Evaluation Procedure for QoS of Short Message Service

International SMS Route Analysis

NINA MULKIJANYAN

KTH Information and Communication Technology

Degree project in
Communication Systems
Second level, 30.0 HEC
Stockholm, Sweden

KTH Royal Institute of Technology
Ascade AB

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Master's Thesis

Nina Mulkijanyan
ninamu@kth.se

Academic supervisor:	Professor Gerald Q. Maguire Jr.
Examiner:	Professor Gerald Q. Maguire Jr.
Industrial supervisor:	Martin Jansson

August 17, 2011

Abstract

Due to its ubiquitous availability, Short Message Service (SMS), first introduced in the 1980s, became not only the most popular way of communication, but also stimulated the development of SMS-based value added services. This application-to-person traffic is delivered to end users through SMS aggregators who provide the link between service providers and mobile carriers. In order to perform optimal traffic routing, the aggregators need to estimate the quality of each potential international route to the specified destination. The evaluation criteria include end-to-end delivery time, as well as correct verification of delivered data.

This thesis suggests a method of quality of service (QoS) assessment for international SMS service which combines two types of tests, end-to-end delay measurements and various verification tests. A prototype of the testing system for international SMS service was developed to generate SMS traffic, collect and analyze results, and evaluate the experienced QoS of the SMS route used in accordance with the proposed approach. As a part of end-to-end delay measurement tests, SMS traffic was sent to Singtel network in Singapore along two routes. The verification tests were executed via different routes to two mobile networks: Singtel and Tele2 (Sweden). The results of the performed measurements determined the route with the highest QoS, i.e. the one with bigger bottleneck bandwidth and lower data loss rate.

The prototype of the SMS testing system can be used by SMS aggregators to verify delivery of a SMS message, check the integrity of the message, figure out interconnection type of the route supplier with the destination carrier and to identify the presence of load balancers in the path. The prototype also makes it possible to compare end-to-end delay times of several routes and compute bottleneck values for each of the tested routes.

Keywords: SMS, QoS, packet-pair, TOPP, end-to-end delay, bottleneck bandwidth, aggregator

Sammanfattning

Tack vare sin utbredda tillgänglighet blev Short Message Service (SMS), som introducerades under 1980-talet, inte bara det mest populära sättet att kommunicera på, utan stimulerade även utvecklingen av SMS-baserade tilläggstjänster. Denna applikation-till-person-trafik levereras till slutanvändarna via SMS-aggregatorer som står för länken mellan tjänsteleverantörer och mobiloperatörer. För att trafikdirigeringen skall vara så optimal som möjlig måste SMS-aggregatorerna uppskatta kvaliten av varje potentiell internationell rutt till det specificerade slutmålet. Kriterierna som bedöms är bl.a. leveranstiden mellan två slutpunkter och korrekt verifikation av levererad data.

Detta examensarbete föreslår en metod för quality of service (QoS) bedömning av internationella SMS tjänster vilken kombinerar två typer av tester, end-to-end fördröjningsmätningar samt diverse verifieringstester. En prototyp av testsystemet för internationella SMS tjänster utvecklades för att generera SMS trafik, samla in och analysera resultat och för att utvärdera den använda SMS ruttens upplevda QoS i enlighet med det föreslagna tillvägagångssättet. Som en del av end-to-end fördröjningsmätningstesterna sändes SMS trafik till Singtels nät i Singapore längs två rutter. Verifieringstesterna utfördes via olika rutter till två mobilnätverk: Singtel och Tele2 (Sverige). Resultaten av de utförda mätningarna fastställde rutten med högst QoS, d.v.s. rutten med högre flaskhalsbandbredd och lägre datafrlust.

SMS-testprototypen kan användas av SMS-insamlare för att verifiera att ett SMS-meddelande levererats, för att kontrollera integriteten hos SMS-meddelandet, för att räkna ut sammankopplingstypen mellan ruttleverantören och destinationsoperatören och för att avgöra ifall det finns lastbalanserare längs rutten. Prototypen gör det också möjligt att jämföra end-to-end fördröjningstider hos många rutter och för att beräkna flaskhalsvärden för varje testad rutt.

Acknowledgement

First of all, I would like to express my gratitude to my examiner and academic supervisor Prof. Gerald Q. Maguire Jr. who is the best supervisor one can dream of. The discussions with Prof. Maguire extended the scope of the thesis and motivated me to design additional tests and perform a more detailed analysis of results.

I am thankful to Ascade AB for giving me an interesting topic and providing me with the environment to perform international testing. I would like to thank Martin Jansson, my industrial supervisor, who has been extremely supportive throughout my whole stay at Ascade.

I must thank Jing Wu for kindly allowing me to reuse her code as well for helping me to master the pecularities of Symbian programming. I cannot fail to thank Roy Sutanto who was very helpful during the testing and measurement phase.

I would like to mention Magnuss Öhrman, Mats Ingelstrom and Elena Lockhart, whose valuable input helped me to define the industrial requirements for an SMS testing system.

Last, but not the least, I would like to mention my family, who has always stood by my side.

Nina Mulkijanyan

Stockholm, July, 2011

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Acronyms and Abbreviations

CDMA	Code Division Multiple Access
ESME	External Short Message Entity
ETSI	European Telecommunications Standard Institute
GMSC	Gateway MSC
GPRS	General Packet Radio Services
GSM	Global System for Mobile Communications
HLR	Home Location Register
IP	Internet Protocol
ITU	International Telecommunications Union
IWMSC	Interworking MSC
KPI	Key Performance Indicator
MS	Mobile Station
MSC	Mobile Switching Center
MT	Mobile Terminated
PDU	Protocol Data Unit
QoS	Quality of Service
SC	Service Center
SLA	Service Level Agreement
SM MO	Short Message Mobile Originated
SM MT	Short Message Mobile Terminated
SME	Short Message Entity
SMPP	Short Message Peer-to-peer Protocol
SMS	Short Message Service
SMS-IP	SMS over IP
SMSC	Short Message Service Center
SS7	Signaling System # 7
UCS2	2-byte Universal Character Set
VLR	Visiting Location Registrar

Chapter 1

Introduction

The chapter introduces the problem of SMS route evaluation, states the goals of the thesis project, and provides an overview of prototype system to be developed as a part of this project.

1.1 Problem Statement

Short Message Service (SMS) remains the most popular way of communication even despite the increasing penetration of smartphones and new messaging services. The main reason for such an active usage of SMS is that no other messaging service can offer global availability comparable to that of SMS: as all mobile terminals support SMS, every subscriber of a mobile network can be reached via SMS.

According to the International Telecommunication Union (ITU) [7] the total number of SMS messages sent worldwide tripled between 2007 and 2010. Today roughly two hundred thousand $(2 * 10^5)$SMS messages are sent every second.

One of the reasons for the tremendous growth of SMS traffic is the increasing number of value added SMS-based services*, so called premium services. Moreover, in order to become a worldwide premium service provider, owning a single Short Message Service Center (SMSC) is not longer necessary; instead the service provider can sign a contract with one or more SMS gateway providers. These gateway providers can be divided into two categories: SMS aggregators and Signaling System 7(SS7) providers [8]. As should be clear from their name, SS7 providers use SS7 connectivity to route SMS traffic, while the aggregators have agreements with one or more mobile

*The examples of value added SMS services are mobile banking, flight check-in, SMS ticketing for public transportation, and many more.

operators to carry bi-directional SMS traffic. The advantage of SS7 routing is the visibility of the complete SMS path. The aggregators can not control the end-to-end delivery of messages because they do not have direct access to SS7 signaling [8].

The European Telecommunications Standard Institute (ETSI) has defined a set of parameters for evaluating the quality provided by an SMS service [9]:

- SMS Service Non-Accessibility Mobile Originated (MO) [%] is the probability that the subscriber cannot use the service even though the service is accessible
- SMS Access Delay MO [seconds] is the time between submitting a message to the SMSC and receiving an acknowledgement from the SMSC
- SMS Completion Failure Ratio [%] is the ratio between the number of messages that are not delivered and the total number of SMS messages sent
- SMS End-to-End Delivery Time [seconds] is the time interval between submission of a message and receiving the message at the destination

However, application of these parameters is not always suitable for describing and evaluating the quality of service (QoS) for SMS. Usually SMS aggregators need to estimate not only the end-to-end delay of each message, but also verify the integrity of the source address, check if all parts of a concatenated message were delivered successfully, and verify correct delivery of a message body (even if it contains special characters). Unfortunately, these other aspects cannot be derived simply from the SMSC's delivery reports. Currently no software exists to evaluate these other aspects of SMS service.

1.2 Goals

The goal of this thesis project is to study the criteria for QoS evaluation of international SMS traffic in terms of each potential route that might be used to carry this traffic, present a conceptual design for a system that could do this QoS evaluation, implement a prototype of the system, evaluate this prototype, and analyze the limitations of this prototype. The prototype will be used to perform a series of tests. These tests will also be designed as part of this thesis project.

1.3 Overview of the Proposed Solution

The proposed system will consist of software and a test SMS message generator connected to an SMS aggregator. This system will send SMS messages to test nodes along a specified route. The test nodes will consist of representative devices (specifically a Nokia E51 and Nokia E52) capable of sending and receiving SMS messages and executing the software to be developed in this project. The node will extract all the available information from the received test message and forward this information and the received message to an application server. This application server is responsible for validating the information and then reporting the results of the evaluation to the end user using software developed in this thesis project. Therefore, there are two sets of software to be developed: one set for the application server and another for the end devices.

Chapter 2

Technical Background

This chapter introduces the technical terms and concepts required to understand the work completed in scope of this thesis project. The chapter gives overview of high level SMS architecture and models of interconnection between SMS traffic carriers, and focuses on the technical realization of SMS, as defined by 3GPP.

2.1 SMS Architecture

The Service Center (SC) or Short Message Service Center (SMSC) is one of the key elements of the overall SMS architecture. A general headset-to-headset view of the SMS architecture is depicted in Figure 2.1. The SMSC acts as relay and store-and-forward entity. The SMSC can be a separate network element or can be integrated into a Mobile Switching Center (MSC) [2].

A short message entity (SME) is a network element capable of sending and receiving a SMS message. A SME can be connected to the SMSC directly or via a gateway; the latter is called an External Short Message Entity(ESME) [2].

Messages submitted by SME to the SMSC are called Short Message Mobile Originated (SM MO) while messages delivered from the SMSC to SME are referred to as Short Message Mobile Terminated (SM MT).

An SMS message submitted from a Mobile Station (MS) is passed to the SMSC via an Interworking MSC (IWMSC). The SMSC may send an acknowledgement to the originator, if such an acknowledgement has been requested. A gateway MSC (GMSC) is used by the SMSC to route an SMS message to the proper destination network [1]. The GMSC queries the Home Location Register (HLR) for routing information and sends the

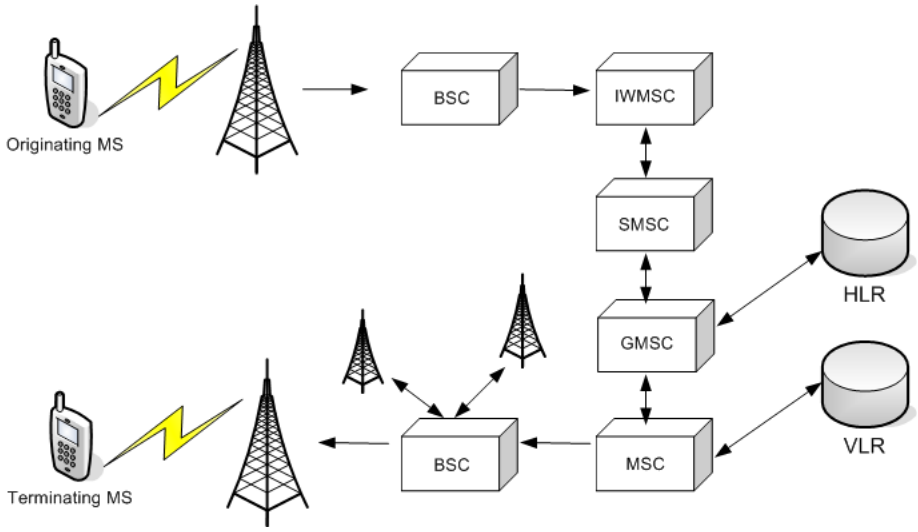


Figure 2.1: SMS architecture (adapted from [1])

SMS message to the serving MSC of the message recipient. The IWMSC and GMSC functionality related to SMS routing can be integrated into the SMSC.

Figure 2.1 does not indicate if the originator and recipient belong to the same mobile network. Note that this figure is valid when the originator and recipient are connected to mobile networks utilizing the same technology, i.e., both end points being GSM/GPRS or CDMA, otherwise the issue of interoperability is raised. To support messaging between different types of mobile networks there needs to be a gateway or the corresponding SMSCs need to be interconnected by a proprietary exchange protocol. [2]

In this context, the delivery of a MT message to a subscriber happens as follows (see Figure 2.2). The originating SME submits the message to the SMSC of the originating network. The originator's SMSC forwards the message to the SMSC of the recipient's network. Finally the recipient's SMSC delivers the message to the destination and sends a status report to the originator's SMSC (if an acknowledgement was requested). The originator's SMSC delivers the status report to the message originator (if acknowledgement was requested). [2]

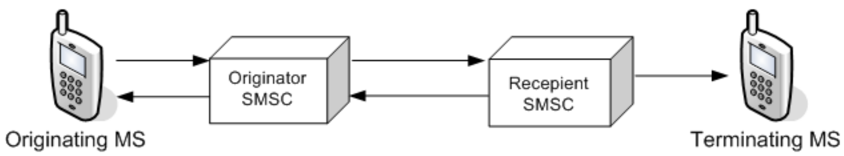


Figure 2.2: Message transfer [2]

However, there is a problem when the originating and terminating networks belong to the same type (CDMA or GSM): when the message is delivered to the destination by the originator's SMSC, then the recipient mobile operator has no control over the incoming SMS traffic. To provide the recipient's SMSC with control, in 2007 the concept of SMS home routing was added to the original GSM specification. According to this concept, each inter-operator SMS message is delivered to the recipient by the receiving operators SMSC, rather than directly by the originator's SMSC. This allows the receiving operator to analyze all of the incoming SMS messages and block some or all of the inbound SMS traffic. [10]

It is also possible to send/receive SMS messages via gateways from/to IP networks. This is referred to as SMS-IP. The typical integration of SMS-IP with SMS is illustrated in Figure 2.3. The ESME connects via an IP channel to a gateway server (e.g. in this case the gateway server belongs to an SMS aggregator). The ESME forwards the inbound SMS-IP traffic to the mobile operator's SMSC. The most widely used communication protocols between the SMSC and the gateway are listed in Table 2.1.

Table 2.1: SMS protocols [5]

Protocol	Owner/Creator
Short Message Peer-to-peer Protocol (SMPP)	SMS Forum/Logica
Universal Computer Protocol (UCP)	CMG (now LogicaCMG)
Computer Interface to Message Distribution (CIMD2)	Nokia
Open Interface Specification (OIS)	Sema Group (now SchlumbergerSema)
Telocator Alphanumeric Protocol (TAP)	PCIA

2.2 SMS Interconnection Models

Transfer of messages directly between different mobile networks requires legal agreements and physical interconnections between the operators. Two models of interconnection exist: peering and hubbing [11]. A comparison of the two interconnectivity models is provided in Table 2.2.

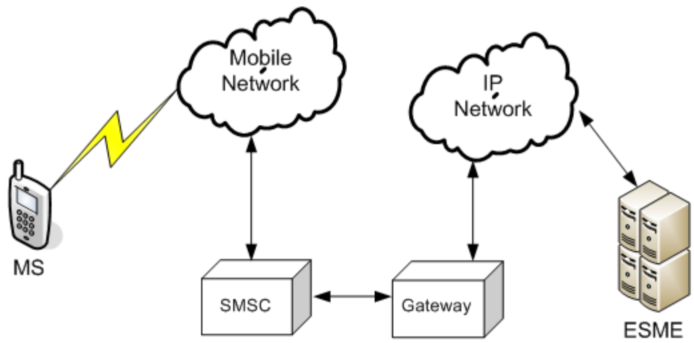


Figure 2.3: SMS-IP integration (adapted from [1])

The GSM legacy bilateral (or peering) model of interconnection requires each network operator to establish direct agreements with each of its partners [11]. The physical and logical interconnections are each point-to-point.

The hubbing (also known as GSM Open connectivity) model of interconnection is based on an agreement between the operator and a hubbing service provider. This agreement allows the operator to route the SMS traffic to a large number of mobile operators without requiring a direct agreement with each of them. [6]

The coexistence of the bilateral and hubbing models is based on categorizing the SMS traffic into person-to-person and application-to-person. The bilateral model makes sense in case of person-to-person communication in a country with a high population density while the hubbing model is more suitable for an application-to-person scenario [11]. The hubbing model also simplifies international SMS exchange by reducing $N * (N - 1)/2$ agreements and interconnections between N operators to a single agreement with a hubbing service provider.

Table 2.2: Peering and hubbing interconnection comparison [6]

	Advantages	Disadvantages
Peering model	Low latency End-to-end delivery confirmation	Complex routing and connection management Implementation and testing (new partners) SPAM control is more difficult High capital requirement (requires owning an SMSC) Mobile Number Portability must be handled Multiple Service Level Agreements (SLA), subscriber care, and operation support Character mapping required (converting between IA5 and ASCII); and possibly other more complex character sets
Hubbing model	Simple billing and settlement Simple routing management Single SLA and connection	Perceived high expense (outsourcing)

2.3 SMS Protocol

2.3.1 Protocol layers

The SMS protocol stack is composed of four layers as displayed in Figure 2.4. SM-AL is an application layer responsible for sending, receiving, and interpreting message content in an SME. SM-TL is a transfer layer that provides service to SM-AL [3]. At the SM-TL layer the message is treated as a Transfer Protocol Data Unit (TPDU) consisting of a number of octets carrying additional information about the message, such as message length, originator, destination, timestamps, etc. [2]. The SM-RL is a relay layer transporting the TPDU between network elements. The SMS router is an optional entity used only in the MT case [3]. At the lowest level, SM-LL, provides a link layer that transmits frames over some physical layer.

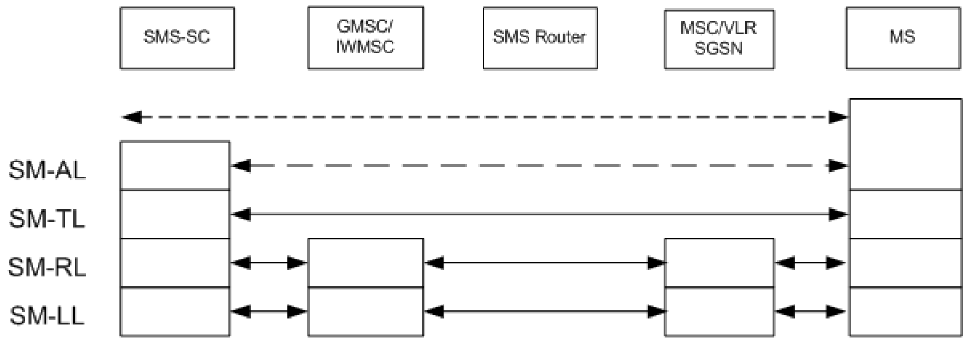


Figure 2.4: SMS protocol layers [3]

2.3.2 TPDU message format

The types of TPDU at SM-TL layer are listed in table 2.3 [12], while a summary of TPDU parameters is presented in Table 2.4. These messages are:

- SMS-SUBMIT conveys a short message from the originating SME to the SMSC.
- An SMS-SUBMIT-REPORT is sent by the SMSC to the originating SME in order to acknowledge the original message submission; if the SMSC failed to route the message, then the report can be negative.
- The SMS-DELIVER TPDU is sent by the SMSC to deliver a message to the recipient's SME.
- An SMS-DELIVER-REPORT is sent by the recipient's SME to the service SMSC upon message arrival.
- An SMS-COMMAND is used by originator SME to request command execution at the originator SMSC [2]. These commands include deleting a previously submitted message, requesting the status of a previously submitted message, cancelling a status report request, etc.

- The SMS-STATUS-REPORT delivers the result of a previously submitted SMS-SUBMIT or SMS-COMMAND to the message originator.

Table 2.3: TPDU types

Command type	Direction	TP-MTI
SMS-SUBMIT	SME -> SMSC	01
SMS-SUBMIT-REPORT	SMSC -> SME	01
SMS-DELIVER	SMSC -> SME	00
SMS-DELIVER-REPORT	SME -> SMSC	00
SMS-COMMAND	SME -> SMSC	10
SMS-STATUS-REPORT	SMSC -> SME	10

Table 2.4: TPDU parameters [2]

Abbr	Size	Reference	SUBMIT	SUBMIT-REPORT	DELIVER	DELIVER-REPORT	STATUS-REPORT	COMMAND
TP-CD	1 octet	TP-Command-Data	No	No	No	No	No	opt
TP-CDL	1 octet	TP-Command-Data-Length	No	No	No	No	No	man
TP-CT	1 octet	TP-Command-Type	No	No	No	No	No	Man
TP-DA	2-12 octets	TP-Destination-Address	Man	No	No	No	No	No
TP-DCS		TP-Data-Coding-Scheme	Man	opt	man	opt	opt	No
TP-DT	7 octets	TP-Discharge-Time	No	No	No	No	Man	No
TP-FCS	1 octet	TP-Failure-Cause	No	Man	No	Man	No	No
TP-MMS	1 bit	TP-More-Messages-to-Send	No	No	Man	Man	No	No
TP-MN	1 octet	TP-Mesage-Number	No	No	No	No	No	Man
TP-MR	1 octet	TP-Message-Reference	Man	No	No	No	No	Man
TP-MTI	2 bits	TP-Message-Type-Indicator	Man	Man	Man	Man	Man	Man

Abbr	Size	Reference	SUBMIT	SUBMIT-REPORT	DELIVER	DELIVER-REPORT	STATUS-REPORT	COMMAND
TP-OA	2-12 octets	TP-Originating-Address	No	No	Man	No	No	No
TP-PI	1 octet	TP-Parameter-Indicator	No	Man	No	Man	Opt	No
TP-PID	1 octet	TP-Protocol-Identifier	Man	Man	Man	Opt	Opt	Man
TP-RA	2-12 octets	TP-Recipient-Address	No	No	No	No	Man	No
TP-RD	1 bit	TP-Reject-Duplicates	Man	No	No	No	No	No
TP-RP	1 bit	TP-Reply-Path	No	Man	No	No	No	No
TP-SCTS	7 octets	TP-Service-Center-Time-Stamp	Man	Man	No	No	No	No
TP-SRI	1 bit	TP-Status-Repost-Indication	No	No	Opt	No	No	No
TP-SRQ	1 bit	TP-Status-Report-Qualifier	No	No	No	No	Man	No
TP-SRR	1 bit	TP-Status-Report-Request	Opt	No	No	No	No	No
TP-ST	1 octet	TP-Status	No	No	No	No	Man	No
TP-UD	variable	TP-User-Data	Opt	Opt	Opt	Opt	Opt	No

Abbr	Size	Reference	SUBMIT	SUBMIT-REPORT	DELIVER	DELIVER-REPORT	STATUS-REPORT	COMMAND
TP-UDHI	1 bit	TP-User-Data-Header-Indicator	Opt	Opt	Opt	Opt	Opt	Opt
TP-UDL	1 octet	TP-User-Data-Length	Man	Opt	Man	Opt	Opt	No
TP-VP	1 octet or 7 octets	TP-Validity-Period	opt	No	No	No	No	No
TP-VPF	2 bits	TP-Validity-Period-Format	Man	No	No	No	No	No

2.3.3 SMS coding scheme

The message can be encoded using one of the several alphabets: GSM 7-bit default alphabet (value 00), 8-bit data (01), or UCS2 (10) [13]. As the maximum SMS message size is 140 bytes, the number of characters depends on the coding scheme used: the message can contain up to 160 characters using the GSM 7-bit coding scheme, 140 octets of 8-bit data, or 70 unicode characters in the case of UCS2. The coding scheme value used is specified by the TP-DCS parameter (see Table 2.5). For general data coding bits 7-4 are 00xx. The message class can take the following values: mobile equipment specific (01), SIM specific (10), or terminal specific (11) use [13]. Message class 00 stands for immediate display also known as "flash SMS".

Table 2.5: TP-DCS format

bit	7	6	5	4	3	2	1	0
meaning	coding group				coding schema		message class	

2.3.4 User Data Header

User Data Header (UDH) Indicator (TP-UDHI) is a 1 bit field in the first octet of the PDUs listed in Figure 2.3 [3]. If the bit is set to 1, it means that the User Data (TP-UD) field contains the header followed by the message body. The header consists of a length field and one or more information elements. Each information element includes an identifier, element length, and data.

The possible utilization of UDH together with corresponding identifiers are listed in Table 2.6.

2.3.5 Concatenated Short Messages

The maximum size of a SMS message is 140 bytes, but as described in Section 2.3.3 the number of characters in a textual short message depends on the encoding. A long message is transferred across the mobile network as several messages which are reassembled at the end device transparently to the message recipient. Table 2.7 illustrates the octet alignment of the information element data.

Table 2.6: Information Element Identifier values [3]

Value (hex)	Meaning
00	Concatenated short messages, 8-bit reference number
01	Special SMS Message Indication
04	Application port addressing scheme, 8 bit address
05	Application port addressing scheme, 16 bit address
06	SMSC Control Parameters
07	UDH Source Indicator
08	Concatenated short message, 16-bit reference number
09	Wireless Control Message Protocol
0A	Text Formatting
0B	Predefined Sound
0C	User Defined Sound (iMelody max 128 bytes)
0D	Predefined Animation
0E	Large Animation (16*16 times 4 = 32*4 =128 bytes)
0F	Small Animation (8*8 times 4 = 8*4 =32 bytes)
10	Large Picture (32*32 = 128 bytes)
11	Small Picture (16*16 = 32 bytes)
12	Variable Picture
13	User prompt indicator
14	Extended Object
15	Reused Extended Object
16	Compression Control
17	Object Distribution Indicator
18	Standard WVG object
19	Character Size WVG object
1A	Extended Object Data Request Command
1B-1F	Reserved for future EMS features (see subclause 3.10)
20	RFC 822 E-Mail Header
21	Hyperlink format element
22	Reply Address Element
23	Enhanced Voice Mail Information
24	National Language Single Shift
25	National Language Locking Shift
26 6F	Reserved for future use
70 7F	(U)SIM Toolkit Security Headers
80 9F	SME to SME specific use
C0 DF	SC specific use

Table 2.7: IED organization

Octet	Meaning	Value range
1	Concatenated short message reference	a modulo 256
2	Total number of short messages in the concatenated message	0-255
3	Sequence number of the current short message	0-255

2.3.6 Application Port Addressing

A short message can be routed to one of several applications running on MS by specifying an SMS application port number, similar to TCP/UDP ports. The length of the port number information element is two octets and four octets in case of 8 bit and 16 bit addressing respectively. The first octet (the first two octets) carries the destination port number while the following (or following two) contains the originator's port number [3].

For 8-bit addressing the valid port number range is 240-255. The range for 16-bit port numbers is shown in Table 2.8.

If port number addressing is applied to a concatenated message, the corresponding information element must be included in each of the short messages composing the concatenated message [3].

Table 2.8: Port number range for 16-bit addressing [3]

From	To	Meaning
0	15999	UDP/TCP port numbers assigned by IANA without the need to refer to 3GPP
16000	16999	Available for use without the need to refer to 3GPP or IANA
17000	49151	UDP/TCP port numbers assigned by IANA
49152	65535	Reserved for future allocation by 3GPP

2.3.7 SM-RL layer protocol units

The service provided by the SM-RL layer to the SM-TL layer allows the transport layer to exchange TPDUs with its peer entities. These TPDUs are carried inside RP-MO-DATA and RP-MT-DATA elements of MS to SMSC and SMSC to MS paths respectively. [3] The format of RP-MO-DATA and RP-MT-DATA protocol units are shown in Table 2.9 and Table 2.10 respectively.

Table 2.9: RP-MO-DATA type [3]

Abbr.	Reference	Description
RP-OA	RP-Originating-Address	Address of the originating MS
RP-DA	RP Destination Address	Address of the destination SMSC
RP-UD	RP User Data	Parameter containing the TPDU

Table 2.10: RP-MT-DATA type [3]

Abbr.	Reference	Description
RP-PRI	RP Priority Request	Indicates whether or not the short message transfer should be stopped if the originator SMSC address is already contained in the MWD
RP-MMS	RP More Messages To Send	Indicates that there are more messages waiting in the SMSC
RP-OA	RP-Originating-Address	Address of the originating SMSC
RP-DA	RP Destination Address	Address of the destination MS
RP-UD	RP User Data	Parameter containing the TPDU
RP-MTI	RP-Message Type Indicator	Indicates if the TPDU is a SMS Deliver or a SMS Status Report
RP-SMEA	RP-originating SME-Address	Address of the originating SME

2.4 SMPP

Short Message Peer-to-peer Protocol (SMPP) is an industry standard protocol for communication between SMSC and SMS application system [14]. SMPP supports an exchange of request and response PDUs within a session between the ESME and the SMSC [14]. The ESME originated session can be registered as a Transmitter(TX), a Receiver(RX), or a Transceiver(TRX). A transmitter session allows the ESME to submit MT messages to the SMSC for further delivery to the MS, while a receiver session is used to receive messages from the SMSC [15]. A transceiver session combines the functionality of the previous two session types, thus supporting both MT and MO messaging.

All SMPP operations can be grouped into one of several categories:

- Session Management
- Message Submission
- Message Delivery
- Message Broadcast
- Ancillary Operations

The SMPP PDU submit_sm is used to submit a message to the SMSC and is the analogue of SMS-SUBMIT TPDU, while deliver_sm is similar to SMS-DELIVER TPDU. However, both message submission and message delivery can be completed with the PDU data_sm.

Chapter 3

Related Work

The chapter covers recent work on SMS QoS evaluation. However, most of the previous works have focused on the problem of packet loss, reliability estimation, and end-to-end latency measurement in normal and overload operating conditions. To the author's knowledge there is no scientific research similar to that proposed in this thesis.

The works described below are indirectly related to this thesis project, but they refer to QoS aspects other than the ones presented by this work. None of them mentions the deployment of an SMS gateway. Additionally all of these works were based on observations on national rather than international level.

The research presented by Canlas, et al. [16] is of interest in the context of the current project as it provides measurement results for end-to-end delay and delivery loss ratio. Their paper does not examine the reasons for packet loss. However, Waadt, et al. [4] focus on message loss caused by a particular situation.

The reliability analysis presented in [17] considers the bulk SMS service as a considerable source of traffic affecting the overall reliability of SMS service.

As the prototype implemented within this thesis project will be later developed for industry use, it was interesting to perform some market research to investigate the existence and type of commercial QoS analysis software. The results of this market research is given in Section 4.1.1.

3.1 A reconfigurable QoS monitoring framework for professional short message services in GSM networks

In [4], Waadt, et al. concentrate on the problem of SMS packet loss caused by forced packet removal at SMSC due to timeouts (i.e., the message timeout has expired before the message has been delivered). They propose a framework for QoS monitoring, alerting, and reconfiguring the SMSC. Their proposed system architecture is presented in Figure 3.1.

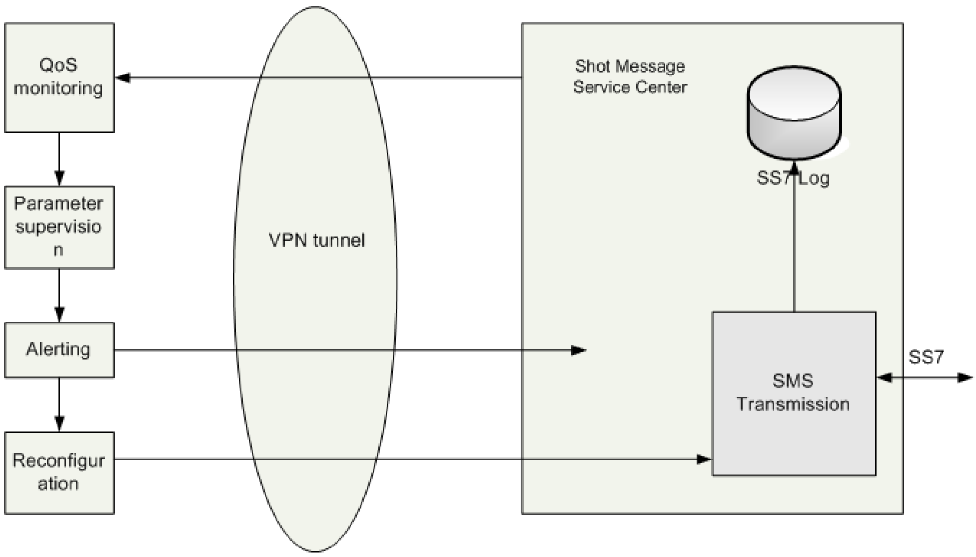


Figure 3.1: Framework for QoS monitoring[4]

To evaluate the QoS of the signaling domain, in addition to well known Key Performance Indicator (KPI) criteria (Service Accessibility SMS MO, Access Delay SMS MO, End-to-end Delivery Time SMS, and Completion Rate SMS Circuit Switched), three additional QoS parameters are introduced:

- Success Ratio SMS (SR SMS) is the ratio of the number of successfully executed * Mobile Application Part (MAP) commands and the total number of MAP commands.
- Error # Ratios SMS (E#R SMS) is the ratio of the number of MAP commands returning a particular error code of the SS7 protocol and the total number of MAP commands.

*To be successful means that they executed with result code 0.

- Effort SMS (E SMS) is the average number of protocol commands made when attempting to transmit a short message.

The QoS parameters values are measured and compared to the values stored in a Parameter Supervision block. If the observed values are out of range, then an alert is sent to the SMSC. The system allows automatic reconfiguration of some SMSC parameters such as an SMS retry scheme or the designated serving MSC.

3.2 A Quantitative Analysis of the Quality of Service of Short Message Service in the Philippines

Canlas, et al. [16] measured the packet-loss, end-to-end delay, and inaccurate prepaid load† in order to formulate an enhanced QoS equation describing the network behaviour, billing performance, and overall service quality of an SMS system.

Three mobile operators were chosen to create nine sending combinations. The following parameters were monitored during the tests: Number of Messages Received, Number of Messages Sent, Time Delay per message, and Load Consumption. Their final equation for the QoS of SMS is the following [16]:

$$QoS = (\frac{M_R}{M_{S,ideal}})^3 * (\frac{M_{S,actual}}{M_{S,ideal}}) * (\frac{TI}{T_D}) * (\frac{1.00\frac{Php^2}{messages^2}}{L_C})$$

where:

QoS = overall QoS [unitless]

M_R = number of received message [messages]

$M_{S,ideal}$ = number of messages attempted to be sent [messages]

$M_{S,actual}$ = actual number of messages sent [messages]

TI = Timeliness Index [seconds]

T_D = average time delay [seconds]

L_C = load consumption

†By inaccurate prepaid billing the authors mean the scenario when the user with a prepaid SMS subscription is charged an amount not equivalent to correct charge for the provided QoS despite the fact that the charge occurred before the service was actually used.

3.3 Analysis of the Reliability of a Nationwide Short Message Service

Meng, et al. [17] studied SMS reliability based on traces from a national cellular operator captured during a three-week period in 2005. The data contains information about 59 million messages. The message delivery failure ratio and end-to-end latency are considered to be the KPIs for service reliability. According to their research the delivery failure ratio is as high as 5.1%, while the latency experienced by 91% of subscribers is less then 5 minutes. However, the same latency value is valid for only 50% of users during a 'flash-crowd'[‡] event.

The authors indicate two factors having a crucial effect on the overall reliability of an SMS service: bulk message delivery and social networks of SMS users. Notably the ratio between the peak traffic rate and average rate for the nine content providers that they considered, varies from 9.4 to 53.7. All of these ratios are significantly higher than the 3.7 ratio for the person-to-person traffic.

The collected data were used to build a graph representing the social network topology formed by SMS subscribers. Their investigation of the topology influence on the propagation speed of a virus spread by SMS showed that the speed does **not** depend on the choice of the first infected node.

3.4 Value Added Services and Content Platforms

One of the goals of Adrian Mahdavi's master's thesis project [18] was to create an SMS Load Generator and Data Collector in order to evaluate the performance of an SMSC in two scenarios:

- sending messages at peak rate (10 SMS/s) during 10 minutes
- sending messages at 70% of peak rate during 120 minutes

The first scenario simulates the subscriber activity during a TV show or quiz show, while the latter illustrates the traffic pattern in the hours before and after Christmas and New Year.

For both cases a series of tests with increasing duration were performed, viz. the observations were made during 10, 20, 30, and 40 minute intervals for the first scenario and during 60, 120, and 180 minute intervals for the second. The results showed that the SMSC was able to process the traffic at the peak rate without losses for a maximum of 30 minutes. Another test,

[‡]A stressful condition caused by coordinated action of a large number of people. This kind of situation occurred on New Year's Eve in 2005.

based on generating and sending 11 SMS/s (110% of the 10 SMS/s rate) during a 30 minute period, worked for the 10 SMS/s rate, but this higher load caused the SMSC to crash.

Mahdavi's tests [18] showed that the SMSC was capable of processing the traffic at 70% of the peak rate. No packet losses were observed during the 60 and 120 minute tests, but during the 180 minute test, 24%(18412 out of 75600) of messages were lost and 0.25% were discarded at the SMSC. However, the SMSC was stable and did not crash as it did with a load of 11 SMS/s.

Mahdavi also provides separate results of performance testing for the external interface and store-and-forward engine's performance.

3.5 Commercial Projects

Commercial products Xplorer SMS Service [19] and SMS Network Solution [20] developed by Ibys Technologies and Tekelec respectively, allow the operator to monitor and evaluate the QoS of an SMS service. The services provided by Ibys Technologies' Xplorer SMS Service include message delivery and transmission time measurement, failure notification, validation of SMS message content and evaluation of SMS service availability. Tekelec's SMS Network Solution [20] is focused more on providing an infrastructure solution for resource allocation for different services, throttling low-priority traffic, and providing bandwidth to the higher-priority applications like bulk messaging.

Chapter 4

Methods

This chapter presents the proposed approach for qualitative evaluation of an international SMS traffic route. The chapter introduces the test and measurement methodology, and provides a high level overview of the prototype system used to perform these measurements.

4.1 Test and Method Description

This thesis project will focus on two aspects of QoS evaluation of *international* SMS traffic:

1. Verification that the SMS route supplier and destination operator support all the standard SMS parameters and no data was modified during the transmission; and
2. Measurement of end-to-end delay of SMS message delivery.

4.1.1 Message Verification

Message verification tests are used to determine if the test message has been delivered correctly and to verify the integrity of the received message. The original message may be modified if the some features are not supported either by the transit carrier or by the terminating mobile operator. The following parameters will be observed via this test framework:

- Sender address - this quite obvious test is necessitated by the fact that some suppliers may block traffic from a given alphanumeric originator
- Alphabet - this test verifies that the destination and transit operators support the current encoding and do not reset the encoding to the default one. The 8-bit alphabet is also used to identify if the operators block externally originated binary traffic.

- SMSC address - the motivation to compare the delivering SMSCs for different routes is to determine what kinds of interconnections are used by the route suppliers for a given destination network. The output of this test for several supplier routes can be analyzed and compared with the result of the end-to-end delay test set to investigate the degree of correlation between interconnectivity model and the delivery time
- SMSC timestamp - comparison of SMSC timestamp with actual delivery time at the node
- Concatenated message - verification of correct delivery of a multipart SMS message to the recipient

4.1.2 End-to-end Delay Measurement

The purpose of this test set is to compare different international SMS routes in terms of end-to-end delivery time and determine bottlenecks in each of the routes. Test SMS messages will be sent via the same SMS aggregator and timestamped at the receiving node upon arrival. All of the tests will utilize packet-pair based methods, viz. the original pair-packet method and TOPP method, which are explained below.

Packet-Pair Method for Bottleneck Bandwidth Estimation

The packet-pair method is used to estimate the bottleck bandwidth of a network path which is caused by the slowest forwarding element in the path [21]. The idea underlying the method is to transmit two equal sized packets with a known time interval between them and observe the arrival times at the destination. If the bottleneck bandwidth of the path is β and the size of the packet is b, then Q_b, the processing time on the bottleneck link, can be determined by equation

$$Q_b = b/\beta$$

If the time interval between sending the packets, Δ_s, is less than Q_b, then the packets will arrive at the destination with the time spacing Δ_r, equal to Q_b, which allows us to calculate the unknown β [21].

Train of Packet-Pairs Method (TOPP)

The described packet-pair method has some drawbacks, e.g. the problem of different types of bottlenecks on separate links. Melander et. al. in [22] addressed this problem and presented the TOPP method. This method is based on sending trains of packet-pairs (a number of packet-pairs with a significant interval between) and gradually increasing the time spacing between the pairs. The output of the measurements is a series of timestamps for each sending rate, which allows us to calculate the mean and determine the experienced bandwidth for each sending rate [22].

4.2 Solution Architecture

The high level design of the proposed solution is presented in Figure 4.1.

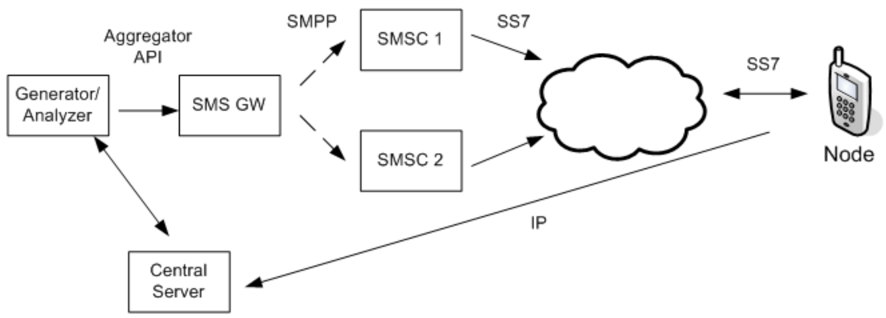


Figure 4.1: Solution design

In order to perform the tests, collect results and analyze the test data the following software components will be deployed: test node, central server, and SMS generator and analyzer. We assume that the SMS gateway is owned and maintained by an SMS aggregator.

The SMS generator creates a specific test setup based on user input, then assigns a unique sequence of characters to identify the message and inserts this string in the message body*. The modified data is sent to the SMS gateway using the API defined by the SMS aggregator; the same data excluding the route identifier is passed to the central server. The parameters necessary for test definition include:

- Alphabet (default GSM 7 bit alphabet, 8 bit data, UCS2 alphabet)
- Message body containing TP-UDH
- Originating address
- Originating address type (alphanumeric, short code, MSISDN number)
- Destination address
- UDH header

*The purpose of sending the identifier in the message might seem not obvious in the scope of the implemented prototype. The need of such identifier is caused by the industry scenario when the central server handles the messages sent by different generators and, thus, needs to route the result to the correct SMS generator.

- SMS route identifier

If the test message has successfully reached the destination node, the node extracts the message identifier along with other information and forwards the data to the central server, which routes the result to the correct SMS generator depending on the message identifier string. The test generator compares the received data with the original message and publishes the test result.

Table 4.1 summarizes the tools and environment used for software development.

Table 4.1: Tools

Node	
OS	Symbian v9.3
Programming Language	Symbian C++
SDK	S60 Third Edition Feature Pack 2 v1.1
Integrated development environment	Carbide IDE v2.7
DBMS	Microsoft SQL Server 2008
Central Server	
OS	Windows Server 2008 R2
Programming Language	VB.NET
Framework	.NET Framework 3.5
Integrated development environment	Microsoft Visual Studio 2008
Test Generator and Analyzer	
OS	Windows XP
Programming Language	VB.NET
Framework	.NET Framework 3.5
Integrated development environment	Microsoft Visual Studio 2008
DBMS	Microsoft SQL Server 2005

Chapter 5

Results

The chapter presents and analyzes the results of measurements, described in Chapter 4.

5.1 End-to-end Delay Measurement

5.1.1 Test Setup

We have chosen one mobile network, Singtel, in Singapore, as the destination network for a series of end-to-end delivery time measurements. The SMS message was sent to the destination via two different SMS routes: Route 1 and Route 2, which delivered the SMS message to a Singtel subscriber along different paths (this was verified by observing the SMSC address contained in the received SMS-DELIVER message). To eliminate the chance that the test messages were blocked by a destination carrier or by one of transit carriers, we decided to use GSM 7-bit alphabet and an MSISDN originator address. The length of the test message text was 160 characters, which is the maximum length for a 7-bit encoded non-concatenated message.

In order to perform the measurements of end-to-end delivery time using the TOPP method described in Chapter 4.1, the intra-pair and inter-pair time intervals need to be defined. We made a series of tests for the chosen destination network to estimate the mean end-to-end delay, which would allow us to draw a conclusion about the acceptable values for the intervals based on the measurement results; the test input parameters to the test are listed in Table 5.1:

Table 5.1: Initial test setup

Parameter Name	Value
Destination	Singtel (Singapore)
Test time	7:00 - 8:00 UTC
Local time at destination	15:00 - 16:00
Transport	Control channel
SMS message encoding	GSM 7-bit
Body size	140 bytes
Number of tests	50
Time interval between packets	10 sec
Route	Route 1

According to this initial test result, the mean end-to-end delay for delivering the SMS message to Singtel mobile network is 4.82 seconds with a standard deviation of 2.63. Based on these values, we decided to perform TOPP-based tests with following setup:

Table 5.2: TOPP test setup for Singtel network

Parameter Name	Value
Intra-pair interval	1, 2, and 3 sec
Inter pair interval	30 sec
Number of packet pairs in train	80
Transport	Control channel
SMS message encoding	GSM 7-bit
Body size	140 bytes
Test time	7:00 - 10:00 UTC

For each route of each measurement series we calculated the mean value and standard deviation of the following observed parameters: end-to-end delay for the SMS message, end-to-end delay for the first message in pair, end-to-end delay for the second message in pair, and time spacing between arrival of the first and second messages.

5.1.2 Measurement Results for Route 1 to Singtel

The tests were performed in accord with the setup specified in Table 5.2. No data loss occurred during the series of tests for this route. The observed distribution of time intervals between arrival of the first and the second test message is illustrated in Figure 5.1. The mean value and standard deviation of the end-to-end delay time for the first and the second SMS message are presented in Table 5.3. No data loss occurred during the series of tests for this route.

Table 5.3: Observed values for Route 1 to Singtel

Parameter Name	Intra-pair spacing (sec)	Mean Value (sec)	Standard Deviation
End-to-end delay for the first message in pair	1	6.48	1.33
	2	7.72	5.05
	3	5.64	1.45
End-to-end delay for the second message in pair	1	13.87	3.04
	2	9.87	5.49
	3	11.28	3.23
Time interval between arrival of the first and second message	1	10.39	3.51
	2	5.15	9.21
	3	8.64	2.92
End-to-end delay for a message	1	10.18	4.89
	2	8.79	5.37
	3	8.45	3.77

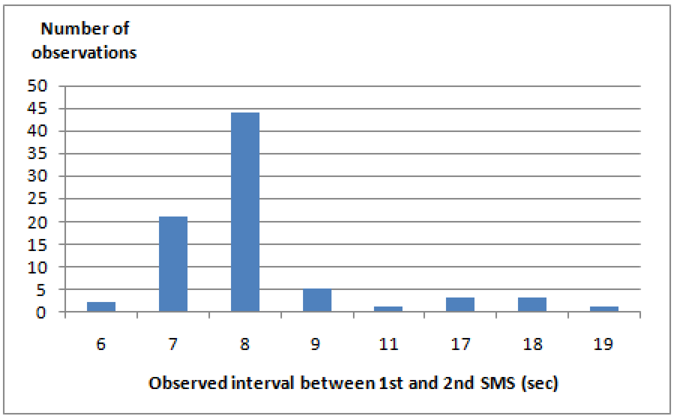
Table 5.3 demonstrates that the mean time spacing between arrival of the first and second messages increases from 8.64 to 10.39 seconds as the intra-pair interval is decreased from 3 seconds to 1 second.

The negative values presented in Figure 5.1 correspond to the case when the second message arrived before the first message from the same pair*. As it can be seen from the figure, such values were observed only once during the test session with 1 second intra-pair interval and twenty times in the series with intra-pair interval of 2 seconds. Thus, for Route 1 and 1 second intra-pair interval, these negatives values do not have significant impact on overall distribution of the time spacing between the first and the second SMS message arrivals. The frequent occurrence of the negative values for the tests with 2 second intra-pair time spacing involves unexpected average values and high standard deviation, making the comparison of the bottleneck bandwidth for these values with the computations based on more valid measurement results, inconsistent.

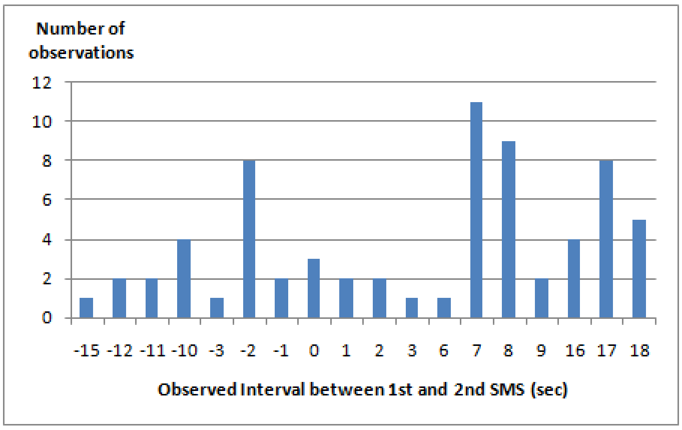
The size of the test SMS comprises SUBMIT TPDU's length (153 bytes) added to originator address (8 bytes) and destination address (7 bytes) contained in RP-MO-DATA, producing in total 168 bytes of data passed along the SMS route. Thus, the bottleneck of Route 1 for intra-pair interval 1 and 3 seconds equals to 16.16 and 19.44 bytes/sec correspondingly.

Assuming that our measurements are correct we can conclude that Route 1 consists of at least two segments with unequal bottlenecks.

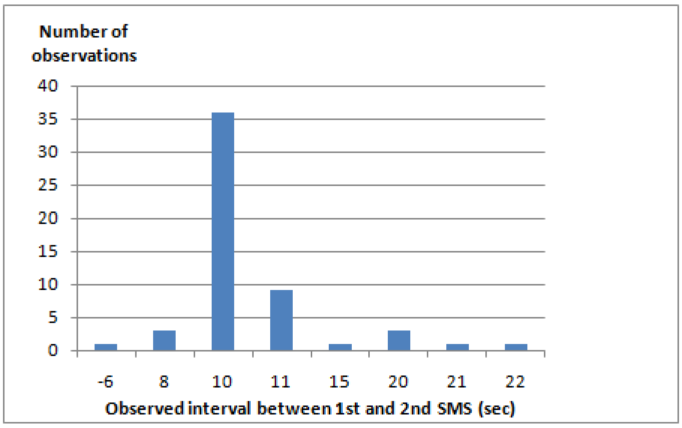
*The second message can be delivered faster than the first message in the pair if the route supplier buffers SMS messages before delivering them to the destination.



(a) Singtel, Route 1, intra-pair interval 3 sec



(b) Singtel, Route 1, intra-pair interval 2 sec



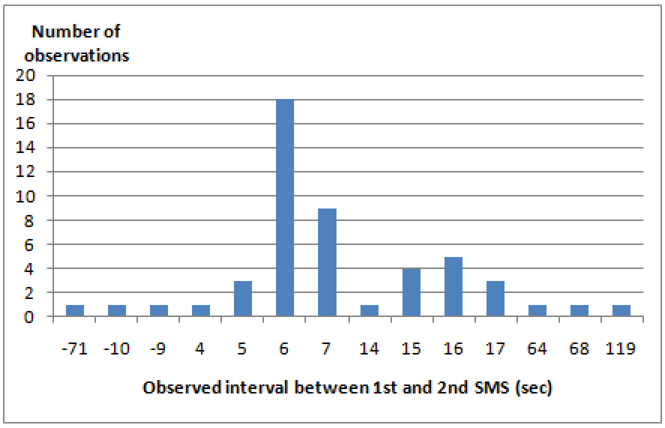
(c) Singtel, Route 1, intra-pair interval 1 sec

Figure 5.1: Singtel, Route 1

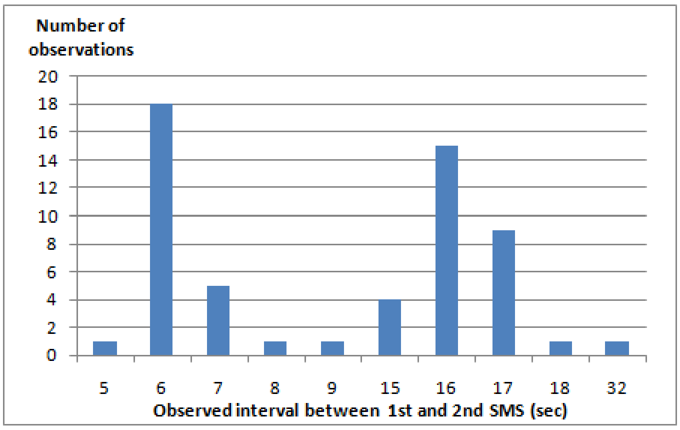
5.1.3 Measurement Results for Route 2 to Singtel

The results received during the series of similar tests for Route 2 differ considerably from the Route 1 results. First of all, we experienced around 40% message loss when sending test messages along this route, which made it necessary to increase the number of packet-pairs in the train to achieve reliable results. Next, the message loss rate was unacceptable for the intra-pair interval of 1 second forcing us to perform the measurements for intra-pair interval of 2,3, and 4 seconds instead of 1,2,3 seconds as before.

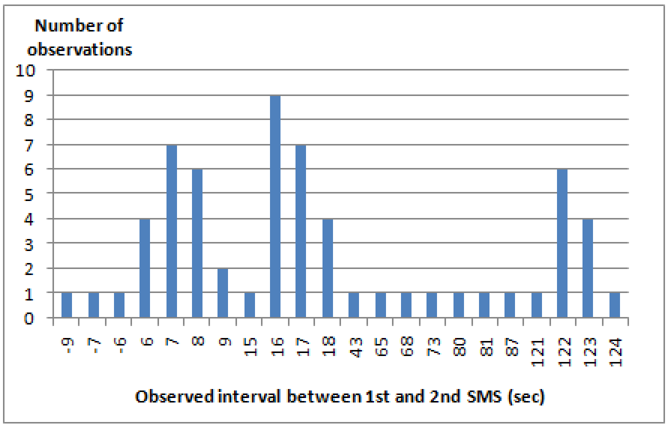
The distribution of time intervals over number of events for route 2 (see Figure 5.2) differs from those discussed in previous section. Distributions observed during the tests for Route 1, starting at some point are approaching normal distribution, while the all the distributions for Route 2 have two peaks. As this behaviour seemed quite strange to us, a more thorough analysis of the results was performed, which revealed several interesting facts. In the case of Route 1, all SMS messages were delivered by the same SMSC while in case of Route 2, the messages were delivered by 4 to 6 different SMSCs located in different countries (Sweden, India, Fiji). Thus, we assume that the route included a load balancer which routed the test messages over different paths. The close observation of results showed that in some cases the first and the second messages from the same pair were delivered to the destination via different paths. Most of the messages were delivered by one of the SMSCs in Sweden. We filtered the results to include only those where both messages in the pair were delivered by this Swedish SMSC. We performed additional tests for each of the intra-pair intervals and analyzed only the SMS pairs passing the above mentioned SMSC. The results are presented in Figure 5.3. The mean values for end-to-end delay are presented in Table 5.4.



(a) Singtel, Route 2, intra-pair interval 4 sec

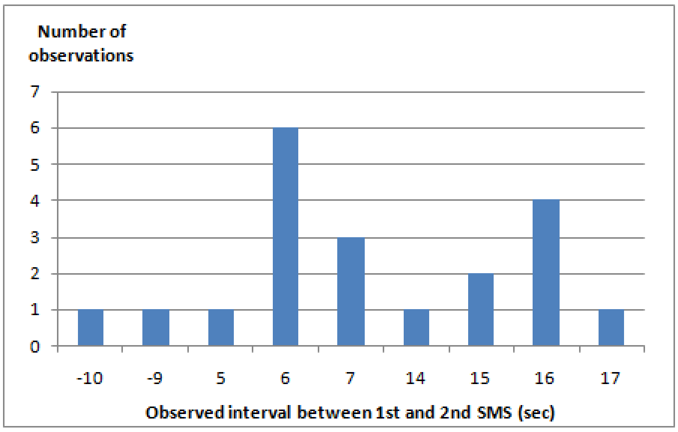


(b) Singtel, Route 2, intra-pair interval 3 sec

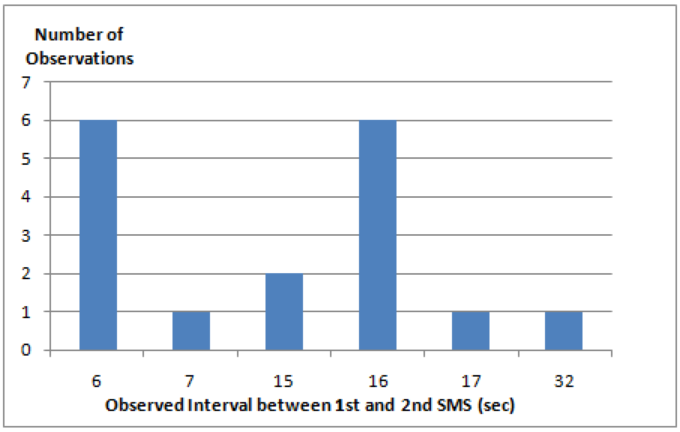


(c) Singtel, Route 2, intra-pair interval 2 sec

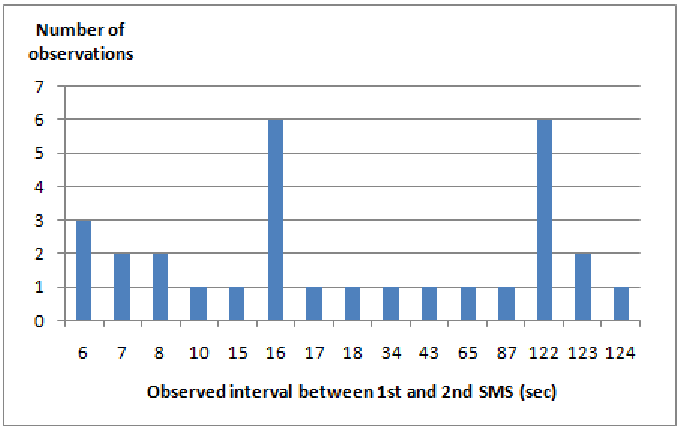
Figure 5.2: Singtel Route 2



(a) Singtel, Route 2, intra-pair interval 4 sec



(b) Singtel, Route 2, intra-pair interval 3 sec



(c) Singtel, Route 2, intra-pair interval 2 sec

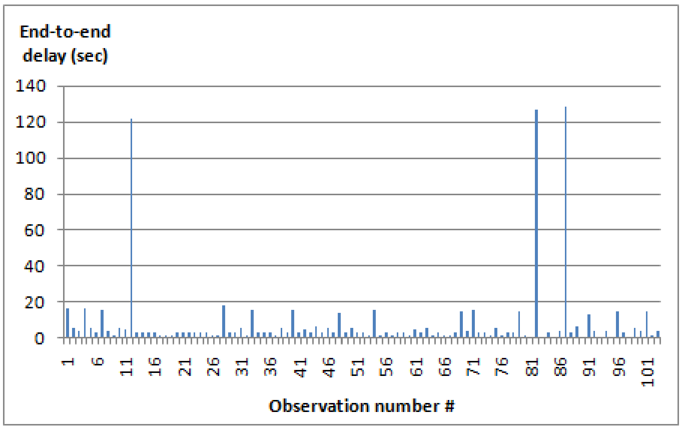
Figure 5.3: Singtel Route 2 via SMSC in Sweden

Table 5.4: Observed delay values for Route 2 to Singtel for a particular (Swedish) SMSC

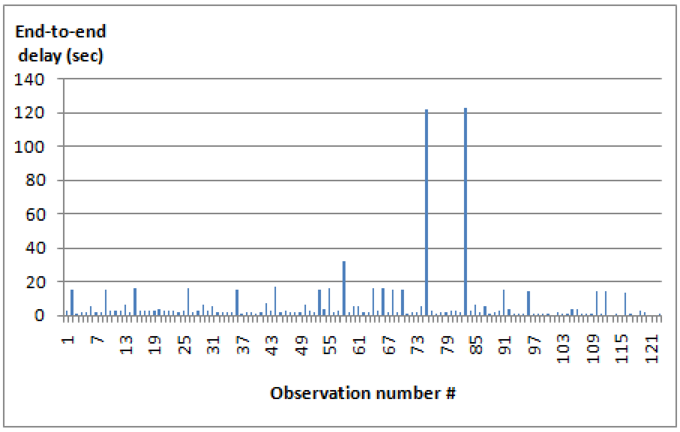
Parameter Name	Intra-pair spacing	Mean Value (sec)	Standard Deviation
End-to-end delay for the first message in pair	2	3.41	2.42
	3	2.61	0.66
	4	3.63	3.10
End-to-end delay for the second message in pair	2	56.06	52.31
	3	18.38	7.52
	4	10.00	5.34
Time interval between arrival of the first and second message	2	55.66	51.96
	3	18.78	7.39
	4	9.38	6.95
End-to-end delay for a message	2	29.73	45.32
	3	10.50	7.47
	4	6.81	5.38

According to Figure 5.3 the distributions retained the two peaks for each test series even though the data was filtered. This behaviour together with high standard deviation for the tests with 2 sec intra-pair interval, encouraged us to create one more chart. Figure 5.4 depicts the observed end-to-end delay values for **all** of the SMS messages that were delivered by the chosen SMSC not distinguishing between the first message in the pair and the second. i.e. the figure includes values for the messages delivered by this SMSC independently whether the other message in the pair was delivered by the same or different SMSC.

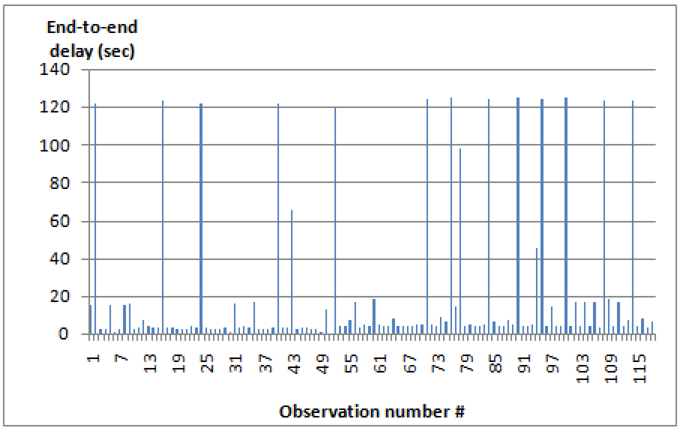
The Figure 5.4(c) illustrates that the end-to-end delay periodically exceeds 100 sec with unsteady period, while in case of figures 5.4(a) and 5.4(b) such outliers are observed only 3 and 2 times respectively. Based on 5.4(c), it may be assumed that the SMS messages are buffered by the route supplier (or by the transit carrier) and delivered to the destination later. The unsteadiness of the period can be caused by the cross traffic. However, this explanation does not match behaviour of 5.4(a) and 5.4(b). Thus, we suggest that the routes supplier buffers the SMS messages only in case of heavy load, i.e. either the change of intra-pair interval evoked the buffering or the load of cross traffic during the series of tests with 2 second intra-pair interval was incomparably higher than in case of the tests with 3 and 4 second intra-pair interval.



(a) Singtel, Route 2, intra-pair interval 4 sec



(b) Singtel, Route 2, intra-pair interval 3 sec



(c) Singtel, Route 2, intra-pair interval 2 sec

Figure 5.4: Singtel Route 2, end-to-end delay for all SMS messages delivered via SMSC in Sweden

The bottleneck bandwidth value for intra-pair spacing of 3 and 4 seconds equals to 8.94 and 17.91 bytes/second respectively.† Thus, the bottleneck bandwidth for inter-pair interval of 3 seconds for Route 1 is approximately twice that of Route 2, making Route 1 superior to Route 2 in terms of bottleneck bandwidth as well as message loss rate.

5.1.4 Comparison of Experienced End-to-end Delay for GPRS Channel and Control Channel

As an SMS message can be delivered from the SMSC to the subscriber via a control channel or via GPRS, we have performed the same test for both control channel and GPRS. The test was performed in the following environment: a train of 70 SMS messages, consisting of 160 characters of GSM 7-bit alphabet, was sent to Singtel network via Route 1 between 8:15 and 8:45 UTC time, with the inter message interval equal to 10 seconds. Table 5.5 and Figure 5.5 illustrate the received results. According to these results, not only is the mean end-to-end message delivery time to the given mobile network smaller for a control channel delivery than for the GPRS delivery, but the standard deviation for the control channel observed values is half less than that of the GPRS channel.

Table 5.5: GPRS vs GSM

Transport	Minimum Value (sec)	Maximum Value (sec)	Mean Value (sec)	Standard Deviation
GPRS	2	19	6.61	3.96
Control channel	2	15	4.84	1.80

However, the results presented in this section cannot be used for evaluation of an SMS route from the SMS aggregator's point of view as the SMS message receiver might not support SMS over GPRS.

5.2 Verification Tests

5.2.1 Sender Address

During these series of tests we sent SMS messages from three addresses of different types, viz. alphanumeric originator address, short code, and MSISDN, to subscribers of Singtel (Singapore) via two routes, Route 1 and

†Due to high standard deviation for the test series with intra-pair interval 2 seconds, we skipped these results and calculated bottleneck bandwidth only for the remaining two series.

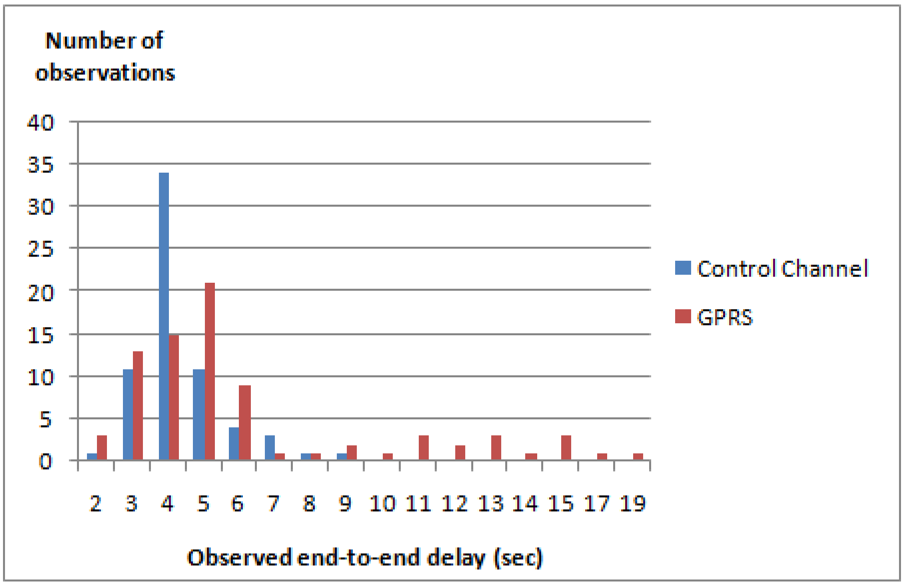


Figure 5.5: GPRS vs GSM

Route 2, and Tele2 (Sweden) via routes RS1 and RS2. In the case of Route 1, RS1 and RS2, all the messages were delivered to the destination. In case of Route 2, the loss rate was equal to the loss rate of SMS messages with an MSISDN originator address sent along the same route. Thus, we conclude that all of the tested routes can be used to deliver SMS messages with any type of originator address to the destinations described above.

5.2.2 Alphabet

We have sent test SMS messages with the non-default valid encodings (8-bit data and UCS-2) to Tele2 and Singtel networks via two routes to each destination. The experienced message loss rate was zero in the case of Tele2, while in the case of Singtel, the loss rate for each encoding was no higher than in case of sending a 7-bit encoded message via the corresponding route. Interestingly, we discovered that when sending messages to Tele2 along one of the routes, messages containing 8-bit data were delivered via an SMSC located in a different country than the SMSC which delivered the 7-bit and UCS-2 encoded messages to Tele2 sent via the same route.

5.2.3 SMSC Address

In the previous sections, the SMSC address contained in the SMS-DELIVER message was used to detect a load balancer placed in the path, or a network

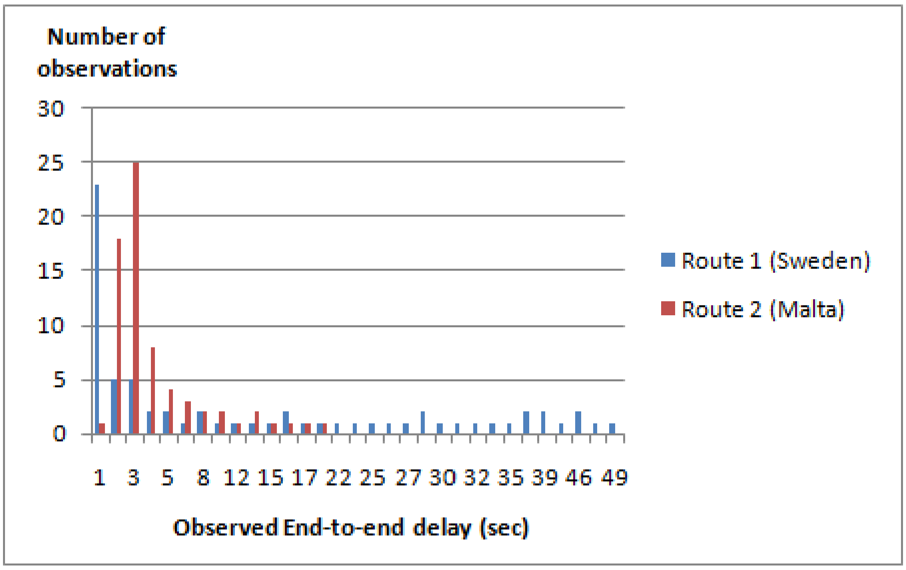


Figure 5.6: Comparison of interconnection models

element which would route messages to the same destination depending on their encoding. In the series of tests described is section, the SMSC address was used to find a supplier which delivered the SMS traffic via the destination operator's SMSC.

We sent a train of 70 SMS messages[‡] with interval of 10 seconds between the messages to the Tele2 network via two routes, one of which delivered the messages via an SMSC located in Malta, while the other used the SMSC with a number belonging to Tele2 resource. The results (see Table 5.6 and Figure 5.6) show that in this case Route 1 has better indicators than Route 2.

Table 5.6: Comparison of interconnection models

Route	Minimum Value (sec)	Maximum Value (sec)	Mean Value (sec)	Standard Deviation
Route 1 (Sweden Tele2)	1	49	13.59	15.39
Route 2 (Malta)	6	411	20.24	66.77

[‡]the message encoding and length are the same as described in Section 5.1.1

5.2.4 SMSC Timestamps

The data collected during the previous tests was used to calculate the SMSC delay for each SMS message, i.e. the service time on the path segment between originator and delivering SMSC. Figure 5.7 presents a comparison of end-to-end and SMSC delay for each SMS message sent to Singtel via Route 1. The mean value and standard deviation are 9.55 sec and 4.20 respectively for end-to-end delay and 1.48 and 0.56 for SMSC delay. It is important to mention, that

$$D_o = D_r + constant$$

where D_o is the observed value of SMSC delay and D_r is the real value of the experienced delay. The presence of the *constant* is caused by the fact that the SMS generator is not synchronized with the SMSC, hence there is a certain time offset between their clocks.

As it can be seen from the figure, the fluctuations of SMSC delay and fluctuations of end-to-end delay are not correlated.

The SMS messages were delivered to the destination (Singtel) via SMSC located in Malta, which implies that the SMSC is connected to the hubbing service. Thus, we can conclude that the delivery via hubbing service is taking longer time than the delivery via direct connection from the SMS aggregator's platform to the SMSC in Malta.

5.2.5 Concatenated Message

As this test was planned to verify that a concatenated message is delivered correctly to the destination, we sent twenty messages consisting of two parts to Singtel network and consisting of three and four parts to Tele2. In both cases, all messages were delivered to the destination, thus both routes are able to carry SMS messages with body size exceeding 140 bytes.

In the process of testing, we found out that the mobile equipment used is not capable of displaying incomplete concatenated messages, i.e. a concatenated message where one or more parts are missing; the test node reported only the messages which had been delivered completely. We sent an incomplete concatenated SMS message from the SMS aggregator's platform as well as from other mobile equipment.[§] In the first case, the destination equipment did not recognize the message arrival. Meanwhile another model of mobile phone was able to receive and display the corrupted message. In the other case, the message was processed by the phone and the output showed that the UDH of the message had been modified: the total number

[§]The scenario when incomplete concatenated SMS messages are deliberately sent to the aggregator's platform in order to avoid billing, is out of the scope of this thesis project.

of parts in the concatenated message was decreased by one, and the reference number was changed as well: without any indication of their being an error.

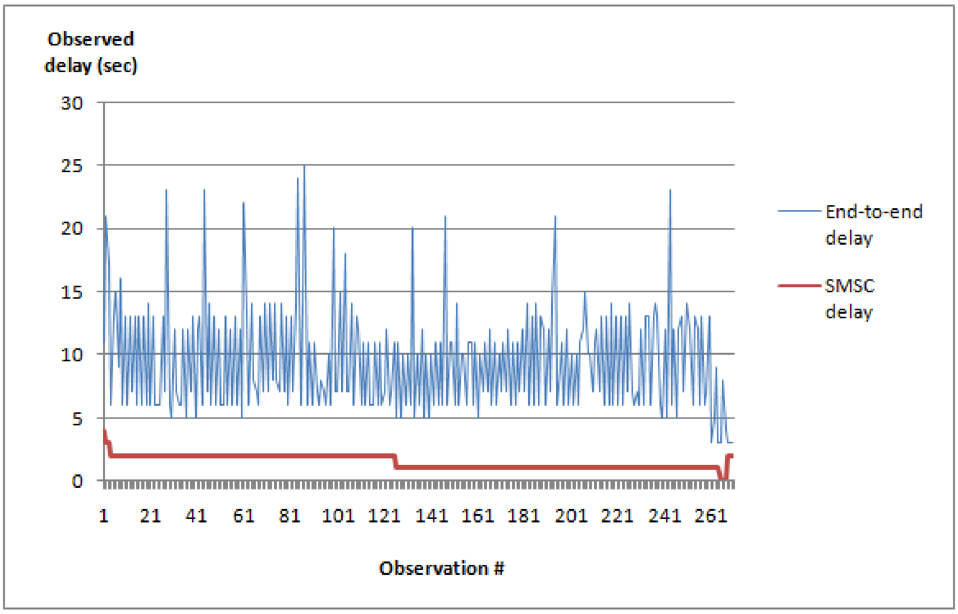


Figure 5.7: Comparison of end-to-end and SMSC delay

Chapter 6

Conclusions and Future Work

The chapter summarizes the results of the performed research and estimates the applicability of the proposed method for evaluation QoS of an international SMS route. The chapter also suggests some improvements of the proposed evaluation method.

6.1 Conclusions

Despite its topicality the problem of QoS evaluation for international SMS traffic was not previously studied properly; most of the existing works concentrate on measurement of the parameters defined by ETSI [9] which do **not** provide information about the correctness of delivered content, e.g. encoding, support of special characters etc.

In this thesis project we addressed the aspects of QoS of international SMS traffic which cannot be studied simply by analysis of delivery reports and acknowledgements. A prototype system for QoS evaluation of SMS traffic was developed and used to perform a number of tests which were classified as verification tests and end-to-end delay measurement tests.

Our results for the verification tests proved that the test messages were delivered along the selected routes unchanged and message loss rates for each test depended only on the route, rather than type of the test. Thus, we did not experience the 'blocking'* problems described by the SMS aggregator during the requirement definition phase. This can be explained by the fact that we could not test all existing routes of the aggregator, i.e. the exploited

*E.g. blocking occurs when SMS traffic of a particular type is blocked by a transit operator.

routes were selected and provided by the aggregator itself which implies that the QoS on this routes was, at least, acceptable.

One of the tested routes to Singtel network (Route 1) was claimed by the SMS aggregator to deliver SMS messages, both text and binary, from all valid originator types, while the other route (Route 2) was guaranteed to deliver only text SMS traffic from an MSISDN originator address. Our test results demonstrated that both routes were able to carry and deliver SMS traffic of all types, but in case of Route 1 we did not experience any data loss, while in case of Route 2 the loss rate was quite high (40%), but uncorrelated with the type of SMS message.

During the series of end-to-end delay measurement tests we demonstrated that the prototype can be used to calculate the bottleneck of the SMS route and to estimate the number of segments in the path.

The prototype of the SMS testing system can be used by SMS aggregators to verify delivery of a SMS message, check the integrity of the message, as well as to extract estimates about the interconnection type of the route supplier with the destination carrier and to detect load balancers implemented by the route supplier or a transit carrier. The prototype is useful when comparing end-to-end delay times of several routes and computing bottleneck values for each of them.

To summarize our results, we can say that the proposed approach of evaluating QoS of an international SMS route by combining this set of verification tests with TOPP-based end-to-end delay measurement tests, provides a detailed analysis of the QoS of the SMS route.

6.2 Future Work

In this thesis project, we have proposed two classes of tests, verification and delay measurement, to evaluate QoS of a specific route. The verification tests can be enhanced by using a different model of mobile phone as a test node, the specifically the one that is able to process concatenated SMS messages missing one or more parts.

The Central Server entity in the proposed system stores all the test results which could not be matched with the existing ongoing tests, which makes it vulnerable to denial of service attacks. This issue needs to be solved in the next version of the system.

Currently, only one test node in the destination network was utilized in testing. We suggest increasing the number of the destination test nodes and distributing the traffic evenly between these new test nodes during the test. The traffic generated by this modified test setup will enable a better estimate of the actual characteristics for real-world.

This thesis does not examine the protocol carrying the SMS message and its influence on the experienced end-to-end delay. The tests could be modified so that the analysis of their results can provide information about the signaling system (SIGTRAN or SS7) used to deliver message.

The system can be modified to identify ported numbers, in countries where Mobile Number Portability is supported, by comparing the end-to-end delay for a ported and non-ported destination number.

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