Paper

New Tool for Investigating QoS in the WWW Service

Tadeus Uhl[1] and Marcus Rompf[2]

[1] *Maritime University of Szczecin, Szczecin, Poland*
[2] *Flensburg University of Applied Sciences, Flensburg, Germany*

Abstract—The subject of this paper is the QoS measurement in the World Wide Web (WWW) service. It will begin with a brief presentation of methods currently used to measure QoS in the WWW service before going on to describe in detail the new tool QoSCalc(WWW). Following that, the potential of the new tool will be put to the test in a series of analysis scenarios. The results and insights obtained will then be presented in several diagrams, and interpreted.

Keywords—*Apdex index, communication network, ITU-T G.1030, measurement tool, Power metric, QoS/QoE determination, Triple Play Services, WWW service.*

1. Introduction

Quality of Service (QoS) plays a very important role in modern digital networks. The term is becoming a household word and can be found among other things in the definition of Next Generation Networks according to the ITU-T Standard Y.2001 [1]. In 2009 the European Parliament and European Council published directives for the networks standardization and services [2], [3], placing great priority on quality of service.

It cannot have escaped anyone's notice that the WWW service has grown enormously in recent years. Almost everybody accesses the information stored on WWW servers. It is impossible to imagine the modern communications society without this service. The end-user can choose between several browsers with which to access the service, hoping that the desired pages located on a server somewhere on the Internet will be loaded and displayed rapidly. Sadly, this is, however, not always the case. Some WWW servers are often overloaded by requests. The information might often be spread over several servers. The time taken to access the pages becomes stretched. Some network sections might become congested. Congestion causes considerable delays which in turn impair communication within the WWW significantly. All this means that the time taken to open a Web page can become very long. To be sure, the delay may be caused in part by the availability of resources at the end-user. Last-mile transmission rates do play an important role as well. So the question arises: how can the quality of the WWW service be measured quickly and objectively no matter where one happens to conduct the test? At the time of writing there are only very few methods that are capable of doing this. One of them is the Standard ITU-T G.1030 [4], a second is the industry-standard method Apdex [5], and

a third is the proprietary metric called "Power" [6]. The first two methods judge the quality of the WWW service from the end-user's point of view, giving a value for the Quality of Experience (QoE). The third method provides not only a way to measure QoE, but also QoS, that is to say the quality of service from the WWW service provider point of view. This method takes not only the time taken to open a Web page into account (which is the case for the first two methods), but also the rate at which the data of a Web page are loaded. That is unique. The metric "Power" has yet to be fully implemented in an efficient tool. This paper aims to do that.

To begin with, the paper in Section 2 provides a short overview of present methods for measuring QoS in the WWW service. Following that, the new tool QoSCalc(WWW) will be described in detail in Section 3. Its capabilities will be put to the test in a variety of study scenarios. The results and insights gained through this study will then be presented in several diagrams, and interpreted in Section 4. The paper will conclude with a summary and an outlook on future areas of work in Section 5.

2. QoE/QoS Measurement Techniques for the WWW Service

2.1. ITU-T G.1030 Standard

The ITU-T G.1030 Standard [4] covers the relationships between the parameters of a service and subjective appraisal of the quality of that service by the end-user. So it is, in fact, a measurement of the Quality of Experience. This method is one of the so-called one-sided QoE/QoS measurement models (see [7] for details). The chief parameter under consideration is the time taken to open a Web page. Various threshold values are used to assess the quality of service subjectively:

- threshold value 0.1 s – maximum value for the reaction time without any impairment to communication,

- threshold value 1 s – maximum value of the reaction time without impairment to the smooth operation of the application,

- threshold value 10 s – maximum value for the time which can elapse during the operation of an application without the user becoming frustrated.
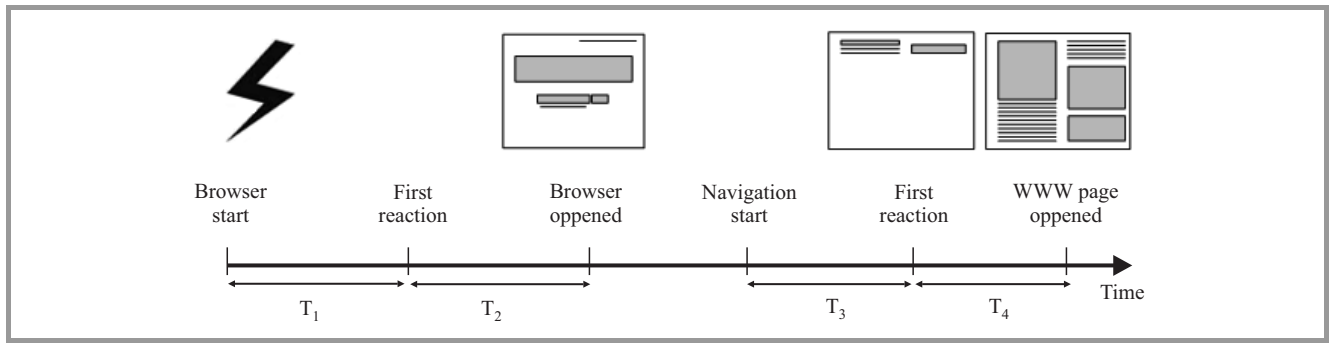
Fig. 1. Time slices in the determination of QoE according to G.1030.
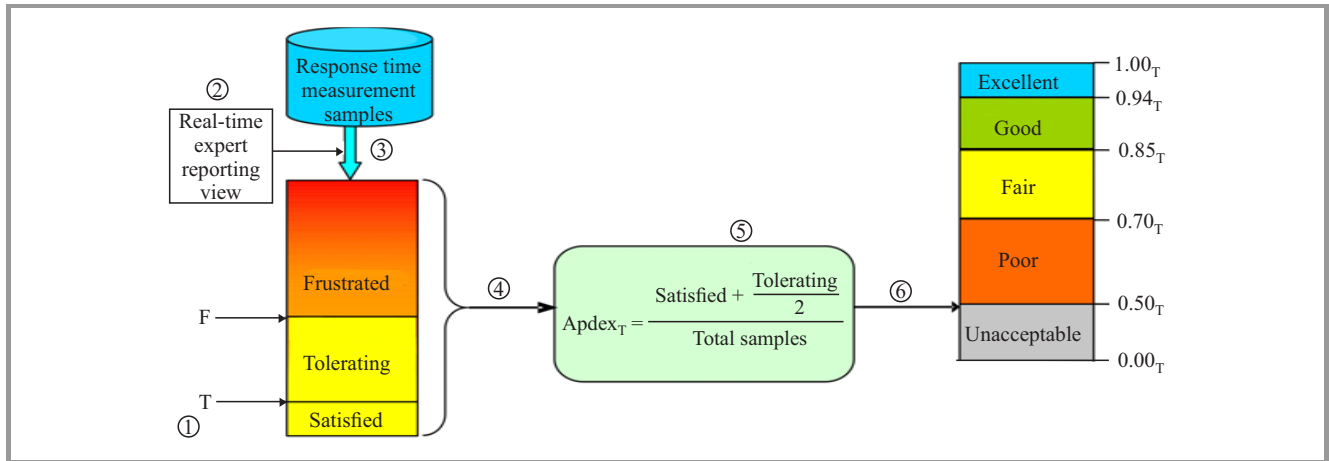

Fig. 2. Apdex process overview.

For the measurement of QoE covered in the Recommendation several time slots are taken into account, as Fig. 1 shows.

The G.1030 Standard includes an experiment description in which a distinction is made between two groups of test persons: (a) test persons with considerable experience and (b) test persons with little or no experience. The information supplied by G.1030 allows one to make the following observations:

- both groups reacted similarly, identifying in their subjective judgements an inversely proportional relationship between service parameters and quality of service;

- persons with little or no experience were more critical than persons familiar with the WWW service;

- as sessions grow longer (in excess of 60 s) the discrepancies between the judgements given by the two groups began to diminish.

The impairment parameter under scrutiny here – whether being measured or appraised – is the time taken for a Web page to open. No account is made of local conditions and parameters. Moreover, this kind of QoE/QoS analysis is extremely time and resource-consuming. Consequently, this measurement technique stands little chance of being used successfully in practice.

2.2. Apdex Index

The Apdex Index Method [5] is a proprietary solution that has yet to be standardized. It, too, is a method for measuring both QoE and QoS in the WWW service. It, too, is a one-sided measuring model. It can be applied without recourse to a group of test persons, but only if specialized tools are then assigned to determine the parameters necessary for this metric. Its chief criterion of evaluation is also the time taken for a Web page to open. The assessment of the quality of service yields a value on a scale from 0 (unacceptable) to 1 (excellent). The assessment depends to a large extent on which threshold time T is used. All relationships (and the metric itself) are clearly shown in Fig. 2.

Steps 1 to 6 have the following meanings:

1. Define threshold T (in seconds) for the application.

2. Real-time expert reporting group – view by application, server, or user.

3. Extract data set from existing measurements for viewing.

4. Count the number of samples in the three performance zones.

5. Calculate the Apdex value (see $Apdex_T$ formula).

6. Display Apdex result.

The T value is the application target time (threshold between satisfied and tolerating users). The F threshold between tolerating and frustrated users is calculated as $F = 4T$. This method can be used in combination with specialized tools in practice.

2.3. Metric Power

The metric Power was first presented in paper [6]. It is a further method of measuring both QoE and QoS that is to be classed as a one-sided measurement model. Unlike the methods described above this method takes a further parameter into account that can be crucial for the WWW service: data download rate. As a result, the method is more versatile and therefore of much more practical use. Equation (1) describes the metric Power.

$$P = \frac{1}{1 + \dfrac{\alpha}{ddr}}, \qquad (1)$$

where: α – delay coefficient, ddr – download data rate in [Mb/s], td – total delay in [s], th – threshold of delay in [s],

$$\alpha = \begin{cases} 0 & \text{for } td \leq th \\ (td - th) & \text{for } td > th \end{cases}.$$

It is obvious that both the download data rate and the total delay (time lapse between the point in time at which the session begins and the point in time at which the Web page is completely built up) depend on the throughput of the used transmission canal. But they also depend on the locality of the WWW server, its activity level, on the content of the Web pages being accessed, and whether that content is static or dynamic. Total delay can therefore vary within a considerable range. The new metric Power takes that into account.

First results, presented in paper [6], have confirmed that the new metric is of real practical use in principle, the only hitch being that it has not until now been fully implemented in a specialized tool, nor undergone exhaustive tests in a variety of realistic scenarios. And that is where this paper comes in.

3. The New Tool for Analysing Quality of Service in WWW

The tool that was developed in the course of this work to analyse QoS in the WWW service has been called QoSCalc(WWW). It can be used for both objective but also subjective analysis of service quality, i.e. QoE. It was created using the programming language C# / .NET 4.5 [8] and works with the Web browser object Internet Explorer [9]. The tool uses the following, fundamental classes:

- SharpPcap: provides the possibility of recording the network traffic of the hardware,

- PacketDotNet: provides the possibility of converting the recorded network traffic into the corresponding format (TCP/IP packet),

- Webbrowser: facilitates navigation and phase separation,

- WebClient: provides general methods for sending data to and receiving it from a resource labelled with a URI,

- DateTime: manages time stamps,

- TimeSpan: for mathematical operations on date-time objects.

The arrows in Fig. 3 clarify how the new tool works, the single steps being:

1. First navigation phase.

2. First data download phase.

3. Page set-up in Web browser object.

4. Storage in computer cache.

5. Start of a complete page refresh.

6. Refresh data download phase.

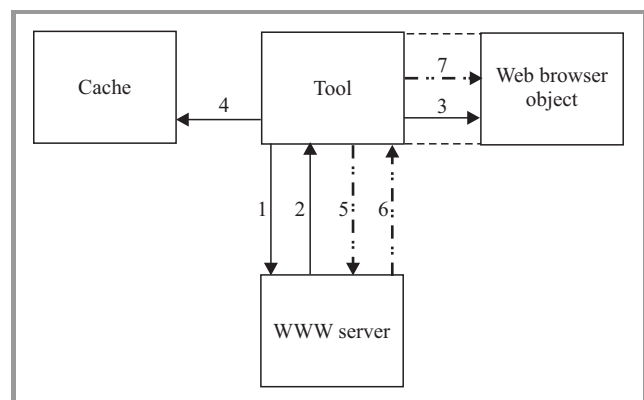7. Refresh page set-up in Web browser object.

Fig. 3. New tool operation principle.

The first navigation phase and the first data download phase assist in timing the start of the measurement. During these phases the tool checks whether outsourcing is being used for the selected Application Service Provider (ASP), or not. If outsourcing is being used, the tool then looks to see how many WWW servers are being used to store contents elements that are being called up. The fact that the called page must always be built up from scratch in the Web browser object can be used to good effect when it comes to determining QoE. When the measurement has been completed, the tool displays – without any further action on the part of the user – the QoS values calculated in accordance with the metrics Power and Apdex.

Figure 4 shows the finished user tool overlay. The user can choose between three languages: English, German and Polish by using the button EN, DE, PL. The user overlay has three main areas: settings, display and results.
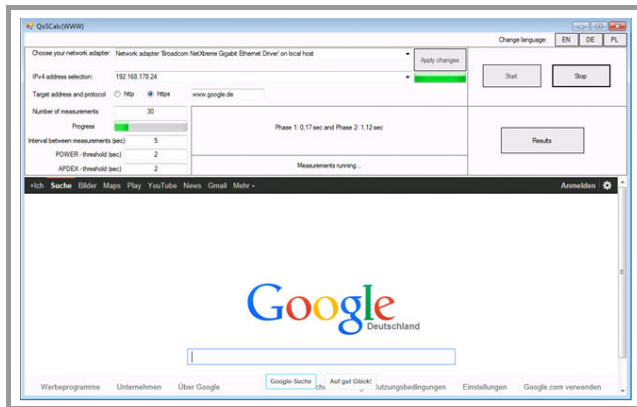

Fig. 4. QoSCalc(WWW) user interface.

In the settings area parameters for the measurement scenarios are set. It contains the following control elements: network adapter (selection box), IPv4 address selection (selection box), target address (text field), protocol (button), number of measurements (text field; default = 30), progress (gas gauge), interval between measurements (text field; default = 2 s), Power threshold (text field; default = 1 s), Apdex threshold (text field; default = 1 s), and accept (button).

In the display area "Preliminary Results" (middle of the user overlay) the confidence interval for the total delay and the results from the metric Power are displayed as soon as the measurement has been successfully completed. The field also outputs the correct target address, along with the instruction to repeat the measurement, should this be necessary.

The results area could be kept relatively simple. It has only three buttons: start, stop and results. The measurement is initiated with the start button. A measurement in progress can be aborted at any time with the stop button. Once a measurement is complete, the results page (shown in Fig. 5) can be called up with the results button.
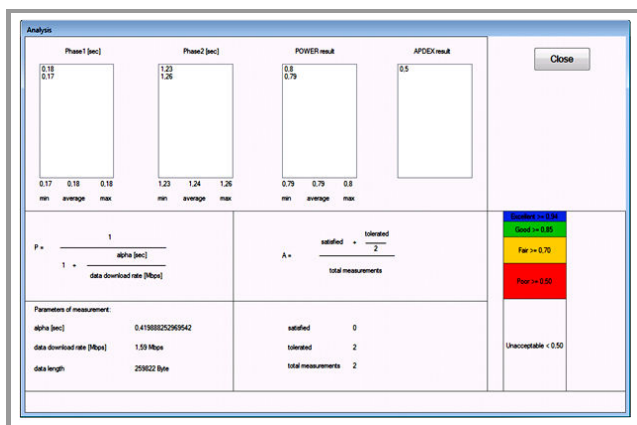

Fig. 5. User overlay of the results page.

The results page comprises 4 scrollable lists. They give the user a clear picture of what the tool has ascertained. As a further help there is a mathematical representation of each metric: P, i.e. metric Power, and A, i.e. Apdex. There is also a colored scale that helps to classify the results. The results page is closed with the close button; the user returns to the main page.

The reliability of the finished tool QoSCalc(WWW) was tested in exhaustive trials. Its operability was then further tested in a real-life environment. This environment and the measurement scenarios in operating within it are described in the next chapter.

4. Measurement Environment, Measurement Scenarios and Measurement Results

Figure 6 shows the measurement environment and how the new tool was implemented. This measurement environment was chosen to provide access both to remote WWW servers on the Internet and a local WWW test server. The authors decided to extend the work scope described in this paper to access external servers in order to be confronted with the problems which real network traffic causes. In addition to the impairment parameters which this causes, a wanulator [10] was included with which network parameters such as packet loss, jitter and delay could be emulated.
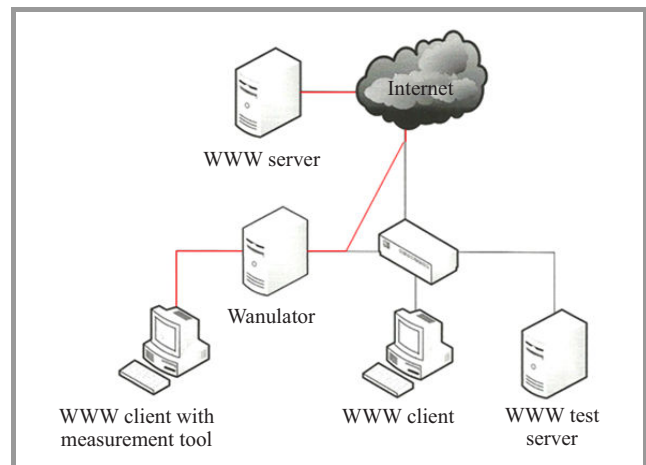

Fig. 6. Arrangement of the measurement environment.

In the following, two measurement scenarios are assumed:

- Scenario 1
  - number of measurements: 30,
  - threshold "Power": 2 s,
  - threshold "Apdex": 2 s,
  - interval between measurements: 3 s,
  - jitter in ms (0, 50, 100, 150, 200, 250, 300).

- Scenario 2
  - number of measurements: 30,
  - threshold "Power": 5 s,
  - threshold "Apdex": 5 s,
  - interval between measurements: 3 s,
  - packet loss in percent (1, 2, 3, 4, 6, 8, 10).

Among others, the following Internet pages were used in the measurement scenarios:

- https://de-de.facebook.com,
- http://www.spiegel.de,
- http://www.chip.de,
- http://www.bundeswehr.de/portal/a/bwde,
- http://www.elektronik-kompendium.de,
- https://www.google.de,
- http://www.amd.com/de/Pages/AMDHomePage.aspx,
- http://www.nvidia.de,
- http://www.fh-flensburg.de/fhfl/index.php.

Representative results from Scenario 1 (with http://www.google.de) are presented graphically in Figs. 7 to 9.
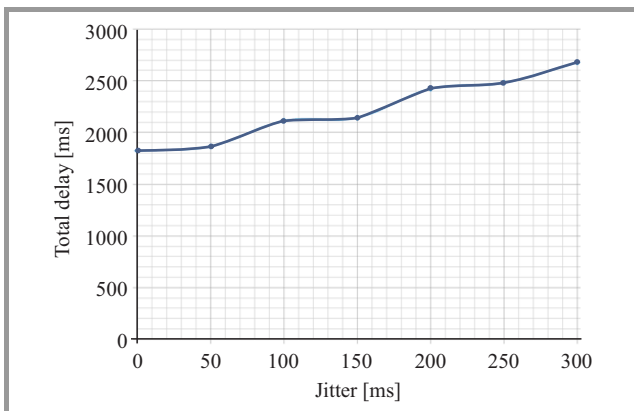
Fig. 7. Total delay as a function of jitter.

It is evident from Figs. 7 to 9 that total delay increases with increases in jitter (which was to be expected). Since the amount of data remains the same whenever the page is called up, the data download rate will decrease accordingly. A comparison between Apdex and Power shows that the two QoS curves develop exponentially but with differing gradients: at a jitter of 50 ms the Apdex curve starts to fall rapidly. The metric Power exhibits much more elasticity, with the subjective appraisal corresponded more to the objective result yielded by Power. While the measurements were being made, it also became evident that the ASP for the Web page www.google.de uses no outsourcing, which
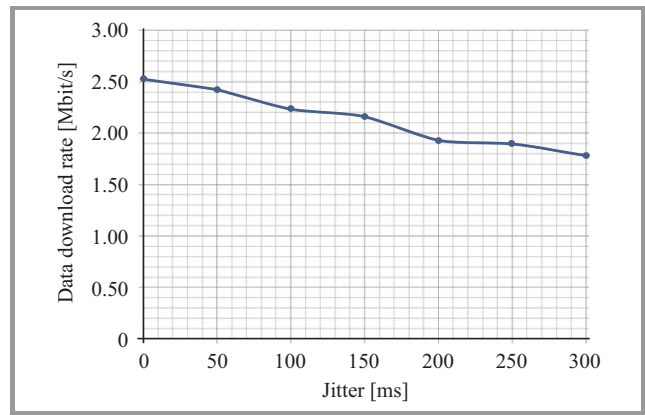
Fig. 8. Data download rate as a function of jitter.
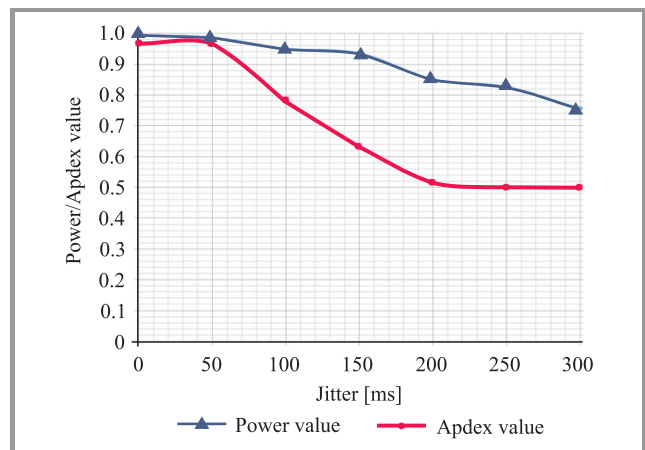
Fig. 9. Power and Apdex values as a function of jitter.

means that the call-up time of approx. 2 s is relatively short.

The representative results from Scenario 2 (with http://www.spiegel.de) are presented graphically in Figs. 10 to 12.

From Figs. 10–12 it is evident that even in a loss-free environment the times taken for a page to open were above the threshold set at 5 s, which resulted in values of less than 1. The time taken is so excessive because the ASP for the Website www.spiegel.de uses outsourcing, which is known to take time. The Apdex values remain almost constant at approx. 0.55. The metric Power demonstrates favorable elasticity too. Whenever packet losses increase, total delay rises rapidly and the data download rate falls noticeably. The small peaks in the download rate at packet losses of 1% and 3% (see Fig. 11) are due to the fact that although statistically the packet loss is higher at 3%, more often than not it was acknowledge packets that were affected when packet loss was measured at approximately 1%, which initiated a resenting of the packets involved. Here again, the subjective evaluation corresponds rather to the objective result of Power.

The results obtained show that the goal of creating an innovative, efficient tool for evaluating the quality of the WWW
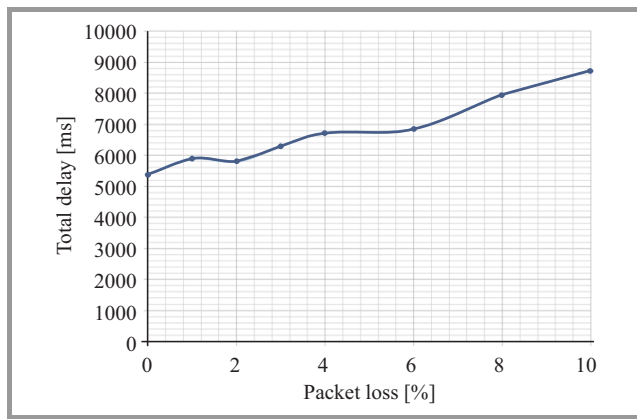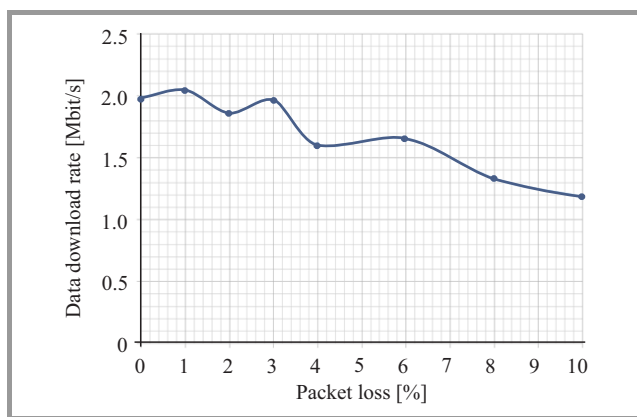
Fig. 10. Total delay as a function of packet loss.

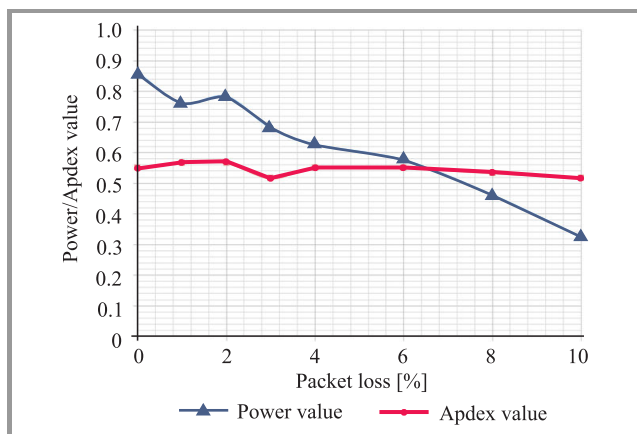**Fig. 11.** Data download rate as a function of packet loss.

Fig. 12. Power and Apdex values as a function of packet loss.

service has been achieved here. The tool operates dependably and can be implemented practically anywhere. Consequently, the new tool is of immense practical importance for the communications industry.

5. Summary and Outlook

This paper has been devoted to the subject of QoS measurement within the World Wide Web (WWW). It has focussed on the creation of a tool for measuring quality of service in the WWW service. The tool has been given the name QoSCalc(WWW). It takes into account all of the most important parameters that can impair the WWW service, primarily the time taken for a page to open and the data download rate of a page. This two-phase approach to analysis relies on a combination of navigation phase and download phase. The prototype tool was tested in a realistic environment in a range of measurement scenarios using different WWW servers. The measurements have proved that the QoSCalc(WWW) measurement tool yields reliable and duplicable results in an authentic environment. With that, the tool has proved its practical capabilities and is ready to be used effectively in determining the quality of the WWW service.

In future work it would be very worthwhile anchoring the tool in a Testing Cloud Environment to make its use available to a wide sector of the public. Moreover, a range of browser implementations would not be amiss. They would help to identify differences in quality from one browser to the next. Accordingly, it would make sense to use other browser implementations in order to evaluate Web pages that cannot be evaluated at the time of writing due to errors in the internal routines of the browser implementations themselves. Beyond that, it would be worthwhile taking a look at individualized logging-in procedures. It would make sense, for instance, to investigate WWW pages onto which user profiles are loaded. Evaluating the process by which user profiles are loaded would bring us closer to understanding the phenomenon QoE. Another implementation in the end-user spectrum that is sorely needed is one to monitor WLAN adapters. Last but not least, the authors would like to point out that the present version of the tool attempts to resolve DNS entries according to IPv4. This could become a problem when IPv6 becomes the norm. Consequently, an implementation of the tool on IPv6 must follow. Work in this direction is already in the offing.

References

[1] Definition of NGN [Online]. Available: http://www.itu.int/rec/T-REC-Y.2001 (accesed: Nov. 2014).

[2] Directive 2009/140/EC of the European Parliament and of the Council of 25 November 2009 amending Directives 2002/21/EC on a common regulatory framework for electronic communications networks and services, 2002/19/EC on access to, and interconnection of, electronic communications networks and associated facilities, and 2002/20/EC on the authorisation of electronic communications networks and services. Official Journal EU L.337/37.

[3] Directive 2009/136/EC of the European Parliament and of the Council of 25 November 2009 amending Directive 2002/22/EC on universal service and users' rights relating to electronic communications networks and services, Directive 2002/58/EC concerning the processing of personal data and the protection of privacy in the electronic communications sector and Regulation (EC) No. 2006/2004 on cooperation between national authorities responsible for the enforcement of consumer protection laws. Official Journal EU L 337/11.

[4] "Estimating end-to-end performance in IP networks for data applications", Recommendation G.1030, ITU-T [Online]. Available: http://www.itu.int/rec/T-REC-G.1030/en (accessed: Nov. 2014).

[5] Application Performance Index - Apdex Technical Specification Version 1.1 [Online]. Available: http://www.apdex.org/specs.html (accessed: Nov. 2014).

[6] T. Uhl, J. Klink, and P. Bardowski, " New metric for World Wide Web Service Quality", *J. Telecommun. Inform. Technol.*, no. 2, pp. 50–58, 2014.

[7] A. Raake, *Speech Quality of VoIP*. Chichester: Wiley, 2006.

[8] SharpPCap [Online]. Available: http://sharppcap.sourceforge.net/htmldocs/SharpPcap/RawCapture.html (accessed: Nov. 2014).

[9] Web browser object Internet Explorer [Online]. Available: http://msdn.microsoft.com/de-de/library/

system.windows.controls.webbrowser%28v=vs.110%29.aspx (accessed: Nov. 2014).

[10] Wanulator [Online]. Available: http://wanulator.de (accessed: Nov. 2014).

Tadeus Uhl received his M.Sc. in Telecommunications from Academy of Technology and Agriculture in Bydgoszcz in 1975, Ph.D. from Gdańsk University of Technology in 1982 and D.Sc. from University at Dortmund (Germany) in 1990. Since 1992 he works as Professor at the Institute of Communications Technology, Flensburg University of Applied Sciences (Germany) and additionally since 2013 as Professor at the Institute of Transport Engineering, Maritime University of Szczecin. His main activities cover the following areas: traffic engineering, performance analysis of communications systems, measurement and evaluation of communication protocols, QoS and QoE by Triple Play Services, Ethernet and IP technology. He is author or co-author of three books and about 130 papers on the subjects LAN, WAN and NGN.
E-mail: t.uhl@am.szczecin.pl
Maritime University of Szczecin
Henryka Pobożnego st 11
70-507 Szczecin, Poland
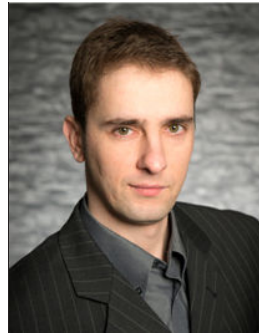
Marcus Rompf received his B.Sc. in Computer Engineering from the Flensburg University of Applied Sciences (Germany) in 2014. Today he is student for Master's degree in Information Technology at Kiel University of Applied Sciences (Germany). His main activities cover the following areas: quality assurance for Triple Play Services and medical imaging solutions.
E-mail: marcus.rompf@fh-flensburg.de
Flensburg University of Applied Sciences
Kanzlei st 91-93
D 24943 Flensburg, Germany