Paper

Measurements and Statistical Analysis for Assessment of Availability of Mobile Network Services

Grażyna Kadamus[1] and Małgorzata Langer[2]

[1] *International Faculty of Engineering, Lodz University of Technology, Łódź, Poland*
[2] *Institute of Electronics, Lodz University of Technology, Łódź, Poland*

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Abstract—Availability is an essential feature of telecommunication services. It influences the quality of experience (QoE) associated with individual networks and with the services offered. Therefore, it needs to be allowed for at each level of network design, and has to be controlled at the operation stage. This is achieved by means of various mathematical and numerical tools. In this project listening quality and speech level, which are quality-related features of mobile network services, are measured and analyzed with the Monte Carlo simulation method. Measurements are taken with assistance of the Diversity Benchmarker, a reliable device designed for mobile network testing. Finally, results obtained are compared to assess the applicability of the Monte Carlo method.

Keywords—availability, Diversity Benchmarker, Monte Carlo, quality of experience.

1. Introduction

The idea of Quality of Service (QoS) is widely recognized as a feature that may decide whether given offering proves successful or fails to attract customers. This rule served as a starting point for this work. In telecommunications, availability constitutes a basic element of QoS and thus of Quality of Experience (QoE), and is included in the design of telecommunication networks. Mathematical solutions that are used to achieve it include various probability distributions and the Monte Carlo method.

This work verities the combination of the two in practice, and aims to show whether application of the Monte Carlo simulation can be beneficial, not only for the statistical simulation, but also for predicting expected values. It was accomplished by means of the statistical analysis of parameters that influence QoE – listening quality and signal level.

However, before the simulation could be performed, measurement data that would serve as a basis for the analysis was obtained. The testing was completed with assistance of the Diversity Benchmarker, a modern system for wireless network testing. This system, newly obtained by the Lodz University of Technology, provides its user with a wide range of measurement and analysis options.

2. Service Quality Management

Although services offered by telecommunications networks are characterized by many specific features, their quality and quality management are subject to the same rules as other products. They also have to undergo constant improvement, which in fact requires, proper network management. This term refers to actions, methods and procedures that enable the system to be operated, administrated, monitored and maintained. It is also required to adhere to certain quality standards while providing the service.

The way network management is dealt with is of paramount importance and it determines the QoS as the degree to which features of provided service support customer satisfaction. Supplement No. 10 to ITU-T E-series Recommendations ITU-T E.800 [1] provides a more precise explanation as: “Totality of characteristics of a telecommunications service that bear on its ability to satisfy stated and implied needs of the user of the service” (p. 1). QoS measures the performance of services provided; includes mechanisms improving performance, network traffic management optimization and management of network resources.

This collective effect comprises numerous single performances, and there are many standards regarding this issue. The fact that only objective measurement means constitute the QoS is of great significance. The so-called end-to-end QoS is about the complete transmission chain. However, the user is omitted in this assessment. Moreover, QoS is very often about characteristics related to the service itself and does not consider information about specific network sections.

QoS criteria are determined for four viewpoints [2] (Fig. 1). The first point of view is related to the customer’s QoS requirements. Non-technical, casual language is used to describe them. The next viewpoint is related to the service provider’s QoS offering and this is in fact planned or targeted QoS. Here, definitions together with respective values to be reached are given separately for each service type parameter. The criteria regarding QoS achieved or delivered is provided QoS. They enable to compare the offered QoS against delivered QoS, which allows to assess provider’s the capability to deliver declared values. The final viewpoint criteria consider customer perception and how QoS is experienced by the customer. It is a non-technical description received by asking for feedback, for example through however, because this is a personal point of view and it is included into QoE.

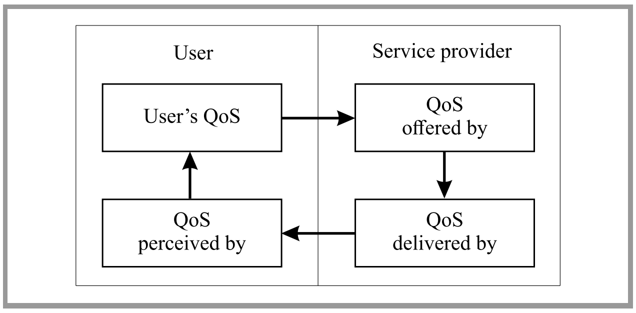


Fig. 1. Four-viewpoint QoS model.

Contrary to the objective QoS, QoE is a highly subjective measure as it is a user's perception of the overall quality of service. QoE takes into consideration both technical and non-technical factors and is influenced, to a great extent, by the customer's personal experiences and expectations, as well as by their emotions, environment, attitude and motivation. It is the QoE that impacts customer satisfaction and this fact should not be underestimated. The level of satisfaction is what virtually shapes their attitude towards the offering and it may result in the customer's decision to drop it when making the choice next time. Although, due to its high subjectivity, the measurable criteria for QoE are difficult to name, QoS gives a better understanding of QoE. Various QoS levels influence it and the empirically obtained relation between them are presented in Fig. 2 [2].

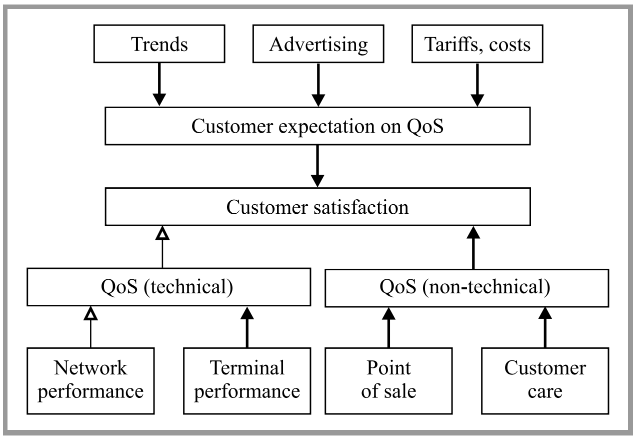


Fig. 2. Relationship between user QoE and QoS.

The model of QoS parameters in telecommunications has, according to the ITU-T E.804 standard, four layers (Fig. 3) [2]. The first one is network availability defined by Eq. (1), the second is network accessibility. The third layer is a combination of service accessibility, service integrity and service retainability. The fourth layer consists of different services.

$$\text{Availability} = \\ = 1 - \frac{\sum_{\text{Outage events}} \text{Capacity loss} \times \text{Outage duration}}{\text{Inservice time}} \tag{1}$$

Although from the customer's point of view accessibility is the first basic QoS parameter, availability, as the first layer, is in fact of paramount importance and determines accessibility and elements in other layers.

3. Measurement and Analysis System

SwissQual Diversity Benchmarker [3] is a measurement system based on a dedicated hardware platform and software used in this project offering high quality equipment for mobile network testing. It is capable of testing multiple technologies. Special models of mobile phones are used as an interface to the mobile network and allow to get an insight into network parameters [4]. The system is controlled externally by a PC computer connected to the Ethernet port in the hardware's control unit. The tests offered by the Diversity Benchmarker played a significant role in the course of this project. The test in question is based on Perceptual Objective Listening Quality Assessment (POLQA), which is an objective voice quality model standard used for benchmarking. POLQA was standardized in 2011 pursuant to Recommendation P.863. The model assumes that the measurement sample is compared with a high-quality signal. The fact that it is referred to as perceptual means that subjective users would assess the quality based on their subjective perception. On the other hand, the term *objective* means that measurements are performed by a device. POLQA combines the two options and is supposed to measure quality as it would be perceived by humans. Voice quality is predicted as in the ITU T P.800 subjective Listening Only Test (LOT), where the sample is compared to the listener's internal reference, and the assessment ranges from 1 (bad) to 5 (excellent). There are two operational modes offered by POLQA. They are narrowband and wideband modes and differ only in the reference signal used.

The measurements were performed in one of the university buildings (B9) of the Lodz University of Technology, Łódź, Poland. The tests were performed around 10 a.m.

Six POLQA tests were performed. For five of them, listening quality data was collected. Before a more detailed analysis is performed, it needs to be mentioned that the operational mode and the effective bandwidth of all tests were of the narrow band variety. Consequently, in terms of listening quality the highest value that could be possibly obtained was 4.5. In Table 1 one can notice that none of the tests recorded a high value. Nevertheless, three of the five results are marked as excellent. Apart from listening quality, the table includes other parameters defined during speech tests, along with their average $\bar{x}$ and median values, variances and standard deviation. Furthermore, the data gathered served also as a basis for Monte Carlo simulation.

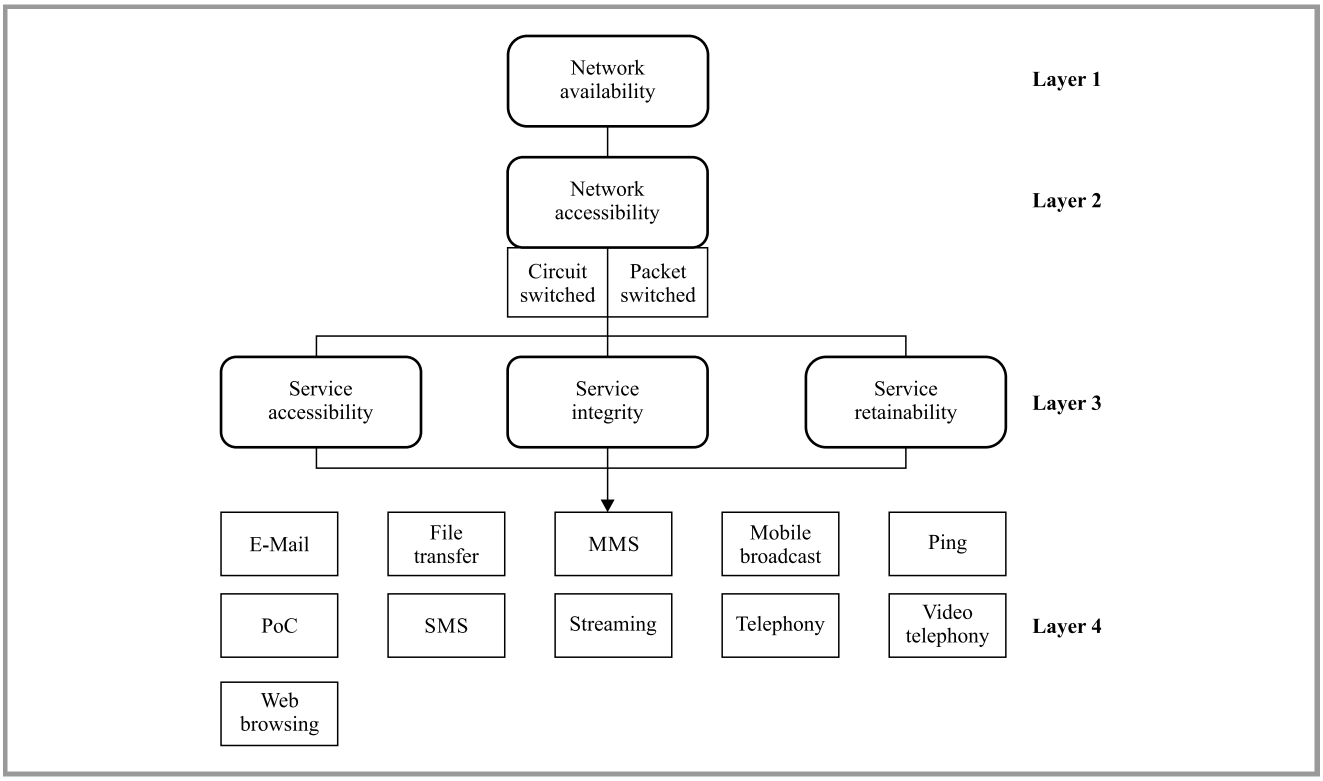


Fig. 3. QoS service parameters model.

Table 1
Five POLQA test results

Test ID/value	Listening quality P.863	Meaning	Speech level [dB]	Noise level [dB]	Static SNR [dB]	Total gain [dB]
159	3.66	Good	−25.5	−79.8	**54.3**	1.4
160	3.79	Excellent	**−25.2**	**−78.6**	53.5	**1.8**
161	**3.54**	Good	**−26.1**	**−79.9**	53.8	**0.8**
162	3.71	Excellent	−25.2	−78.7	53.6	1.7
163	**3.81**	Excellent	−26	−79.5	**53.5**	0.9
Average ($\bar{x}$)	3.702	Excellent	−25.60	−79.30	53.74	1.32
Median	3.71	Excellent	−25.50	−79.50	53.60	1.40
Standard deviation (s)	0.10894953	x	0.43011626	0.612372	0.336155	0.4549725
Variance (s^2)	0.01187	x	0.185	0.375	0.113	0.207

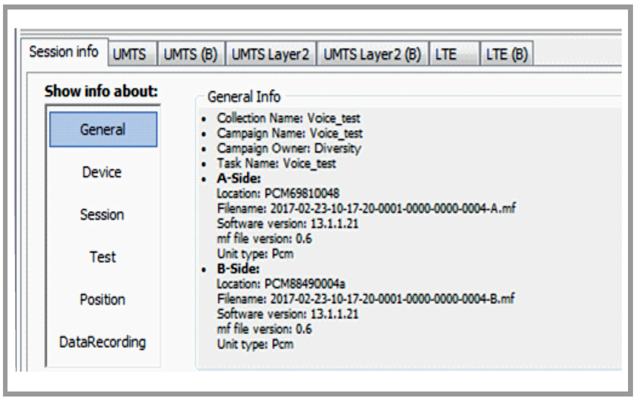
Two parameters were subject to the simulation and they were listening quality and speech level.

4. Monte Carlo Simulation

For availability evaluation, numerical methods constitute an alternative to the analytical approach. One of them is the Monte Carlo simulation. It uses randomly generated numbers in order to assess output parameters. No specified assumptions for input values are required and, additionally, distributions that are considered very difficult to solve can be addressed with the use of Monte Carlo, which makes it an attractive option [5].

Logic system models, such as Reliability Black Diagram (RBD), are used to perform Monte Carlo to evaluate the system. Based thereon, system availability is repeatedly evaluated with the regeneration of parameters before each step. The parameters are restricted by the distribution used. When the probability density function of the random numbers generated is $f(x)$, then the distribution function is represented by:

$$F(x) = \mathbb{P}(t \le x) = \int_{-\infty}^{x} f(t)\,\mathrm{d}t\,. \tag{2}$$



- Collection Name: Voice_test
- Campaign Name: Voice_test
- Campaign Owner: Diversity
- Task Name: Voice_test
- **A-Side:**
  Location: PCM69810048
  Filename: 2017-02-23-10-17-20-0001-0000-0000-0004-A.mf
  Software version: 13.1.1.21
  mf file version: 0.6
  Unit type: Pcm
- **B-Side:**
  Location: PCM88490004a
  Filename: 2017-02-23-10-17-20-0001-0000-0000-0004-B.mf
  Software version: 13.1.1.21
  mf file version: 0.6
  Unit type: Pcm

Fig. 4. Session info – general.

In order to perform Monte Carlo, relevant distribution had to be determined in accordance to which the random variables [6] could be generated. As far as listening quality is concerned, Weibull distribution was used to describe it, with is function given by Eq. (3) allowing to generate variables. This decision was motivated by the fact, that Weibull distribution can be adopted to virtually any data.

$$F^{-1}(U) = \theta[-\ln(1-U)]^{\frac{1}{\beta}} . \tag{3}$$

Still, before one can take advantage of this formula, scale parameter θ and shape parameter β have to be determined. Both are present in the formulas for mean $\mathbb{E}(X)$ and variance $\mathrm{Var}(X)$ of the distribution. The parameters were estimated with the assistance of these equations and Microsoft Excel.

$$\mathbb{E}(X) = \theta\Gamma\left(1+\frac{1}{\beta}\right) , \tag{4}$$

$$\mathrm{Var}(X) = \theta^2\left[\Gamma\left(1+\frac{2}{\beta}\right) - \Gamma^2\left(1+\frac{1}{\beta}\right)\right] . \tag{5}$$

Monte Carlo values generated for listening quality are summarized in a histogram in the next graph in Fig. 5. The Weibull distribution obtained is skewed left. The shift is reflected in the relation between the extreme values generated and the average, namely by the fact that the average is closer to the maximum than to the minimum.

Speech level is usually characterized with normal distribution and the simulation was performed in accordance with Eq. 2. The only parameters required here were average $\bar{x}$ and standard deviation s. They were taken from the measurement values from Table 1 ($\bar{x} = -25.6$ and $s = 0.43012$) and no additional estimations were needed. Subsequently, relevant formulas to generate 3000 random variables fitting the relevant distribution were used and thus Monte Carlo simulation was performed.

5. Comparison and Conclusions

The last phase was about the comparison of Monte Carlo and measurement values. This comparison is presented in Tables 2 and 3 and contains basic statistical indexes of the obtained results. The relative error in the last column makes it more transparent. As far as listening quality is concerned, it shows that the difference between Diversity- and simulation-obtained average constitutes merely 0.07% of the measurement mean, which is virtually negligible. Similarly, the median determined among randomly generated values is almost the same as the original one. A slightly greater discrepancy is observed for variance and, consequently, for standard distribution. Monte Carlo results are more scattered. Nevertheless, the difference is still relatively small, i.e. remains within 2.5% of the relative error. For the speech level the Monte Carlo values again are very close to Diversity-obtained results. Moreover, they are even more accurate, as the relative error obtained does not exceed 0.04%. The average is most accurate again, while the greatest discrepancy is observed for the median.

The results of the Monte Carlo simulation suggest that the method is indeed effective and allows to replace numerous measurement repetitions or complicated mathematical calculations with a simple simulation. It should also be stated that the relevance of the results obtained within this very

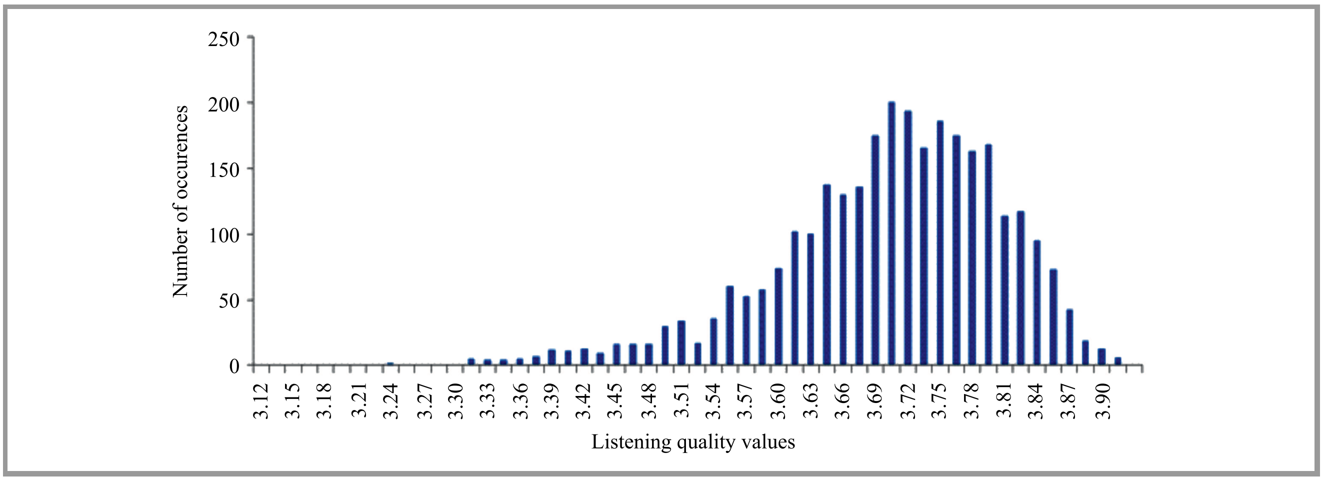


Fig. 5. Histogram of obtained listening quality values using Monte Carlo.

Table 2
Listening quality – comparison of measurement and Monte Carlo simulation

	Measurements	Monte Carlo	$\frac{\lvert X_{meas}-X_{MC}\rvert}{X_{meas}} \times 100\%$
Average ($\bar{x}$)	3.702	3.704	0.07
Median	3.71	3.718	0.22
Standard deviation (s)	0.10895	0.10767	1.17
Variance (s^2)	0.01187	0.01159	2.33
Minimum value	3.54	2.99	x
Maximum value	3.81	3.96	x

Table 3
Speech level – comparison of measurement and Monte Carlo simulation

	Measurements	Monte Carlo	$\frac{\lvert X_{meas}-X_{MC}\rvert}{X_{meas}} \times 100\%$
Average ($\bar{x}$)	−25.6	−25.596	0.01
Median	−25.5	−25.586	0.34
Standard deviation (s)	0.43012	0.42974	0.09
Variance (s^2)	0.185	0.18468	0.17
Minimum value	−26.1	−27.04	x
Maximum value	−25.2	−24.08	x

project could be argued. This is due to a small number of measurements that were taken in the first place, with assistance of the Diversity Benchmarker. Making this number higher would offer information about the scope of simulation and a more reliable scatter of data would be provided. This would allow to obtain more accurate extreme values that could be reflected in the simulation assumption. With more confident measurement the researcher could move on to Monte Carlo simulation.

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Grażyna Kadamus obtained her B.Sc. degree in Telecommunications and Computer Science from Lodz University of Technology. Łódź, Poland, in 2017. She is currently continuing her studies for M.Sc. in Management and Production Engineering from the International Faculty of Engineering at Lodz University of Technology.

E-mail: 190095@edu.p.lodz.pl
International Faculty of Engineering
Lodz University of Technology
Żwirki 36
90-001 Łódź, Poland

Małgorzata Langer graduated in Analogues and Digital Circuits of Automatics and got her Ph.D. degree in electronics at Lodz University of Technology (TUL). After several years in international marketing, she joined TUL in 1988, first as an IT specialist at the Institute of Material Science, and then at the Institute of Electronics. She works as an Associate Professor in the telecommunications team and delivers lectures and performs practical sessions (in Polish and in English) for students of various courses. Her main science and research interests are in telecommunications, QoS, QoE, management, non-deterministic object simulation, some aspects of new unconventional technologies in microelectronics, reliability, etc. She is an author and co-author of over 80 publications, including quoted ones, and has been involved in several international, national and university research and didactic programs.

E-mail: malgorzata.langer@p.lodz.pl
Institute of Electronics
Lodz University of Technology
Wólczańska 211/215
90-924 Łódź, Poland