when dealing with IP network timing parameters. RFC 4689 defines "jitter" as: "The absolute value of the difference between the Forwarding Delay of two consecutive received packets belonging to the same stream." The RFC 3550 defines the "Interarrival jitter" with only positive values. Another way to look on the PDV is to compute the variance of consecutive packets one-way delay using its mean value without the absolute value definition. This assures the positive and negative PDV, which is also used to derivate the de-jitter buffer parameters. This work defines it as Packed Delay Variation, PDV. The main difference between these definitions is in the choice of the probability density functions (PDF) which may apply to modeled density functions. These PDFs must not have a non-zero mean value of the PDV. An existing PDV with only positive values has always a mean value greater than zero.

This work deals with the PDV defined according to both, the RFC 3550 (RFC 3550 PDV) and the negative defined PDV named only simply as PDV.

3. State of Art

An analytical description of an IP network that carries several types of traffic with queueing systems implemented is very hard to derive. An additional complexity is given be the need to distinguish between separate flows because the definition of PDV designates it.

Current situation on modeling the PDV can be divided into three main branches. The first uses computer simulations to answer the questions of the usability of a current PDF [1]. The second is trying to analytically derive these functions with no very precise usability to long range dependent traffic like IPTV or Internet [2]. The third branch is trying to estimate ranges within the PDV should be found [4], [5]. Because the third branch uses also M/M/1 systems or Jacksons networks like the second, the output is not usable for the current work. For these reasons, computer simulations are used.

According to [6] the PDV PDF can be modeled as an Alfa-stabile PDF with Gaussian, Levy and Cauchy subdistributions. Also the Laplace probability distribution is applicable.

4. Network Simulations

For general results, a network with a defined architecture should be used. We simulate an IPTV network with the aim to describe the PDV behavior in the cases of traffic multiplexing and reordering (Fig. 1). Traffic multiplexing takes place at a simple FIFO switch with independent IPTV streams at the input and a one multiplexed output. Traffic reordering describes the case, when background traffic e.g. VoIP or data is exchanged within a network node.

The observed situations are chosen pursuant to [5], where the traffic reordering of the data stream has a high influence on resulting PDV. There is an assumption that the traffic reordering in a network with implemented QoS does not have the same influence like expected in analytical models designed for data networks with no quality management [6].

The simulator itself uses a local clock that is independent of the input. The clock defines the time precision of the network node. Any time error caused by using a local clock in the first network node is not passed through the other nodes as long the time resolution of other network nodes stays at least at the same precision. The inputs are recorded so it is possible to make different network or nodes simulations with the absolutely same input.

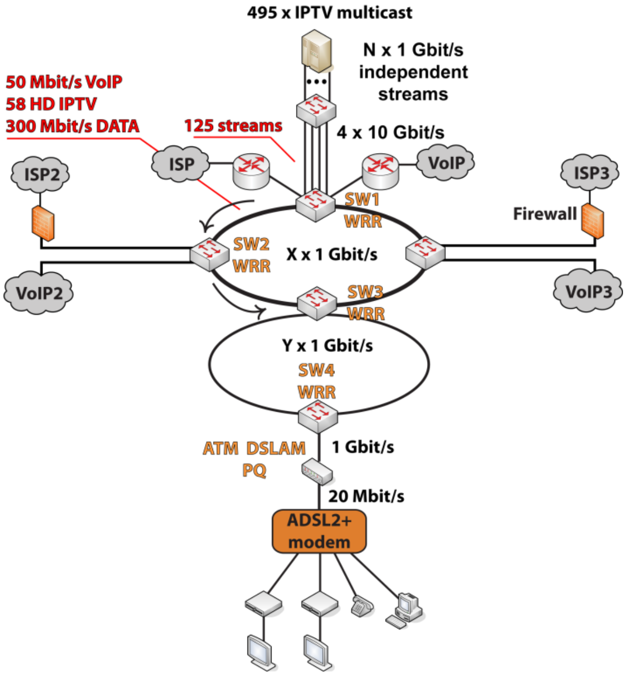

Fig. 1: Simulated IPTV network.

4.1. Simulation Setup

The simulated network is divided into two main sections (Fig. 1). The first section contains an IPTV Head End which simulates multiplexing. Because it is not easy to generally describe an IPTV server, we used 495 independent multicast streams. Every stream uses its own 1 Gbps line. In this way is assured that everyone stream is independent of each other. Then these streams are evenly multiplexed on four 10 Gbps Ethernet lines which means about 124 IPTV streams per link. The switch uses the FIFO queueing system. Further SW1 switch chooses 58 from 125 IPTV streams and multiplexes additional VoIP and data streams using the WRR queuing system. We only simulate one of many links.

The second section consists of SW2, SW3, SW4 switches (all using WRR) and a DSLAM (PQ). At these places traffic reordering takes place. Reordering the traffic means changing interarrival times of the VoIP and DATA packets. Moreover some IPTV streams are not passed down to lower network links. So SW3 passes down 42 from 58 input IPTV streams. DSLAM sends to a one customer only one or two IPTV streams, one VoIP and a 2 Mbps data stream. As a simplification the DSLAM uses an ADSL2+ line with only a one permanent virtual circuit.

The PQ queueing system is configured as follows. The VoIP traffic uses the most prioritized class, and then the IPTV is in the second and data in the third class. The WRR is configured to prefer the IPTV and VoIP over the data class. Therefore the following weights are used: 0,2 for VoIP, 0,7 for IPTV and 0,1 for DATA. This configuration ensures that the VoIP and IPTV classes do not suffer of losses, when the actual data class bandwidth needs are above-average. Also the data class suppression does not take place because the WRR algorithm does not block any configured class.

Other factors affecting PDV like dynamic routing, network nodes setup and their load, firmware versions, different queueing system implementations etc. are not implemented in the simulator because these factors cannot be described generally. It is our intent not to implement these factors because we want to deal only with the impact of the queueing system, traffic sources, service rate and the network interconnections.

4.2. Results

Figure 2 shows the PDV PDF of the FIFO switch within the Head End. This shows that the PDV has a high first mode and a very flat bottom. This happens because the output link of this switch is not very loaded and also the variable bit rate traffic is aggregated at a high number of streams. There are no known probability functions that can fit such a behavior.

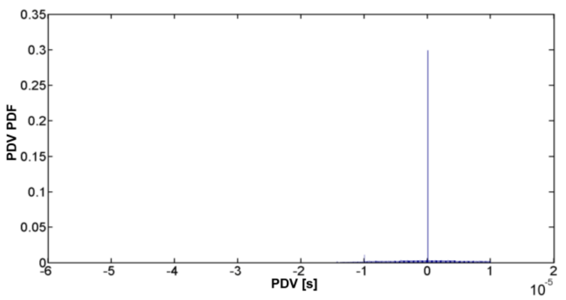

Fig. 2: PDV PDF computed between the input and output of the FIFO switch in Head End.

Figure 3 shows the PDF of RFC 3550 PDV between chosen switches SW1 and SW2, SW3 and SW4. There is no visible difference between these graphs. This means that the PDV of monitored IPTV stream does not grows up a lot and that the PDV PDF is formed on the first switch SW1. So the traffic reordering in the nodes SW2, SW3 and SW4 does not have an effect at all. This happens because the main VoIP traffic is only at the load 0,05 of the output links (1 Gbps). The data traffic has a bigger size, but the WRR is configured to prefer the VoIP and IPTV classes. Further the links between these switches are not very loaded because it is a Walled garden environment. All these PDF can be modeled as a Log-normal PDF.

Figure 4 shows the PDF of RFC 3550 PDV computed between the input of SW1 and output of the DSLAM for one (a) or two (b) IPTV streams. Figure 5 shows the same but for the PDV PDF (no RFC 3550 definition). These graphs are showed for the same histogram bins, so the aisle lines on the Fig. 5 are only summed values of PDV that does not fit into the histogram boundaries. As the figures show the PDF has a flat bottom with a single one mode. As the graphs show the main PDV source in an IPTV network are slow access links in the access network.

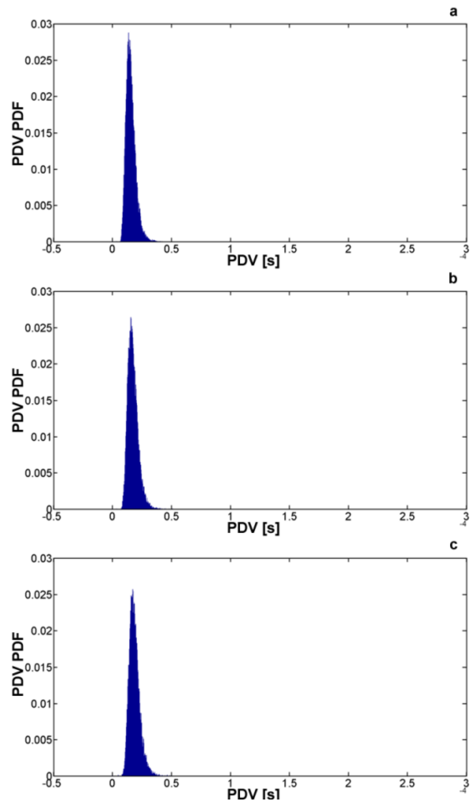

Fig. 3: PDF of RFC 3550 PDV between the nodes SW1 and SW2 (a), SW1 and SW3 (b) and SW1 and SW4 (c) for a selected IPTV stream.

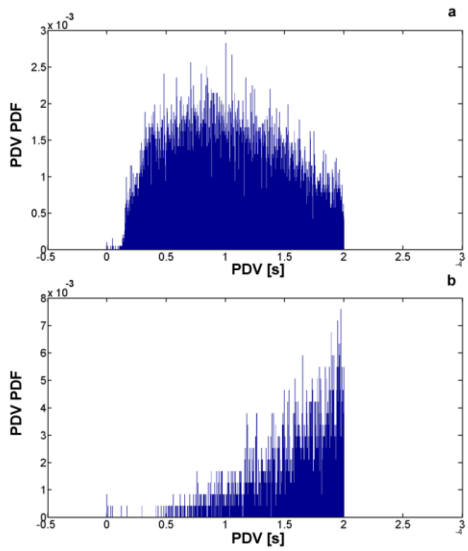

Fig. 4: PDF of RFC 3550 PDV between the nodes SW1 and DSLAM for one IPTV stream (a) and between SW1 and DSLAM for two IPTV streams (b).

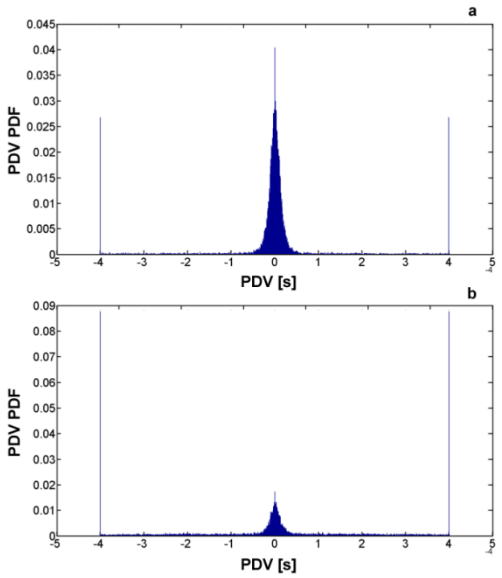

Fig. 5: PDV PDF between the nodes SW1 and DSLAM for one IPTV stream (a) and between SW1 and DSLAM for two IPTV streams (b).

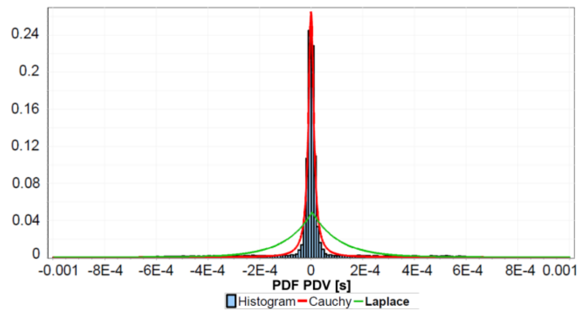

Fig. 6: Approximation of PDV PDF computed between the input of SW1 and output of DSLAM for one IPTV stream with the Cauchy and Laplace PDF.

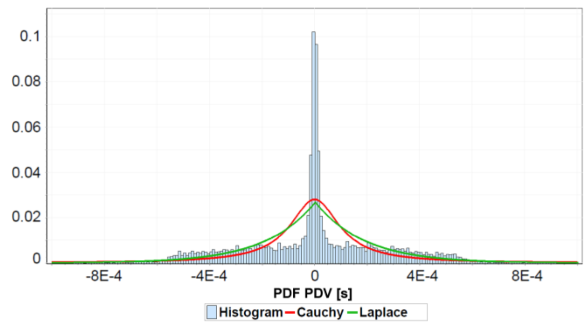

Fig. 7: Approximation of PDV PDF computed between the input of SW1 and output of DSLAM for two IPTV stream with the Cauchy and Laplace PDF.

Figure 6 shows the approximation of the PDV PDF between the SW1 and DSLAM switches when one IPTV stream is received. The best approximation is a Cauchy PDF. Figure 7 shows the approximation of PDV PDF when two IPTV streams are received on the ADSL2+ line. We could not use any of known PDF to precisely approximate such a curve. Also the Gaussian or Levy distribution functions could not be used. This happens because the incoming traffic on a 20 Mbps line consists of very small and very large IP packets.

5. Conclusion

On the base of realized simulations, we can make some conclusions. At the first, current PDV models are more aimed to the number of network nodes as on their character and load. Our simulations prove that when a QoS applied network is used, the already known mathematical models are not usable for the estimation of the resulting PDV. The traffic reordering is a more complex problem as it is used in current models. The reordering effect depends on the queuing system used, on the amount of reordered traffic and not at least of the traffic class.

Also the network model itself shows some applicable results. The Head End and his nearer switches do not have a very high influence on the resulting IPTV quality. It is because these nodes are well dimensioned and a higher traffic accumulation on high speed links is used. On the other hand, the ADSL line has the most visible impact on PDV exactly from the opposite reasons as in the case of Head End. The application of PQ on these types of lines is a good choice because it causes smaller PDV in comparison with the WRR.

Acknowledgements

This work is a part of research activities conducted at Slovak University of Technology Bratislava, Faculty of Electrical Engineering and Information Technology, Department of Telecommunications, within the scope of the projects "Analysis of the impact of traffic parameters on voice quality in IMS networks", supported by the STU University grant programme "Grant programme to support young researchers". The support was also provided by the Center of Excellence for SMART Technologies, Systems and Services II., ITMS 26240120029, co-funded by the ERDF.

References

[1] KYEONG-SOO, K., S. K. SEOK and L. G. BYEONG. On Jitter Characteristics in Multi-Node Packet Network Environment: The White Gaussian Noise Assumption Is Valid? In: *T*SP Lab: School of Electrical Engineering at Souel National University* [online]. 1999 [cit. 2012-11-01]. Available at: tsp.snu.ac.kr/int_conf/ic_48.pdf.

[2] DAHMOUNI, H., A. GIRARD and B. SANSO. Analytical Jitter Model for IP Network planning and design. In: *First International Conference on Communications and Networking (ComNet 2009)*. Hammamet: IEEE, 2009, pp. 1-7. ISBN 978-1-4244-5134-0. DOI: 10.1109/COMNET.2009.5373565.

[3] CHROMY, E., J. DIEZKA, M. KAVACKY and M. VOZNAK.

Markov Models and Their Use for Calculations of Important Traffic Parameters of Contact Center. *WSEAS TRANSACTIONS on COMMUNICATIONS*. 2011, vol. 10, iss. 11, pp. 341-350. ISSN 1109-274.

[4] ITU-T Recommendation Y.154. *Network performance objectives for IP-based services*. Geneve: International Telecommunication Union, 2011.

[5] DAO, N. L., T. L. NHAT and L. L. HUU. Defining Quantiles for Estimating IP Packet Delay Variation in NGN Core Networks. *REV Journal on Electronics and Communications*. 2011, vol. 1, no. 3, pp. 175–182. ISSN 1859–387X.

[6] DOMINGUEZ, R. L., T. D. ROMAN, M. D. RODRIGUEZ, and R. C. VARGAS. Jitter in IP Networks: A Cauchy Approach. *IEEE Communications Letters*. 2010, vol. 14, iss. 2, pp. 190–192. ISSN 1089-7798.

[7] CHROMY, Erik and Matej KAVACKY. Asynchronous Networks and Erlang Formulas. *International Journal of Communication Networks and Information Security (IJCNIS)*. 2010, vol. 2, no. 2, pp. 85-89, ISSN 2076-0930.

About Authors

Michal HALAS was born in 1978 in Slovakia. He graduated from Slovak University of Technology and received the electronic engineering degree in 2003. Since this year he has started postgraduate study at Department of Telecommunications STU Bratislava. In 2006 he received his Ph.D. from Slovak University of Technology Nowadays he works as a lecturer in Department of Telecommunications of FEI STU in Bratislava and topics of his research interests are Speech quality, IMS and IP telephony.

Stanislav KLUCIK was born in 1984. He received his M.Sc. degree at the Department of Telecommunications from the Faculty of Electrical Engineering at the Slovak University of Technology in 2009, is now a Ph.D. student. His research interests are in IP network performance, IPTV systems, VoIP and Power Line Communication.