Performance Model of Key Points At the IPTV Networks

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Abstract

In this paper we propose a new analytical model for modeling of the key points at the IPTV networks. This model uses Gamma distribution with Intergroup Characteristics for modeling self similar nature of processes in key points of IPTV network.
Enclosed Gamma Distribution results are compared with results from real measurements. Calculated discrepancies confirm that enclosed analytical model is optimal estimation model for process modeling of the key points at the IPTV network.
The used methodology for real-time analyses of the key points at the IPTV Network is very important for achieving IPTV service best performance.

Keywords: IPTV Network, Measurements, Monitoring, Analytical model, Real-time measurements.

1. INTRODUCTION

This research analyses measurement parameters for a key points of IPTV network over the period March 2008 - June 2010. The data includes information about the stream outage distribution, delay factor and stream loss in key points of overall IPTV Network defined in hours and minutes per each day in a sample defined time periods.

Categories that included equipment failure and human error are not analyzed into the research. In addition, information about the total number of customers served by the affected IPTV network, as well as total service population and service population density of the state affected in each point, also was not direcly analyzed into the research.

The resulting database included information about 2.010 values over this period. The database was used to carry out analyses for stream outage distribution, delay factor and stream loss in key points of overall IPTV Network per given time interval.

The research encloses mathematical model of Gamma Distribution with Intergroup Characteristics and networking model for typical IPTV Network.
We perform comparison analyses of the values of stream outage distribution, delay factor and stream loss in key points of overall IPTV Network.

With comparison analyses we found 2.32% disrcapances for delay factor into the Back Up Pop Router, 5.83% for stream loss pparameter into the Head-End eqipment, 3.56% for stream outage distribution parameter into the Head-End Eqipment, 5.02% for first iteration measurement stream loss parameter into Core Router, 3.67% for second iteration measurement stream loss parameter into Core Router.

Also, the enclosed mathematical model is compared with other models that are user in similar resrches into the field. There were not founded any similarity with other already developed models in this field.

2. IPTV ARHITECTURE

A typical IPTV network is consisted with functional blocks (see figure 1 defined below), [16], [17]:

- National head-end: Where most of the IPTV channels enter the network from national broadcasters
- Core network: Usually an IP/MPLS network transporting traffic to the access network
- Access network: Distributes the IPTV streams to the DSLAMs
- Regional head-end: Where local content is added to the network
- Customer premises: Where the IPTV stream is terminated and viewed.

2.1 Factors that Affect Service into the Network

Main factors that can be measured into the IPTV network and have important influence on the quality of the services into the network are:

(A) Encoding and Compression, The quality of the video being distributed across the network can be affected right at the source; i.e., at the video head-end. The encoding and compression process usually creates a trade-off between the quality of the video and the desired compression level, [17].

(B) Jitter, Defined as a short-term variation in the packet arrival time, typically caused by network or server congestion. If the Ethernet frames arrive at the STB at a rate that is slower or faster, as determined by the network conditions, buffering is required to help smooth out the variations. Based on the size of the buffer, there are delivery conditions that can make the buffer overflow or underflow, which results in a degradation of the perceived video.

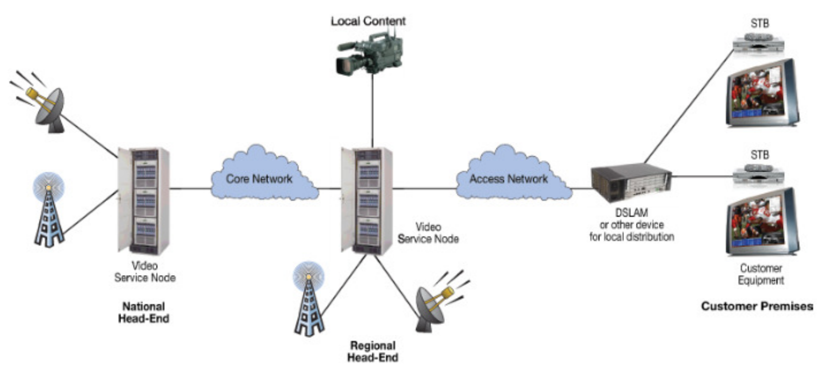

FIGURE 1: General IPTV Network Topology

(C) Limited Bandwidth, as core IP infrastructure is usually based on optical networks with a low level of congestion, bandwidth limitations (and the total amount of video-stream data that can be sent) is limited mostly by the access network or the customer's home network supported rate. When traffic levels hit the maximum bandwidth available, packets are discarded, leading to video quality degradation.

(D) Packet Loss, Loss of IP packets may occur for multiple reasons—bandwidth limitations, network congestion, failed links and transmission errors. Packet loss usually presents a busty behavior, commonly related to periods of network congestion.

2.2 Quality of Experience (QoE)

Due to the structure of Ethernet and IP networks, the quality of the video/audio traffic is primarily influenced by network jitter and packet loss. With the type of video encoding that is used in MPEG or other similar compression algorithms, the actual impact to the user perception depends

on the packet type that is lost in the network. In MPEG-2, the transported packets that are used to form an image are divided into I-frames, P-frames and B-frames. In simple terms, I-frames contain a complete image, while P-frames and B-frames contain predicted information from the other frames.
Figure 2 provides a sample of the relationships between the various types of frames included in a group of picture (GOP). As shown, I-frames are independent and provide input to support the other frames; this means that an error in the I-frames will have more repercussions to the image being viewed than losing P-frames or B-frames, [17].

2.3 Key Points into IPTV Networks

There are four major locations that need to be monitored for IPTV service delivery into IPTV network. Generally demarcation points in each of the four areas must be defined considering the different groups and units within a service provider's organization that will handle issues based on where they are found.
First Network Monitoring point is "Head-End" monitoring point. The first monitoring location is between the traditional cable head-end, and the network interface.

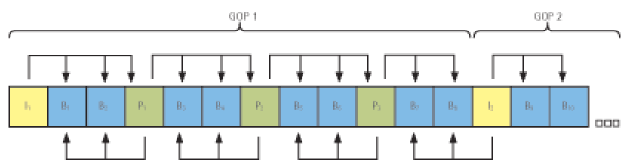

FIGURE 2: Typical group of picture (GOP) relationship in MPEG.

The second monitoring point is network transport monitoring. This would typically be monitored at the VHO/Regional center egress from the transport network and represents issues that can occur in the transport of video from the SHO to the VHO.
Third Monitoring Point is "Last Mile" monitoring point. The third monitoring point is the VDSL or FTTH line. Some T&M can be done at the egress from the VHO or at a remote DSL cabinet with the use of a permanent or longer term leave behind test device. In addition to IPTV measurements with a measurement probe in the DSLAM qualification of the copper lines can be completed without having a technician "onsite".
The last demark being the actual Set-Top-Box, residing behind the Residential Gateway, and connected through a variety of LAN technologies (Ethernet, MOCA, HPNA, etc.).

2.4 Measurements With Probes

There are several recommended ways for measurements into the key points, [18]:

- Option One: In-line equivalent passive monitoring - Passive monitoring is the safest method for adding a probe because the probe cannot impact service. If a probe is required to be in-line then an in-line equivalent can be setup using two mirror ports on a router.
  Advantages: Provides an equivalent setup to in-line, but assures passive behavior meaning the probe will never impact the service. Disadvantages: Requires two ports on a router/switch. Depending on the router/switch mirror ports can be service impacting.
- Option Two: Passive Monitoring, Potentially Measurement Impacting - The second option is to mirror both ingress and egress of a line under test to a single mirror port, likely on two different VLANs using distinct VLAN IDs.
  Advantages: Provides all line data as if in-line, and assures passive behavior meaning the probe will never impact the service. Disadvantages: Because you are mirroring a full duplex line onto a single direction of a mirror port line, there is a potential for congestion on the mirror port that could impact measurement.
  From a probe perspective, this doesn't look exactly like an in-line setup so the probe must support this configuration (i.e. support measurement VLAN's) or the measurement

of concern must not be directional in nature (for example, getting a “program ID” wouldn’t matter).

- Option Three: Active, but no uncast monitoring - Sometimes passive monitoring is not possible. For example if you would like to test the response of a D-Server to a channel change request you would need to join the service. Any multicast can be joined to provide semi-passive monitoring of multicast streams. In this case you can setup a probe to be a part of the service (e.g. in the VPLS domain of the service similar to how an end-user would be attached if directly Ethernet connected).

3. INTRODUCING THE MODEL OF SELF-SIMILAR PROCESSES FOR PERFORMANCE MODELING OF KEY POINTS OF THE IPTV NETWORK

In this study Self-Similar process with Gamma Distribution is introduced as a new approach for analyzes of key points of IPTV Network.
Self-similar processes are types of stochastic processes that exhibit the phenomenon of self-similarity, [15]. A self-similar phenomenon behaves the same when viewed at different degrees of magnification, or different scales on a dimension (space or time). Self-similar processes can sometimes be described using heavy-tailed distributions, also known as long-tailed distributions. Example of such processes includes traffic processes such as packet inter-arrival times and burst lengths. Self-similar processes can exhibit long-range dependency.

The design of robust and reliable networks and network services has become an increasingly challenging task in today's world. To achieve this goal, understanding the characteristics of traffic plays, performance models, bottlenecks into the networks, throughput, specific functions of the packets that are transmitted over the network, key points into the network is more and more critical role. Empirical studies of measured traffic traces have led to the wide recognition of self-similarity in network traffic.

3.1 Fractals in Self Similar Processes

B. Mandelbrot introduced the term ‘fractal’ for geometrical objects: lines, surfaces and spatial bodies having a strongly irregular form, [1]. These objects can possess the property of self similarity. The term ‘fractal’ comes from the Latin word fractals and can be translated as fractional or broken. The fractional object has an infinite length, which essentially singles it out on the traditional Euclidean geometry background. As the fractal has the self-similar property it is more or less uniformly arranged in a wide scale range; i.e. there is a characteristic similarity of the fractal when considered for different resolutions. In the ideal case self-similarity leads to the fractional object being invariant when the scale is changed. When self-similar traffic is mentioned, it will be assumed that its time realizations are fractals.

3.2 Self Similarity Processes in Telecommunication Networks

Modern investigations show that self-similarity can occur as a result of combining separate ON/ OFF sources, which can be strongly changeable (i.e. ON and OFF periods have DHT and infinite variances, e.g. Pareto distribution). In other words, the superposition of the ON/OFF sources exhibiting the infinite variance syndrome results in self-similar combined (aggregated) network traffic, tending to fractional Brownian motion. Moreover, the research of various traffic sources shows that the highly changeable ON/OFF behavior is the typical characteristic for the client–server architecture, [1].

3.3 Characteristics of Video Traffic

Video signals can be analyzed as a sequence of continuous pictures or as e sequence of ‘frames’. Each fixed picture should be presented by the coding algorithm in the digital form and should be compressed to decrease the bandwidth. Normally, in order to decrease the bandwidth, typical transmission of video signals cover the transmission of the full initial frame and then transmission of the difference frames. This method of transmission is called inter frame coding.

Since the ongoing frames differ little from each other (for the motion is continuous) to avoid transmission errors it is possible to ensure the periodic transmission of the full frame, where varying the frames no longer depends on the previous frames.
For these and some other reasons video traffic differs from broadband data traffic and, therefore, the models and the conclusions revealed for video data cannot be used for other traffic types, [1].
Every frame has MPEG coding. The MPEG standard uses three modes for frame coding. They are called intra frame (I), predicted (P) and interpolating (B). The I frame is the JPEG (Joint Photography Experts Group) coding of a separate frame (i.e. without using time redundancy).
During coding the coding template is usually given, i.e. an accurate sequence determining the time moments of the full frame arrival. This template is referred to as the GOP (group of pictures) and appears to be self-sufficient for decoding the frame sequence.
From the video sequence correlation function can be seen that MPEG coding introduces strict periodicity. To avoid this periodicity MPEG data can be grouped into blocks of 12 frames, called the GOP.

Since the frames inside this template do not differ very much from each other (only the difference between them is transmitted), this leads to the existence of an essential correlation of their sizes. During transmission of the next full frame the correlation between them practically disappears. For this reason the video traffic differs considerably from the usual traffic of the telecommunication network. Therefore, the conclusions and the models obtained for the usual network traffic cannot be applied for the analysis and modeling of video traffic.

3.4 Model for Intergroup Characteristics

The intergroup traffic character can be described by the first-order and second-order statistical characteristics of I frame processes, [1]. Gamma distribution is a good approximation of the I process:

$$F_{X_I}(r) = \frac{r^{m_I - 1}}{\Gamma(m_I) l_I^{m_I}} e^{-r/l_I}, \forall r > 0$$

Where m_I is the shape parameter and I is the scaling coefficient. They are related by the m value and the variance σ^2_I of the I frame trace using the following relations:

$$m_I = \frac{\sigma_I^2}{\mu_I^2} \quad \text{And} \quad l_I = \frac{\sigma_I^2}{\mu_I}$$

The I frame trace has self-similar properties and can be characterized by the SRD parameter l_I, LRD parameter H_I and the 'boundary parameter' K_I. Thus the autocorrelation function calculated as has the form

$$R_{X_I X_I}(m) = \begin{cases} e^{-\lambda_I m}, m \le K_I \\ Lm^{-\beta_I}, m > K_I \end{cases}$$

where $\beta_I = 2 - 2H_I$. The same procedure can be used to describe P and B frame distributions.

Can be shown that the ACF of I processes for analyzed sequences has two different characteristics: the self-similar character (long-range dependence), described by the Hurst exponent H_I, and exponential decay similar to the function $e^{-\lambda_I x}$ over short time intervals.
Two regions are divided by coefficient K_I characterizing the boundary. For example, in the case of the cartoon the exponent H_{Ij}=0.873, λj=0.891 and coefficient K_{Ij} = 30 frames. The same character is typical for the correlation functions of B and P frames.
Taking into account that the gamma distribution is fully characterized by the mean and the variance, it is necessary to analyze the statistical characteristics of the processes reflecting the B and P frame size distributions for the given I frame sizes.

This model reflects two main statistical characteristics of the real video sequence: the quotient distribution with the heavy tail and the long-range part of the autocorrelation function.

4. EXISTING MODELS FOR ANALYZES OF IPTV NETWORK PARAMETERS

Into research area can be found other approaches for performing analyzes for different topics of IPTV Networks, IP Networks, User Behavior, WWW Traffic, VBR Performance Analyses, etc. [9], [10], [11], [12], [13], [14], [19], [20], [21]. Analyzes for performance parameters into key points of IPTV Network with Self-Similar Process with Gamma Distribution can be found into the research area in the World for the first time.

Previously was described the managing of the IPTV service (performance monitoring data such as device usage and error logs, user activity logs, detail network alarms and customer care tickets) with design of Giza. In this research was presented the first characterization study of faults and performance impairments in the infrastructure of a large IPTV service provider in North America. Analysis are performed from the spanned routers in the backbone to set top boxes (STB) and residential gateways (RGs) in home networks, including hardware and software crashes to video quality impairments. This research was covered on University of Texas and AT&T Lab, [3].

Another approach was research for modeling of channel popularity dynamic in large IPTV systems with Zipf-like model for distribution. In that research, was analyzed and modeled channel popularity based on user channel access data in a nation-wide commercial IPTV system. Into the document was found that the channel popularity is highly skewed and can be well captured by a Zipf-like distribution, [4].

User Behavior for CUTV service via STB devices is modeled with non stationery Poisson process with Catching Algorithm. This paper shows that transport capacity requirements of the network supporting interactive television services risks growing enormously, if these services continue to gain in popularity. Caches deployed in strategic places in the network supported by good caching algorithms can alleviate this large increase in traffic volume for CUTV services where content is still of interest to many viewers, but which viewers do no longer watch it simultaneously. This research was prepared by Alcatel-Lucent Bell Lab and Ghent University, [2].

Performance bounds for peer-assisted live streaming for IPTV network are analyzed with distributed multi tree configuration with bottleneck removal algorithm by Princeton University. In this research, were studied three performance metrics: minimum server load, maximum supported rate, and minimum tree depth, under three cases: unconstrained peer selection, single peer selection, and constrained peer selection. The analysis on the performance bounds also suggest the tradeoffs between tree depth, server load, and degree bound, [5].

Real time monitoring of video quality (model for mapping of packet losses from which can be analyzed loss distortions) in IP networks is analyzed with GE model. The goal of the research was to devise a lightweight solution that would allow real-time, large-scale monitoring of video quality. First contribution was the development of a loss-distortion model that accounts for the impact of various network-dependent and application-specific factors on the quality of the decoded video. Second contribution was in using this model to define a relative video quality metric, rPSNR, that can be evaluated without parsing or decoding the transmitted video bit streams, and without knowledge of video characteristics - thereby significantly reducing complexity while still providing reasonably accurate video quality estimates. The robustness and accuracy of the rPSNR-based method were demonstrated through a broad range of simulations and experiments, [6].

At the end, the model for VBR traffic with Gamma distribution can be found into the research prepared by Moscow State technical University of Service and Moscow Power Engineering Institute. This model reflects two main statistical characteristics of the real video sequence: the quotient distribution with the heavy tail and the long-range part of the autocorrelation function.

Since this model does not approximate the SRD accurately enough, it is suitable for modeling the set of a large number of video sources. In this case the quotient distributions are close to Gaussian and the singular correlation effects are random over the short time spaces, [1].
Implementation of social features over regular STB is described in the material prepared in University of Aveiro. Developing a Social TV application for a commercial IPTV platform regarding the STB hardware and software limitations compelled the team for alternative technical implementations and mishaps were topic on this research. These limitations along with the usual constraints of designing for television also led to different experiments concerning the information layout and interaction patterns, resulting in some directions to other iTV developments over regular browser based set-top boxes, [1].

The self similarity nature of WWW traffic was described into the paper prepared by Boston University. The self similar processes are implemented over the WWW traffic via transferred files and over silent time periods, [8].

5. SELF-SIMILARITY WITH GAMMA DISTRIBUTION FOR REAL TIME TRAFFIC INTO KEY POINTS OF IPTV NETWORK EXPERIENCES

5.1 Measurement Configuration

This research analyses stream outage distribution, delay factor and stream loss at the key points of overall IPTV Network into the period March 2008 - June 2010. The real measurements database includes around 2010 values about the stream outage distribution, delay factor and stream loss at the key points of overall IPTV Network defined in hours and minutes per each day in a year for defined research time period interval of almost two years.
The range value per each figure parameter comes from about 260 up to 4.250 values metric for stream outage distribution parameter, from about 1.080 up to 1.800.000 value metric for stream loss and from about 190 up to 520 values metric for delay factor.
The simplified subject configuration of IPTV network is shown in Figure 3.
The telecommunication network (TN) covers a considerable terrain and combines a large number of various protocols of the link layer. The figure shows only the generalized network structure. There are terrestrial and satellite communication channels inside the network.
In the network configuration shown in Figure 3 the device (example: Cisco Catalyst 3750) is the network 'kernel'.

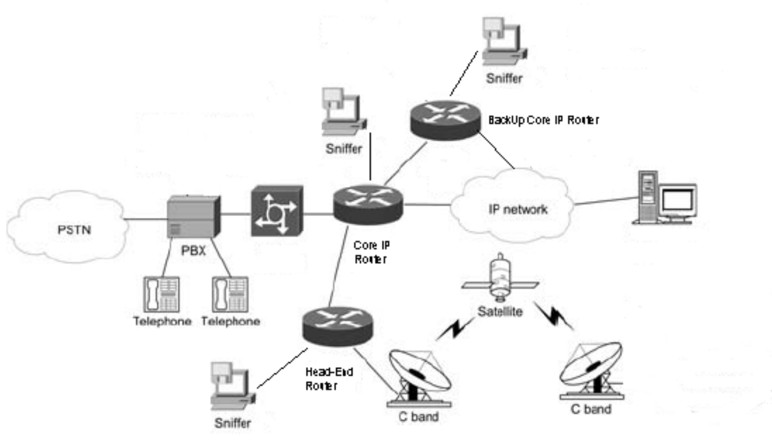

FIGURE 3: Telecommunication Network Measurement Point – Real Points for analyses.

The key network analyses performed during this study are performed on this key point:

- Measurements on key points in IPTV Network. For realization of real time measurements, the free port of network "kernel' equipment, Head-End equipment and Backup of network 'kernel' equipment are connected through the fiber optic interface to the personal computer (PC). The PC has the measurement software and the scheduler, which initiated

the chosen traffic measurement program every 15 minutes. At the link layer the connection was realized over the fast Ethernet protocol. The chosen device port was configured as the SPAN port. As measurement software, the sniffer software catches all packets falling into the interface. As a result about 90 files were recorded.
Since the sniffer software caught total traffic passing through the Head-End Equipment, Core Router and the Backup Core Router Equipment the recorded (by the IP addresses known in advance) log-files were subjected to filtering in order to allocate the measurements for IPTV packets.

- Key Measurement Parameters. Stream Outage distribution as number in packets is the total number of packets that are out during the15-minute time period. Delay Factor is defined as a number in milliseconds that is the maximum value of delay factor before setting an alarm condition. Stream loss as a number in packets is the total number of media packets lost for 15-minute inspection period.

These measurement parameters are recorded into about 90 files by measurement software and systemized, analyzed and compared with the results from the mathematical model.
During the research the frames for connection which made the TCP operate at the transport layer were not taken into consideration.

5.2 Measurement Practice
Into the real time measurements the following traffic characteristics were registered:

1. Total traffic. This traffic, measured in bytes and packets, demonstrates the packet number (or the total packet size in bytes) for which the MAC address of the appropriate device or the MAC address of the destination was present in the field of the source's MAC address.
2. Input traffic. This traffic, classified during the analysis as incoming into the router and used for the measurement, was fixed in the packet form as well as in the total volume in bytes or packets.
3. Output traffic. This is the traffic that is classified at the analysis as outgoing from the router and used for measurement. This parameter is also fixed in packets and in the total volume in bytes or packets.

Shape parameter	Log-log correlation	Variance Time	R/S Statistics
$\alpha = 2.0$	H = 0.592	H = 0.544	H = 0.672
$\alpha = 1.7$	H = 0.758	H = 0.794	H = 0.684
$\alpha = 1.4$	H = 0.7996	H = 0.8198	H = 0.811
$\alpha = 1.1$	H = 0.828	H = 0.745	H = 0.884

TABLE 1: Hurst exponent estimate (example).

The SPAN session is opened on Ethernet port of the routers. The terminal with the loaded sniffer software is connected to this port. Therefore, during the measurement only the traffic of the ports involved in the SPAN session will be analyzed.
The following scenario was configured:

- Step1. All the traffic considered for IPTV Stream into the Head-End equipment, Core Router and Backup Core Router was analyzed.
- Step 2. The considered traffic is measured via SPAN session.
- Step 3. The parameters: stream outage, delay factor and stream loss are measured.
- Step 4. The measurement results were defined into Documents.
- Step 5. The enclosed curve from the real measurement was analyzed for catching the best effort mathematical model.
- Step 6. Enclosed mathematical model with Gamma distribution is defined with specific parameter values related with real measurements.
- Step 7. The values of the real measurements are related with results from the mathematical model.

- Step 8. Performing the comparison analyzes calculation of the discrepancies between the results from the analytical model and results from the real measurements.

5.3 Assumed Self Similar Model

It is assumed that the self-similar model as mathematical model can explain the behavior of the real IPTV traffic into the key points of the IPTV network.

With analyzes of different types of mathematical functions that can be found into the theory of self -similar processes is assumed that the Gamma distribution with intergroup characteristic can be used as a mathematical model for performance analyzes of key points of the IPTV network.

The Intergroup characteristic is described with first order and second order statistical characteristic of I frame processes.

$$F_{X_I}(r) = \frac{r^{m_I - 1}}{\Gamma(m_I) l_I^{m_I}} e^{-r/l_I}, \forall r > 0$$

For the assumed model in this research we define the parameter values as follows: H = 0.873, λ=0.891, L = 100 and k = 30.

The parameter β is calculated with formula β = 2-2*H, and receive value β = 0.25.

The shape parameter and the scaling coefficient are related by the μ value and σ^2 of the I frame process by equations:

$$m_I = \frac{\sigma_I^2}{\mu_I^2} \quad \text{and} \quad l_I = \frac{\sigma_I^2}{\mu_I}$$

So, they receive values in range from 0.1 to 2.5.

5.4 Comparison Analyzes

Next, we show through comparative evaluation that considered self-similar process as mathematical model defined with Gamma Distribution with Intergroup characteristic with first order and second order statistical characteristic of I frame processes is important for discovering of the stream outage distribution, delay factor and stream loss parameters in key points of overall IPTV Network. A qualitative comparison of all this technique is provided in this Section.

To compare Analytical model with Gamma Distribution and RMSOD (Real Measurements for Stream Outage Distribution), RMDF (Real Measurements for Delay Factor) and RMSL (Real Measurements for Stream Loss), we use two years database aggregated at RMSOD, RMDF and RMSL with resolution measurements per hour for each day in a year for sample time period.

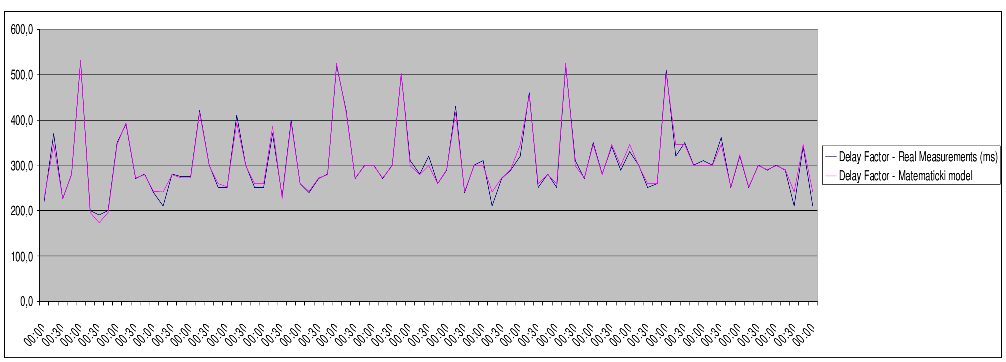

FIGURE 4: Comparison Analyzes for delay factor for Back Up Core Router into IPTV Network.

We describe our experiences in applying Analytical model for Gamma Distribution on the RMSOD, RMDF and RMSL database and we demonstrate how we can apply the suite of techniques in Gamma Distribution to receive the value for stream outage distribution, delay factor and stream loss parameters into the overall IPTV network. In this research, we consider the values from the RMSOD, RMDF and RMSL database for the related sample period as our input series. These are the direct measures reflecting the stream outage distribution, delay factor and stream loss parameters of overall IPTV network performance impairments. We apply Analytical model with Gamma Distribution and founding the differences. We find that Analytical Model with Gamma Distribution particularly useful in defining the value of stream outage distribution, delay factor and stream loss parameters of IPTV network for every time period. This is an important conclusion for IPTV Network detailed diagnosis that would exhaust cost effective operation into IPTV networks.

- 1st class of measurements. We perform the correlation analysis for delay factor data collected over time period of 21 hours with measurement intervals of 15 minutes. The correlation time window is set on 15 minutes. We observe strong correlations between values of analytical model and values for delay factor in the Backup Pop up router into the IPTV network in defined time period. We have also validated the discovered dependencies of delay factor into the Backup Pop up router of the IPTV network with analyzed model. We found discrepancy level for this time period of about 2.32% (Figure 4).
- 2nd class of measurements. We perform the correlation analysis for delay factor data collected over time period of 7 days with measurement intervals of 24 hours. The correlation time window is set on 24 hours. We observe strong correlations between values of analytical model and values for stream loss parameter from Head-End equipment into the IPTV network in defined time period. We have also validated the discovered dependencies of stream loss parameter from Head-End equipment into the IPTV network with analyzed model. We found discrepancy level for this time period of about 5.83% (Figure 5).

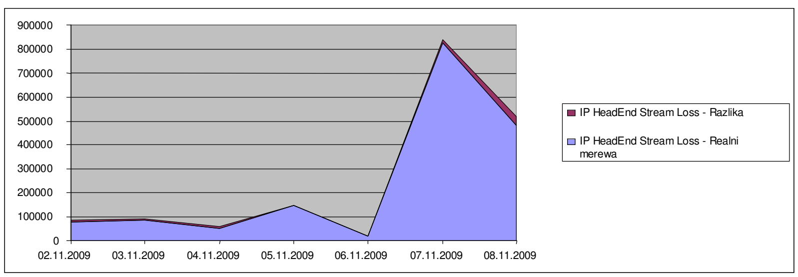

FIGURE 5: Comparison Analyzes for stream loss for Head End Equipment into IPTV Network.

- 3rd class of measurements. We perform the correlation analysis for stream outage distribution data collected over time period of 7 days with measurement intervals of 24 hours. The correlation time window is set on 24 hours. We observe strong correlations between values of analytical model and values for stream outage distribution parameter from Head-End equipment into the IPTV network in defined time period. We have also validated the discovered dependencies of stream outage distribution parameter from Head-End equipment into the IPTV network with analyzed model. We found discrepancy level for this time period of about 3.56% (Figure 6).

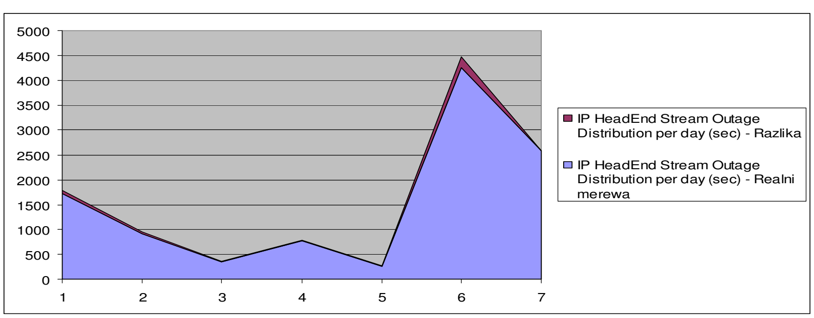

FIGURE 6: Comparison Analyzes for stream outage distribution for Head End Equipment into IPTV Network.

- 4th class of measurements. We perform the correlation analysis for stream loss data collected over first time period of 11 days with measurement intervals of 24 hours. The correlation time window is set on 24 hours. We observe strong correlations between values of analytical model and values for stream loss parameter from Core Router equipment into the IPTV network in defined time period. We have also validated the discovered dependencies of stream loss parameter from Core Router equipment into the IPTV network with analyzed model. We found discrepancy level for this time period of about 5.02% (Figure 7).
- 5th class of measurements. We perform the correlation analysis for stream loss data collected over second time period of 11 days with measurement intervals of 24 hours. The correlation time window is set on 24 hours. We observe strong correlations between values of analytical model and values for stream loss parameter from Core Router equipment into the IPTV network in defined time period. We have also validated the discovered dependencies of stream loss parameter from Core Router equipment into the IPTV network with analyzed model. We found discrepancy level for this time period of about 3.67% (Figure 8).

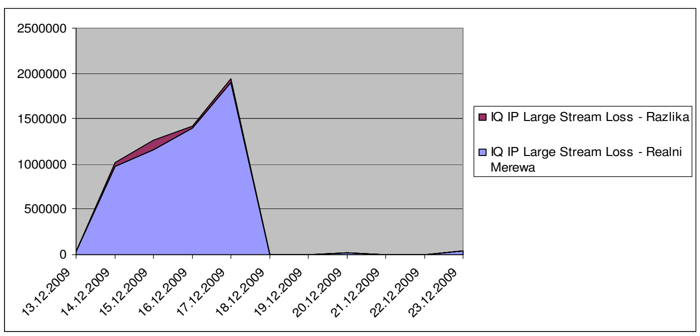

FIGURE 7: Comparison Analyzes for stream loss for Core Router into IPTV Network.

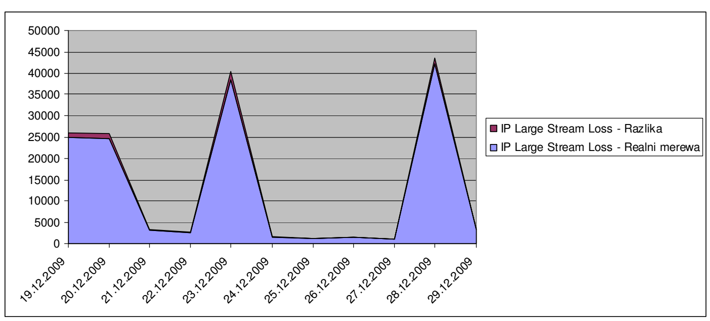

FIGURE 8: Comparison Analyzes for stream loss for Core Router into IPTV Network.

6. CONCLUSION

The first characterized research for outage distribution parameter, stream loss parameters and delay factor parameter at the key points of IPTV network is finished and described in this paper.
Research consist strict specification of covered model with details for defined parameters and used functions based on fractal shapes represented by self similar processes and description of used network IPTV topology.

An achieved result confirms that covered research model can be used for performing real time analyses at the key points of the IPTV networks.
The simplicity of the covered model and the accuracy of the enclosed results confirms that the described research have extra high level of quality and can be used as the base in further analyses, studies and researches in the field.

The covered model can be implemented for performing analyzes of the stream at the CPE devices into the IPTV network, analyzes related with handling of the HD stream into the IPTV network, analyzes of IPTV stream into the 4G networks and other.

The research has impact on better automation of IPTV operations in order to achieve better detection and troubleshooting performance.

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