Broadband Access to the Internet via Mobile Interfaces

Paweł Bardowski
Janusz Klink
Wroclaw University of Technology, Poland
pawel.bardowski@pwr.wroc.pl
janusz.klink@pwr.wroc.pl

Maria Jolanta Podolska
Office of Electronic Communications, Warsaw, Poland
M.Podolska@uke.gov.pl

Tadeus Uhl
Flensburg University of Applied Sciences, Germany
tadeus.uhl@fh-flensburg.de

***Abstract*—This paper addresses the regulatory framework and technical aspects of broadband access to the Internet via mobile interfaces in Europe. It begins with a concise presentation of the most important conditions of the European Commission's regulatory framework. Following that, there is a discussion of the main network parameters involved in the evaluation of quality of network access via mobile interfaces according to the European Telecommunications Standards Institute (ETSI). Next, the open source tools for measurement of QoS values via mobile interfaces and the those used in this paper in the IP environment are described briefly. Then the measurements of broadband access conducted with these tools are presented graphically, and interpreted. The paper concludes with a summary and outlook on further work.**

Keywords-communications networks, communications services, multimedia applications, internet access, quality of service, QoS measurement techniques and tools

I. INTRODUCTION

Globalisation in today's modern society demands increasingly faster transport platforms with communication channels characterised by efficiency and high quality that often behave like virtual paths. Such a brand of communication is not only vital in times of catastrophe, e.g. war, terrorist attacks and natural disasters; they are also indispensable in commerce, banking, education, research, for monitoring objects, for entertainment and many other branches of endeavour. New forms of digital networks and electronic services are going to have to get to grips with this situation. Furthermore, mobile access to the digital networks is beginning to play an enormously important role. Mobility is very important in today's society and has attained something of a flagship quality. Reliable mobile broadband access to the Internet is taken for granted these days.

In order to survive on today's telecommunications market, it is no longer enough to offer a wide range of serves at competitive rates: the quality of those services is becoming an increasingly decisive factor. This presents both network and service providers on the one hand and the National Regulatory Authorities (NRAs) in the Member States of the EU on the other with a new challenge.

To begin with, the regulatory framework and technical aspects of broadband access to the Internet in Europe will be described briefly. Following that, there is a discussion of the main network parameters involved in the evaluation of quality of network access via mobile interfaces according to the European Telecommunications Standards Institute (ETSI). Next, the open source tools for measurement of QoS values via mobile interfaces and the those used in this paper in the IP environment are described briefly. Then the measurements of broadband access conducted with these tools are presented graphically, and interpreted. The paper concludes with a summary and outlook on further work.

II. REGULATORY FRAMEWORK IN EUROPE

Convergence of telecommunications, media and information technology requires that all the networks and services related to the transfer of information be bundled in a single regulatory framework. In adopting the regulatory framework for electronic communications networks and services the European Parliament and the European Council have been guided by, among other things, the desire to establish full competition between businesses operating on the telecommunications market while at the same time giving customers the free choice of provider by giving them unlimited access to information about the quality of services that the providers offer. 25th November 2009 the European Parliament and the European Council adopted the so-called Communications Package that includes: Directive 2009/140/EC [1] and Directive 2009/136/EC [2]. Following publication of these documents, all EU Member States were obliged to publish and adopt the laws, regulations and administrative provisions necessary to comply with these directives by 25th May 2011.

In 2010 the European Commission contracted BEREC (Body of European Regulators for Electronic Communications) with the investigation of the key issues influencing an open and neutral Internet. The Expert Working Group BEREC, composed of experts and representatives of various European Union regulators worked on the report *" BEREC Guidelines for Quality of Service in scope of Net Neutrality"* [3], which is due to be published before autumn 2012.

In April 2012 the Communications Committee of the European Commission presented NRAs with a document for consultation. It was a working draft of a Commission Recommendation on the procedures provided for in Article 22 (3) of Directive 2002/22/EC on universal service and users' rights with regard to electronic communications networks and services, recommended in Directive 2009/136/EC [2]. This project provided information about the form and procedure of reporting that the NRAs should use, and contained a draft of the measures it intended to impose on entrepreneurs who provide publicly available telecommunications services. It extends to cases of slowdown or degradation of business traffic (that result in deterioration of the quality of services to the detriment of consumers), and includes information on the minimum requirements (level indicators) in terms of quality. It is expected that the European Commission Recommendation on the notification procedure foreseen in Article 22 (3) Universal Service Directive will be published in the Official Journal of the European Commission towards the end of 2012.

In March 2007 Document [4] appeared in the Official Journal of the EU containing norms and specifications for networks and services in electronic communication. Chapter VII of the Document details the recommended quality parameters of electronic services from the point of view of the end-user. These parameters are also to be found in two ETSI Guides: ETSI EG 202 009 [5-7], ETSI EG 202 057-1 [8-11] and in Recommendation ITU-T G.1020 [12], ITU-T Y.1541 [13].

III. PARAMETERS IN MOBILE NETWORKS TO THE ETSI

The very special conditions prevalent in mobile networks distinguish them categorically from conventional fixed line networks. For this reason it was necessary to modify the quality parameters given in the Guides mentioned in the previous chapter. Recommendation ETSI TS 102-250-(1-6) [14-18] contains not only the quality parameters modified for mobile networks but also definitions, descriptions of making measurements and ways to process them.

The following section describes the special conditions for measurements made in GSM/UMTS networks:

1) Coverage maps with signals in 2G and 3G technologies, to be precise:

a) for GSM technology:

- Level of the received signal RxLev (RxLev > - 92dBm for ≥18 step),
- Quality of the received signal RxQual (RxQual ≤ 5).

These parameters are representative of the received level and the quality of the call.

<u>Level</u>

Every GSM mobile measures the parameter RxLev. During the call this parameter corresponds to the power level received by the mobile on the transmission channel. The measurement scale varies from - 110 dBm to - 47 dBm although the mobile actually reports another value (step) which varies from 0 to 63 with 0 corresponding to -110 dBm and 63 corresponding to – 47 dBm or greater.

<u>Quality</u>

Every GSM involved in the process of a call measures the parameter RxQual. This parameter varies from 0 (best) to 7 (worst).

b) for UMTS technology:

- RSCP (Received Signal Code Power) is the collected RF energy after the correlation/descrambling process, usually given in dBm (RSCP > - 92dBm),
- RSCP (Received Signal Code Power) is the collected RF energy after the correlation/descrambling process, usually given in dBm (RSCP > - 92dBm),
- Ec/Io is the ratio of the received energy per chip (= code bit) and the interference level, usually given in dB (Ec/Io > - 12 dB).

2) Establishment of measurement sites (urban, rural, motorway, etc.).

3) Establishment of duration, frequency and time of measurements.

4) Establishment of measurement scenarios, mode of operation of the measurement terminals (automatic, not automatic), portability of the measurement terminals (fixed, mobile).

The following contains a list of QoS parameters (according to the ETSI Specification mentioned above) for various services in the GSM/UMTS networks.

<u>Voice Service</u>

- Telephony Service Non-Accessibility in [%],
- Telephony Setup Time in [s],
- Telephony Speech Quality on Call Basis in [MOS].

<u>Data Transmission FTP, E-Mail Service (download/upload) and HTTP Service</u>

- Service Non-Accessibility in [%],
- Setup Time in [s],
- IP-Service Access Failure Ratio in [%],
- IP-Service Setup Time in [s],
- Mean Data Rate in [kbps],
- Data Transfer Cut-off Ratio in [%].

<u>SMS Service</u>

- SMS Service Non-Accessibility MO in [%],
- SMS Access Delay MO in [s],
- SMS Completion Failure Ratio in [%],
- SMS End-to-End Delivery Time in [s].

<u>MMS Service</u>

- MMS Send Failure Ratio in [%],
- MMS Send Time in [s],
- MMS End-to-End Failure Ratio in [%],
- MMS End-to-End Delivery Time in [s].

It becomes evident that a large number of parameters are needed to evaluate QoS in digital networks and electronic services. This work focuses on establishing the data rate at the mobile interface to the broadband network. It is this parameter in particular that forms a basis for contracts between network / Internet providers and their customers. That the bandwidths agreed on in the contracts are actually provided in practice must be monitored. This is the essence of the EU Directives quoted in Chapter 1. Measurements of the available bandwidths at the access points are essential. This paper is devoted to that very important issue.

IV. The QoS measurement tools used

It is clear that there are already an adequate number of standards that define the parameters of QoS in digital networks and electronic services. And there are several companies on the telecommunications market, e.g. Nextragen [19], Opticom [20], Empirix [21], IXIA [22], NetIQ [23], Ip-Label [24], Telchemy [25], Shenick [26], VoIP Future [27] et al. that provide systems to measure these parameters. Using commercial measuring tools can, however, prove very costly, being in some cases subject to licence. So, a good alternative for conducting such necessary measurements is the use of open-source tools. There are dozens of these measuring systems, including, for instance, the licence-free Measurement Lab [28] or die tools from the "SpeedTest" suite [29]. They were used in the following way.

Measurement Lab (M-Lab) is an open, distributed server platform for researchers to deploy Internet measurement tools. The goal of M-Lab is to advance network research and grant the public a certain amount of autonomy by enabling them to gain useful information about their broadband connections for themselves. The M-Lab tool lets users perform the following tests:

1) *Network Diagnostic Tool (NDT):* test your connection speed and receive sophisticated diagnosis of problems limiting speed.

2) *Glasnost Test*: test whether certain applications or traffic are being blocked or throttled on your broadband connection.

3) *Network Path and Application Diagnostics (NPAD)*: diagnose common problems that impact last-mile broadband networks.

4) *Pathload2*: see how much bandwidth your connection provides.

5) *ShaperProbe*: determine whether an ISP is performing traffic shaping.

6) *BISmark Gateway*: apply to host a router device to test Internet connectivity over time.

7) *WindRider*: detect whether your mobile broadband provider is performing application or service specific differentiation.

8) *SideStream*: collect statistics about the TCP connections used by the measurement tools running on the M-Lab platform.

9) *Neubot*: perform periodic tests to measure network performance and application-specific traffic throttling.

The measurement system M-Lab, its strengths and its weaknesses have been extensively described in paper [30] which confirmed that the tools NDT and Neubot are very helpful when it comes to determining data rates at the interface to the broadband network. Consequently, both of these tools were used extensively in the course of this work.

Some of the most important measurement tools in the SpeedTest suite are [31]:

1) *SpeedChecker,*
2) *Speedtest.net,*
3) *Speedtest.pl,*
4) *Speedtest.com.pl.*

The first of these tools, SpeedChecker [29] is a simple tool, written in Flash, that examines the data rate available at the interface to the broadband network. To obtain really accurate measurements, use of the browser Google Chrome is recommended. The tool allows the user to make several adjustments, for instance, determining the type of test to be conducted, choice of server used for the test, where to collect and store the measurement results. Other tools belonging to the suite are similar in structure and also make it possible to determine the data rate at the interface to the broadband network. The tools from the SpeedTest suite have been described in detail in paper [32] and their practicability in an IP environment examined. It has become evident that the tool SpeedChecker is the most stable in operation. For this reason it was used throughout the rest of this work.

V. The measurement environment

The measurement environment (see Fig. 1) was so conceived as to enable tests of access to the Internet via mobile interfaces as it is offered by various providers. The measurements were chiefly aimed at determining the data rate for upload and download using the service HTTP. Depending on which measurement tool is used, it can be possible to determine further parameters of QoS, such as delay, jitter, packet loss probability. Yet the focus of the paper always remained on determining the QoS parameter data rate. The measurement environment is stationary and is situated in one of Poland's larger cities (approx. 800,000 inhabitants). The performances of five network providers were tested: Aero2 [33], Play [34], T-Mobile [35], Plus [36] and Orange [37]. Areo2 offers Internet access free of charge using HSPA+900 technology and LTE2500TDD. The other four network providers are commercial providers offering individual customers Internet access at set rates. Because the G3 Standard is the prevalent technology in mobile networks, it was used and examined throughout the work that formed the core of this paper.

The measurement environment shown in Fig. 1 consists of five identical 32-bit PCs (Intel® Core™ 2 Duo – E7500 @ 2.93GHz, 2 GB RAM), running the operating system Windows Vista. A wireless modem (MF668 HSPA+21 Mbps) from the ZTE Company is attached to each Computer. Each modem is equipped with a SIM prepaid card that allows Internet access through one of the five network providers mentioned above. The different tariff structures of the five network providers were taken into consideration, the price per 1 GB being: Areo2 free of charge, Orange € 3.40, Play € 2.40, Plus € 3.80, T-Mobile € 2.60. Apart from that, the network providers offer different packet sizes and restrict the file sizes in each transfer. Furthermore, the procedure for loading the SIM card varies considerably, ranging from a quite simple procedure for Play to a really awkward one for Orange.

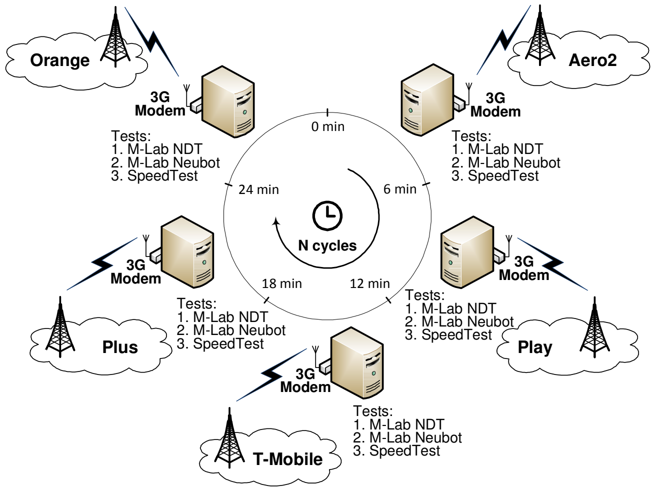

Figure 1. The measurement environment

Two tools from the open source platform Measurement Lab, NDT and Neubot, and the tool SpeedTest (English version is SpeedChecker) were selected as measurement systems for the measurement environment. The choice of these measurement tools was influenced by insights gained by the authors in previous examinations of broadband access to the Internet over fixed line networks (cf. Chapter 3). Their experiences convinced them that the three tools mentioned above work reliably and deliver comparable results regardless of the measurement scenarios under examination. The M-Lab platform also offers the tool WindRider for the examination of Internet access over a mobile interface. As it runs under the Linux operating system, however, it is not compatible with the Windows Vista operating system, that was used here.

In the measurement environment shown in Fig. 1 several series of measurements were started and executed in rotation. A measurement cycle lasted 30 minutes and was executed at preselected times of day and night for one week. All three tools mentioned above were used to establish the Internet access data rates of five network providers for both upload and download. The results obtained are presented in the next chapter, and interpreted.

VI. THE RESULTS OBTAINED

The size of the statistical population that was made available for inference of the measured values lay between 250 and 280 for each of the parameters covered by the scope of this work. The figures contain the mean values (small squares), the minimum and maximum values (whiskers) and the standard deviation (boxes). Approx. 70 % of all measured values lie within the boxes for each parameter measured.

Both upload and download data rates and the round trip delay time (latency) were measured in the networks of the five providers named in Chapter 4. The data rates were measured on the application layer in order to highlight the actual data rate available for an application. The measurements were conducted using the following tools: NDT, Neubot and SpeedTest. The reasons for their selection are given in Chapter 4.

Figs. 2 and 3 show the upload and download data rates yielded by the measurement tools named above for the five Internet providers in the test. Aero2, Play and Plus provide comparable though low data rates. T-Mobile and Orange can offer much higher data rates, but they fluctuate greatly (500 to 700 kbps at a measured mean data rate of approx. 2 Mbps). The data rates acquired correlate with the values of the RTD times measured in the same environment. They were the following: T-Mobile 88 ms, Orange 108 ms, Plus 126 ms, Aero2 152 ms. (This parameter could not be measured for Play due to problems with the Neubot tool).

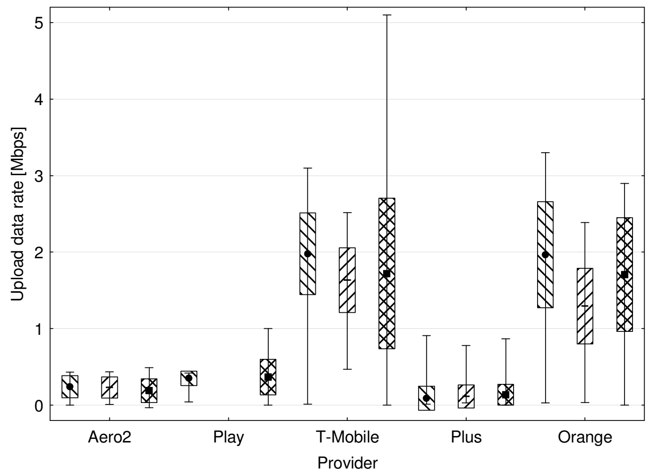

Figure 2. Upload data rate (NDT, Neubot, SpeedTest)

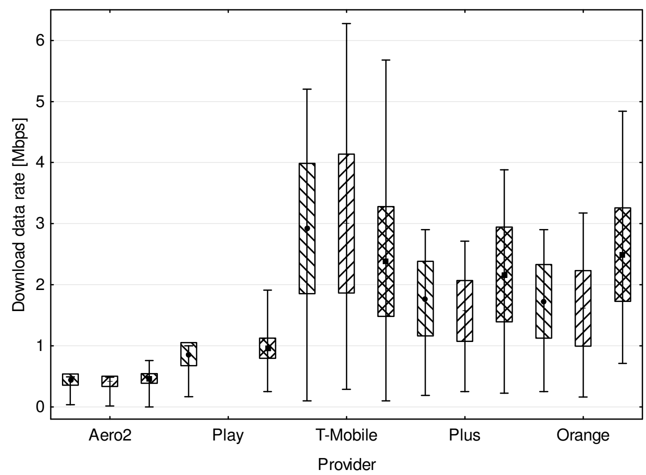

Figure 3. Download data rate (NDT, Neubot, SpeedTest)

It is also possible to present the data rates that were actually provided as a function of the time of day. Figs. 4 to 8 show the results obtained.

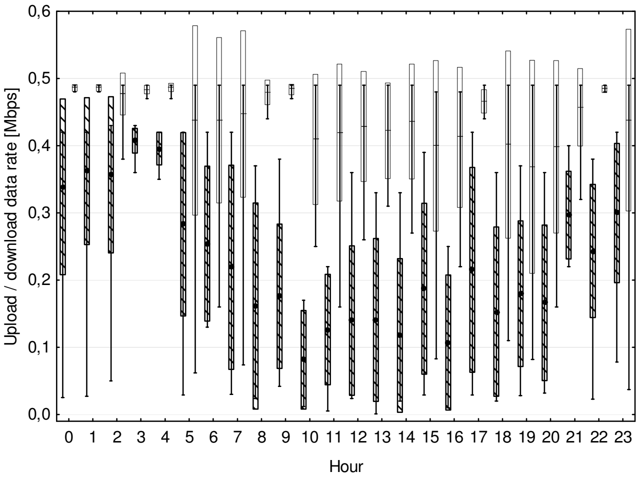

Figure 4. Aero2 - 24hour upload / download data rate (UP, DOWN)

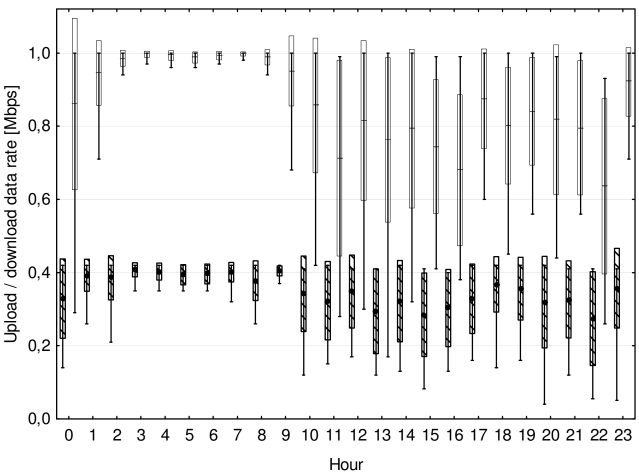

Figure 5. Play - 24hour upload / download data rate (UP, DOWN)

Figs. 4 to 8 allow us to make the following observations. Of all providers, Aero2 provided the lowest upload and download data rates. This is, however, completely in accordance with the claims of this provider of Internet access, and is free of charge (from 10.05.2012 onwards no more than 512 kbps). The values fluctuate greatly from day to night. It is worth mentioning that Aero2 functions along the lines of the "best effort" principle.

Furthermore, it could be demonstrated that the provider Play provides twice as high a data rate as Aero2. But that comes at a price. And Play's upload and download data rates too are subject to considerable fluctuations during a day-time / night-time cycle.

Examinations of the Internet provider T-Mobile have shown that the mean data rates can be high (approx. 2 Mbps for both upload and download). The fluctuations in the data rates during the day-time / night-time cycle can be quite large too, and even just in the night alone.

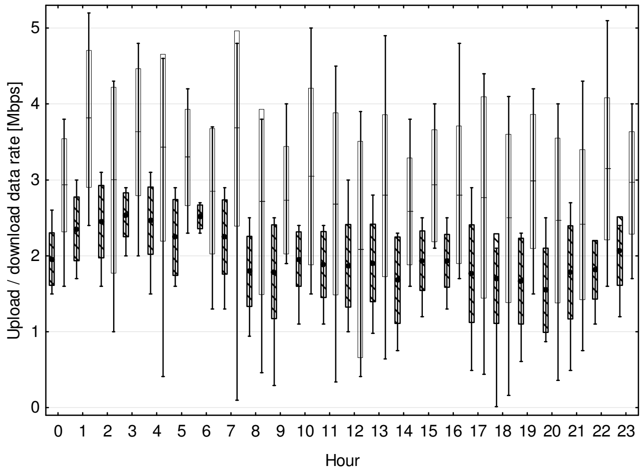

Figure 6. T-Mobile - 24hour upload / download data rate (UP, DOWN)

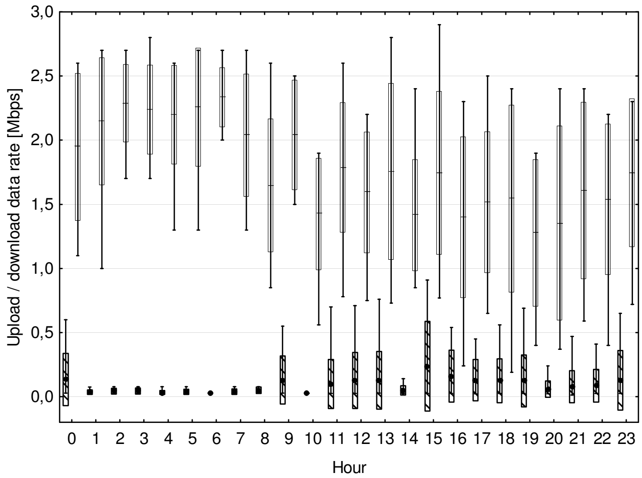

Figure 7. Plus - 24hour upload / download data rate (UP, DOWN)

The data rates measured for the Internet provider Plus reveal a similar pattern to that of T-Mobile. The upload data rate is, however, really low (approx. 100 kbps) although the download rate is remarkably high (approx. 1.8 Mbps).

Measurements of the data rates provided by Orange also show large fluctuations during the day-time / night-time cycle, but here the upload and download rates show no great discrepancy. There were even times when upload rates exceeded download rates, which seems unusual.

In conclusion, it can be said that T-Online provides the fastest access to the Internet, followed by Orange and then Plus. The performances of Play and Aero2 turn out pretty poor in comparison.

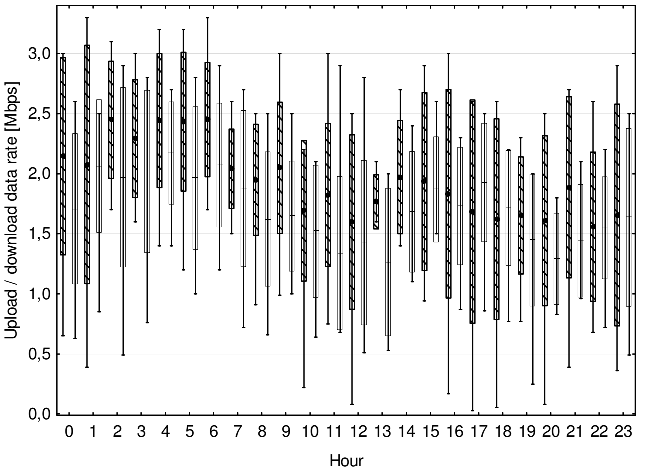

Figure 8. Orange - 24hour upload / download data rate (UP, DOWN)

The study focussed primarily on the very important network parameters upload and download data rates. It is not possible, however, to comprehensively characterise an Internet access point, going off this parameter alone. Additional network and service parameters must be taken into consideration as well, as Chapter 3 convincingly shows. These additional QoS parameters must be taken into account in further studies at all costs. The authors have already started work in this direction.

It could also be demonstrated that open source measurement tools are quite capable of quantifying the most important network and service parameters effectively. This must make them an attractive alternative to commercial measuring systems.

VII. CONCLUSION AND OUTLOOK

The focus of this paper has been a concise presentation of the regulatory framework and technical aspects of broadband access to the Internet via mobile interfaces in Europe. A part of this paper discussed the most important impairment parameters in mobile networks and digital services in the light of the latest recommendations of the ITU-T and the ETSI. But the focus of this paper lay in a large-scale investigation into the measurement of QoS parameters at mobile interfaces to the Internet. Very valuable measurements were made in a real IP environment using open source tools. The series of measurements have confirmed the suitability of such tools for quantifying QoS parameters (data rate, RTD) in digital networks.

The results contained in this paper permit the very first assessment of the services of Internet providers from an objective, technical point of view. From the end-user's point of view, however, there are further non-technical parameters that influence their judgment of Internet access, e.g. price per megabyte of transferred data, flexibility of the upload / download process, and how the cards operate. Measurements of additional QoS parameters are necessary (see Chapter 3) before the quality of a service can be assessed completely. And then there is also the question of suitable QoS measuring systems. It is altogether a very complex matter indeed that must be tackled in further-reaching work. The authors are already planning their strategy.

REFERENCES

[1] 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 (hereinafter: Better Regulation Directive). (Official Journal EU L.337/37.

[2] 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 (hereinafter: Citizens' Rights Directive). (Official Journal EU L 337/11.

[3] http://berec.europa.eu/doc/consult/bor_12_32_guidelines.pdf; page last viewed June 2012.

[4] COMMISSION DECISION of 11/XII/2006 List of standards and/or specifications for electronic communications networks, services and associated facilities and services, replacing all previous versions (Official Journal EU L 86/11 of 27.03.2007) – Chapter VII.

[5] ETSI EG 202 009-1 V1.2.1 (2007-01) User Group; Quality of telecom services; Part 1: Methodology for identification of parameters relevant to the User.

[6] ETSI EG 202 009-2 V1.2.1 (2007-01) User Group; Quality of telecom services; Part 2: User related parameters on a service specific basic.

[7] ETSI EG 202 009-3 V1.2.1 (2007-01) User Group; Quality of telecom services; Part 3: Template for Service Level Agreements (SLA).

[8] ETSI EG 202 057-1 V1.2.1 (2005-10) Speech Processing, Transmission and Quality Aspects (STQ); User related QoS parameter definitions and measurements; Part 1: General.

[9] ETSI EG 202 057-2 V1.3.1 (2009-02) Speech Processing, Transmission and Quality Aspects (STQ); User related QoS parameter definitions and measurements; Part 2: Voice telephony, Group 3 fax, modem data services and SMS.

[10] ETSI EG 202 057-3 V1.2.1 (2007-01) Speech Processing, Transmission and Quality Aspects (STQ); User related QoS parameter definitions and measurements; Part 3: QoS parameters specific to Public Land Mobile Networks (PLMN).

[11] ETSI EG 202 057-4 V1.2.1 (2008-07) Speech Processing, Transmission and Quality Aspects (STQ); User related QoS parameter definitions and measurements; Part 4: Internet accesss.

[12] ITU-T G.1020 (11/2001) Series G: Transmission Systems and Media; Digital Systems and Networks; Quality of Service and Performance; End-User Multimedia QoS Categories.

[13] ITU-T Y.1541 (06/2006) Series Y: Global Information Infrastructure, Internet Protocol Aspects and Next Generation Networks-Quality of Service and Network performance; Network performance objectives for IP-based services.

[14] ETSI TS 102 250-1 V2.2.1 (2011-04) Speech Processing, Transmission and Quality Aspects (STQ); QoS aspects for popular services in GSM and 3G networks; Part 1: Identification of Quality of Service criteria.

[15] ETSI TS 102 250-2 V2.2.1 (2011-04) Speech Processing, Transmission and Quality Aspects (STQ); QoS aspects for popular services in GSM and 3G networks; Part 2: Definition of Quality of Service parameters and their computation.

[16] ETSI TS 102 250-3 V2.2.1 (2011-04) Speech Processing, Transmission and Quality Aspects (STQ); QoS aspects for popular services in GSM and 3G networks; Part 3: Typical procedures for Quality of Service measurement equipment.

[17] ETSI TS 102 250-4 V2.2.1 (2011-04) Speech Processing, Transmission and Quality Aspects (STQ); QoS aspects for popular services in GSM and 3G networks; Part 4: Requirements for Quality of Service measurement equipment.

[18] ETSI TS 102 250-5 V2.2.1 (2011-04) Speech Processing, Transmission and Quality Aspects (STQ); QoS aspects for popular services in GSM and 3G networks; Part 5 Definition of typical measurement profiles.

[19] http://www.nextragen.de; page last viewed June 2012.

[20] http://www.opticom.de; page last viewed June 2012.

[21] http://www.empirix.com; page last viewed June 2012.

[22] http://www.ixiacom.com; page last viewed June 2012.

[23] http://www.netiq.com; page last viewed June 2012.

[24] http://www.ip-label.de/index.php/de; page last viewed June 2012.

[25] http://www.telchemy.com/index.php; page last viewed June 2012.

[26] http://www.shenick.com; page last viewed June 2012.

[27] http://www.voipfuture.com; page last viewed June 2012.

[28] http://measurementlab.net; page last viewed June 2012.

[29] http://speedtest.net.pl; page last viewed June 2012.

[30] J. Klink, M. J. Podolska, T. Uhl, "Regulatory Framework and Technical Aspects of Broadband Access to the Internet in Europe", 2nd Baltic Conference on Future Internet Communications, 25 - 27 April 2012, Vilnius, Lithuania.

[31] J. Klink, P. Bardowski, M. J. Podolska, T. Uhl, "Otwarte narzędzia do pomiaru szerokopasmowego dostępu do Internetu", paper submitted to the Conference KSTiT, 14 - 17 September 2012, Warsaw, Poland.

[32] http://www.broadbandspeedchecker.co.uk; page last viewed June 2012.

[33] http://www.aero2; page last viewed June 2012.

[34] http://www.play.pl; page last viewed June 2012.

[35] http://www.t-mobile.pl; page last viewed June 2012.

[36] http://www.plus.pl; page last viewed June 2012.

[37] http://www.orange.pl; page last viewed June 2012.