Evaluation of the Quality of Experience for 3D Future Internet Multimedia

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Abstract — **Multimedia streams achieved unexpected penetration over wireless networks during the last few years. Provisioning of 3D video stream-based applications and 3D movies transferring – which are becoming significant contents of wireless network traffic – is a big challenge for Internet Service Providers (ISP). Very little empirical results are known about the user perceived quality of these kinds of services. In this paper, we attempt to tackle this challenge by carrying out a real network scenario where 3D multimedia streams are provided through a GPON-based transport network and customers' IEEE802.11n standard based Wi-Fi access is available for video delivery. 20 test cases were distinguished by video samples suffering various Quality of Service (QoS) degradations, Wi-Fi TX-Power changing and alteration between secure and not secure data transport. 90 human subjects took part in this investigation who evaluated perceived visual quality by Mean Opinion Score (MOS). QoE were also influenced by other factors like channel interference in Wi-Fi network, acceptance of 3D technology, and personal prior technical knowledge and experience of participants (Level of Comprehension, LoC). The goal was to investigate relationships between combinations of the previously mentioned service parameters and their effects on perceived quality. It was also examined how the available environmental information during measurement scenarios affected evaluator behavior.**

Keywords **— Quality of Experience, Quality of Service, Mean Opinion Score, Wi-Fi network, 3D multimedia services, subjective evaluation**

I. INTRODUCTION

The world of the Internet has approached a historic turning-point, where mobile platforms and applications are poised to replace the fixed host/server model that has dominated since its inception. Video streaming over the Internet is one of the most important applications and 3D video streaming is expected to become even more popular than 2D multimedia applications. Continuous feedback on perceived quality of streaming videos is likely to be a major determining factor in the success of future multimedia applications.

Recently standardized wireless systems like the latest IEEE802.11 standards, WiMAX or Third Generation Partnership Project (3GPP) Long Term Evaluation (LTE) enable transmission of multimedia data with high bandwidth requirements, but the nature of wireless technology (characteristics of the transmission channels) still brings up challenging issues for Internet Service Providers (ISP). Satisfaction of the customer needs more than mere network performance, classified by Quality of Service (QoS) parameters like delay, jitter, packet loss and throughput. The enhanced level of vision quality perceived by end users is also important, known as Quality of Experience (QoE).

The Future 3D Media Internet has generated a significant amount of research work recently, which should be designed to overcome current limitations of network architecture, involving content and service mobility, new forms of 3D content provisioning, etc. [1][2]. More research subjects focus on the close link between QoE and QoS [2][3][14][15] and the evaluation of stereoscopic images [4][5], but more investigations are needed for appropriate QoE provisioning in wireless networks. The assessment of QoE in multimedia services can be performed either by subjective or objective methodologies [6]. Subjective quality is the users' perception of service quality (ITU-T P.800) [7] which is in fact the most reliable method, but requires time, money, human observers and controlled test environments. Objective measurements can be performed in an intrusive or nonintrusive way. Full reference and reduced reference video quality measurements are both intrusive. Quality metrics such as Peak-Signal-to-Noise-Ratio (PSNR), SSIM (Structural Similarity Metric), Q value, VQM and PEVQ are full reference metrics. VQM and PEVQ are commercially used and are not publicly available [8].

First, we carried out experiments based on subjective evaluation of 3D video streams, where 50 participants observed QoE changes due to the degradation of QoS parameters. The results of this experiment are published in [1]. We followed up on our experiments with more subjective quality tests focusing on throughput degradation by bandwidth limitation [9].

This contribution is publishing a few results of subjective tests with full-reference method carried out by 90 participants focusing on describing the relationship between QoE and QoS degradation, combined with Wi-Fi TX-Power alteration for

3D contents delivery in a real home network scenario, where the network was a representative combination of a GPON-based transport network and IEEE802.11n standard based Wi-Fi access at customer side. Since privacy and authenticity are frequent requirements in video streaming, some measurements were made with secure HTTP live video streaming traffic based on OpenVPN tunnel with same conditions like in case without protection, investigating and comparing both results.

Our work also includes studies on the link between subjective QoE measurement results and environmental information available to the evaluator. Expectations may indeed influence evaluation [17], so we intended to extend our investigation with this understudied topic. We analyzed the possible distortion phenomena through Level of Comprehension (LoC) [16], since prior technical knowledge and experience determines the usage of the available information.

The paper is structured as follows. In Section II the network environment is explained. Section III describes the method of the performed measurements. Section IV discusses results. Finally, the paper is concluded by Section V.

II. THE NETWORK ENVIRONMENT

The appropriate test network topology (Fig. 1) was planned and realized based on GPON transport network which was efficient with 2.5 Gbit/s download speed and 1.5 Gbit/s upload speed [10] via broadband and responsible to provide access to a Linux OS video server with 3D multimedia streams on the service provider side. The HTTP output was generated by VLC v1.1.3 program on the video server. The MS Windows OS based client on the customer side through the Wi-Fi Access Point (ASUS WL-500W) delivered HTTP live video streaming. Videos were displayed on Nvidia Vision Player v1.7.5.

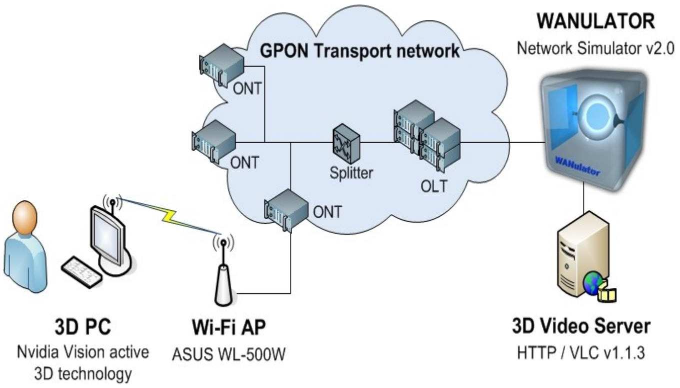

Fig. 1. Network topology of the experiment

WANulator simulated different network QoS conditions, such as jitter, packet loss and bandwidth limitation. The TX-Power value was set directly on the Wi-Fi Access Point. The hardware configuration of the server and the client are shown in TABLE I. The Wi-Fi transport was monitored by CommView program.

TABLE I. HW CONFIGURATION OF THE SERVER AND CLIENT

SERVER	**IntelCore 2Duo, 2.13GHz, 1GB RAM**
CLIENT	**IntelCore 2Quad, Q8300, 2.5GHz, 4GB RAM, NVIDIA GeFOrce GT 240 Video-card**

III. METHOD OF MEASUREMENTS

Band-limited unreliable communication channels can introduce artifacts on the transmitted 3D content, but QoE of 3D video applications can be influenced by several other factors, such as human factors (e.g. prior technical knowledge, acceptance of 3D technology), system factors (e.g. network related, like delay, jitter, packet loss or throughput), device related (e.g. display size and resolution), media related (e.g. video resolution, encoding, frame rate) and so on. Overall 3D quality degradation is the sum of 2D image degradation plus the perception of depth [11].

We aimed to acquire some information regarding these specific factors from participants being in the age range from 18 to 38. They had to fulfill queries gathering information on name, age, gender, being spectacled or not, and existence of prior 3D movie experience. Information on their acceptance of 3D technology was provided by scoring with integers in the range of 1 to 10.

TABLE II. FEATURES OF THE INVESTIGATED 3D VIDEO

Video codec	**Frame size**	**Video bit rate**	**Video frame rate**	**Audio codec**	**Audio bit rate**
XviD (MPEG-4)	3360x1050	8000Kb/s	30 fps	MP3	128Kb/s

Full reference based subjective QoE test was carried out. Participants, 90 persons (77 men, 13 women, 38 wearing glasses, with the average age of 23.5) watched a short part (approximately 1 minute) of the 3D stereoscopic Coyote Falls animated movie, features of which are shown in TABLE II. They had to evaluate the following aspects (questions) focusing on the empirical quality of the video for 20 test cases (see TABLE III).

Q1: Rate the continuity of the video content.
Q2: Rate the image quality.
Q3: Rate the 3D experience.
Q4: Rate the synchronization of audio/video content.
Q5: Rate the overall experience.

At first, participants watched the reference test case, where video was transported without any QoS parameter degradation or limitation, with default Wi-Fi TX-Power (71mW) and with the lack of secure data transport. The reference test case was not a subject of evaluation tasks at this point of the measurement, however, it was included in the series of test cases (see TABLE III). After this, they were split up into two groups: Group A and Group B. The video evaluation tasks of Group A (56 persons) were “blind tests”, which means that the participants did not have any information regarding the parameters of the test cases. The members of Group B (34 persons) were aware of all the test case parameters in form of a parameter matrix (see TABLE III). As mentioned earlier, we also aim to investigate the possible distortions phenomena based on environmental information; this section of our study shall focus on the results of Group B.

The test users scored the videos of the 20 test cases (TC) via a 10-point quantitative discrete scale, where 10 represented the quality of the reference test case and 1 was the lowest score for evaluation. A 10-point scale allows more detailed and precise quality assessment compared the 5-point ACR scale, by providing evaluation space for lesser differences in perceived quality; even though 5-point ACR scales are considered to be the most commonly utilized method of assessment.

TABLE III. TEST CASES OF THE MEASUREMENT

Test case	Security (Y/N)	TX Power [mW]	Jitter [ms]	Packet loss [%]	Bandwidth lim. (Y/N)
1	N	71	30	0	N
2	N	71	0	1	N
3	N	71	60	1	N
4	N	71	30	1	N
5	N	71	60	0	N
6	N	71	30	0	Y
7	N	71	60	2	N
8	N	71	0	2	N
9	N	71	0	0	N
10	N	71	30	2	N
11	N	71	60	0	Y
12	N	71	0	0	Y
13	Y	71	0	0	N
14	Y	71	30	1	N
15	Y	71	60	2	N
16	Y	71	0	0	Y
17	N	35	0	0	N
18	N	35	30	1	N
19	N	251	0	0	N
20	N	251	30	1	N

IV. RESULTS

Gathered information was split up by the investigation aspects to 4 groups (see TABLE IV). Results were statistically analyzed according to the following main groups of approaches:

- **Group 1**: How does the presence of secure data transport affect QoE results?
- **Group 2**: How does the alteration of Wi-Fi TX-Power affect QoE results?
- **Group 3**: How does additional jitter and packet loss affect QoE results?
- **Group 4**: How does the throughput degradation by imperceptible bandwidth limitation affect QoE results?

The main focus was on the impact of Security and TX-Power value changing to QoE measurement results, since the aspects of Group 3 and 4 were already deeply investigated in above mentioned contributions [1][9]. Comparisons were applied to both groups of participants with the purpose of observing relationships between the results of the two groups.

TABLE IV. GROUPED TEST CASES OF THE MEASUREMENT

G	Aspect of Investigation	Test cases	Other parameters
1	**Security** (No – Yes)	9-13	TX-P=71mW;BW.lim=NO;Jitter=0ms;PL=0%
		4-14	TX-P=71mW;BW.lim=NO;Jitter=30ms;PL=1%
		7-15	TX-P=71mW;BW.lim=NO;Jitter=60ms;PL=2%
		12-16	TX-P=71mW;BW.lim=YES;Jitter=0ms;PL=0%
2	**TX-Power** (71,35,251mW)	9-17-19	Sec=NO;BW.lim=NO; Jitter=0ms; PL=0%
		4-18-20	Sec=NO;BW.lim=NO; Jitter=30ms; PL=1%
3	**Jitter** (0, 30, 60ms)	9-1-5	TX-P=71mW;Sec=NO; BW.lim=NO; PL=0%
		2-4-3	TX-P=71mW;Sec=NO; BW.lim=NO; PL=1%
		8-10-7	TX-P=71mW;Sec=NO; BW.lim=NO; PL=2%
		12-6-11	TX-P=71mW;Sec=NO; BW.lim=YES;PL=0%
4	**Bandwidth limitation** (No – Yes)	5-11	TX-P=71mW;Sec=NO; Jitter=60ms; PL=0%
		1-6	TX-P=71mW;Sec=NO; Jitter=30ms; PL=0%
		9-12	TX-P=71mW;Sec=NO; Jitter=0ms; PL=0%

As it has been stated earlier, the reference test case, which was defined to be 10 on a scale of 10, was included in the measurement (see test case 9 in TABLE V). It is exciting to see how it obtained 8.64 in case of Group A, and even though participants of Group B were aware of test case parameters, they assessed it with a mean score of 9.24.

A. Security Aspect

The investigation of Group A was based on the security presence during the HTTP live video streaming. In secure cases (Security=1) OpenVPN secure tunnel was built through the single UDP port between the video server and the client – certificate with signature algorithm SHA1 with RSA Encryption, with RSA Public key 1024 bit and RSA Private Key 825 byte. Appropriate test cases with mean QoE results are shown in TABLE V.

TABLE V. MEAN QOE VALUES FOR SECURITY ASPECT TEST CASES

Test case	Security (No–Yes)	Other parameters	Mean QoE of Group A	Mean QoE of Group B
9	No	TX-P=71mW;BW.lim=NO;	8.64	9.24
13	Yes	Jitter=0ms;PL=0%	7.87	8.58
4	No	TX-P=71mW;BW.lim=NO;	3.87	4.84
14	Yes	Jitter=30ms;PL=1%	3.66	4.26
7	No	TX-P=71mW;BW.lim=NO;	1.79	1.80
15	Yes	Jitter=60ms;PL=2%	1.57	1.60
12	No	TX-P=71mW;BW.lim=YES;	7.91	8.30
16	Yes	Jitter=0ms;PL=0%	7.19	7.79

We can obtain interesting conclusions based on these results. People who were not aware of parameter values evaluated samples more rigorously, but all results can be considered irrelevantly different in groups (0.90 Confidence Intervals are overlapping) and secure transmission had only a small impact to the perceptible quality.

In the best case (without any QoS degradation) the third question (Q3) – the 3D experience – achieved the lowest scores due to the rather low mean value (5.82 from 10) of the participants' opinion on 3D technology. This is caused by the 3D visualization itself; presence of depth leads to visual fatigue and eyes strain, which prevents users from watching 3D content for a long time. This directly affects users' perception and QoE. It needs to be noted that the evaluation of a single participant was removed from the final set of results (originally 91 participants) due to the inability to watch the selected 3D content. Although the measurement was completed and every aspect of every test case was evaluated, the given scores were usually 1.

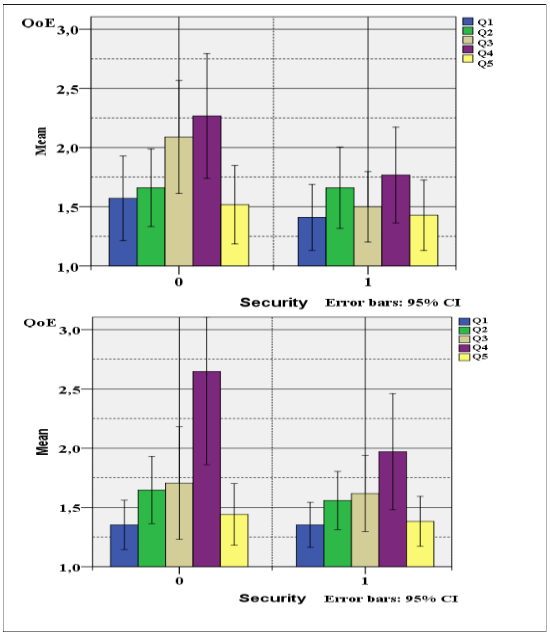

Fig. 2. The worst TC 7-15 (TX-P=71mW;Jitter=60ms; PL=2%). Group A results above and Group B results below

The worst test case evaluation results of Group A and B are demonstrated by Fig. 2. Here neither audio nor video was enjoyable. Overlapping got more serious and some scenes were frozen during streaming with video shifting downwards.

In case of Group B, transmission received slightly lower scores, but still 0.90 Confidence Intervals were overlapping. When we compare the best TC and the worst TC by individual aspects (Q1-Q5), we find some differences in the distortion phenomenon. In case of continuous video streaming, 3D experience was evaluated with the lowest value due to some human aspects which were explained above. However, during the worst case, where some scenes were frozen and video was shifting downwards, the aspect of continuity (Q1) and the overall quality (Q5) were evaluated with the lowest scores. In case of QoS degradation, continuity was the most relevant feature. Security had only an irrelevant impact to the perceptible quality.

B. *Wi-Fi TX-Power Aspect*

Another important issue is the impact of Wi-Fi characteristics to QoE measurement results. Our investigation was focusing on the IEEE 802.11n standard based 2.4 GHz band communication Wi-Fi TX-Power changing, while other parameter values were not directly modified during the tests. Distance between the AP and PC client was fixed 4m during the entire measurement.

CommView for Wi-Fi monitoring was used for gathering and analyzing network packets of wireless 802.11n network. Channel 9 was solely used for video streaming; it was not used for any other communication, since any communication on channel 7 and 11 could have influenced channel 9 data carrying. Channel 7 was not monitored due to the lack of traffic. Measurements were carried out by the AP default TX-Power (71mW) and minimum (35mW) and maximum (251mW) values of the AP setting. TABLE VI shows calculated mean QoE by the gathered participants rating.

TABLE VI. MEAN QOE VALUES FOR TX-POWER ASPECT TEST CASES

Test case	**TX-Power [mW]**	**Other parameters**	**Mean QoE of Group A**	**Mean QoE of Group B**
17	35	Sec=NO;BW.lim=NO; Jitter=0ms;PL=0%	8.13	8.70
9	71		8.64	9.24
19	251		8.46	9.04
18	35	Sec=NO;BW.lim=NO; Jitter=30ms;PL=1%	4.19	4.54
4	71		3.87	4.84
20	251		4.53	5.05

Analysis of gathered information by the CommView on channel 9 and 11 shows low CRC error (only 0.014% of the traffic) and packets' repeating occurs only when packet loss value were increased.

The Wi-Fi transmit characteristics did not change relevantly due to the TX-Power value alteration (see TABLE VII). This can be explained by the fixed small distance (4m) between the Wi-Fi AP and the customer PC.

TABLE VII. WI-FI CHARACTERISTICS OF TX-POWER ALTERATION

TX-Power [mW]	**Signal [dBm]**	**Noise [dBm]**	**SNR**	**Signal Quality**
35	-39	-86	47	68%
	-40	-84	44	66%
71	-39	-81	42	68%
	-40	-91	51	66%
251	-39	-85	46	68%
	-40	-86	46	66%

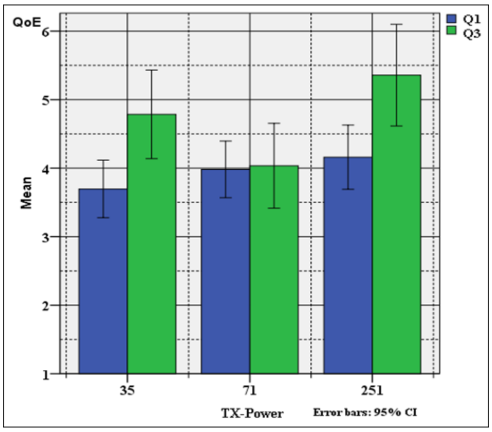

Fig. 3. TC 18-4-20 by TX-Power aspect

Based on the values of TABLE VII and the small fixed distance (4m), the calculated Wi-Fi transmit attenuation varied between 50 and 60dB, which did not reduce the signal quality, even in case of minimum 35mW TX-Power, due to the low noise and short distance between the AP and client PC.

Figure 3 shows mean QoE values of TC with TX-Power changing of Group A for Q1 (video continuity) and Q3 (3D experience) aspects. The continuity was more important than the 3D experience with presence of QoS degradation (Jitter=30ms, PL=1%), but TX-Power alteration did not affect their evaluation since 0.95 Confidence Intervals are overlapping.

C. *Jitter Aspect and Bandwidth limitaiton Aspect*

QoE was influenced by the degradation of QoS parameter values, which caused spectacular continuity degradation of the HTTP live video stream. Bandwidth limitation was calculated on the average bandwidth demand of the 3D video stream and only the spine values were cut down by the limitation, which affected only the highest motion level scene at the end of the video, hence the QoE was not affected relevantly.

TABLE VIII. MEAN QOE VALUES FOR JITTER ASPECT TEST CASES

Test case	**Jitter [ms]**	**Other parameters**	**Mean QoE of Group A**	**Mean QoE of Group B**
9	0	Sec=N; TX-P=71mW;	8.64	9.24
1	30	BW.lim=NO;	8.57	8.61
5	60	PL=0%	7.49	8.08
2	0	Sec=N; TX-P=71mW;	8.51	8.68
4	30	BW.lim=NO;	3.87	4.84
3	60	PL=1%	1.93	2.71
8	0	Sec=N; TX-P=71mW;	7.91	8.02
1	30	BW.lim=NO;	2.45	3.14
7	60	PL=2%	1.80	1.80
12	0	Sec=N; TX-P=71mW;	7.91	8.31
6	30	BW.lim=YES;	7.72	8.02
11	60	PL=0%	6.29	7.02

TABLE IX. MEAN QOE VALUES FOR BW.LIM ASPECT TEST CASES

Test case	**BW.lim** (No–Yes)	**Other parameters**	**Mean QoE of Group A**	**Mean QoE of Group B**
9	No	TX-P=71mW; Sec=NO;	8.64	9.23
12	Yes	Jitter=0ms;PL=0%	7.91	8.31
1	No	TX-P=71mW; Sec=NO;	8.57	8.61
6	Yes	Jitter=30ms;PL=1%	7.72	8.02
5	No	TX-P=71mW; Sec=NO;	7.49	8.08
11	Yes	Jitter=60ms;PL=2%	6.29	7.02

Relationship between QoE and network QoS parameters is known and because the investigation of QoE-QoS relationship in case of 3D stereoscopic video was already explained in [1] and [9], we do not put this issue in perspective now, only publish the results of evaluation for jitter aspect (see TABLE VIII) and bandwidth limitation aspect (see TABLE IX).

D. *Analysis based on Level of Comprehension*

As mentioned earlier, mean evaluation results of the two groups of participants showed no major difference. That could easily imply that the awareness of environmental information caused no significant alteration of evaluation. Before jumping to such conclusions, let us examine the matter at hand from a different point of view.

By dividing the participants of Group B into subclasses, based on their prior technical knowledge and experience, we shall see how the environmental information affected each level of LoC separately. For this purpose, we distinguished three different levels (−1, 0 and +1), where the higher number denotes a higher level. Matching participants with their most relevant LoC levels was performed by recorded conversations, in which a set of questions related to the background of the concerned technologies and solutions was asked. In the final result set, the group consisted of 34 participants, due to the exclusion of the previously mentioned test subject. The evaluation scores of 11 participants represent level −1 and +1, and level 0 is represented by 12.

Test cases regarding the alteration of TX-Power, jitter and bandwidth limitation generally present similar relations compared to the mean results in case of all three LoC levels. The word *limitation* commonly depicted a negative effect on the experienced quality, resulting according evaluation. However, certain participants belonging to level 0 and −1 scored in the opposite direction, since some of them thought that bandwidth is a parameter similar to jitter and packet loss in effect, thus the limitation of such parameter should be advantageous. An interesting idea regarding TX-Power was that it is similar to sound volume in some manners; too high is just as unfavourable as too low. There were a few of course who deemed TW-Power to be prejudicial, but their evaluation did not have a weighty effect on the mean score.

The most interesting and noteworthy outcome of separation based on LoC is obviously the set of results regarding security presence (see Figure 6). As we have witnessed in the mean evaluation performed by Group A, secure transmission received slightly lower scores compared to the unprotected counterparts. However, unlike the other parameters presented in this section, the ideas regarding security diverged much more; the total magnitude of opposing evaluation was high enough to invert relations on the echelon of mean results.

The majority of LoC level −1 and some of level 0 were influenced by the notion that the presence of security shall enable a higher level of service quality through its protective nature. Yet there were indeed barely noticeable differences in favour of the unprotected test cases. The participants of all three LoC levels experienced the same audiovisual quality; still the direction of evaluation is clearly the opposite.

The occurrence of this distortion phenomenon was made possible by the socio-psychological theory of cognitive dissonance [12]. Its purpose is to eliminate dissonant states of cognitions. The two conflicting cognitions involved in this case are perception (what the user actually experiences) and preconception (prior expectations towards quality). On one hand, perception describes unprotected test cases to be slightly better, but on the other hand, preconception suggests that those should provide a lower level of quality compared to what secured test cases have to offer, due to the lack of security. While perception is considered to be rather objective, preconception is much more subjective and personal, since expectation itself is a mental product. Dissonance reduction gives preference to personal cognitions, so in this case it is favourable to support preconceptions. Post-decision dissonance also played a role in forming these results. In order to justify previously upheld preconceptions and to maintain consistency among decisions, evaluators tend to get attached to preconceptions once supported.

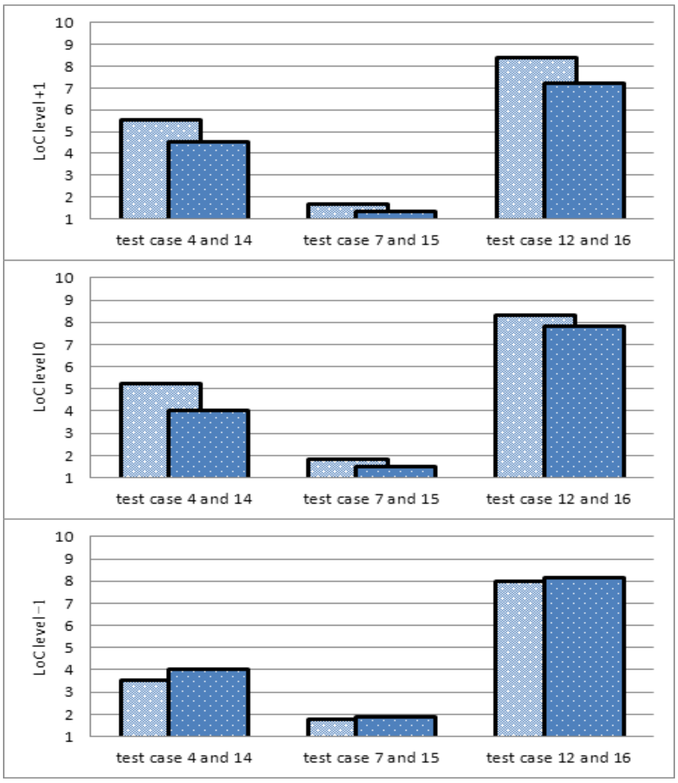

Fig. 4. Evaluation of security test case pairs, separated by LoC (dark blue bars represent secure test cases and their counterparts are in light blue)

It also needs to be noted that the evaluation of participants belonging to LoC level +1 is distorted as well to some extent. In their case, the common idea regarding security presence was the extra resources required to implement secure transmission, which should decrease performance. This can easily alter barely noticeable differences to become clearly noticeable, resulting greater differences in scores.

V. CONCLUSION

The paper has given a detailed insight into the relationship between user experience and specific network parameters. QoE was affected only irrelevantly by the presence of security during transmission, but its combination with the degradation of QoS parameters – like jitter and packet loss – spectacularly deteriorated continuity and 3D experience. It was proven that power efficiency can be achieved without notable degradation of service performance; default transmission power in home and small office networks is not required to maintain acceptable quality, given that no other channel interferes.

It has also been presented how cognitive dissonance played a role during evaluation. Preconceptions based on information regarding the given service were compelling enough to have their evident effect on the mean scores of specific participants, distinguished by Level of Comprehension.

REFERENCES

[1] Kulik I., Trinh T.A. „Investigation of Quality of Experience for 3D Streams in GPON" In. Ralf Lehnert (Ed.) EUNICE 2011. LNCS, vol. 6955, pp.157 – 168 Springer, Heidelberg (2011)

[2] Casas P., Belzarena P., Vaton S. „End-2-End Evaluation of IP Multimedia Services, a User Perceived Quality of Service Approach" 18-th ITC Specialist Seminar of Quality of Experience, Karlskrona, Sweden, May 2008. pp. 13-23

[3] Fiedler M., Hossfeld T., Phuoc Tran-Gia „A Generic Quantitative Relationship between Quality of Experience and Quality of Service" IEEE Network, March/April 2010, Volume 24, Issue 2, pp. 36 – 41

[4] Mrak M., Grgic M., Kunt M. High-Quality of Visual Experience, Chapter 3. You J., Xing L., Perkis A. „Quality of Visual Experience for 3D Presentation – Stereoscopic Image" Signals and Communication technology, 2010, I, pp. 51-77

[5] Xing L., You J., Ebrahimi T., Perkis A. „Estimating Quality of Experience on Stereoscopic Images" ISPACS 2010 – International Symposium on Intelligent Signal Processing and Communication Systems, Chengdu, December 2010

[6] Zahariadis T., Daras P., Laso-Ballesteros I. „Towards Future 3D Media Internet" Network & Electronic Media – Summit, St. Malo France, October 2008.

[7] International Telecommunication Union. *Methods for subjective determination of transmission quality*. ITU Recommendation P.800 (08/96), August 1996.

[8] F.Kuipers, R. Kooij, D. Vleeschauwer, K. Brunnstörm. „Techniques for Measuring Quality of Experience" Wired/Wireless Internet Communications, 8th International Conference, WWIC 2010, Luleå, Sweden, June 1-3, 2010. Proceedings, pp 216 – 227

[9] Kulik I., Trinh T.A. „Evaluation of the Quality of Experience for 3D Future Internet Multimedia" Acta Polytechnica Hungarica – Journal of Applied Sciences, Volume 10, Issue Number 1, 2013, pp 25 – 42

[10] Cale I., Salihovic A., Ivekovic M. „Gigabit Passive Network – GPON" ITI 2007 – International Conference on Information Technology Interfaces, Cavtat, Croatia, June 2007, pp. 679 - 684

[11] Chaminda T.E.R Hewage, Maria G. Martini „Quality of Experinece for 3D Video Streaming" IEEE Communications Magazine, May 2013, Volume 51, Number 5, pp. 101 – 107

[12] L. Festinger. *A theory of cognitive dissonance*. Stanford, CA: Stanford University Press, 1957.

[13] A. Sackl, P. Zwickl, S. Egger, P. Reichl. The role of cognitive dissonance for QoE evaluation of multimedia services. 2012 IEEE Globecom Workshops (GC Wkshps), pp. 1352–1356

[14] S. Khirman and P. Henriksen, "Relationship between Quality-of-Service and Quality-of-Experience for Public Internet Service," 3rd Passive Active Measurement Wksp., Fort Collins, CO, Mar. 2002.

[15] Rugel S., Knoll T.M., Eckert M., Bauschert T. „A Network-based method for measuring of internet video streaming quality" 1st European Teletraffic Seminar, Poznan, Polland, February 2011

[16] P. A. Kara, L. Bokor, S. Imre. Distortions in QoE measurements of ubiquitous mobile video services caused by the preconceptions of test subjects. In: IEEE/IPSJ International Symposium on Applications and the Internet SAINT2012. Izmir, Turkey, 2012.07.16-2012.07.20. IEEE, pp. 409–413.

[17] A. Sackl, K. Masuch, S. Egger, R. Schatz. Wireless vs. wireline shootout: How user expectations influence quality of experience. 2012 Fourth International Workshop on Quality of Multimedia Experience (QoMEX), pp. 148–149.