Service Quality Modeling

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***Abstract*— The paper presents the selected issues of service quality modeling. The author presents a classification of the main phenomena connected with quality from both the provider's and the user's point of view. It is underlined that service quality will be one of the main issues of next generation networks, like 5G, where the user's perspective will be of a great importance. The main contribution of the paper is the presentation of the method of building the Quality of Experience (QoE) models, based on two popular services, i.e., messaging and web browsing. The author emphasizes that some existing QoE models based on average values do not reflect users' expectations and there is a need for building new, more sophisticated models, which take into account more parameters and also their transient behaviors.**

Keywords-Service quality; QoS; QoE; quality model.

I. INTRODUCTION

The rapid development of current Information and Communication Technologies (ICT) applies not only to the improving of the telecommunication networks infrastructure, but also to the service provision process.

For the last several years, service quality has become more and more important.

The term 'quality', as defined in an International Standards Organization (ISO) document [1], means 'the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs'. Based on this, the International Telecommunication Union (ITU) formulated the definition of Quality of Service (QoS), as 'the collective effect of service performances that determine the degree of satisfaction of a user of the service' [2].

For many years, a major effort was concentrated on ensuring a high level of network performance parameters. Thus, the operator was perceived as the main subject responsible for the quality of services provided to the users. Such an approach was often justified, because the network operator (NO) played the role of the service provider (SP), and was therefore the main actor in the service delivery chain.

Nowadays, in most cases, these two roles are separated. Moreover, users connect to the services via networks, which are managed by many different NOs.

Figure 1 presents different viewpoints on service quality, taking into account the relationships between the end-user (customer) and the service provider; it is based on a

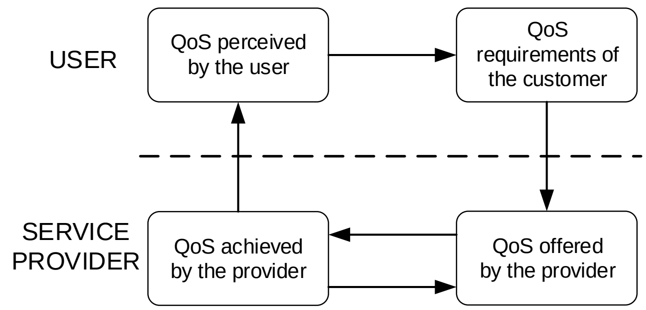

Figure 1. Different viewpoints of QoS [3].

QoS framework presented by ITU-T in G.1000 Recommendation [3]. A very similar approach can be found in [4].

The upper part of the Figure 1 presents the user's point of view on the QoS, while the bottom part shows the problem from the provider's perspective. Every user has his own requirements concerning the specific service. These requirements are manifested to the provider and may be expressed in non-technical language. The customers are not usually familiar with the technical specifications of the service and they are not concerned with how the services are provided. Instead of the technical aspects of the design of the network, users are concerned with the final result, i.e., end-to-end (e2e) service quality. Service quality, as seen by the user, focuses on user-perceived effects and does not take any assumptions about the internal design of the network or performance indicators. The user's needs are described in network-independent terms using a common language, which is understandable by both the user and the service provider. The QoS offered by the SP is a statement of the level of quality that is expected to be offered to the customer [3]. It is expressed by the values assigned to QoS parameters. Each service should be described by its own set of parameters. The principal use of such a form of QoS is for network and Service Level Agreements (SLAs) planning. It is often defined in a statistical manner where the average, minimum and maximum values of the parameters play an important role.

It is also very important for the service provider to achieve the same level of quality that was previously offered. Moreover, the most important is the QoS perceived by the users. The quality here is often expressed in terms of degrees of satisfaction, which are usually not technical terms. It is assessed by customer surveys and from their own comments

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on levels of service. Perceived QoS can be used by the service provider to determine the customer satisfaction of service quality. A high level of the quality perceived by the user influences his expectations for the future. It usually causes an increase in user demands addressed to the SP.

The rest of this paper is organized as follows. In Section 2, the author presents a more detailed classification of the service quality approaches and also the main objective and subjective factors which influence the quality experienced by users. Section 3, presents the main factors that really concern users in the scope of QoE. It shows which factors are the most important for the average user and they are then taken into account during the quality assessment. It gives information about the important parameters that should be primarily measured and controlled. Section 4, discusses the problem of building the QoE models and presents some results. At the end, in Section 5, the author summarizes the whole work and presents some challenging problems that should be solved in order to improve the service QoE modeling process.

II. QUALITY

In [5], a general model of the QoS was presented. The author distinguishes three dimensions of quality. The first one is called '*Intrinsic QoS*', which relates to its technical characteristics and is determined by the design of the transport network design and the provisioning of network access, terminations and connections. The required quality can be achieved by, among others, the appropriate selection of transport protocols and QoS assurance mechanisms. The intrinsic QoS rating cannot be influenced by user perception. The second dimension of the quality is that of perceived QoS, which reflects the user's (customer's) experience of using a service. It is influenced by his expectations when compared to observed service performance. These expectations are usually affected by the user's experience with a similar telecommunications service, and also other customers' opinions. It can be seen that different users may have their own expectations of the service and the same intrinsic quality may not guarantee the same level of user satisfaction [6].

Figure 2 shows the general QoS model according to ITU/ETSI and IETF approaches [6].

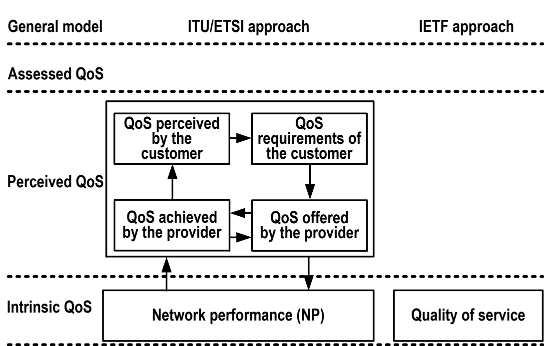

Figure 2. The general quality model - ITU-T/ETSI and IETF approaches.

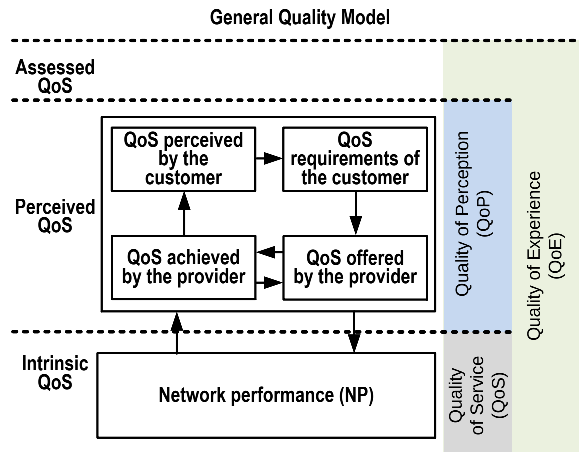

Figure 3. An amendment to the general quality model.

The provider must also take into consideration nontechnical parameters that are meaningful to the users in order to ensure a high level of assessed QoS, which is exposed when a user decides whether to continue using a service [5]. Sometimes 'intrinsic QoS', according to the ETSI approach, is called QoS and instead of 'perceived QoS' the term 'Quality of Perception' (QoP) is used. The 'assessed QoS', in turn, evolves towards the so-called Quality of Experience (QoE) and may be treated as a resultant of all the technical and nontechnical parameters influencing the service quality experienced by the user (Figure 3).

The approach presented in Figure 3, especially with regards to the intrinsic QoS, is not complete because it only shows the influence of transport factors (network performance) on the quality perceived by the end user. These factors are in the scope of the NO's responsibility.

The fact is that other factors also have an impact on QoP. These are service and application factors. The first one is in the scope of the SP's liability, while the second one depends on the user's equipment. Therefore, there is a need to strengthen efforts in all three of these areas, i.e., service provision, network performance and the end-user's application capability, in order to achieve a warm appreciation of the service quality perceived by the users.

As mentioned above (see Figure 3), the final user's decision in terms of using a specific service in the future is QoE. The problem is, that end-users themselves are not really uniform with respect to their QoE requirements, which

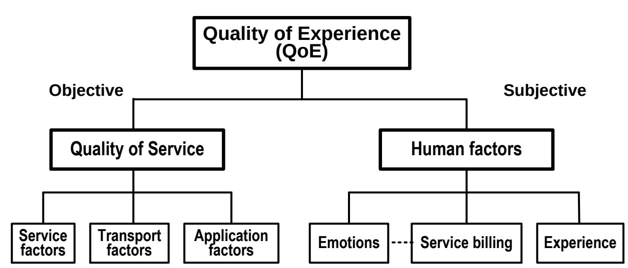

Figure 4. Quality of Experience components.

may be affected by their prior knowledge and expectations, along with the current usage context. All these factors have a strong influence on their QoE needs [7]. Figure 4 presents key subjective (human) factors that, together with objective ones, form the whole picture of QoE.

III. WHAT MATTERS IN QUALITY ASSESSMENT

Service quality will become more and more important, not only for existing services, but also for new emerging technologies and services on the Information and Communications Technology (ICT) market. One of the most awaited solutions is a fifth-generation mobile network (5G), which is expected to be operational by 2020 [8]. It is assumed that it will integrate new applications and services as well as evolved versions of existing ones [9].

5G is a system both for things and for human-centric devices and services. It is envisioned as a system to serve both the user and society. What makes 5G different from previous generations of communication networks is that it will not be designed to offer fixed values of data rates anywhere, anytime and to anyone, but to perform more meaningful, flexible and personalized network management based on the understanding of the end-user's and service's needs [8]. Therefore defining the quality requirements for all users in terms of latency, data rate, coverage, reliability, security, etc. is important, however, more attention should be paid to individual user QoE. Thus, satisfying the users' requirements implies the necessity to move from a system-centric to a more user- (or human-) centric design. In order to do this we first have to understand what users really want.

Future 5G networks will be characterized by high bandwidth with speeds in excess of 10 Gb/s, various mobility levels, and energy and cost-efficient solutions with the augmentation of the wireless world's intelligence, but they should also meet the satisfaction of users. The main challenges for 5G technology are the greatly increased amount of data generated by evolved applications, a massive number of devices to connect to different radio-access technologies, and the need for high quality services [22]. The 5G will be a heterogeneous network architecture consisting of a mixed use of infrastructure elements such as macro-cells, micro-cells, and pico-femto-cells based on interworking different cellular and wireless local area network standards. Emerging monitor and control applications with very low wireless data rates combined with very low energy consumption and with ultra-low latency (<1 ms) are expected to be components of 5G systems.

A new problem with QoE arises from the fact that different users, services and applications have different requirements [10]. Thus, customer personalization and services differentiation mechanisms should be implemented in emerging technologies (e.g., 5G) to ensure high level of QoE.

As was mentioned in the previous section, QoE may be affected by a lot of factors. It is valuable to know which of them really concern users in terms of service quality. In a recent study [11], the most important were the following: reliability (47%), coverage (36%), data speed (9%) or other (5%). It means that users, first of all, care about reliability, i.e., consistency in their perceived experience. Consistency refers to the uninterrupted, seamless and nearly invariable excellent service quality. It spans across different dimensions, like time, space, network infrastructure, operator, service provider and end-user equipment (hardware and application software) [8].

The second important factor describing the quality experienced by users is coverage, i.e., availability of the service. Data speed is located in third place. A relatively low number of respondents mentioning it among meaningful parameters indicates that this factor is far less important than the previous ones. This is information for SPs and NOs on what kind of factors should be recognized as the Key Performance Indicators (KPIs) that influence users' QoE. As a consequence, these indicators should be first and foremost measured.

IV. QOE MODELS - CASE STUDIES

When it comes to a specific service, it is important to recognize what kind of KPIs really matter to the customers who use the service, and how these KPIs influence the service quality experienced by them. In other words, it is a problem of building proper QoE models for the individual services. Now, we are witnessing a rapid development of so-called OTT services (Over-The-Top-service), in which customers use applications such as iMessage, WhatsApp, Facebook Messenger, SnapChat etc. and generate a high volume of data traffic where information should be delivered as quickly as possible. Moreover, these applications are not treated as uni- but as bidirectional means of communication (e.g., for chatting), where message delivery time plays a crucial role. One of the applications examined by the author was messaging service [12]. The tests were done in a laboratory network, where 40 selected users were sending and receiving messages (1200 in total) between each other. A special tool was used to control the network delay. The users were not informed about the delay set-up, but experienced the effects of these activities, i.e., they perceived the occurrence of service interactivity disturbances. After each session, the users were asked to assess the quality of the service based on their recent perception and to give a grade form 1 (the lowest) to 5 (the highest). Each e2e message delivery time was captured and stored in a database. Figure 5 presents the relation between the message delivery time and the users' grades, representing their QoE, in the MOS scale. The single dashed column represents the average value of the users' grades of all the messages that were delivered in a specific time period. The whiskers represent a 95% level of confidence. Statistical analysis showed a significant (~80%) correlation between message delivery times and the users' evaluation grades. Next, regression analysis was performed and, using ordinary least squares (OLS) estimation, the approximate relation between message delivery time and the users' grades (in the MOS scale) was determined as follows:

$$MOS = -\,0.1\,T + 4.9 \tag{1}$$

where T – message delivery time.

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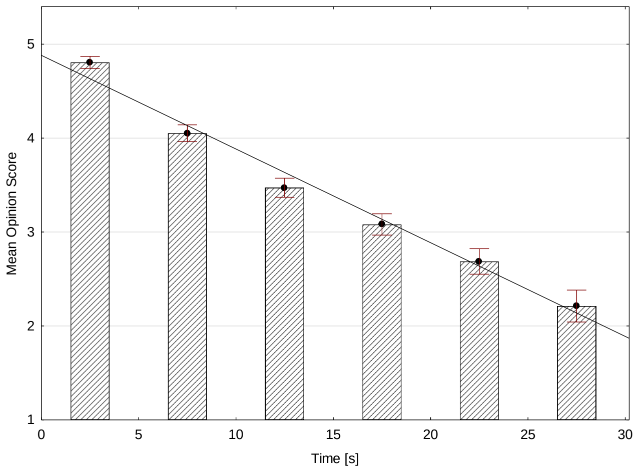

Figure 5. Message delivery time vs. MOS for Messaging service.

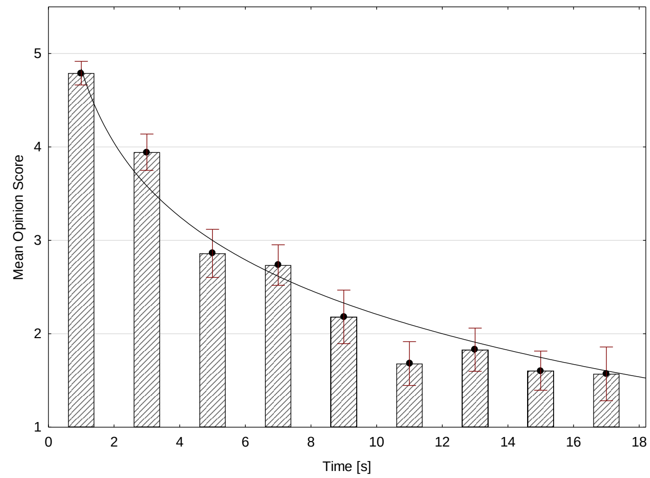

Figure 6. Page response time vs. MOS for WWW.

We made a validation of the model, using the Mann–Whitney–Wilcoxon (MWW) test [13], which showed a good estimation of the users' quality perception under the assumption of a 95% confidence interval (significance level $p<0.05$).

Similar research on the QoE model was carried out by the author for the WWW service. In this case, delay also plays a crucial role in the service delivery process [14]. There were 70 users taking part in the test and more than 1500 test measurements were conducted. Network transmission delays were controlled by a special emulator in the laboratory test-bed, where group of testers tried to use the WWW service. Two static web pages were launched on the test server and the contents of these pages were different. One of them was prepared according to ETSI reference page requirements [15] while the second was a photo gallery. The time that elapsed between the initiation of the call-up and the actual appearance of the page on the screen was measured and stored into the database. End users appraised quality subjectively (QoE) and expressed their experience in the MOS scale. The results showed that people taking part in the evaluation test were quite critical with regards to the service under analysis. A rapid decrease in the quality was observed for the web page opening times covered in the first few seconds. The longer web opening times are, the lower the grade users give, and for longer delays, especially exceeding 10 s, users' grades tend to be lower but more stable.

The obtained relation between objectively measured page response times and subjective users' grades (in the MOS scale) is presented in Figure 6. Thorough analysis of the WWW service quality as a function of the page opening time (for longer times) indicates logarithmic relationship between these values, as follows:

$$MOS = -\,2.6 \log_{10} T + 4.8 \qquad (2)$$

where T – web page opening time.

The models presented by (1) and (2) are valid for the emulated times between 1 s and 30 s.

For the times shorter than 1 s, the MOS value is 5. The author did not take into account the times longer than 30 s. These values were unacceptable for both the interactive messaging communication and WWW service.

The logarithmic line in Figure 6 represents the MOS value as a function of web opening times with 80 % correlation.

Statistical analysis proved that the model fits the data very well, with coefficient of determination (R2) above 0,9. It means that obtained outcomes are replicated by the model at a level of at least 90%. Confirmation of such user quality of experience distribution can be found in the analysis results presented by ITU-T in Rec. G.1030 [14].

Based on these two examples, it cannot only be seen that objective parameters describing the quality of service are important, but subjective as well. It concerns all services offered by SPs. Moreover, taking into account the users' perspective during the quality assessment process is also valuable from a business point of view. For example, for customers who want to watch a You Tube video, information regarding the number of stallings will be more important than, among others, the downlink data rate and latency.

V. CONCLUSION AND FUTURE WORK

Many scientific papers show the relationship between QoS and QoE using metrics based on the average values of measured parameters (e.g., mean throughput, mean Round-Trip Time, etc.). It makes QoE models easier to define and understand. However, such an approach has some limitations, because it assumes that QoE is determined by the averaged stimulus.

More detailed analysis shows that transient behavior has a more significant influence on a user's perception than average values [16][17][18][19][20]. This conclusion was derived from the results of research on the quality of the WWW service, where the authors examined the influence of network bandwidth on the quality perceived by users during a Web browsing session [17].

Two scenarios were analysed: first - with a constant, and second - with a variable bandwidth. The average bandwidth

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in the second scenario had the same value as the constant bandwidth of the previous one (i.e., 2 Mbps). In spite of this, a significant difference in the quality experienced by the users was noted.

The QoE value, expressed in a the MOS scale, in the first case was around 4, while in the second case it dropped to 3. The characteristics of network performance, presented in some papers, indicates that taking into account the variability of transmission parameters, e.g., duration and intensity of throughput drops, leads to better QoE prediction than models based only on average throughput [21]. Another problem is how to identify a proper set of KPIs, which in turn should be measured and controlled in order to derive more precise QoE models. Currently, many of these models take into account the small number of parameters that influence the quality of services. Further work will be devoted to broadening the list of parameters that may influence the experience of users, which will help us to build more precise QoE models.

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