Internet Access Service Quality Perceived by the User

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***Abstract*— This paper presents the selected issues of Internet Access Service quality. A special attention was paid to the user's point of view. According to the European documents, users have right to be informed of IT services offered by their providers. The providers are involved in service quality measurement, but they often put emphasis on the objective parameters, which are relatively easy to measure and to compare with other competitors' offers. The issue is: how service quality is perceived by users and, finally, how to correlate these two different points of view. The author discusses the selected objective measures of the Internet Access Service and presents different factors that influence the Internet quality perceived by users. The author shows how the users assess Internet Access through the lens of services they use. An example of building the Quality of Experience model for the WWW service will be presented.**

Keywords-Internet access; quality assessment; QoS; QoE; WWW quality model.

I. INTRODUCTION

The Internet is supposed to be used as a vital medium for conducting business, as well as aiding work, play and communication between users in the next years. I will also be the center of the future economy, which will be based on network-based knowledge. Therefore, it has a wide appeal with service providers and consumers, research and regulation authorities, etc. [1][2][3].

In March 2010, the European Commission has launched a strategy titled "Europe 2020", which sets the objectives for smart, sustainable and inclusive growth of the European Union by 2020. The Digital Agenda forms one of the seven pillars of the strategy and defines the key enabling role that the use of Information and Communication Technologies (ICT) will have to play in Europe in future years. It is supposed to support a better quality of life, e.g., through better health care, safer and more efficient transport, a cleaner environment, new media opportunities and easier access to public services and cultural content. It is assumed that by 2020 all Europeans will have access to Internet speeds of above 30 Mbps and at least 50% of the households will subscribe to Internet connections above 100 Mbps.

According to the European Commission, the digital sector grows seven times faster than other parts of industry. Thus, in September 2016, new Commission strategy documents on Connectivity for a European Gigabit Society were adopted [4]. They set a vision of Europe where "availability and take-up of very high capacity networks enable the widespread use of products, services and applications in the Single Digital Market". A vision of "Broadband Europe" assumes the building of the Gigabit Society by 2025 and relies on three main strategic objectives:

- Gigabit connectivity for all main of socio-economic drivers,
- uninterrupted 5G coverage for all urban areas and major terrestrial transport paths,
- access to connectivity offering at least 100 Mbps for all European households.

Consumer research has revealed that price is still the most important attribute taken into account when choosing an Internet access service for 20% of users [5]. The second decision-making factor is the data cap, i.e., the monthly limit on the amount of data a user can use with an Internet connection. Moreover, what happens when a user hits their limit is a very important issue. Internet Service Providers then (ISPs) engage in different actions such as slowing down data speeds, charging extra fees, or preventing further usage.

The next important factors, which may influence user attitude to an ISP offer, are service differentiation and traffic management such as prioritization, blocking or throttling. These practices aim to preserve the appropriate conditions for providing high-quality services. Nonetheless, in recent years these activities have raised questions about network neutrality, which assumes that all content and applications should receive equal treatment. Moreover, neutrality also means that providers neither impose nor discriminate in favor of using a particular type of technology [6][7].

Consumer awareness of network neutrality and traffic management is rather low. On one hand most people have very little knowledge about these terms and, on the other hand, they do not see the influence of these issues on their Internet usage. As is shown in [8], consumers care very little for all the technicalities connected with data transport and the role of ISPs. Users are not interested in net neutrality or traffic management practices and instead are tied to their experience of traffic management effects.

The WIK-Consult study, which concentrates on contract-based consulting services for public and private institutions, asked a series of questions about the way consumers would respond to specific changes in the traffic management policies operated by their ISP, e.g., the introduction of throttling on video traffic, or of data caps. A significant majority of respondents said that they would even change the provider in response to some significant changes in the traffic management policies of their ISP [5].

The issues mentioned above show a much higher interest of users in their ISP traffic engineering operations when these activities touch the concrete services and influence the users' experience. Nowadays, users not only trust the service level agreements of their providers, but also want to be able to check them.

This paper, as an extended version of [1], is organized as follows. In Section II the author presents a general overview of IAS structure. Next, in Section III, the main parameters that may influence quality are discussed and the objective quality measurements of IAS, according to the present standards, are presented. Section IV describes the subjective service quality issues, i.e., perceived by users. The author underlines the difference between objective quality measures and the subjective users' perception of different services used by them. He validates the need to build quality models for the most popular services and mentions WWW browsing as one of them. In Section V, the Quality of Experience (QoE) model for the WWW service is discussed. The author presents the laboratory test-bed, measurement results and method of the model derivation. The paper ends with a conclusion and the plans for future work.

II. INTERNET ACCESS SERVICE

One of the major factors influencing the decision of users when choosing an ISP is the Internet Access connection throughput offered by the provider. However, there are many misunderstandings regarding this term. Physically, it is a combination of different connections and services that are needed to establish a functioning Internet access. Each of them can be treated as a separate service. Most users, however, treat Internet access as an access to the end-to-end services available on the Internet. A purely physical access to the Internet has no practical meaning to them. Thus, Internet access is generally understood as a platform that provides access to Internet services.

It should be noted that some e2e services, that require two-way communication, engage Internet accesses of each end-user taking part in the meeting (Fig. 1).

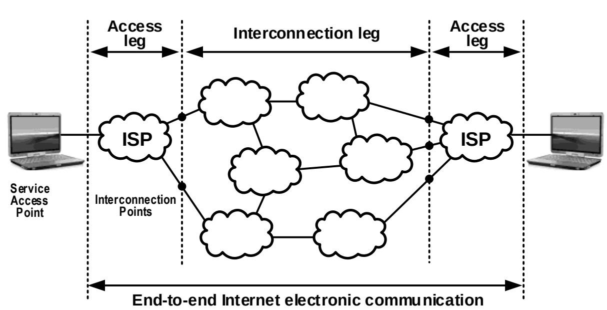

Figure 1. Illustration of the contributing elements of the e2e communication [28].

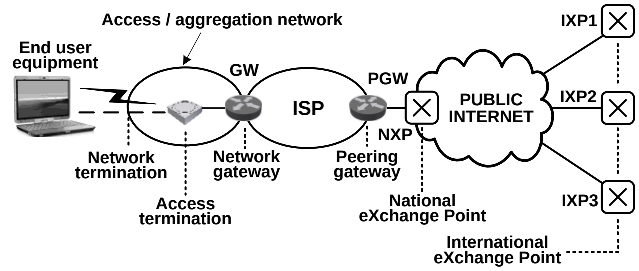

Figure 2. General overview of elements and network sections of IAS.

From the technical point of view, however, the primary meaning of the term Internet access should be understood as a physical and logical access to the core of the network, including all functionalities needed to enable the user to establish a connection to further entities in the Internet and to run advanced services [9].

Providers often advertise the maximum values of the throughput, which is rarely accessible, due to variable traffic load and the still increasing demand for data transmission bandwidth in recent years. Many users often expect such throughputs for most of the day, irrespective of the time and network conditions. According to the CISCO forecast, presented in Visual Networking Index [10], global IP traffic will increase nearly threefold over the next 5 years and by 2020 will reach 2.3 ZB per year. Moreover, traffic load varies significantly during the day. Busy-hour (the busiest 60-minute period in a day) Internet traffic is growing more rapidly than average Internet traffic. It increased by 51 percent in 2015, compared with a 29-percent growth in average traffic. It means that service providers will face even higher network load fluctuations and more serious traffic engineering problems than up to now.

Users can be connected to the various ISPs via the access networks, using wired or wireless connections. Communication over the Internet requires data interchange over different National and International eXchange Points (NXPs and IXPs). Fig. 2 presents a generic overview of the elements, network sections and interfaces of the IAS according to [11].

A very important issue is the proper definition of the Internet Access Service (IAS). The answer to this question is not only crucial for the users, who are usually not familiar with the technical details, but also for the providers as well, because it determines the user-to-network and network-to-network interfaces and also the responsibilities of the providers.

Finally, it says how IAS quality should be measured and how the results can be interpreted and compared between different providers and their end-users. It is especially important in the light of European regulation [12] on the rights of users to be informed about the quality of their services.

III. IAS MEASUREMENTS

Identifying the parameters that may affect the quality of service, locating the points at which the measurements should be performed and specifying the measurement scenarios is a sequence that should be done before the measurements. Simply speaking, one should specify "what, where and how" should be measured to provide ISPs and users with a thorough knowledge of the quality of service.

The measurements fall into two groups: so called "In-net" and "Over-The-Top" (OTT). The first case covers the ISP's area - the area on which it acts. European Consumer Center (ECC) Report [11] specifies a list of technical quality parameters proposed to be measured during a technical evaluation of IAS.

Many National Regulatory Authorities (NRAs) or other national institutions agree that the list is too long. They also consider it to be too complicated and incomprehensible to the average user. Thus, they propose the selection of a subset of parameters. After consulting an abundance of documents [9][11][13] and different points of view, the ECC has proposed a list of minimum technical parameters that take their influence on the most popular Internet applications into account. Table I, based on [11], illustrates popular services and the relevance of the network performance parameters to the performance or quality of those services. The relevance ranges from "−" (irrelevant) to "+++" (very relevant). The following quality metrics have been selected: data transmission rate, delay, delay variation, packet loss ratio, and packet error ratio.

The data transmission rate is probably the most relevant parameter, nearly mentioned in every ISP's offer. It is defined as the data transmission rate that is achieved separately for downloading and uploading specified test files between a remote website and a user's terminal equipment [9]. The next parameter is delay, defined as half the time (in ms) that is needed for an ICMP packet to reach a valid IP address. This parameter also has a significant influence on many applications available over the Internet and is already being used by many NRAs, operators and web-based speed meters. There are also some applications that are very sensitive to delay variation and this parameter is therefore selected for measurements. The exact definition of delay variation can be found in [13][14].

IP packets can sometimes be dropped, e.g., due to a small buffer size of the network nodes or poor (radio) connection, even if the transmission rate, delay, and delay variation remain good enough. Such packet loss can significantly affect all data-based applications.

TABLE I. RELEVANCE OF NETWORK IMPAIRMENT PARAMETERS TO VARIOUS APPLICATIONS

Service	*Data transmission speed*		*Delay*	*Delay variation*	*Packet loss*	*Packet error*
	Down	*Up*				
Browse (text)	++	−	++	−	+++	+++
Browse (media)	+++	−	++	+	+++	+++
Download file	+++	−	+	−	+++	+++
Transactions	−	−	++	−	+++	+++
Streaming media	+++	−	+	−	+	+
VoIP	+	+	+++	+++	+	+
Gaming	+	+	+++	++	+++	+++

Moreover, UDP-based applications, such as Voice over IP may also not work properly in such conditions. Packet loss ratio can be defined as the ratio of the total lost IP packet occurrences to the total number of packets in the population under examination [14]. The parameter that may have an influence on the quality of service is the packet error rate and was therefore also included in the basic set of measured parameters shown in Table 1. The IP packet error ratio is sometimes called the packet error ratio and is defined as the ratio of the total faulty IP packet occurrences to the total number of successful IP packet deliveries plus the faulty IP packet occurrences within a population of interest.

Internet access is no longer provided by a single network or service provider, as was the case with traditional voice communication in Public Switched Telephone Networks (PSTNs). Nowadays, a user gains an indirect access to the public Internet, as shown in Fig 2. Therefore, the overall quality of services (or, in general, Internet access) is a combination of the performance of all the elements involved in the connection.

Different approaches to QoS measurements are discussed in literature. One of the classifications points out the methods as follows:

- carried out by the carefully selected users running the measurement tests from designated locations (or users' homes) and using special purpose equipment [11][15][16],
- large-scale user-driven tests, performed by software agents installed on PCs, tablets, smartphones, etc. [15].

On the other hand, the measurements can be performed by network or service providers, regulators or designated third-party institutions. Different solutions are used in different countries. Many providers do it individually but their results may be regarded by users as non-objective. Thus, external institutions are needed here. Such institutions are very often national regulators or the external companies hired by the regulators. The first solution is used, e.g., in Portugal [15], while the second approach, based on "QoS Memorandum" [17], is used in Poland.

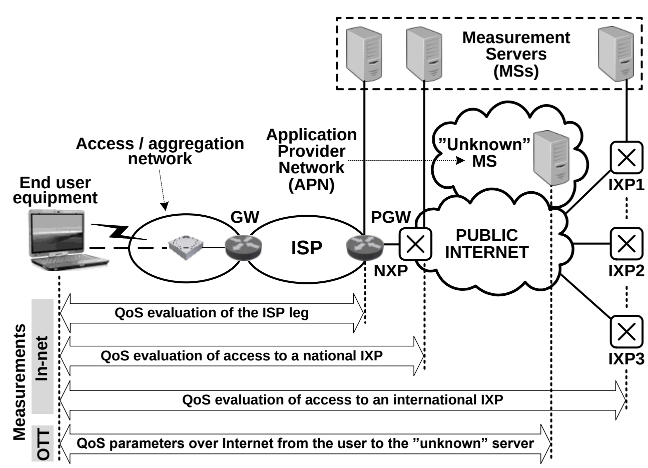

Figure 3. Internet Access Service quality assessment.

On the European level, the minimum set of QoS parameters and measurement methods for retail Internet Access Service has been described in [11]. According to this, the measuring points to be used during the IAS quality assessment may be specified (Fig. 3).

Three evaluation methods (scenarios) are relevant to the measurements connected with IAS quality assessment. The methods encompass an examination of the access network, the ISP network and the network connections to NXP or IXP.

Their names are listed below:

– QoS evaluation within the ISP leg,
– QoS evaluation between the Network Termination Point (NTP) and NXP(s),
– QoS evaluation between the NTP and IXP(s).

Depending on the scenario, the measurement server should be located in the right place (cf. Fig. 3).

In order to test only the access network, the test server should be located as close as possible to the gateway (GW) between the access network and the ISP network. In the case of evaluating the entire ISP leg quality, the test server should be placed near the public Internet interface (PGW in Fig. 3). According to the definition, the ISP leg consists of the access network part and the ISP network part of the connection of the customer to the ISP [11]. Based on [9], a measurement set-up for the ISP leg quality evaluation is presented in Fig. 4.

It should be possible to perform the tests both by the ISP and the user (assuming that the ISP provides a software client or a web based application for this purpose).

The test server shall be connected to the edge of the ISP network (Fig. 5) [11].

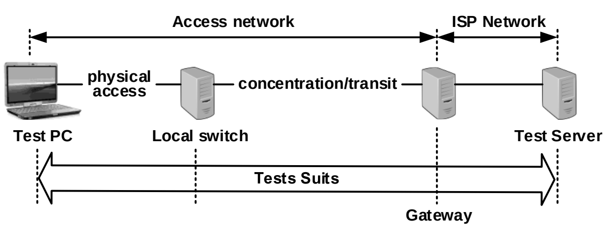

Figure 4. Measurement set-up for the ISP leg quality evaluation.

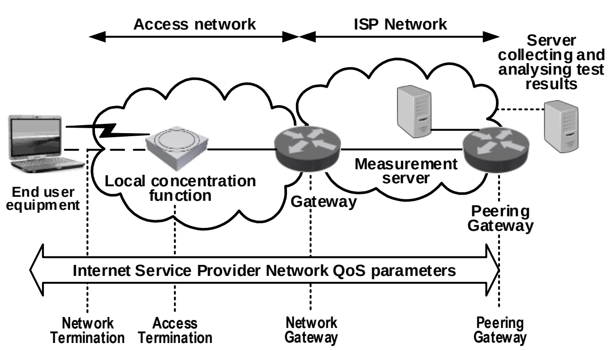

Figure 5. QoS evaluation of the ISP leg.

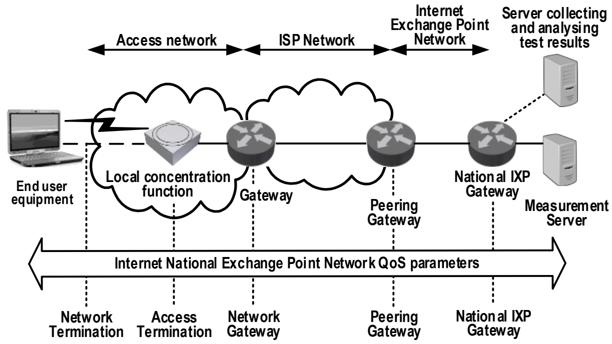

Figure 6. QoS evaluation of access to a national IXP.

Locating the test server in the National eXchange Point (NXP) allows the network performance parameters of different ISPs to be compared (Fig. 6).

The comparability of the IASs of different ISPs can be reached in the best way, if all ISPs are connected on a similar way to the central measuring point.

In the case of bigger countries it can be difficult to fulfill this condition. There may be few IXPs present and due to that, the ISPs are not connected on a similar way to the central measuring point. However, the impact of these circumstances may not be considered significant enough to make the values incomparable, because the bottleneck of the ISP's network usually do not lie within the backbone of the ISP's network but within the Access leg and/or Interconnection points [11].

The quality results achieved in this scenario seem to be far closer to the quality of Internet connection, as perceived by users, than the results in the "ISP leg" scenario.

It is recommended to perform this kind of measurements by the measuring organization, which can be NRA, other relevant national institution or an independent organization. The measuring tools are not strictly specified by any standardization document. These can be dedicated hardware solution, software client or web based applications.

It can be seen that the Internet Access Service quality assessment is therefore a very demanding issue, especially as users care about their own quality experience, which is commonly understood as unrestricted, high-quality and having a reliable access to the applications they use and the content they seek out online. This is the reason for performing the second type of measurements presented in Fig. 3. They were called "OTT measurements", because they allow the performance parameters of specific applications run by the users to be tested and thus they, in general, better reflect the quality of service as perceived by the user.

Nonetheless, these are measurements of the objective parameters and, in the next step, should be transformed into the quality measures as perceived by users. Mapping the measured QoS factors to the QoE ones is often quite a complicated process. The next paragraph presents an example of WWW service quality assessment as perceived by users.

IV. SERVICE QUALITY PERCEIVED BY USERS

In this paragraph, the author presents an example of the service quality assessment procedure based on the WWW service. The WWW is one of the most popular services, if not the most important of all, used by Internet users. Many of them assess the Internet quality through the lens of web browsing and information searching on the Internet. The main parameter that influences the service quality, as perceived by the user, is web page opening (loading) time. In other words, the end-to-end (e2e) delay between the user's request and the time when the page is open on the user's display is the most important. The WWW service quality evaluation procedure will be treated as one of the factors that influence the user's perception of the IAS. The WWW service evaluation in the real network may be performed as shown in Fig. 7.

The objective QoS parameter that is measured here is delay between the times when user sends a request to open required web page and the time when the information appears on the display of his PC.

Beside objective measuring of the web page opening times, the subjective user's perception of the service should be determined. In another words, service quality perceived by the end-users, i.e., the relation between QoS and QoE, should be found. It means that the QoE model for the service should be determined. By presenting the WWW quality assessment, the author would like to underline that measuring and presenting only the objective network performance parameters to the customers, discussed in previous sections of the paper, may not be sufficient for determining the IAS quality as perceived by the users. There is a need to check the service quality experienced by them. Building such a model requires a big amount of tests to be conducted. The best way to determine the QoS-QoE relation is to perform the tests in a controlled environment.

One of the important things is to prepare a proper measurement scenario, taking into account main factors influencing web-QoE. Many of these factors are known, but in literature they are sometimes grouped into different categories and not all of them are taken into account in every research.

According to [18], the influence factors (IFs) may be grouped according to the following categories:

– user influence factors (UIFs),
– system influence factors (SIFs),
– context influence factors (CIFs).

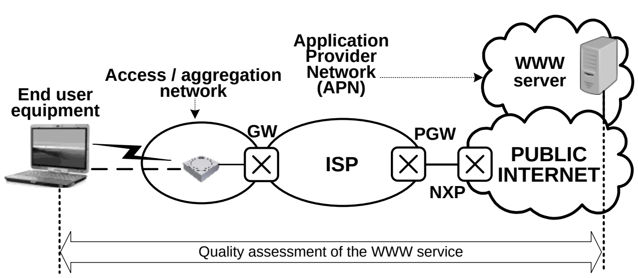

Figure 7. WWW service quality assessment.

A very similar, but a little bit different, categorization is presented in [19], where four categories are listed, as follows:

– user,
– technology,
– content,
– environment.

Referring to the previous classification, it can be noted that the most significant UIFs seem to be user's perception, interest, expectations, experience of application and/or network performance, etc. In today's ICT environment, the users' expectations, satisfaction and (perceived) quality of experience (QoE), are being recognized as crucial determinants for the success of the technology, even more important than technological performance and excellence [20].

The set of SIFs consists of:

– server-related influence factors,
– content-related influence factors,
– delivery network influence factors,
– client influence factors.

To better understand the relations between SIFs, a typical Web-QoE delivery chain was shown in Fig. 8 [18].

According to the classification listed above, the most important SIFs are response time (determined by CPU, operating system, memory, software, etc.) and capacity of the links connecting the server to the Internet. However, the perceived response times may be lowered by the cashing elements in the delivery network.

The next sub-set of SIFs constitute content-related influence factors. They are very crucial for web-QoE, especially because the Web content is typically constituted by a mix of different element types. It consists of text, pictures, audio and video files. Additionally, the structure of the HTML pages (and the scripts) determines the actual loading behavior of the page according to the utilized objects (number, type, size, order, etc.) [21].

Another group of SIFs are client influence factors. These are: web-page loading procedure, processing power, browser implementation, operating system, TCP/IP stack, configuration etc.

The last, but not least, factor which may have a critical influence on the user behavior and his QoE is the context in which a web page is accessed. The range of CIFs spans:

– location: cafeteria, office, home,
– interactivity: high/low level interactivity,
– task type: business, entertainment,
– task urgency: urgent vs. casual (without time constraints).

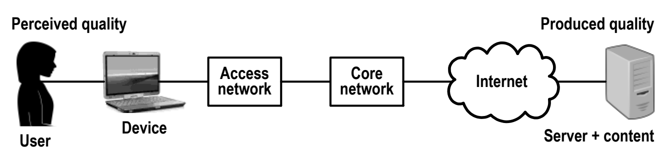

Figure 8. Delivery chain for a typical web-page.

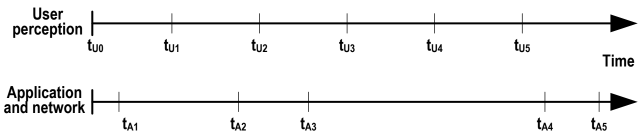

Figure 9. User's perspective of the perceptual events in a web page view cycle.

As it was mentioned before, the time (delay) is one of the main factors that influence user perception of the service. When user requests a web page, the download of content from web server is initiated and progressively fetched and rendered by the browser. During this time the user encounters several events that indicate the progress of the page loading process. However, the objectively measureable times are a little bit different from the characteristic moments of web browsing process that are perceived by the user and decide on user's appraisal of the service (see Fig. 9). For more details regarding the impact of these different points of view on the web-QoE assessment please see [22] and [18].

According to [18], the meaning of the times presented in Fig. 9 is as follows:

t_{U0} the moment in time when the user requests a new web page (typically by clicking or pressing enter "Enter"),

t_{U1} the moment in time when a change in the status bar happens,

t_{U2} the moment in time when the previously viewed web page vanishes (the content of the requested page has not yet started to render),

t_{U3} the moment in time when the first element of the requested page appears on the screen,

t_{U4} the moment in time when, from the user's point of view, the page is sufficiently rendered such that he can access the required information,

t_{U5} the moment of time when the visible portion of the web page (as determined by screen or browser windows size) is fully rendered,

t_{A1} the moment in time when the initial HTTP request is sent by the browser,

t_{A2} the moment in time when the first HTML element is received,

t_{A3} the moment in time when the HTML page is processed by the browser (observed at application level),

t_{A4} the moment of time when all objects of the page are downloaded from the server at the browser's device,

t_{A5} the moment of time when the page is completely rendered and displayed on the screen.

It should be noted that the distance between the perceptual events in Fig. 9 is shown as being equal, but in real-world browser implementations they may be different.

The influence factors listed above show that the Web-QoE description is not a simple task. It requires a big effort and usually is time-consuming and expensive. The question arises: how to measure the users' satisfaction of IP-based services as WWW?

One of the methods of expressing the users' satisfaction is an Application Performance Index (APDEX) [23]. It is an industry open standard that allows to measure the satisfaction with the response times of web applications and/or services and their conversion into one commonly understood factor (*AI*).

The magnitude of this factor can be described as a value on a scale between 0 and 1. It can be calculated using (1) as follows:

$$AI = (S_R + (T_R / 2)) / N_R \qquad (1)$$

where: AI – an evaluation score according to the Apdex method; S_R – satisfied requests (number of users' requests when the service response times were satisfied for them); T_R – tolerating requests (number of users' requests when the service response times were tolerated by them); N_R – the total number of users' requests.

The final result (AI) depends heavily on the threshold time T. It is the value of the delay which, in the user's opinion, represents a negligible reduction of service quality (Fig. 10). Thus, it can be assumed that the web page load time of no longer than T guarantees high user satisfaction of WWW service. On the other hand, it was observed that $4T$ is the upper limit of delay tolerated by the user. In practice, this problem involves fixing the maximum value of T that will guarantee, in the user's opinion, a very good quality of service. In other words, T should be the maximum time which does not distract the user's attention from the service during waiting for an application response. For delays which are longer than T and do not exceed $F = 4T$, users notice a deterioration in the service quality, but they tolerate it.

APDEX can also be treated as a simplified Service Level Agreement (SLA) solution that gives application owners better insight into how satisfied users are, in contrast to traditional metrics like average response time, which can be skewed by a few very long responses.

Finding the QoS/QoE relation is often a starting point to the cost-effective service provision and quality management process. This often leads to finding of more sophisticated relationships between objectively measured parameters and subjective quality as perceived by the users. Such kind of investigation, including preparation of the a special laboratory test-bed and measurement scenario, and performing of the tests, was presented in the next section.

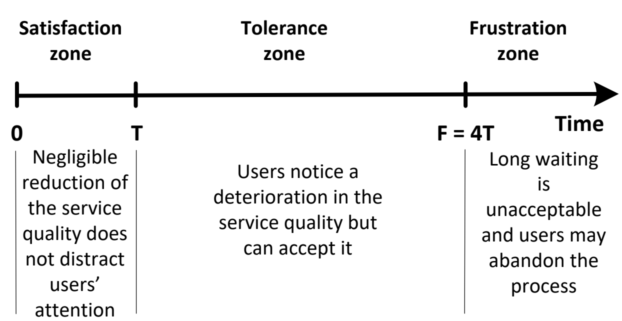

Figure 10. Threshold values for the Apdex Method.

V. THE LABORATORY TEST-BED

The laboratory test-bed used by the author is presented in Fig. 11. It consists of a WWW client with a dedicated measuring tool, a test server that hosts a set of special prepared WWW pages and the Network Emulator (NE).

All the machines and software run under the MS Windows operating system. As a user client, the Mozilla Firefox browser was used while the measuring tool was the Wireshark protocol analyzer. The NE was capable of emulating the impairment parameters such as network delay, jitter and packet loss. This stage of the measurements only studied the impact of the delay on the service quality as perceived by the users. The delays were randomly generated by the NE on the interval from 0 to 20 s, while the users tried to open the web pages on the test server. Next, the packets were captured by the Wireshark and analyzed. The users did not know the strict values of the delays, but they did see the effects of the delay and tried to assess whether the web page opening time was acceptable or not. It was clear that these delays had a decisive influence on the WWW service quality as experienced by the users. It was expected that increase in end-to-end delay would lead to deterioration of users' satisfaction of the service. Quality of Experience was expressed by the user's evaluation grades according to the Mean Opinion Score (MOS) scale [24].

During the experiment the subjects (testers) were asked to independently rate each sample and provide their opinions using a "rating scale". The purpose of the scale was to translate a subject's quality assessment into a numerical value that can be averaged across subjects and other experimental factors. The Absolute Category Rating (ACR) 5-point scale (most common) was used, as follows:

– Excellent 5,
– Good 4,
– Fair 3,
– Poor 2,
– Bad 1.

The ACR scale is a discrete scale, meaning that the subject's response is limited to one of the five values listed above. However, the averaging process used to combine results from different subjects means that MOS values are not confined to integer values [25]. The first observations confirmed the expectations, that users' grades should be inversely proportional to the e2e delays. It was also noticed that the subjective opinion of users depended highly on the page properties, i.e., their content, layout, construction (static, dynamic), etc. For subjective measurements the WWW reference page was needed. Static web pages were launched on the test server and the contents of these pages were different, but they were of the same style. In this experiment as a content a photo gallery was used.

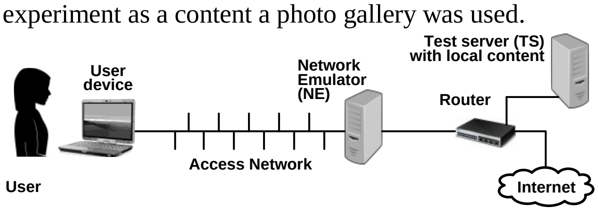

Figure 11. The laboratory test-bed for the WWW QoE assessment.

The main goal was to build as simple web page as possible, but with interesting content.

As a result, the obtained QoE model was similar to the presented in [22], where the test page was prepared according to the ETSI reference page requirements [26]. The relatively small differences require further study. Therefore, the next investigations will be devoted to carry out more detail QoE analysis, taking into account different contents of the web, i.a. based on the ETSI recommendations. It should also give the answer the question of the impact of the content on the experiment results.

It should be also noted that the structure and preparation of the test groups can have the influence. The testers evaluating the quality of the WWW service, as described in [22], were divided into two categories: the first consisted of professionals, the second included non-professionals, i.e. people with little computer experience. Evaluation results presented by the two categories had similar trends, though the marks they awarded were inversely proportionate to the page opening delays. In long-period observations, however, a significant difference between these groups was observed: professionals tended to be more radical in their evaluations than non-professionals, who were relatively moderate.

The current scenario assumed that every user, when evaluating web opening times (equivalents of end-to-end delays during normal web browser use), should give his grade after seeing several photos so that he would be better able to make a judgment. The test was performed on a user's PC (WWW client with a measurement tool). Additionally, Wireshark software installed on the client's PC (as a second tool) was used to capture IP packet streams and to register the end-to-end delay time. This was defined as the difference between the point in time at which the web page was requested and the point in time at which all data needed for the display of the web page were received. The end-to-end delay was varied throughout the course of the experiment using the NE. It was noticed that the web page opening times that were registered at the user site played a crucial role in the subjective evaluation of WWW service quality (QoE). There were groups of "professional" users (each group of 10) taking part in the experiment (70 users in total). They gave their subjective grades for WWW service quality in a range from 1 to 5 on the MOS scale. More than 1500 test measurements were conducted. In the next step the statistical analysis has been performed.

VI. THE QOE MODEL

The measurements show that the grades of users are inversely proportionate to the web page opening times. To speak in more detail, the people who took part in the evaluation test were quite critical with regards to the service under analysis: a rapid decrease in the quality can be observed for the web page opening times (T) covered in the first few seconds. It shows that users are very critical in their opinions and do not accept long delays. The longer the web opening times, the lower grades users give. For the delays exceeding 10 s, the grades of users tend to be significantly lower at a level of 2, which means that such long times are unacceptable for WWW users.

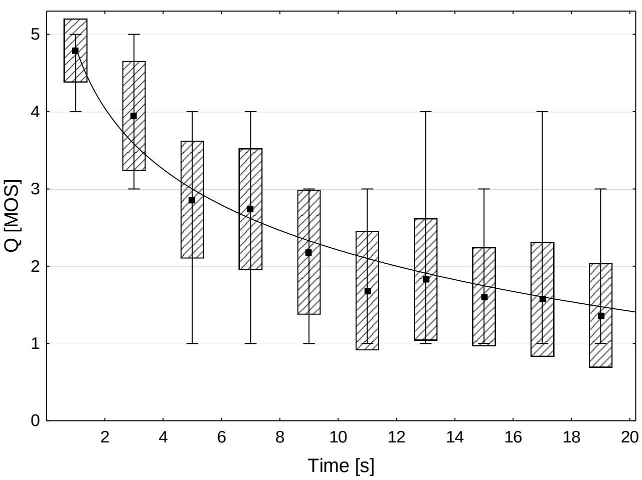

Figure 12. Subjective evaluation of WWW page opening times in MOS scale.

The analysis of the results leads to the conclusion that users had a considerable problem with evaluating web page opening times with very high fluctuations. The measurement results obtained by the author are consistent with those presented in literature [22]. It can be noticed that users are willing to award very high grades for the service (MOS = 5) when opening times are under 2 s, while the lower grades (MOS less than 2) are given when opening times are 8 s and more. In individual cases the evaluation grades may differ significantly from the majority of the scores and thorough statistical analysis should therefore should be carried out. As can be seen in Fig. 12, the mean values for the specific page opening times were not only determined, but min and max values and standard deviation as well.

The correlation between the opening times and the user grades achieved here is at a level of 80 %. The standard deviation is indicated by the boxes in Fig. 12, while whiskers represent the distances between the minimal and maximal values of the captured page opening times. This shows a high level of user uncertainty during the evaluation process.

As it is known from the former experiments [22][27], during long waiting times many users begin to consider whether waiting for the page to open makes sense, and many of them resign. To find a precise relation between the captured values of web opening times and the quality experienced by users, a regression model was used.

This model derived by the author can be described by the following formula:

$$\begin{cases} Q = 5 & \text{for } T < 1\text{s}, \\ Q = 4.84 - 2.63 \log_{10} T & \text{for } T \in [1\text{s}; 1\text{min}], \end{cases} \quad (2)$$

where: T is the web page opening time.

The logarithmic line (Fig. 12) represents the Q value (in MOS scale) as a function of web opening times. The statistical analysis proved that the model fits the data very well, with the coefficient of determination (R2) above 0.9. It means that the obtained outcomes are replicated by the model in at least 90 % of the time. This model is valid for the page opening times T not exceeding 1 minute, which is even more than the longest times emulated in the experiments (20 s). Subjective evaluation however showed that web-page opening times longer than 10 s are not acceptable by the users, thus they may not be taken into account in further practical applications.

A confirmation of the user's QoE distribution, obtained in the paper, can be found in the analysis results presented by the above-mentioned ITU-T recommendation [22], where attention had also been drawn to the logarithmic nature of the relation between QoS and QoE in such a case. A possibility of determining the prospective MOS value by managing the opening times is very valuable and more convenient for the provider than performing the subjective evaluations, which are time consuming and more expensive.

VII. Conclusion and Future Work

Internet Access Service is a key factor that influences a user's perception of all the services provided on the Web. Thus, service providers have to do all their best to offer a good quality IAS. Moreover, they should monitor the network transmission parameters and be up to date with their values. Usage of the appropriate measurement methods is therefore very important. The methods can use different scenarios. In order to make the results credible and comparable with others, these scenarios should be clear and measurement interfaces and procedures have to be clearly defined.

The paper shows the different measurement solutions that can be used. In the second part of the paper the author stressed the importance of subjective quality assessment methods, which are based on the experience of users and give more information about their perception. They assess the Internet Access quality through the quality of the services that they use. One of the most popular is the WWW service. Therefore, the author presented the example of a web browsing quality evaluation scenario, specified the key quality parameter and showed the results of measurements. At the end, the QoE model was proposed and discussed. The main conclusion is that the quality measurements should not only take into account the objective parameters, but subjective parameters as well. Obviously, the set of the parameters depends on the service.

Future work will be devoted to WWW QoE model enhancement by specifying a wider set of parameters to be measured and to also build reference web pages that will be more representative for current Internet content.

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