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APPROACH TO QoS/QoE MONITORING AND PARAMETRIC MODEL FOR IPTV SERVICE

Łukasz Trzcianowski, Sławomir Kula

Institute of Telecommunications
Warsaw University of Technology
Nowowiejska 15/19, 00-655 Warsaw, Poland

Summary: The main purpose of this paper is to present approach to QoS/QoE monitoring and parametric model creation for IPTV service. Monitoring system was used to perform on-line monitoring both MPEG TS parameters and subjective assessments (MOS). The second part of this work present parametric model for IPTV service, which describes relationships between single network parameters such as: jitter, packet loss, packet corrupt and throughput and subjective/objective quality measures (MOS, MSE). Created model shows influence of modified network conditions on the perceived video quality for variety vide o sequences extracted from IPTV network stream. This work also presents methodology of tests and their results which can be used to estimate the perceived quality for changes associated with modification of single network parameters.

Keywords: IPTV, quality of service, quality of experience, optical network, parametric model, monitoring system

1. INTRODUCTION

Dynamic evolution of telecommunications services and multimedia oriented interactivity is the reason for creation of new applications. Their attractiveness from customer side is not only measured by the price but also by the quality. Service provider looks at the quality from the perspective of network parameters, whereas from user side much more important is his satisfaction with the service provided. For that purpose it is needed to create monitoring system that will allow users and operators to check the quality of service. In this paper authors present the quality monitoring methodology and preliminary results of its application in practice for IPTV service. To find out how network parameters affect quality measures it was needed to test dependencies between them. Mentioned relations are required to estimate end-to-end quality and user satisfaction. Created in this way "E-model" can be used not only for monitoring reasons but also as a reference in the network planning processes. At present, there are two parametric models standardized by ITU – T organization (ITU – T G.107 for telephony and ITU – T G.1070 for videoconference). None of them is related to

IPTV service, that is more complex because of integration with on demand services and ability to interact with users. In this paper authors present their "E-model" for IPTV service which was created based on test results which show relationships between modified single network parameters and quality measures which are associated with user satisfaction and signal degradation. Apart from that they also present approach to create model for all the parameters.

2. THE CONCEPT OF MONITORING THE QULITY FOR IPTV SERVICE

In developing the monitoring the quality of IPTV service it is needed to consider both service provider and end-user needs. Designed based on that system should give the operator ability to find relationships between users' complaints and network events. For the provider more important are network and signal parameters and on the other hand client want to be satisfied from provided service. That is why monitoring has to include not only checking network parameters but also user satisfaction. For that reason monitoring device should be located on the user side. Monitoring system should be implemented as software solution in Set Top Box. This device in normal situation is needed to decode and display television programs. Authors found problems with access to STB system, so the implementation was done by using additional external devices and applications. Due to use of additional tools, implemented system cannot be applied universally as a commercial solution.

3. LABORATORY NETWORK (PON/FTTH)

In Institute of Telecommunications at Warsaw University of technology it is located the distribution-access part of FITL network over which operator Multimedia Polska S. A. provides triple play services such as: broadband Internet, VoIP and IPTV. All of them are transmitted in aggregated stream to OLT device (*FiberHome AN5116)* in which optical signal is divided into particular ONU devices (*FiberHome AN5116).* In these units signal is converted from optical form to electrical form and services are transitioned to appropriate ports on which services were configured. Television signal, associated with IPTV service is delivered to one of FE ports and later on this signal is decoded in Set-Top-Box device (*iCAN2810W*) and at the end it's displayed on the monitor. To receive television materials connection between monitor and STB was replaced by appropriate system (for monitoring reason) or computer with software which allows to receive and save IPTV content (for tests related to parametric model creation).

Laboratory network architecture is presented in the figure below (Fig. 1):

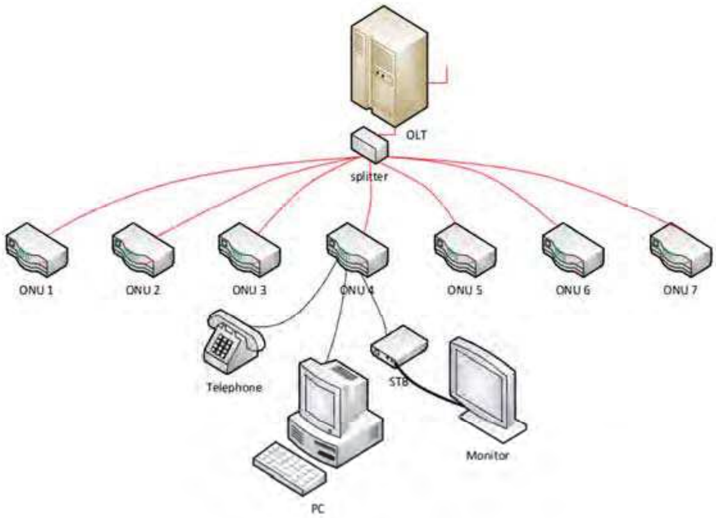

Fig. 1. Laboratory network scheme

4. MONITORING SYSTEM

Monitoring system was implemented at the end of laboratory network (Fig. 2). It connects PON/FTTH network and end-user devices.

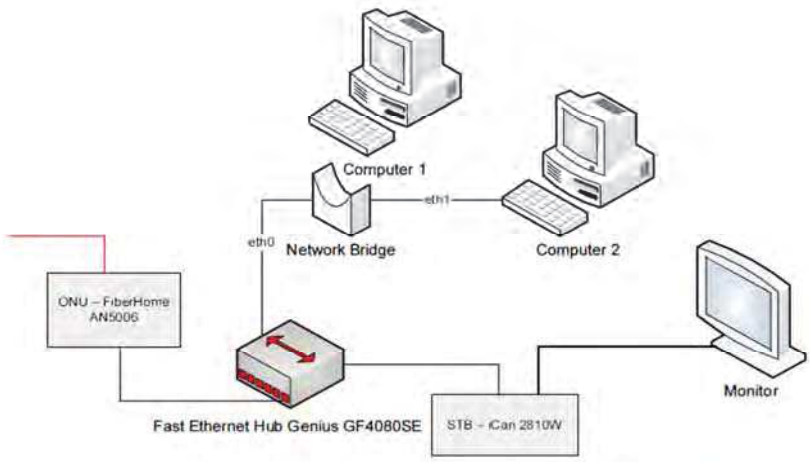

Fig. 2. Monitoring system scheme

Optical signal is transmitted over fibre to ONU device and then services are divided into particular Fast Ethernet ports. To monitor IPTV service authors inserted Hub between ONU and Set Top Box. This device works at physical layer of the OSI model and it moves all network traffic from input port to output ports. One of Fast Ethernet ports was connected to STB, which by using HDMI connector provides video signal to monitor (*ASUS VH222D*) where it is displayed without any distortions. The same video signal from another Fast Ethernet port is transmitted to "Computer 1" that is responsible for changing network conditions according to settings. This device has two network interfaces: eth0 and eth1 connected by network bridge. Two ways of IPTV transmission allow to monitor distortions and degradations in real time. Created in this way monitoring system can be used not only to monitor parameters for received packets but also to check user satisfaction from provided service in various network states.

5. USED TOOLS ─ MONITORING TESTS

Agilent Triple Play Analyzer (ATPA)

This application is a software program allows to perform analysis and monitoring of the network traffic for Triple Play Services. In addition to the traffic statistics collection this tool can also determine and measure values typical for particular services. In case of IPTV service ATPA application can analyze parameters associated with MPEG TS and its components – PES (*Packetized Elementary Stream*).

MODTRAFNET

This custom-made application allows to automate the whole process associated with performing changes for particular network parameters. It is NETEM – based application with GUI interface. It supports the following network modifications:

- emulating delays determined by time value
- emulating jitter determined by average delay value and its variation
- emulating packet loss determined by percentage rate
- emulating packet reordering determined by delay value and by percentage values of changes.

VLC

VLC application is multimedia platform that allows to play audio and video files in various file formats such as: MPEG – 1, MPEG – 2, MPEG – 4, DivX, DVD, MP3, OGG. Application also supports streaming in both client and server role. It is also powerful server to stream live and on demand video in several formats/containers to Internet.

ANMS2000

ANMS2000 is dedicated management system for FiberHome devices. It can be used to manage AN5116-02 system including handling of equipment configuration, property, status, alarm and view. This tool was used to reduce the bandwidth for IPTV service in laboratory PON/FTTH network (please see 2).

6. MONITORING TESTS

This section describes monitoring tests and their results for given network conditions. The network changes were performed by setting appropriate values for the following parameters:

- packet loss
- packet corrupt
- bandwidth
- jitter

In case of MOS measures authors used commercial parametric model implemented in ATPA application.

Bandwidth

Bandwidth was modified by using ANMS2000 system which manages FTTH devices. This parameter was changed from 3 Mb/s to 10 Mb/s. Measurements were carried out using ATPA analyzer. Duration for signal sample was set on 10s and test duration was set on 100s. It allows to obtain appropriate accuracy without notable extension of testing time.

Reducing bandwidth parameter to 5 Mb/s doesn't cause any changes in the MPEG TS stream throughput. Fluctuations in the chart above (Fig. 3) are caused by various types of sequences transmitted in television (high motion, low motion sequences etc.). With the further gradual decreasing the bandwidth parameter the value of throughput for MPEG TS stream rapidly declined. For bandwidth parameter set on 4Mb/s users saw single distortions in received video and for bandwidth parameter set on 3 Mb/s service cannot be provided ("picture freezing effect"). Threshold for bandwidth limitations acceptance was defined as 4 Mb/s according to received MOS results.

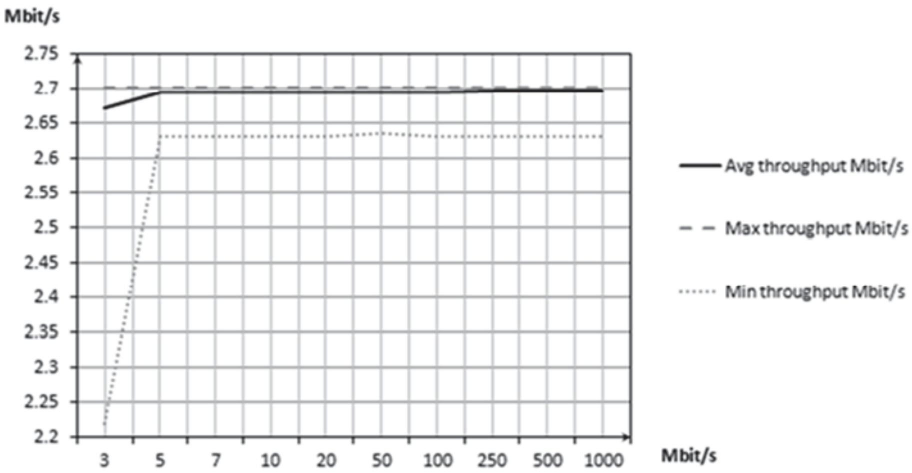

Fig. 3. MPEG TS stream – bandwidth modifications

Jitter (variability over time of the packet latency across a network)

Jitter parameter was modified by using MODTRAFNET application from 0 to 5 ms and average delay was set on 100 ms (Fig. 4). Measurements were carried out using ATPA analyzer. Tested measurements were: PCR jitter, MOS.

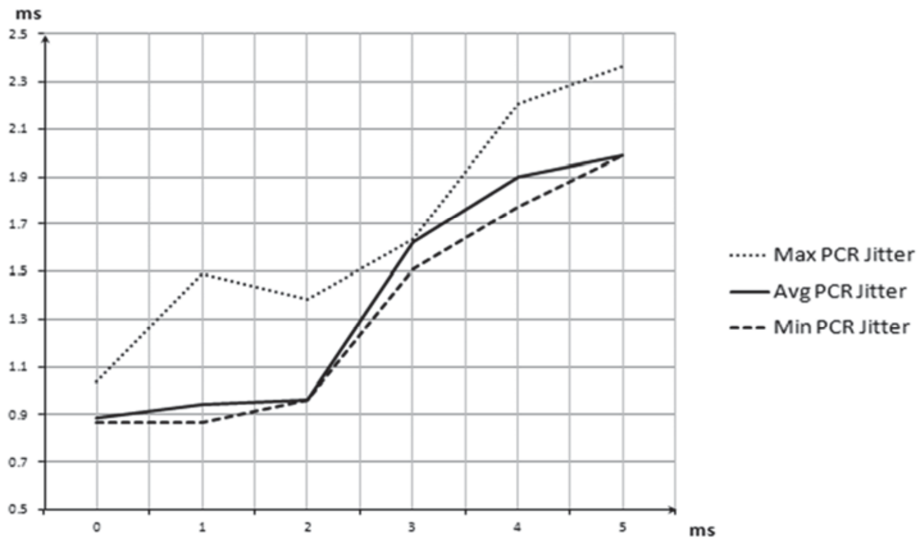

Fig. 4. PCR jitter – jitter modifications

Jitter has greater impact on the quality than the delay itself. Even a small values of this parameter can cause significant distortions at the video frame level what is related to problems with synchronization in the MPEG TS. The big value of jitter cannot be compensated by buffers and it causes a lot of distortions in the video. Above chart shows that jitter is related to PCR parameter which is associated with synchronization between sound and video in MPEG TS. Indeed huge jitter has negative impact on this synchronization by causing errors which are very difficult to detection. Very good quality of video can be obtained till 3ms and limit of acceptability is 2 ms then MOS is greater or equal 4.

Packet loss

Packet loss parameter was modified by using MODTRAFNET application from 0 to 5% (Fig. 5). Packet were lost random (uniform distribution) without any correlation. Measured parameters were MOS and losses in MPEG TS stream.

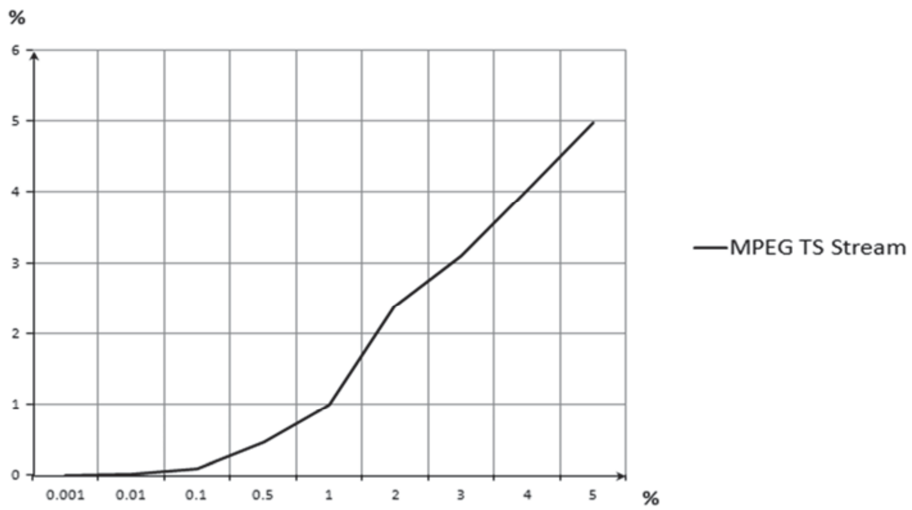

Fig. 5. MPEG TS packet loss – packet loss modifications

Packet loss in MPEG TS stream and general in the network traffic is comparable. Slight discrepancies are caused by additional packets f.e. related to network protocols SPT, IGMP etc. and also by various materials transmitted in the IPTV service (high and low motion sequences). Threshold of acceptability was defined as 0,1% of packet losses then MOS factor is still greater or equal 4.

Packet corrupt

Packet corrupt parameter was modified by using MODTRAFNET application from 0 to 5 %. Packet were corrupted random (uniform distribution) without any correlation same as in case of packet loss. Measured values were MOS and typical errors for MPEG TS such as: transport errors, sync byte errors, late PAT errors, PCR discontinuity errors.

Statistic of occurrence for these errors is presented in the chart below (Fig. 6):

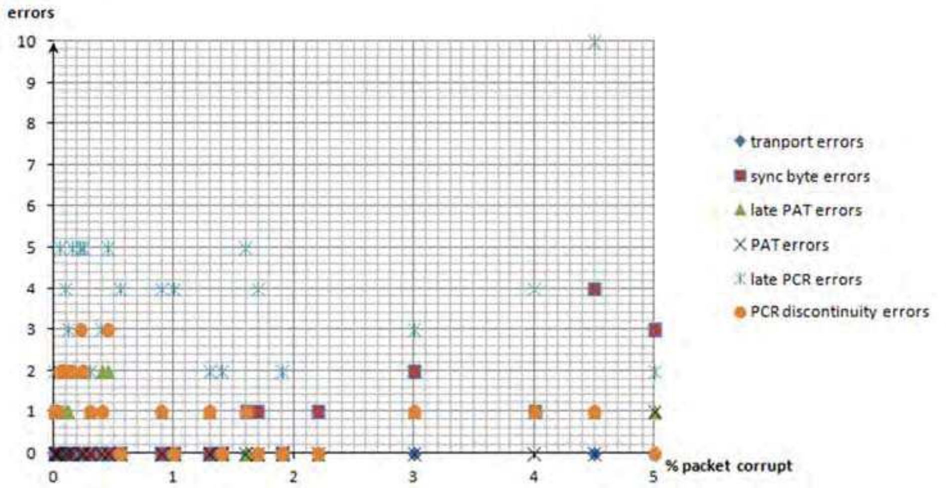

Fig. 6. MPEG TS packet corrupt – packet corrupt modifications

Errors are mainly random and the frequency of their occurrence depends on the length of the analyzed fields in MPEG TS stream (PES streams). For fields with larger length probability of damage is greater than for others f.e. "PCR" field is more frequently damaged than "Transport Error" field. The analysis of threshold acceptance for this parameter shows that 0,1% is acceptable value for packet corrupt, then MOS value is greater or equal 4.

7. PARAMETRIC MODEL ─ INTRODUCTION

In monitoring results presented in earlier sections the commercial parametric model implemented in TPA application was used. To verify if this model is correct for tested IPTV service authors created another model for standard quality measures: MOS, MSE. The main aim was to create parametric model for IPTV service which can show relationships between single network parameters and video signal quality.

8. TOOLS USED FOR PARAMETRIC MODEL CREATION

NETEM

NETEM is a network-simulator which provides Network Emulation functionality for testing protocols by emulating the properties of wide area network. Used version emulates the following changes:

- emulating delays determined by time value
- emulating jitter determined by average delay value and their variation
- emulating packet loss determined by percentage rate
- emulating packet reordering determined by delay value and by percentage values of changes.

In case of emulating modifications in network traffic it is possible to set percentage value of correlation, which determines relationships between the probability of occurrence particular modification in the next packet and current packet.

TBF linux application

TBF is a pure shaper and never schedules traffic. It is non-work-conserving and may throttle itself, although packets are available, to ensure that the configured rate is not exceeded. TBF can be described by the following parameters:

- limit (buffer),
- latency,
- MPU,
- burst,
- rate.

This tool is often used as bandwidth modifier for real-time applications.

MSU Video Qulity Measurement Tool

Application MSU Video Qulity Measurement Tool is a program for performing objective assessment. In set of available measures are : *MSE, PSNR, MSU* and *VQM.* Quality is determined by the comparison of input files, which can be in the following formats: *AVI, AVS, YUV* and *BMP*. MSU VQMT application has enhanced functionality such as: metric visualizations, saving particular frames from compared sequences etc. After finish of the process there is possible to determine the metric value by generating appropriate report in *.csv format.

MSU Perceptual Video Tool

MSU Perceptual Video is a tool for subjective video quality evaluation. With the use of this application it is possible to conduct subjective measurements with methods that are described in ITU – R BT.500 standard. Program can use 6 methods listed below:

- DSIS (*Double Stimulus Impairment Scale*),
- DSCQS (Double Stimulus Continuous Quality Scale) type 1 i 2,
- SCACJ (*Stimulus Comparison Adjectival Categorical Judgement*),
- EBU SAMVIQ (*Subjective Assessment Method for Video Quality evaluation*),
- MSUCQE (*MSU Continuous Quality Evaluation*).

Four of them are described in mentioned ITU recommendation. To perform tests it is necessary to create tasks (files with *.tsk extension). They consist of information about input files and comparison methods. After processing summary report can be generated (*.csv file).

VLC

(please refer to 4.)

9. TEST SYSTEM AND SAMPLES

Reference samples were extracted from IPTV television streams. Their duration was set on 10s. Samples were created to best present various content transmitted in video stream in IPTV service. They were extracted from the following SDTV channels: TVP1, TVP2, VoDInfo, am@zing. Limitation for the tests related to using only SDTV samples was caused by the fact that HDTV channels were encrypted by provider and it was not possible to decrypt them in VLC application.

Created reference samples with technical parameters are presented below (Fig. 7).

Fig. 7. Reference samples

Extracted from the stream reference probes (video signal fragments) had very good quality and subjective comparative tests with studio materials delivered by provider show that they are indistinguishable and that is why they could be used to generate test probes. For creating processed samples the following system was used (Fig. 8):

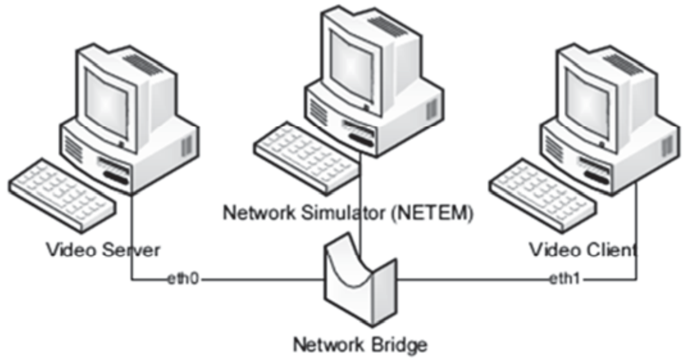

Fig. 8. Test system scheme

System consist of three computers. “Video Server” computer sent reference probes streamed in the network to “Video Client”. These probes in the next step were received and saved by “Video Client” creating new samples. Network traffic modification was performed by “Network Simulator” computer (it has two network interfaces which were connected by the network bridge). Modified parameters were: jitter, packet corrupt, packet loss and bandwidth. Generated from reference probes by appopriate modified network conditions probes were used as processed materials in subjective and objective quality tests.

10. TEST PROCEDURES

To determine parametric model for IPTV service using described in earlier sections reference and processed probes appropriate objective and subjective tests were performed. By analysis authors created dependencies which in the next step were used to create the model. In case of objective tests due to the nature of occurring changes it was chosen Mean Squared Error (MSE) and for subjective tests chosen metric was MOS in standard 5-stage scale. To measure these metrics authors used MSU Video Quality Measurement Tool and MSU Perceptual Video Tool for subjective tests (please refer to 7.). Subjective test were performed according to DSIS method. In the tests participated 20 people in different age groups (from 17 to 46). To increase the results reliability, they were trained about test procedures, used metrics, tools etc. In calculations of average value for MOS metric 95% was chosen. Received results and their analysis allow to determine dependencies between network parameters and chosen quality measures.

11. PARAMETRIC MODEL – JITTER

Jitter was modified by using NETEM tool. This parameter was changed from 0 to 5ms when average delay was set on 100 ms. Tested quality measures were: MSE for objective tests and MOS for subjective tests (Figs. 9, 10). Tests show that jitter has a significant impact on the perceived quality especially when application buffer is set on small value. In objective tests degradation level most increased when jitter value was greater than 2 ms. The most rushing declines in subjective tests was observed in the range of values from 1 ms to 2 ms. First visible distortions were observed at the value of 1ms. It was also noted that negative changes in video caused by jitter modification has greater influence on high motion sequences.

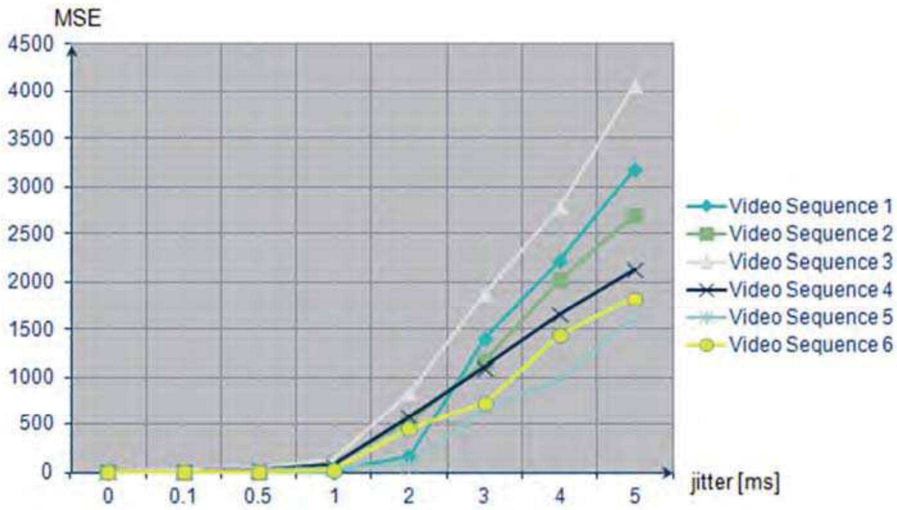

Fig. 9. Jitter – MSE

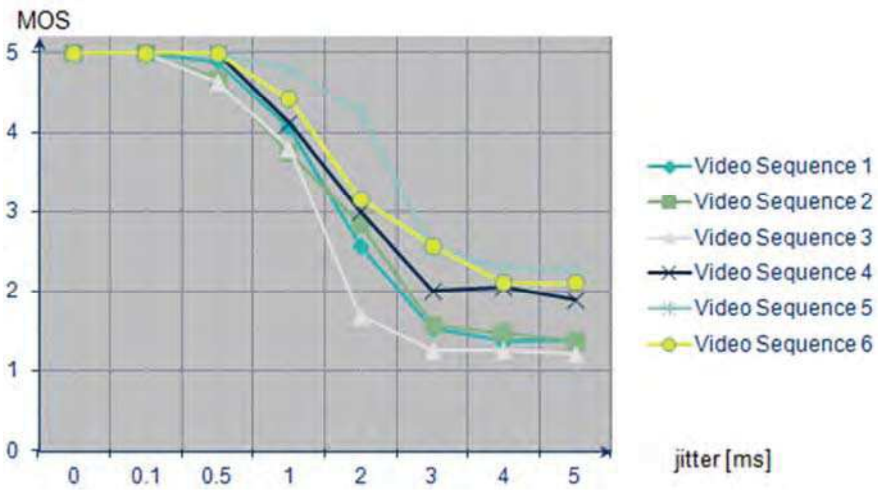

Fig. 10. Jitter – MOS

Dependencies for the worst case from presented in the charts above can be described by the following forms:

$$\boldsymbol{MSE} = 119{,}08 \cdot (jtr[ms])^2 + 239{,}5 \cdot jtr[ms] - 70{,}652 \qquad (1)$$

$$\boldsymbol{MOS} = 0{,}0243 \cdot (jtr[ms])^5 - 0{,}3598 \cdot (jtr[ms])^4 + 1{,}8791 \cdot (jtr[ms])^3 - 3{,}778 \cdot (jtr[ms])^2 + 0{,}9175 \cdot jtr[ms] + 4{,}9668 \qquad (2)$$

By analyzing the level of image degradation for delay variation it's possible to determine limiting value of this parameter above which degradations begin to have negative influence on the quality. For tested sequences the limit of acceptability for jitter is 1ms then MOS is greater or equal 4.

12. PARAMETRIC MODEL – PACKET LOSS

Percentage of packet loss was modified by using appropriate mechanisms of NETEM tool from 0% to 5%. Packets were lost random (uniform distribution) without correlation. The quality level was determined using Mean Squared Error metric for objective tests and MOS factor for subjective tests (Figs. 11, 12). Clearly more degraded were high motion sequences and less sensitive on changes in this parameter were slow motion sequences with small number of details. Additionally subjective tests showed that for the most sensitive sequence degradations are visible by users when level of packet loss is about 0,3%. The most common distortions are individual artifacts and blurring effects. For larger values of packet loss percentage it was possible to observe "freezing" effects in the playback picture. The negative effects intensified with the increase in the level of losses. Single, non-visible distortion, especially occurring in the background hasn't any negative impact on the subjective quality but long-lasting distortions cause customer irritation and in effect also low quality assessment.

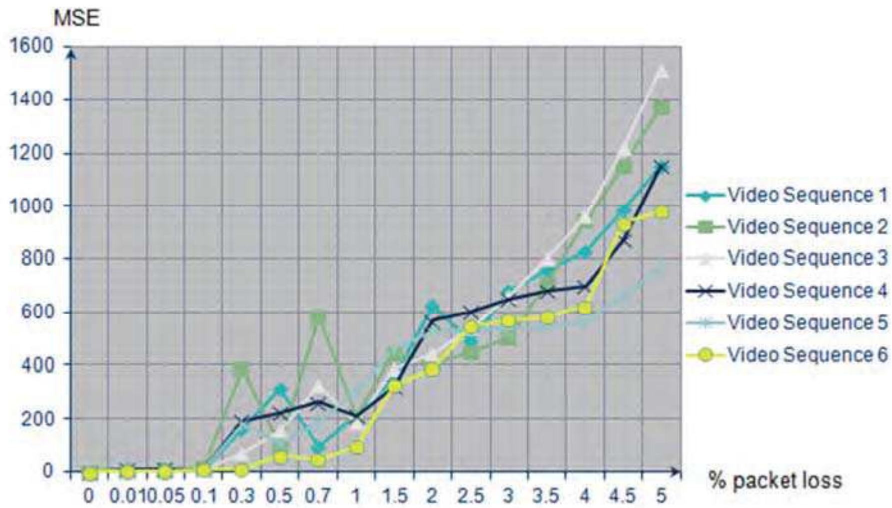

Fig. 11. Packet loss – MSE

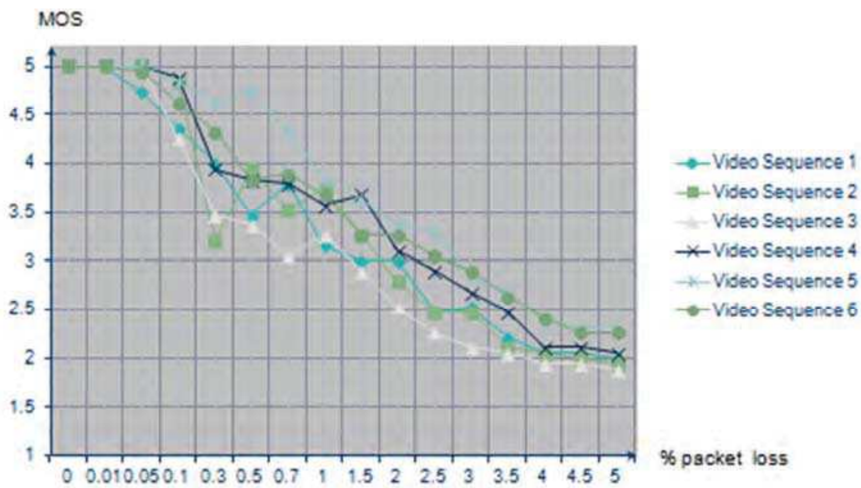

Fig. 12. Packet loss – MOS

Relationships for the worst case from tested can be described by the following forms:

$$\boldsymbol{MSE} = 13{,}657 \cdot (p\_loss[\%])^2 + 180{,}2 \cdot p\_loss[\%] - 124{,}96 \quad (3)$$

$$\boldsymbol{MOS} = 0{,}0132 \cdot (p\_loss[\%])^2 - 0{,}4485 \cdot p\_loss[\%] + 5{,}6634 \quad (4)$$

Analyzing received in objective and subjective tests values of quality measures and their dependencies allow to define acceptable level of packet loss. It was determined on the value of 1% packet loss.

13. PARAMETRIC MODEL – PACKET CORRUPT

Packet corrupt percentage value was modified from 0 to 5% (the same as in case of packet loss) by using appropriate mechanisms of NETEM application. Packet corrupt was performed by introducing bit distortion in the packet body. These distortions were creating random (uniform distribution) without any correlation. Measured metrics were: MSE for objective tests and MOS for subjective tests (Figs. 13, 14). The most detailed sequences were more sensitive to packet corrupt distortion than others. Less influenced in the tests were high motion sequences, however please note that these sequences were more degraded than low-motion probes. The nature of changes MSE for the next frames of particular sequence and its influence on the quality is similar to this received in packet loss tests. Here also level of degradation depends not only on amount of degraded data but also on their content. Errors in the "Intra" frames, even at lower amount of distortions may cause more degradations than for larger amount of destroyed data but when differential frames are damaged. It causes visible jumps of quality metric values in the charts. For the most sensitive sequences the first image distortions were visible for testers from 0.3% of distortions. Degradations, which mostly occurred are related to color bias, blurring and artifacts effect.

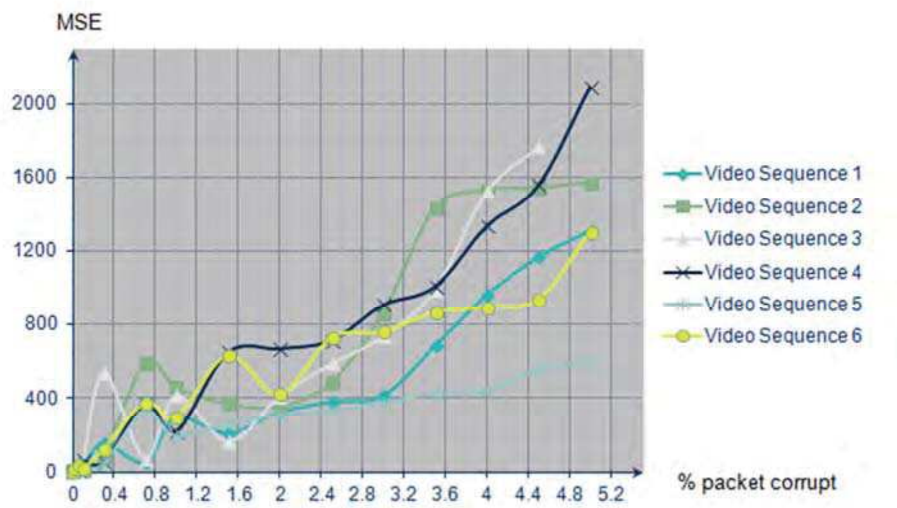

Fig. 13. Packet corrupt – MSE

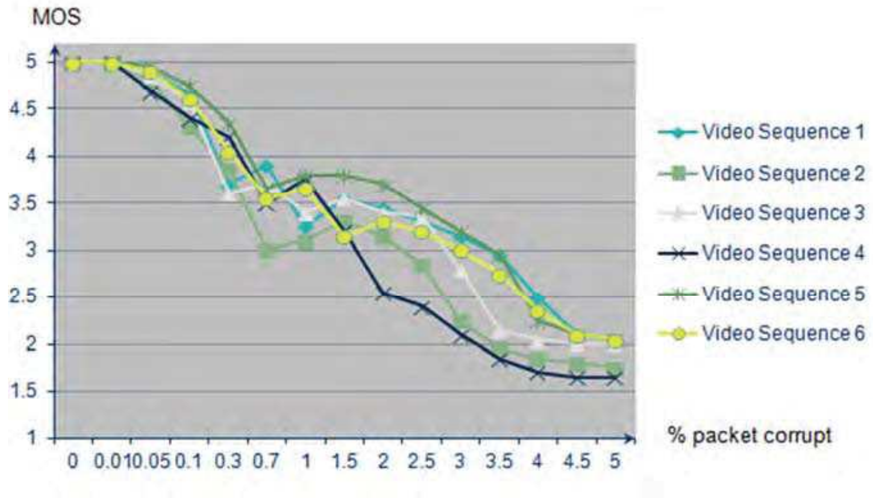

Fig. 14. Packet corrupt – MOS

Similar as in earlier examples received dependencies for all tested sequences were used to determine the worst case approximate functions, which can be described by using below forms:

$$\boldsymbol{MSE} = 30{,}046 \cdot (p\_corr[\%])^2 + 229{,}78 \cdot p\_corr[\%] - 38{,}37 \quad (5)$$

$$\boldsymbol{MOS} = -0{,}0001 \cdot (p\_corr[\%])^4 + 0{,}0043 \cdot (p\_corr[\%])^3 - 0{,}043 \cdot (p\_corr[\%])^2 - 0{,}1959 \cdot p\_corr[\%] + 5{,}3845 \quad (6)$$

Threshold for acceptance packet loss degradation was defined in test process as 0.1%.

14. PARAMETRIC MODEL – BANDWIDTH

Bandwidth was modified by using TBF mechanisms (Token Bucket Filter with shaper). This parameter was changed in depending on the sequence from value much more than maximum throughput of particular video sample to the value by which displaying cannot be performed. Chosen quality measures were: MSE for objective tests and MOS for subjective tests (Figs. 15, 16). Analysis shows that this parameter is critical for keeping quality on acceptable level. Limitations in value of this parameter have huge impact on quality degradation. Especially high-motion sequences are sensitive to negative effect caused by this parameter. Important was also maximum throughput. Distortions occurred due to TBF mechanisms were similar to those observed in large packet losing. Typical degradation when throughput value was insufficient for the service “picture freezing” occurred.

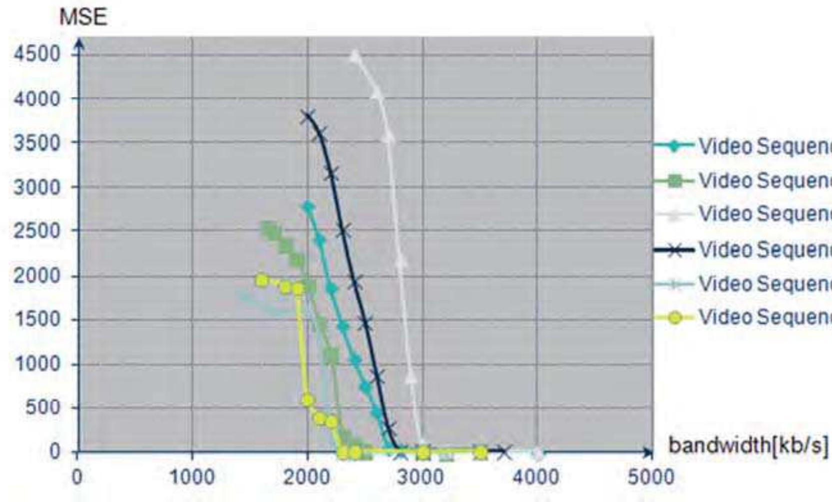

Fig. 15. Bandwidth – MSE

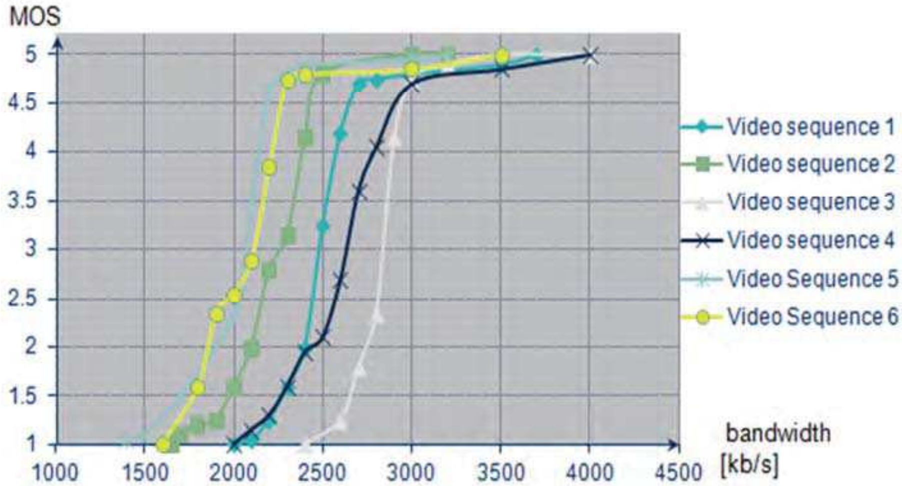

Fig. 16. Bandwidth – MOS

For all measured sequences the worst case can be described by the following forms:

$$\boldsymbol{MSE} = 1{,}74 \cdot 10^{54} \cdot (thrp[kb/s])^{-14{,}87} \quad (7)$$

$$\boldsymbol{MOS} = -3 \cdot 10^{-6} \cdot (thrp[kb/s])^2 + 0{,}0233 \cdot thrp[kb/s] - 37{,}171 \quad (8)$$

The analysis of the study threshold acceptance for this parameter shows that 3 Mb/s is acceptable bandwidth for IPTV service.

15. COMMON RELATIONSHIP – PROPOSED APPROACH

Presented test results show only dependencies between single network parameters such as: jitter, bandwidth, packet loss, packet corrupt and quality measures (MSE/MOS). To create common relationship between them it is needed to use statistics tools like analysis regression and correlation. Obviously it is necessary to have enough numbers of tests. After determining the correlation scatter plot between individual variables and quality measures it is needed to use correlation coefficient (chosen depending on data) to determine correlation. Then after finding relationships between variables it is needed to determine their nature. For this purpose it can be used graph of regression which is a statistical tool to determine the best-fit curve for set of points. This dependence should be determined for all combinations of network parameters and in effect it would be possible to define common relationship including dependencies between all network parameters and quality measures.

16. SUMMARY

Monitoring tests presented in this paper showed how network changes affect MPEG TS parameters and the quality - user satisfaction (MOS). Prepared parametric model is related only to single network parameters and it present dependencies between these parameters and quality measures for video signal in IPTV service. Additionaly, authors introduced the concept of co-determination the impact of all network parameters to the service. The work associated with the development of the parametric model for IPTV service will be continued. In results this model can be used in network planning processes and also in monitoring quality systems.

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PODEJŚCIE DO USŁUGI MONITOROWANIA QoS/QoE I PARAMETRYCZNY MODEL DLA IPTV

Streszczenie

Głównym celem artykułu jest przedstawienie podejścia do monitorowania QoS/QoE i tworzenia modeli parametrycznych dla usługi IPTV. System monitorowania został użyty do monitorowania on-line parametrów (TS) MPEG i subiektywnej oceny (MOS). Druga część pracy prezentuje model parametryczny dla usług IPTV, który opisuje relacje między poszczególnymi parametrami sieciowymi, takimi jak: jitter, utrata pakietów, pakiety uszkodzone i przepustowość oraz subiektywnych/obiektywnych miar jakości (MOS, MSE). Stworzony model pokazuje wpływ zmiany warunków sieciowych na postrzeganą jakość wideo dla różnych sekwencji wideo pochodzących ze strumienia IPTV. Praca przedstawia również metodologię badań i wyniki, które można wykorzystać do oszacowania postrzeganej jakości zmian związanych z modyfikacją poszczególnych parametrów sieciowych.

Słowa kluczowe: IPTV, jakość usług, jakość doświadczeń, sieci optyczne, model parametryczny, system monitoringu