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Dimensioning aspects of SMS systems in mobile networks

Janusz Klink[1], **Tadeus Uhl**[2]✉

[1] University of Technology Wrocław, Telecommunications and Teleinformatics Department
Wrocław, Poland, e-mail: janusz.klink@pwr.wroc.pl
[2] Maritime University of Szczecin, Faculty of Economics and Transport Engineering
11 H. Pobożnego St., 70-507 Szczecin, Poland, e-mail: t.uhl@am.szczecin.pl
✉ corresponding author

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Abstract

This paper focuses on factors affecting the dimensioning of Short Message Service (SMS) systems in mobile communications networks. Problems associated with Quality of Service (QoS) in modern communications networks in general are described, along with the main parameters that define QoS in SMS systems. The functionality of the SMS in terms of European Telecommunications Standards Institute (ETSI) standards is then explained. The creation of a queuing model is described for an SMS system which is based on ETSI documentation and will be analysed in calculations. The parameter completion rate plays an important role in SMS. Practical aspects of the End-to-End (E2E) delivery time for SMS systems are also discussed. The approach suggested in this paper and the insights gained in the course of this work can be of valuable practical use in the planning and analysis of real SMS systems.

Introduction

SMS has witnessed phenomenal growth in the last 20 years. Today, almost seven billion people regularly use a SMS, many of them almost every day. With the increased number of mobile subscribers throughout the world, SMS has gained enormously in popularity and been described in numerous scientific papers (Turel, Serenko & Bontis, 2006; Portio Research, 2014b; Portio Reasearch, 2015; Klink & Bardowski, 2016). Moreover, messaging is the largest single revenue-generating mobile service on the telecommunication market after voice (Portio Research, 2014c). Although the popularity of SMS has experienced a slight decrease in private use, there is an upward trend in business use.

A significant growth in the number of mobile subscribers is to be observed in the Middle East, Asia, Africa and Latin America. Thus, the dominance of SMS in the immediate future is unthreatened. According to (Portio Research, 2014c), SMS will continue to be among the major worldwide communication tools for the next decade. The increase in the processing power of mobile devices has made them significantly more multi-functional and allows Internet browsing, emailing, multimedia and instant messaging (IM). Despite the rapid growth of so-called Over-The-Top (OTT) messaging apps and Voice over IP (VoIP) services, SMS is still generating more than half the total mobile messaging revenue (Portio Research, 2014a). Consequently, SMS quality evaluation is important in terms of the professional deployment of the service (Waadt et al., 2005).

Constant availability has become a prerequisite of both travelling professionals and mobile lifestyles. Boarding passes via SMS and SMS Transaction Authorisation Numbers (SMS-TAN) for banking are now commonly used, making SMS more suitable for business processes in which security, reliability and technical independency are key factors.

Given that it is cheaper to use SMS than to purchase a mobile data package or subscribe to a data roaming plan in order to use IM applications to send a small number of messages, travellers have continued to use SMS. SMS is common to all phones and almost all users; IM, in contrast, usually requires smartphones with dedicated apps, as well as specific knowledge on the part of the user as to how these are used, which can be a barrier for some sections of society, particularly the elderly (Portio Research, 2014a). Furthermore, SMS is of great importance to local governments, which make use of it to notify not only immediately affected citizens but also the public at large in the event of emergencies (Meng et al., 2007). There has been a noticeable increase in text messaging applications in healthcare, as a part of mobile Health (mHealth) programmes, for behaviour modification, disease management and surveillance, prevention and public health education, data collection, etc. (Mechael et al., 2010; Schilling et al., 2016).

Business capability goes hand-in-hand with business competitiveness, where these factors are of crucial importance. "Service Level Agreements" are signed to guarantee a specific E2E QoS which can, however, seldom be verified conclusively by the average service subscriber.

Apart from the price, major factors that enable service providers to keep their customers are wide availability, simplicity of use and good quality. Service quality is becoming an increasingly important factor for users when it comes to choosing a network operator or service provider (Turel, Serenko & Bontis, 2006; Seo, Ranganathan & Babad, 2008; Virvilaite, Saldiene & Skindaras, 2009; Portio Research, 2014a, 2014b, 2014c, 2015). Many operators have devoted significant resources to creating efficient mechanisms for handling message traffic (Zheng & Regentova, 2005). It should also be noted that a service-oriented management is focused on service quality rather than network performance (Du et al., 2009). Thus, an effective evaluation of service quality can help a service provider increase customer satisfaction and plays a key role in influencing a user's decision to stay with, or change, provider. As reported in (Soldani, Li & Cuny, 2006), over 80% of customer defections (churning) are due to frustration with the product or service and the inability of the service provider to deal with this effectively. Very often this leads to a cascade reaction, whereby one frustrated customer will tell other people about his or her bad experience, and so forth. An operator cannot assess the level of service quality from customer complaints alone, but should adopt a more proactive attitude. Statistics have shown that only about 3% of users report problems whereas about 90% of customers will not complain before defecting. This churn directly affects the profitability and image of the operator or service provider. Such a situation can be prevented by the devising a strategy to manage and improve QoE (Tran & Mellouk, 2010). QoE-based mechanisms for control and management of resources are widely discussed in the literature (Monteiro & Nunes, 2007; Yamada et al., 2007; De Vleeschauwer et al., 2008) and growing competition among service providers and network operators is forcing them to provide high-quality services. Regulations undertaken at the European level (Directive 2009/140/EC, 2009; BEREC, 2012) are an additional factor motivating telecommunications industry operators to improve quality.

In November 2009, the European Parliament and European Council ratified Directive 2009/136/EC (Directive 2009/136/EC, 2009). To comply with this directive, providers of electronic communications services allowing calls should ensure that their customers are adequately informed about the limitations of the services and about the routing of emergency calls. Furthermore, any literature about those services which are not provided over a switched telephone network should also include information about the level of reliability of access and about caller location associated with the service provided over a switched telephone network, taking into account current technology and quality standards, as well as any QoS parameters specified under Directive 2002/22/EC (Universal Service Directive).

With regard to QoS in particular, EU member states shall ensure that national regulatory authorities are empowered to require service providers to publish comparable, adequate and up-to-date information for end-users on the quality of their services, when requested. These national regulatory authorities may require, among other matters, that the QoS parameters be measured and that the content, form and manner of the resulting information be published. In addition, the national regulatory authorities should be able to set minimum QoS requirements to prevent degradation, traffic-slowing and traffic-hindering. As a result, it can be said that the European Parliament and the European Council are fully aware of QoS and all that it entails, and are ensuring that member states apply their directives.

A particular example of this can be seen in the case of Poland, where significant amendments to the telecommunications law have been introduced (The Telecommunication Law, 2004). Moreover, the Electronic Communications Office's initiative

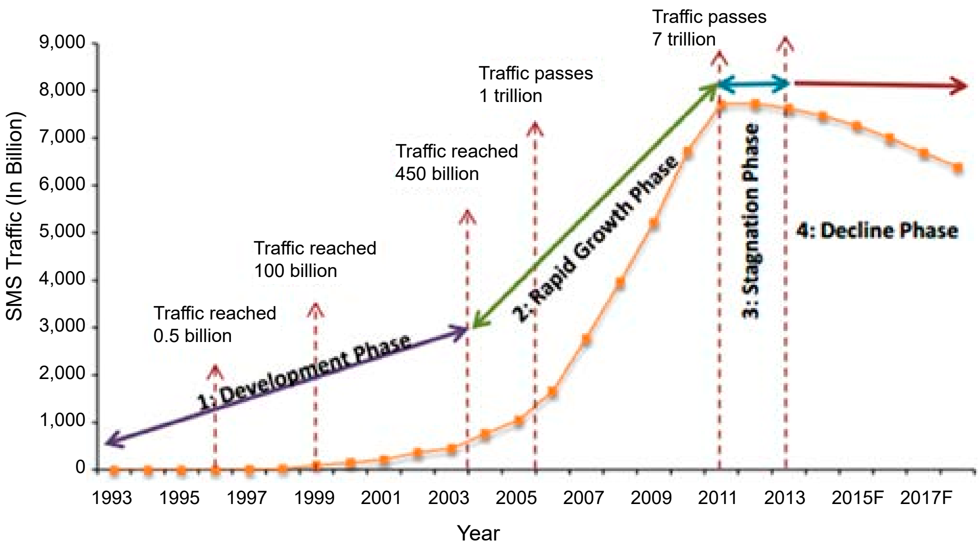

Figure 1. SMS Traffic Growth (1992–2018 [Forecasted]) (Portio Research, 2014a)

(2012), a Memorandum on Cooperation for Improving the Quality of Services in the Telecommunications Market, has been ratified. The first stage of works was finalised in the form of an official report (UKE, 2014), which was published by the Electronic Communications Office in February 2014.

In 2011, the ETSI Technical Committee Speech and Multimedia Transmission Quality (STQ) produced two multi-part technical specifications to cover "QoS aspects for popular services in mobile networks" (ETSI TS 102 250-2 V2.2.1, 2017) and "User-related QoS parameter definitions and measurements" (ETSI EG 202 057-2 V1.3.2, 2017). The second part of (ETSI TS 102 250-2 V2.2.1, 2017) in particular addresses the topic of "Definition of Quality of Service parameters and their computation", containing an abstract definition which gives a generic description of the parameters, abstract equations and corresponding user and technical trigger points. The second part of (ETSI EG 202 057-2 V1.3.2, 2017) is devoted to the topic "Voice telephony, Group 3 fax, modem data services and SMS".

Recent research on the current telecommunications market has revealed that SMS continues to play an important role despite the advent of OTT messaging, which has also become very popular. Figure 1 shows SMS traffic growth.

It can clearly be seen that, with about 7.6 trillion messages, SMS was still popular in 2013. A decline phase may have set in; however, SMS still warrants attention.

Growth in Application to Person (A2P) markets has boomed in recent years. In 2010, A2P represented just 11.7% of total SMS traffic worldwide, while in 2015 it reached 22.4% of the total traffic: in just five years, therefore, the significance of A2P SMS approximately doubled (Portio Research, 2015). For this reason, a focus on the "old" but nonetheless dependable SMS service is warranted, with a view to practical dimensioning.

Sensible dimensioning is a crucial practical aspect of planned and existing communications systems. It may be carried out in two ways: a) purely theoretically, using a suitable model; or b) using measurements of existing systems. In the first case, an attempt is made to extrapolate, with exact calculations, the dimensioning of systems that have already been analysed; in the second case, suitable measuring systems are used to record data about all the important system parameters of an existing, operating system with a view to optimising them. It is also possible to employ a combination of the two methods, and precisely such a combination will serve as the basis for an SMS in the course of the work described in this paper.

The examination will start with a presentation of the QoS parameters for SMS as they stand in ETSI Recommendation TS 102-250-2. A brief explanation of how the service works will follow. This information will be used as a basis for designing a queuing model for the SMS system, which will then be analysed mathematically. The paper will then turn to the E2E Delivery Time, using measurements from actual installations, before concluding with a summary and an outlook on further work.

QoS parameter for the SMS

This chapter introduces the main QoS parameters recommended by ETSI TS 102-250-2 (ETSI TS 102

250-2 V2.2.1, 2017) and ETSI EG 202 057-2 V1.3.2 (ETSI EG 202 057-2 V1.3.2, 2017).

SMS Service Non-Accessibility

Service non-accessibility denotes the probability that the end-user cannot access the SMS when requested and while it is offered by the display of the network indicator on the user equipment.

SMS Service Access Delay

Service access delay is the time period between sending a short message (SM) to the network and receiving a send confirmation from the network at the origin side.

SMS Successful SMS Ratio

This ratio describes the probability that a user can send a SM from a terminal to the Short Message Centre, and is applicable for service providers offering the SMS. Therefore, it is recommended that result-providing statistics should return the percentage of successfully sent SMs, the number of observations and the calculated absolute accuracy limits of this with 95% confidence. Measurements should be scheduled so as to reflect accurately traffic variations over the hours of a day, the days of the week and the months of the year. The parameter is intended to reveal network accessibility and congestion in the signalling channels of the SMS system in the service operator's claimed area of coverage.

Completion Rate for SMS

This describes the ratio of correctly received SMs to those sent and is also applicable to SMS service providers. It is recommended that result-providing statistics should return the ratio of sent and correctly received SMs, the number of observations used and the calculated absolute accuracy limits of this with 95% confidence. Measurements should be scheduled so as to reflect accurately traffic variations over the hours of a day, the days of the week and the months of the year.

E2E Delivery Time for SMS

This is the period that elapses between the sending of a SM from the sender's terminal equipment to a Short Message Centre and the receiving of that message on the receiver's terminal equipment, and is applicable for service operators providing the SMS. Result-providing statistics should return the mean value in seconds for sending and receiving SMs, the time in seconds within which the fastest 95% of SMs are sent and received and the number of observations performed. Measurements should be scheduled so as to reflect accurately traffic variations over the hours of a day, the days of the week and the months of the year. The above-mentioned QoS parameters estimating measurements should be derived from real traffic or test calls for SMs sent among a representative population of local exchanges or a combination of the above.

A measurement system can be designed for these QoS parameters by taking the "Completion Rate for SMS" and the "E2E Delivery Time for SMS" into account. At the time of writing, there are very few measuring systems in use that can determine the above parameters, one of which is "QualiPoc Android" from the company SwissQual AG, a subsidiary of Rohde & Schwarz (SwissQual, 2017). Another suitable measuring system, "QoSCalc(SMS)", is being developed at the Flensburg University of Applied Sciences (Rompf & Uhl, 2016).

An explanation of how the SMS system works in practice is given in the next section.

Functional principle for the SMS

This chapter will describe SMS in the light of the QoS aspects recommended in ETSI TS 102-250-2 (ETSI TS 102 250-2 V2.2.1, 2017), which presents the specified functional principle as shown in Figure 2.

A transmission begins with a Mobile Station (MS) requesting access to the Visitor Location Register (VLR). Once access is granted, the message is transferred to the Mobile Switching Centre (MSC) along with a "sendInfo", and, being a Mobile Originated Short Message Service, it is forwarded to the Short Message System Interworking MSC (SMS-IWMSC) or Short Message Service Gateway MSC (SMS-GMSC). Subsequently, the SM is transferred to the Service Centre (SC) and a delivery report is sent back, routed through the SMS-IWMSC and MSC, to the MS.

Figure 3 shows a successful SM transfer as soon as the receiver, for example another MS, is registered at the SC. The SC initiates the message transfer to the SMS-GMSC or SMS-IWMSC. The SMS-GMSC requests the routing information from the receiver's Home Location Register. Having obtained the routing information, the SM is forwarded to the MSC. The information needed to deliver the SM is requested from the VLR. The VLR responds with the respective Mobile Subscriber ISDN Number, which is used to deliver the SM to the receiver. Once it has

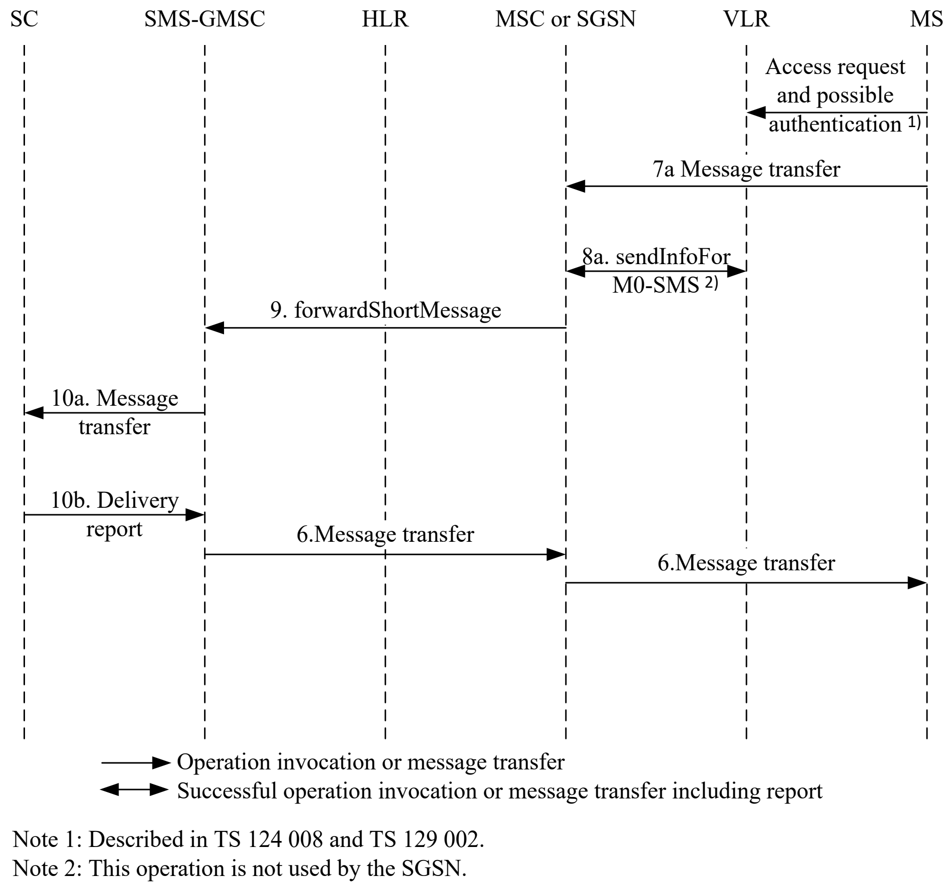

Figure 2. SMS transaction flow – originating user equipment (ETSI TS 102 250-2 V2.2.1, 2017)

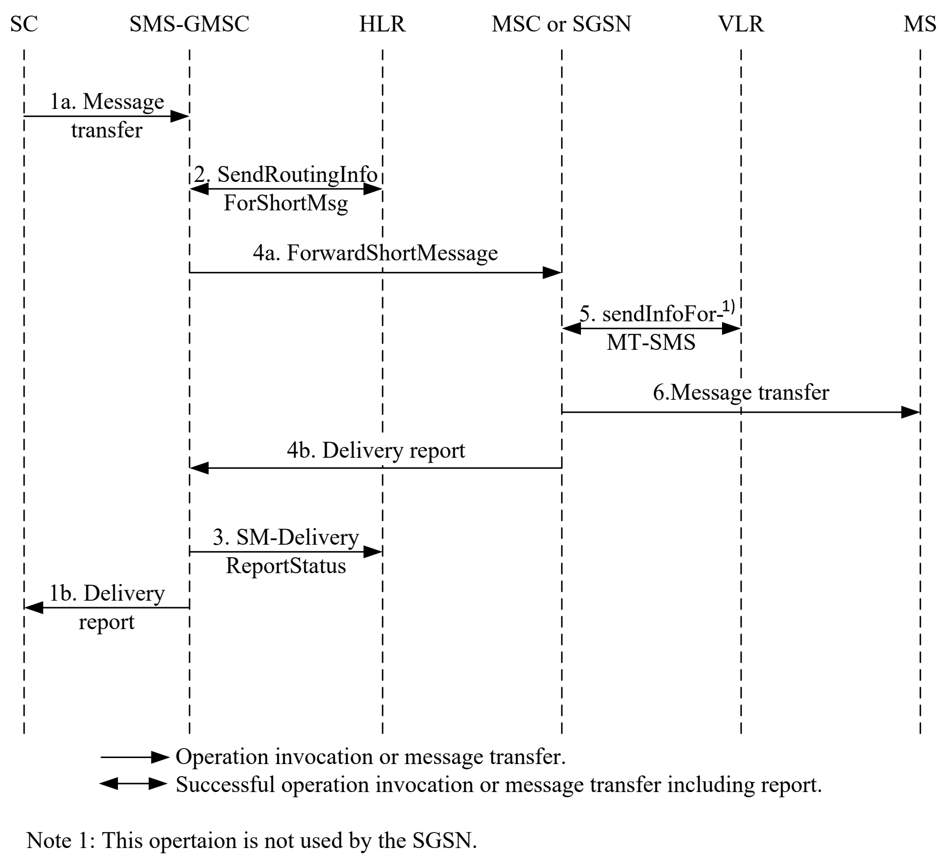

Figure 3. SMS transaction flow – terminating user equipment (ETSI TS 102 250-2 V2.2.1, 2017)

been delivered, a Delivery Report is sent back to the SMS-GMSC or SMS-IWMSC and finally to the SC.

The next section describes the development and subsequent analysis of a queuing model for the SMS system, based on ETSI Recommendation TS 102-250-2.

Dimensioning for SMS systems

Theoretical Approach

Figure 4 shows a queuing model for the SMS System developed in accordance with ETSI Recommendation TS 102-250-2.

First, incoming SMs are received and stored in the SMSC. The receiving system can be described as an M/M/1/n queuing system. The dispatcher routes the processed SM to a particular exit depending on the destination address. Each departure system can be represented as an M/M/1-FIFO. Time_Out stations are necessary because the delivery of SMs is secure.

The information contained in Figure 4 can be used to construct the path graph shown in Figure 5.

The first segment of the path graph represents the section in the mobile network between the sender's handset and the SMSC. Mobile communications networks use radio channels. Assuming a Markov arrival process and using the Erlang B formula, it is possible to calculate the blocking probability in the first segment, i.e. $P_1 = B_{\mathrm{Erl}}$.

$$P_1 = B_{\mathrm{Erl}} = \frac{\frac{A^N}{N!}}{1 + A + \frac{A^2}{2!} + \cdots + \frac{A^N}{N!}} \tag{1}$$

where N is the number of available radio channels, and A is the offered load in [Erl].

The second segment of the path graph represents servicing systems within the SMSC. Assuming an exponential distribution of SM lengths, it is possible to calculate the blocking probability $P_2 = P(n)_{M/M/1/n}$ in the second segment.

$$P_2 = P(n)_{M/M/1/n} = \frac{(1-\rho)\rho^n}{1-\rho^{n+1}} \tag{2}$$

where ρ is the utilisation factor of the queuing system, and n is the storage capacity in messages.

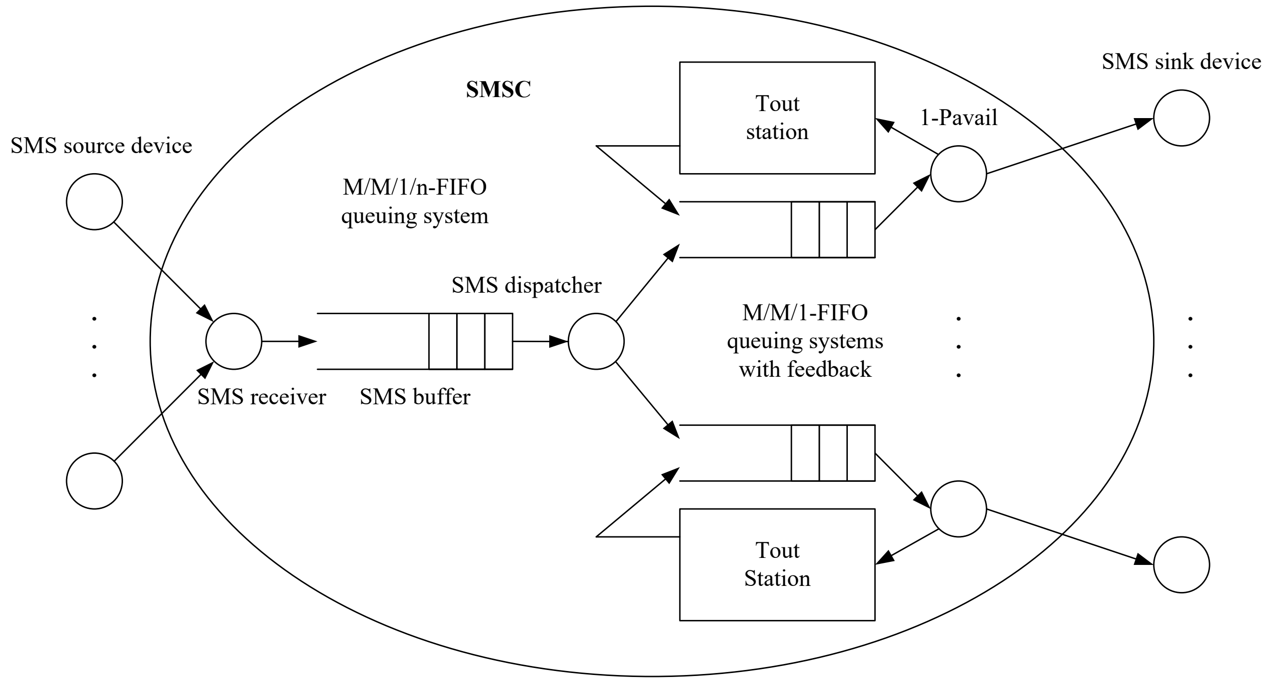

Figure 4. Queuing model for the SMS system

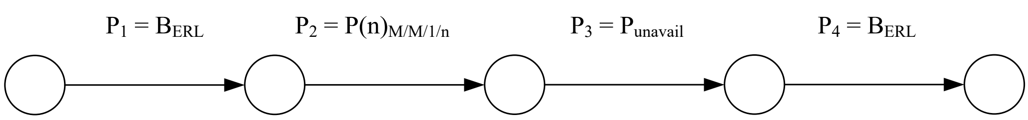

Figure 5. Path graph of an SMS

The third segment represents the case of the receiver's being unavailable. The probability is given as $P_3 = 1 - P_{avail}$. The fourth segment represents the section of the mobile network between the SMSC and the handset again. The probability of blocking can be calculated on the basis of the Erlang B formula here as well.

Taking into account the blocking probabilities entered into the individual segments of the path graph, it is possible to calculate the probability that an SM will not be received over the mobile network:

$$B_G = 1 - \prod_{i=1}^{4} (1 - P_i) \quad (3)$$

In a real mobile network $P_1 = B_{ERL}$ has a value of approx. 0.02. For sensibly dimensioned SMS systems, it can be assumed that P_2 will not exceed a value of 0.03. It is further assumed that the probability of a user's handset being switched off is $P_{unavail} = 1 - P_{avail} = 0.05$. Since the numbers of radio channels at the entrance and at the exit are equal, it can be assumed that $P_4 = P_1$. Using these assumptions and Equ. (3), it is possible to calculate the probability that the SM will not be received. It has the value $B_G = 0.115$ here.

Figure 6 shows the curves progressions for the probability B_G as a function of the parameter $P_{unavail}$ for three values, 1%, 3% and 5%, of the probability $P_1 = P_2 = B_{Erl}$, which are, in practice, used to dimension line-switched mobile wireless networks. Furthermore, it is assumed that the probability $P_2 = P(n)_{M/M/1/n}$ is zero, which means that the SMSC is optimally dimensioned (which is the case in practice). It is evident that $P_{unavail}$ has a decisive influence on probability B_G, making its progression linear. Differences in the values of B_G as a function of B_{ERL} are only noticeable for small values of $P_{unavail}$; after that, B_G outweighs $P_{unavail}$ completely.

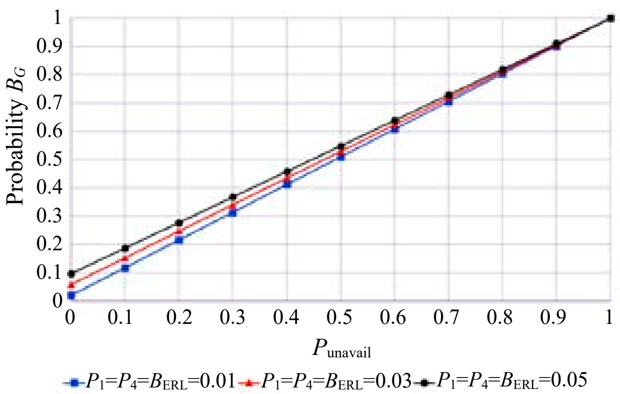

Figure 6. Progression of the probability B_G as a function of the parameter $P_{unavail}$ for different values of the parameter B_{ERL}

It is evident that this type of analysis is very helpful in dimensioning an SMS system, and is thus of great practical benefit.

Practical Approach

Without concrete, realistic parametrising of the queuing model, theoretical analysis of E2E delivery time is normally very limited. Measurements of this parameter, using values drawn from real life, offer significant help. Such measurements can be found in papers (Bardowski, Klink & Uhl, 2014; Klink et al., 2016; Rompf & Uhl, 2016). (Rompf & Uhl, 2016), for instance, contains the results obtained from several measurements of E2E delivery times achieved using various network providers, which were gained in a real-life environment. Figure 7 shows an example of such a series of measurements made in Switzerland, using the Swisscom provider.

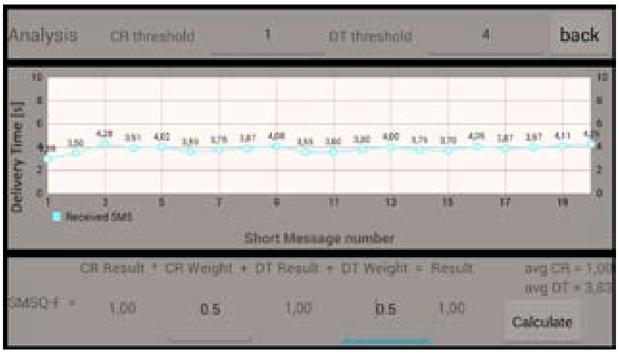

Figure 7. Distribution of E2E delivery times in the Swisscom network in Switzerland (Rompf & Uhl, 2016)

Figure 8 represents the distribution of E2E delivery times measured in Poland, using the T-Mobile provider.

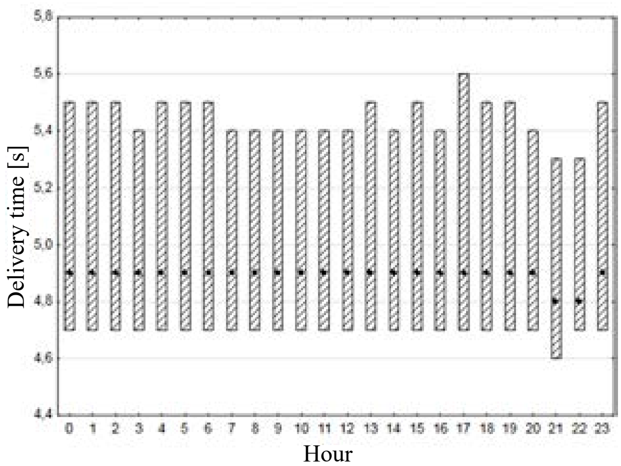

Figure 8. Distribution of E2E delivery times in the T-Mobile network in Poland (Bardowski, Klink & Uhl, 2014)

Figure 9 represents the distribution of E2E delivery times measured in Germany, using the T-Mobile provider.

Figure 9. Distribution of E2E Delivery Times in the T-Mobile network in Germany (Klink et al., 2016)

Figures 7–9 show that, interestingly, E2E delivery times lie in the region of a few seconds, whichever of the three countries the measurements were taken in. Furthermore, delays prove to be constant, with confidence intervals lower than 10% regardless of when the measurements were made. The results presented in (Klink et al., 2015), yielded by an appraisal of the QoE of SMS systems, have shown that persons taking the tests will award a score of "very good" whenever the E2E delivery time does not exceed ten seconds. It can therefore be said that both systems under current observation are very suitably dimensioned.

The approaches presented in this chapter, and the theoretical and practical insights gained, are of significant value for the dimensioning of SMS systems.

Conclusions

SMS continues to play an important role in current communications networks and generates worldwide a business volume in the order of hundreds of billions of dollars. The QoS of SMS in networks is more important than ever, and modern networks must be dimensioned to ensure high QoS. Sensible dimensioning depends on suitable models or reliable measurements from existing installations, or both. The focus of this paper has been on this aspect of SMS.

Firstly, the QoS parameters for SMS systems as they stand in ETSI Recommendation TS 102-250-2 were presented, taking into account that completion rate and E2E delivery time are clearly the most influential QoS parameters. The functionality of SMS was then described, as the basis from which a queuing model for an SMS system was derived. Formulae were also presented, without which any calculation of the probability of delivery of SMs is virtually impossible. From the calculation of this probability, the parameter completion rate for SMS could be calculated with relative ease, offering significant practical benefit. A second QoS parameter, namely E2E delivery time, was then explored, with a focus on the measurements of this variable. This combination of theoretical and practical considerations of QoS parameters has yielded several indications for the accurate dimensioning of SMS systems.

There is no alternative to measuring the QoS parameters of the service in real installations. Suitable measurement devices and systems are, of course, essential. It is therefore surprising that there are still few tools for measuring a SMS system; the authors of the present paper consider it a matter of urgency that such tools be devised.

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