

MEASUREMENT OF QoS
FOR GSM INTERNATIONAL ROAMER



REPORT

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List of Acronyms

ACA	Australian Communication Authority
ACMA	Australian Communications and Media Authority
ACIF	Australian Communications Industry Forum
ANACOM	Autoridade Nacional de Comunicações (Portegese Regulator)
ANATEL	Agência nacional de telecomunicações (Brazilian Regulator)
CCD	Chargeable Call Duration
CCR	Call Completion Rate
CED	Call Establish Duration
CLI	Caller Line Identification
CO1	Pakistani Cellular Operator 1
CO2	Pakistani Cellular Operator 2
CSAD	Call Setup Alert Duration
CSR	Call Success Rate
CU	Central Unit
DTMF	Dual Tone Multiple Frequency
EG	ETSI Guide
ESA	Endpoints Service Availability
ETSI	European Telecommunication Standard Institute
GPRS	General Packet Radio System
GR	GlobalRoamer
GSM	Global System for Mobile Communication
GUI	Graphical User Interface
IP	Internet Protocol
IR	International Roaming
ISDN	Integrated Services Digital Network
ITU-T	International Telecommunication Union - Telecommunication-Standardization Sector

IVR	Interactive Voice Response
KPI	Key Performance Indicators
LAN	Local Area Network
LU	Local Unit
MCMC	Malaysian Communications and Multimedia Commission
MMS	Multimedia Messaging Service
MO	Mobile Originated
MS	Mobile Subscriber
MT	Mobile Terminated
NWD	Nation Wide Dialing
Ofcom	Office of communications
PRD	Permanent Reference Document
PSD	Post Selection Delay
PTA	Pakistan Telecom Authority
QoS	Quality of Service
SITE	SIGOS Integrated Test Environment
SMS	Short Service Message
SMSC	Short Service Message Centre
SSR	SMS Success Rate
TRAI	Telecom Regulatory Authority of India
TS	Technical Specifications
WAN	Wide Area Network
WAP	Wireless Application Protocol

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Applicable Standards

1. **ITU-T** Recommendation E. 230
Telephone network and ISDN operation, numbering, routing and mobile service
Chargeable duration of calls.

2. **ITU-T** Recommendation E. 600
Telephone network and ISDN, Quality of service, network management and
traffic engineering:
Terms and definitions of traffic engineering.

3. **ITU-T** Recommendation E. 771
Series E: Telephone network and ISDN
Quality of service, network management and traffic engineering – Traffic
engineering – Mobile network traffic engineering:
Network grade of service parameters and target Values for circuit switched
public land mobile services.

4. **ITU-T** Recommendation E. 800
Telephone network and ISDN, Quality of service, network management and
traffic engineering:
Terms and definitions related to quality of service and network performance
including dependability.

5. **ETSI** TS 102 250-2 V 1.4.1
Speech Processing, Transmission and Quality Aspects (STQ);
QoS aspects for popular services in GSM and 3G networks;
Part 2: Definition of Quality of Service parameters and their computation

6. **ETSI** TS 102 250-5 V 1.3.1
Speech Processing, Transmission and Quality Aspects (STQ);
QoS aspects for popular services in GSM and 3G networks;
Part 5: Definition of typical measurement profiles

7. **ETSI TS 132 005 V3.7.0**
Universal Mobile Telecommunications System (UMTS);
Telecommunications Management;
Charging and billing;
3G call and event data for the Circuit Switched (CS) domain
(3GPP TS 32.005 version 3.7.0 Release 1999)

8. **ETSI** EG 202 057-3 V1.1.1
Speech Processing, Transmission and Quality Aspects (STQ);
User related QoS parameter definitions and measurements;
Part 3: QoS parameters specific to Public Land Mobile Networks (PLMN)

9. **GSM Association** PRD IR.42 (Version 3.3)
Definition of Quality of Service parameters and their computation

1 EXECUTIVE SUMMARY

Pakistan Telecommunication Authority (PTA) has been actively monitoring quality of service (QoS) of domestic GSM networks. Recognizing the rapid increase of international roaming (IR) users due to phenomenal growth in GSM subscribers and services in Pakistan, PTA has taken a timely initiative to measure QoS available to Pakistani international roamers abroad. This initiative, while protecting the interests of IR users, will also provide an insight into the state of this aspect of the growing competitive market. QoS data published by regulators helps users in making the right choices and facilitates operators in selecting the right roaming partners and resolving any interconnection problems with them. Since IR users are high-revenue customers representing business and government decision makers, availability of good QoS enhances the positive image of the state of telecom industry in Pakistan and facilitates further investments in telecom sector.

Measurement of QoS during IR is somewhat more sophisticated because of the involvement of multiple networks and countries. This consultancy was aimed at developing a methodology and measurement of key QoS parameters for basic call and SMS services of two GSM operators of PTA's choice during IR.

A powerful methodology based on a globally distributed but centrally controlled automated test call system was demonstrated in this consultancy for measuring QoS. Optiwave in collaboration with Keynote Sigos installed a local unit of the GlobalRoamer system in Islamabad for this purpose. This system has been developed by our partner, MS Keynote Sigos of Germany, and installed in approximately 60 countries under the brand name of **GlobalRoamer**. In this methodology there is no need for anyone to travel abroad. A minimum of two IR enabled SIM's of each GSM operator whose services have to be tested are sent to Germany, where they are installed in a central SIM multiplexer of the GlobalRoamer. The SIM multiplexer reads the data of each SIM and transports it via IP connectivity to the local units of the GlobalRoamer installed in 60 countries. The local unit operates as a GSM handset with multiple SIM's. Upon receiving a command from the central server of the GlobalRoamer in Germany over an IP link, the local unit in Pakistan can initiate a cell phone call to local unit in any of the 60 countries and vice versa. The scheduling of tests (time and daily frequency of tests) can be programmed in the central server in Germany, remotely from Optiwave's office. The schedule and the roaming countries were mutually defined and agreed by Optiwave and PTA.

GlobalRoamer allows measurements of a wide range of services and QoS parameters. It is important to select the most relevant QoS parameters and focus on them. The QoS parameters recommended by Optiwave Technologies (OWT) for basic call and SMS are listed in Table 1 along with reference values wherever applicable. The reference values have been recommended in the light of relevant standards, where available, or reference values adopted by international regulators, and some international industry data.

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Table 1: QoS Parameters for Basic Call and SMS

QoS Parameter for Basic Call	Reference Value
Call Success Rate (CSR)	85%
Received CLI	90%
Post Selection Delay or Call setup alert time	Maximum Mean Value:16.5 sec Upper limit: 25.0 sec
Chargeable Call Duration	Call duration tolerance: -2.5 to+1.5 sec
QoS Parameter for SMS	Reference Value
SMS Success Rate (SSR)	95%
SMS End to End Duration	Upper limit: 90 sec

For both operators a total number of 240 test calls and 240 test SMS were conducted to measure the QoS parameters listed in Table 1 for three countries Malaysia, South Africa, and USA. For each country two test calls per day were made from the roaming country to Pakistan and two test calls per day from Pakistan to the roaming country for a period of ten days. The fundamental results of Call Success Rate (CSR) and SMS Success Rate (SSR) are summarized in Table 2. Other salient results are listed below:

- **Post Selection Delay.** The measured value of this parameter met the reference value in general for all three destinations.
- **Received CLI's.** Average received CLI for both operators and all three destinations was correct for 71% of the completed calls. In the roaming country the received CLI was correct for 74% of the completed calls and in Pakistan it was correct for 68% of the completed calls. In the case of Malaysia none of the completed calls originating from Malaysia recorded correct CLI.
- **Chargeable Call Duration.** 32% of the 55 second calls were billed as 2 minute calls. 80% of the 55 second calls originating or terminating in US were billed as 2 minute calls. For South Africa, chargeable duration as matched the measured chargeable duration.
- **Tariff Rating.** The billed tariffs were consistently lower than the tariffs advertised on the website for both operators.
- **SMS End to End Duration.** The average end to end duration was 12 seconds as compared to the upper limit of 90 seconds for both operators and all destinations.
- **SMS Tariff.** The billed tariff for SMS was in general consistent or marginally lower than the published tariff.

Table 2: Summary of CSR and SSR Results

QoS Parameter	Operator	All Three Destinations	Malaysia	South Africa	USA
CSR	Combined	66%	38%	83%	79%
	CO1	74%	48%	93%	83%
	CO2	58%	28%	73%	73%
SSR	Combined	86%	96%	68%	95%
	CO1	91%	100%	73%	100%
	CO2	82%	93%	63%	90%

Owing to the limited sample size, the results of these tests have to be taken as indicative rather than absolute. Nevertheless these results identify some weak links in QoS. First of all interconnection of both operators with Maxis in Malaysia appears to have some problems. Second, availability of CLI's is a matter of concern. Third, billing for the case of US is quite inaccurate.

For a more representative picture, testing needs to be conducted for an extended period of one month covering all GSM operators of Pakistan. Tests to measure speech quality and GPRS related QoS parameters are also recommended. Quarterly or at least six monthly monitoring should be considered so that there is a regular feedback and revised set of countries can be tested in each round of testing. There is also a need to develop a comprehensive definition of Billing Error Ratio. The current scope was limited to call duration and tariff application. There are a number of other parameters such as additional calls, timely delivery etc that are included in the billing error ratio.

2 INTRODUCTION

2.1 Motivation for QoS Monitoring During IR

Definition of quality of service (QoS) parameters and monitoring of these parameters has been the responsibility of regulators worldwide. According to an analysis of ITU World Telecommunication Database by Robert Milne [1], regulators are responsible for setting QoS standards in 76% of the countries and monitoring QoS in 84% of the countries. Quite a few regulators are conducting QoS tests and publishing their results on a regular basis. A few examples Anatel of Brazil, Ofcom of UK, ACMA of Australia, and TRAI of India. Anatel has been publishing results for a total of 22 KPI's with benchmarks on a monthly basis since September 2003 [1]. Ofcom has published measurement results of 3 KPI's every 6 months since April 1999 [12]. TRAI published measured values for 10 KPI's with target values on a quarterly basis from April 2003 to June 2005. In 2005 TRAI revised and started publishing 14 KPI's with benchmarks for every quarter [5]. In countries where the industry itself has taken the lead in creating mechanisms of QoS monitoring, regulators have relied on these mechanisms. The significance and motivation for QoS monitoring by regulators have been elaborated in detail by Robert Milne [1] in his paper presented in an ITU seminar in Geneva on ICT QoS Monitoring in 2006. Here it will suffice to reproduce a summary of the key objectives for monitoring QoS by regulators:

- Helping customers to make informed choices
- Checking claims of operators
- Understanding the state of the market
- Maintaining or improving QoS in the presence of competition
- Maintaining or improving QoS in the absence of competition
- Helping operators achieve fair competition
- Making interconnected networks work well together

PTA is fully cognizant of its responsibilities and it has been monitoring the QoS of Pakistani GSM operators. The tools available to PTA allow it to monitor QoS of Pakistani GSM networks, but they do not cover QoS during international roaming (IR). Does it make sense for PTA to monitor QoS for a niche market such as IR? Is monitoring of QoS during IR too complex, expensive, and labor intensive? The former question is addressed in the next section. Here we focus on the motivation for QoS monitoring (QoS) during IR while addressing the latter question.

IR market is a high-end market, where the customers are relatively more quality conscious. Poor quality can have an adverse impact on the customers business. The users expect good value for money because of the high IR charges. While it may not be simple for PTA to intervene as far as tariffs are concerned because of involvement of international carriers, it can certainly help customers of operators by making published IR QoS data available. It will also facilitate Pakistani GSM operators in

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resolving interconnection issues and selecting the right roaming partners and solving their interconnect problem.

The number of IR subscribers may not be high but their contribution to the overall revenue is significant. The cost of a single call made or received during IR is more than the current monthly ARPU of GSM operators in Pakistan. Moreover, the IR users are no longer limited to business community or the elite society; the hajjis and other common Pakistani travelers to Middle East are also benefiting from IR service. Monitoring of QoS will certainly help PTA in developing an insight into the current state of IR market. Finally making interconnected networks work together is perhaps most relevant in the case of IR, where multiple networks are involved in a single call and the total number of interconnect agreements with roaming partners may be in excess of one hundred.

In conclusion, all the reasons for regulators to undertake QoS monitoring of GSM networks are also applicable on the IR market. In fact, there relevance is more acute for this niche market. Since PTA is convinced about the need to undertake QoS monitoring of Pakistani GSM operators, it has designed this consultancy with the objective of developing a QoS monitoring mechanism for IR.

2.2 Purpose and Scope of the Consultancy

This consultancy was designed by PTA to meet the following objectives:

- To develop methodology to carry out Quality of Service (QoS) tests for international roaming users who are customers of Pakistan cellular mobile operators.
- To develop QoS parameters for international roaming users of items identified in scope.
- To develop reference values (where possible) for the parameters.
- Testing to measure to QoS parameters.
- To identify best international practices for international roaming QoS tests and carve out roadmap for broadening the scope of international roaming QoS testing for Pakistan.

It has to be clarified that development of a methodology does not necessarily mean proposing and implementing a novel technique that is not in vogue anywhere else in the world. It can be demonstration of an existing methodology for the testing of QoS for roamers of Pakistani GSM operators.

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The scope of the consultancy was limited to:

- **Call Establishment:** Verification of call establishment for calls originating in Pakistan and terminating on international networks at roaming user and vice-versa. Details shall include call set up time, call duration, caller and called party identification with proper synchronization of caller and called party timing.
- **SMS Termination & Receipt:** Verification of SMS originating in Pakistan and terminating on roaming user and vice-versa along with parameters like time-lag between transmitting and receipt of SMS with comparison with international benchmarks. Both sender and receiver terminals shall be synchronized.
- **Accounting Accuracy:** Verification of accuracy of billing of roaming users with respect to the publicly advertised rates, actual rates charged, actual duration of the call and duration mentioned in the bills.

There were two aspects of the consultancy. First was a study aimed at defining the QoS parameters listed above and recommending benchmarks of those parameters. The second aspect was measurements of those parameters for two Pakistani GSM operators of PTA's choice. The number of countries, frequency of calls etc. are given in the test plan. The total number of test calls and test SMS was limited to 240 each.

3 METHODOLOGY FOR QoS MONITORING

3.1 Options for QoS Monitoring

As mentioned earlier that 84% of the regulators are monitoring QoS worldwide and quite a few monitor QoS on a regular basis. To monitor QoS, regulators have relied on one or more of the following methodologies.

- Review of CDR's obtained from operators.
- Manual test calls.
- Automated test calls.

The first method relies on the raw data provided by the operator and thus does not yield independent information. There is no mechanism of identifying the intrinsic errors in CDR's. Moreover, CDR's do not necessarily represent end user experience; nor do they provide any information about the integrity of the communication. After the introduction of automated test call systems, even operators no longer rely on CDR data. Most Tier 1 operators are using automated test call systems to cross check CDR data, monitor quality, perform IREG testing, diagnose network faults etc.

In the manual test method, testing is done by a testing team that performs different service testing using a cell phone and records the measurements. This technique does yield some representative results. However, it suffers from the following disadvantages:

- Results are error prone due to human intervention
- Synchronization is not possible
- Measurements are intrinsically imprecise
- Timing information is incomplete
- Scope of monitoring is limited as several QoS parameters cannot be measured and total number of tests are limited
- Fault identification or troubleshooting are not possible
- Comparability of data between operators is not always possible
- Testing is time consuming and cumbersome
- Expensive

Moreover, this technique is quite impractical for monitoring QoS during IR, where travel to several countries may be involved. To overcome the problems of international travel some operators end up sending their SIM's to their roaming partners, who perform different tests and send their results back. Sending SIM's to roaming partners does not overcome the limitations of manual testing. This option of sending the SIMs to the roaming partners of GSM operators is not always available to regulators. More importantly regulators are interested in independent rather than subjective data.

The preferred methodology for QoS monitoring is the use of automated test call systems. This methodology can overcome all of the above limitations of manual testing.

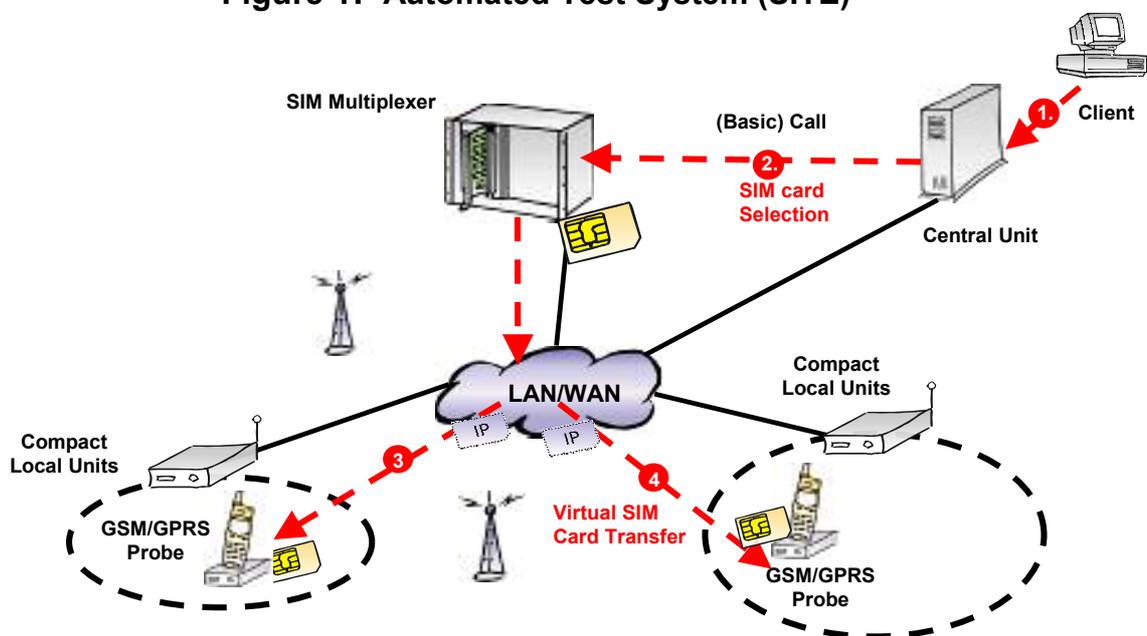
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Both operators and regulators are now increasingly using this methodology to monitor QoS. Some of the regulators that are using automated test call systems are Ofcom of UK[4], ACMA of Australia[2], and Anacom of Portugal[3]. For domestic networks operators and regulators have the option of deploying their own automated test call systems. For QoS monitoring during IR, centrally controlled distributed test system is the key. The only issue is that a global deployment of a centrally controlled distributed test system is not a very viable option. In this case leasing of a centrally controlled but globally deployed distributed test system is the most logical solution. This is exactly the route we have adopted for this consultancy. Optiwave partnered with Keynote Sigos which has a global deployment of its centrally controlled QoS monitoring system by the name of GlobalRoamer. GlobalRoamer is a tool especially developed and deployed for the purpose of testing QoS during IR. It is deployed in almost 62 countries covering all five continents, deployment is not an option. Almost all Tier 1 operators utilize the services of GlobalRoamer for monitoring the user experience of roaming subscribers.

3.2 GlobalRoamer Architecture

Figure 1 illustrates the architecture of the GlobalRoamer system. GlobalRoamer is based on SITE system of Keynote Sigos which consists of Central Unit, a SIM multiplexer, and number of Local Units, and client servers. The local units have IP connectivity with central unit and the SIM multiplexer. The client servers are also connected to the central unit through a LAN\WAN. The functionality of each item is explained in subsequent paragraphs.

Figure 1: Automated Test System (SITE)



3.2.1 Clients

Clients are connected through IP connection to central unit. A clients PC performs configuration and scheduling of tests and takes out results and reports. Online graphical user interface (GUI) enables easy system operation and administration. Several clients may simultaneously use the SITE\GlobalRoamer system.

3.2.2 Central Unit

The Central Unit is the test control unit of SITE. O&M Manager, Scheduler, Resource Manager and Test Execution Manager are the main components of the Central Unit. It is possible to increase the number of parallel running testcases by additional servers – the Central Unit Extensions.

SITE can schedule testcases (a series of steps to test a particular condition of a service, SITE has more than 100 test cases) at any time via the scheduler. Tests that are to be performed regularly may be repeated periodically. To avoid a conflict of existing resources, an intelligent resource management system controls access to interfaces and SIM cards, thus assuring smooth operation and maximum test parallelism. The possibility to integrate Central Unit Extensions in SITE additionally to the Central Unit allows a large number of parallel running tests without any impact on the performance.

3.2.3 Data Bases

Data bases are required for configuration and storing information, test execution, test results and measurements of tests that have already been performed. Furthermore the entire SITE hardware status is monitored by the database, from the individual test units and attached test interfaces to SIM card information. The Central Unit Data Base contains all central information except testcase KPIs and test details. The KPI Data Base contains KPI values resulting from testcase runs. The Report data base contains the detailed information on all reports created by the report manager or saved from the GUI. The SITE Agent monitors the status of all units (CU, CU Extensions, SIM Multiplexer and LUs) and interfaces. The Execution Data Base contains all details about test execution, i.e. the test parameters, the resource management results, test step KPIs and trace data.

3.2.4 SIM Multiplexer

The function of the SIM Multiplexer is to handle SIM cards. By cascading the SIM Card Boards a great number of SIM cards can be made available to the system. Idea of SIM multiplexing is illustrated in Figure 1.

3.2.5 Local Units

Local units are installed at different geographically places. It is connected through IP with Central unit. It acts as a mobile subscriber having the virtual SIM card assigned by the SIM multiplexer and performs the tests scheduled by the client. There are more than 60 local units installed globally and are able to test hundreds of mobile networks. Each local unit can handle multiple tests simultaneously.

3.3 GlobalRoamer Advantages

GlobalRoamer is simply an international deployment of the SITE system with central unit and SIM multiplexer in Germany and the local units in almost 60 countries. The users or clients can be in any part of the world as long as they have IP connectivity with the central unit. For testing purpose the SIM's are shipped to Germany where they are placed in the GlobalRoamer SIM multiplexer. The subscriber information of the SIM card is read out and transmitted via a LAN/WAN to any test location. Each card may be virtually transmitted to any location through IP, where real voice, SMS and data calls are performed by Local Units upon the instructions of the clients received via the central unit. In this way, many services can be rapidly tested without a single SIM card ever having to be physically shipped to the remote test locations. It is important to note that the test call is generated from one Local Unit to another Local unit. Since a Local Unit is the equivalent of a handset which interconnects with the GSM network over air interface, the test call is an end-to-end test exactly simulating the user experience. The advantages of GlobalRoamer include:

- **Large global deployment**
- **Availability of large library of tests**
- **Wide acceptance among international operators**
- **End to End QoS testing**
- **Simplicity**
- **Efficiency due to a automated test scheduler**
- **Inexpensive**
- **Full Synchronization**
The testing equipment (hardware + software) is fully automatic, so each event is fully synchronized.
- **Accuracy and Precision.**
Automated measurements are highly accurate and precise e.g time measurements are taken in milliseconds.
- **Comparable Conditions**
Due to timing synchronization and accuracy. QoS parameters of different operators can be compared.
- **Valid results**
With different traces, point of failure can be analyzed.
- **Accurate and Automated Reporting**
With automated report template, errors are avoided.

3.4 GlobalRoamer Application

GlobalRoamer is a Java application which executes on central server in Germany, clients are provided login/password to access the system through browser, define tests and generate tests report etc. GlobalRoamer application has two templates:

- Test template.
- Report template

In order to facilitate the test definition process GlobalRoamer offers test templates, most important services that can be tested with the current GlobalRoamer system are available. It has an immense library of testcases for individual services. Tests are defined in test editor and scheduled by the scheduler. Once the tests are defined, they are launched automatically on scheduled time with out the need of system administration and monitoring. During execution of testcases local units are synchronized with central unit that issues commands and measures timestamps of status updates. Having over 100 testcases GlobalRoamer can test Speech (basic call, voice quality), SMS, GPRS, MMS, WAP, IVR, Recharge and Streaming.

The testcase results in:

PASS when:

- Testcase starts and ends successfully and all the tested parameters have passed.

FAIL due to:

- The failure of service.
- The failure of any parameters verified during execution of testcase.
- The cancellation of testcase by the client after the allocation of resources.

INCONC due to:

- The unavailability of resources i-e local unit not available.
- The registration process with the roaming network cannot be completed during the allotted time.
- Testcase timeout reached before all the measurements are collected.

Further details of failed testcases are analyzed through traces to find the reason for failure, these traces are based on the detailed information produced during test execution some of these parameters are specific to test cases and are referred to as **KPI (Key Performance Indicators)**. The KPI's defined in GlobalRoamer are being

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used by more than 100 international operators. Hence, these KPI's are also representative of the industry practice.

GlobalRoamer offers a simple trace and MSC (Message Sequence Chart). Contents of both the traces are same but interpretation is different. A simple trace gives a raw data about occurrence of events with their timestamps while MSC shows occurrence of events between one or more testcase sides with directed arrows for easy understanding.

GlobalRoamer report template enables users to create, view and forward reports which have been generated of the report data base measurement (KPI's). Reports can be illustrated in different ways e.g by chart, histogram, lines etc. Reporting tool shows these KPI in graphical format and helps in defining QoS parameters. Furthermore these values can be exported to spreadsheets for further offline analysis.

4 QoS PARAMETERS FOR BASIC CALL AND SMS

Before undertaking any evaluation of QoS, it is important to define QoS. QoS is defined by a set of parameters, metrics, key performance indicators (KPI's), measures, determinants [1]. All these terms are used in technical literature pertaining to QoS. For the purpose of simplicity, we will restrict ourselves to two terms- QoS parameters and KPI's. These two terms will be used interchangeably in this document. The reason for also adopting KPI, is the usage of this term in GlobalRoamer reports.

A wide range of QoS parameters or KPI's have already been defined for each service by standards bodies such as ITU, ETSI, GSM Association etc. Despite the availability of definitions by standards bodies, a number of regulators are providing their own definitions of KPI's as well. TRAI's definition of Call Success Rate (CSR) [5], for example, is not consistent with that of ITU-T definition for CSR given in Recommendation E 600. In this document we have adopted relevant ITU-T definitions, only in the cases where ITU-T definition is not available we have adopted the definition of another standard body or regulator.

A small subset of the available QoS parameters is adequate to cover all aspects of quality. Although some regulators have defined their own QoS parameters, there is no need to define new parameters unless there is a unique requirement, which is not being met by the predefined QoS parameters. In this section, we first define selection criteria and then apply this criteria to recommend the most suitable QoS parameters for basic call and SMS. It is important to clarify that KPI's remain the same whether a basic call is local, international, or an IR call. Some of the benchmarks may vary, however. Benchmark or reference values for some of the recommended KPI's are also discussed in the light of international practices.

4.1 Selection Criteria

As mentioned above a complete set of KPI's must cover all aspects of QoS. The four fundamental aspects of quality of service are:

- Network accessibility
- Connection quality
- Network retainability
- Billing accuracy

Network accessibility has to do with getting on to the network and availability of desired service. Connection quality is what determines how good was the user experience while utilizing the desired service. Was the user able to complete the full conversation or download a complete file through a GPRS session has to do with network retainability [6]. Finally, it is important that the user is charged accurately.

In addition to covering the above aspects of quality, the QoS parameters should be:

- Important to subscribers
- Measurable
- Comparable between operators

Besides following the above criteria, we have preferred QoS parameters for which an ITU definition is available. Minimizing the total number of KPI's and tests has also been an objective.

4.2 Relevant Basic Call KPI's

Some of the commonly used KPI's relevant to the parameters in our scope of work for basic call are listed below:

- Call Success Rate (CSR)
- Call Completion Rate (CCR)
- Endpoint Service Availability (ESA)
- Received CLI
- Post Selection Delay (PSD)
- Chargeable Call Duration (CCD)

In order to understand the precise meaning of each of the above terms, we first reproduce their definitions from applicable standards in Table 3 and 4. As a next step we illustrate the meaning using Figure 2 and 3. Furthermore, these KPI's characterized into two categories as non-timing and timing KPI's. Non-timing definitions and KPI's are discussed in the following text. Definitions of non-timing terms are as given in Table 3.

Table 3: Definitions of Non-Timing Terms of Basic Call

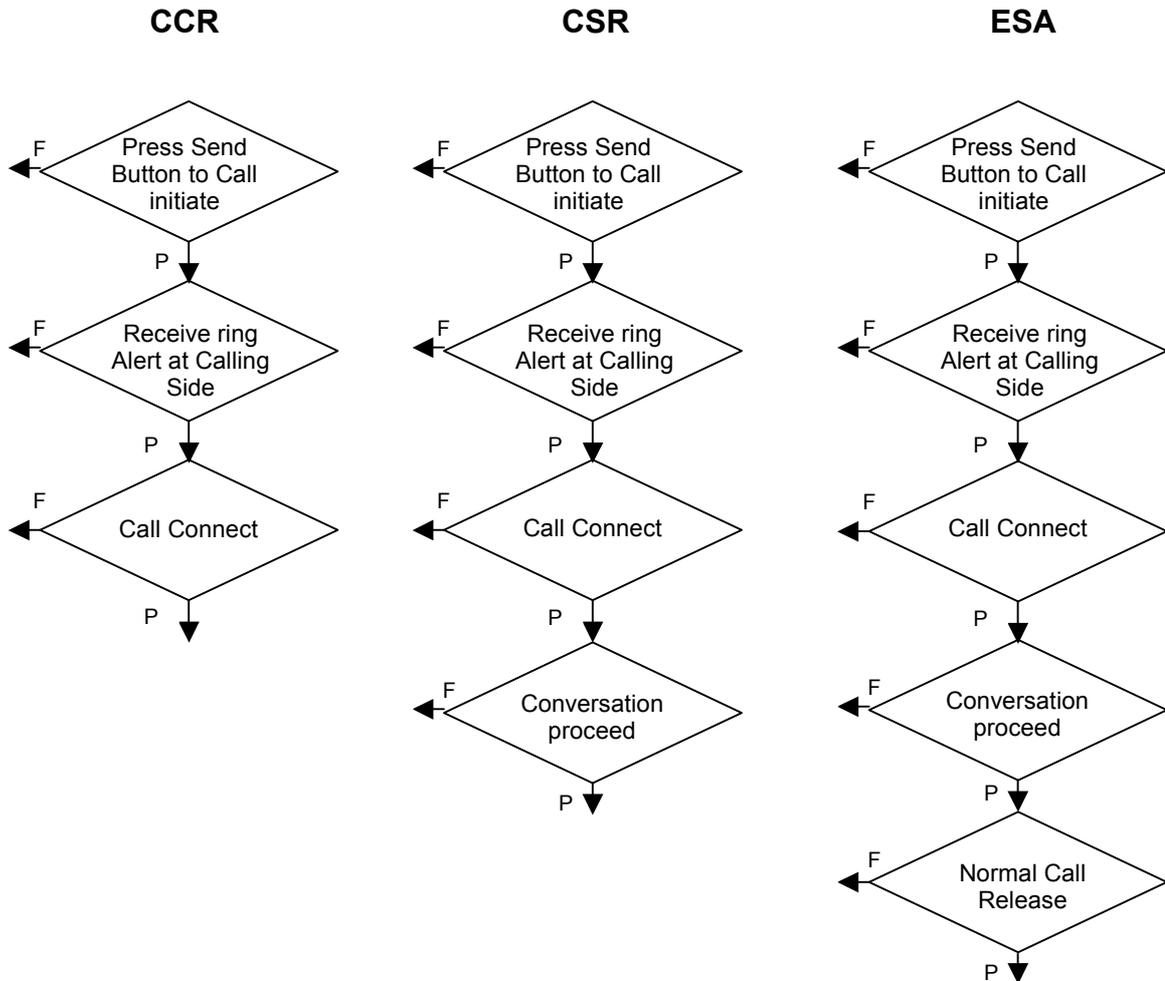
Term	Standard Body	Explanation
Call Attempt	ITU-T	An attempt to achieve a connection to one or more devices attached to a telecommunications network.
	ETSI	Push Send button on the mobile terminal.
	GSM Assoc.	Successful pressing send button on the mobile terminal.
Successful call Attempt	ITU-T	A call attempt that receives intelligible information about the state of the called user
	ETSI	Alerting or busy tone heard by the A-party coming from B-party and B-party rings.
	GSM Assoc.	Alerting or busy tone heard by A- party.

Completed Call Attempt	ITU-T	A successful call attempt that receives an answer signal.
Successful Call	ITU-T	A call that has reached the wanted number and allows the conversation to proceed.
	GSM Assoc.	GSM Association's "Successful Call Establishment" is equivalent to successful call and defined as, "Open connection between A-party and B-party, where both parties can hear each other".
Connection Retainability	ITU-T	The probability that a connection, once obtained, will continue to be provided for a communication under given conditions for a given time duration.
Intentionally Terminated telephony call	ETSI	Release of connection directly by A- or B-party.
	GSM Assoc.	Equivalent term used by GSM Association is intentionally terminated call which is defined as, "Release of connection directly by A- or B-party".

Most of the terms of ITU-T in Table 3 are taken from ITU-T recommendation E.600 which describe telephony definitions in relation to traffic engineering derived from experience of typical telephony service while E.600 is also applicable to the cellular services as it is also used in cellular recommendations of ITU-T like recommendation E.760 [Series E: overall network operation, telephone service, service operation and human factors; Quality of service, network management and traffic engineering – Traffic engineering – Mobile network traffic engineering; Terminal mobility traffic modeling]. While the term connection retainability is taken from E.800 which is a general QoS recommendation and universally applicable to all telecommunication services and the network arrangements. However, terms reproduced from ETSI And GSM association standard documents are purely cellular which are TS 102 250-2 (V1.4.1) and PRD IR.42 (V 3.3) respectively.

The non-timing KPI's are Call Completion Rate (CCR), Call Success Rate (CSR), Endpoint Service Availability (ESA) and received Caller Line Identification (CLI). The definition of these terms may vary from regulator to regulator. Figure 2 and Figure 3 are helpful in understanding the differences between CSR, CCR, and ESA.

Figure 2: Comparison between CCR, CSR and ESA



A call is a completed call once the call is connected. A completed call does not necessarily mean that conversation can proceed as there is no integrity check of the traffic channel. From the user perspective this is not a very useful parameter. Nevertheless, it has been adopted by a number of regulators because of ease of measurability. Network generated statistics can provide CCR. TRAI initially adopted CSR but subsequently reverted to CCR as it could not obtain CSR statistics from the operator CDR's. CCR only covers network accessibility.

According to the definition provided in recommendation E.600 of ITU-T a call is a successful call once conversation can proceed. To measure CSR integrity of the

assigned traffic channel has to be checked as well. From a user perspective CSR is a more useful KPI. It covers network accessibility as well as network quality to some extent. Measurability of CSR is an issue if a regulator adopts the QoS monitoring methodology in which it is dependent upon operator CDRs. With an automated test call system like GlobalRoamer measurability of CSR is not an issue at all. The equivalent parameter of CSR defined by GSM association is Call Setup Success Ratio (CSSR) in PRD IR.42 V3.3.

As illustrated in Figure 2, ESA goes one step further and verifies a normal release of a call as well. Hence, ESA checks network accessibility, network quality, and retainability. It is a more useful parameter from customer's point of view. Measurability is again not an issue with the methodology we have adopted. ESA is a KPI that some regulators have adopted but we could not find an ITU-T definition for ESA.

GlobalRoamer can measure any of the above parameters. A single basic call test of GlobalRoamer can provide information about all of the above parameters as well as other KPI's including call duration. The combination of CSR and call duration captures all the information in ESA. Call duration has to be examined independently for verifying billing accuracy. We are therefore recommending CSR, instead of CCR and ESA. As far as reference or target value is concerned, ITU-T provides no recommendation. Some regulators do specify target values. In specifying a target value for CSR, regulators rarely distinguish between a local, international, or IR calls. In the absence of any distinction, it can be assumed that the target value is applicable on all types of calls. PTA has specified a CCR value of 95% in the first three years and 98% after three years in the GSM licenses issued by PTA. It is unreasonable to expect a CSR value in the same range. Malaysian regulator specifies an ESA value of 90% or better for intra network as well as inter network calls [7]. Keeping in mind that ESA is a more stringent parameter, one could adopt the same value for CSR. However, industry data of international operators suggest that even 90% CSR is a difficult reference value. There is no point in recommending an unachievable target. We recommend a value of 85%. This value may be upgraded by PTA as the QoS improves.

Availability of CLI is also important during international roaming. It allows subscribers to select relevant calls and avoid unnecessary charges. Absence of CLI forces subscribers to answer every call. This KPI certainly needs to be monitored as far as IR calls are concerned. GSM association also defined Received CLI as a QoS parameter namely CLI Transparency in PRD IR.42 V3.3.

Definitions related to the timing domain are explained as follows .

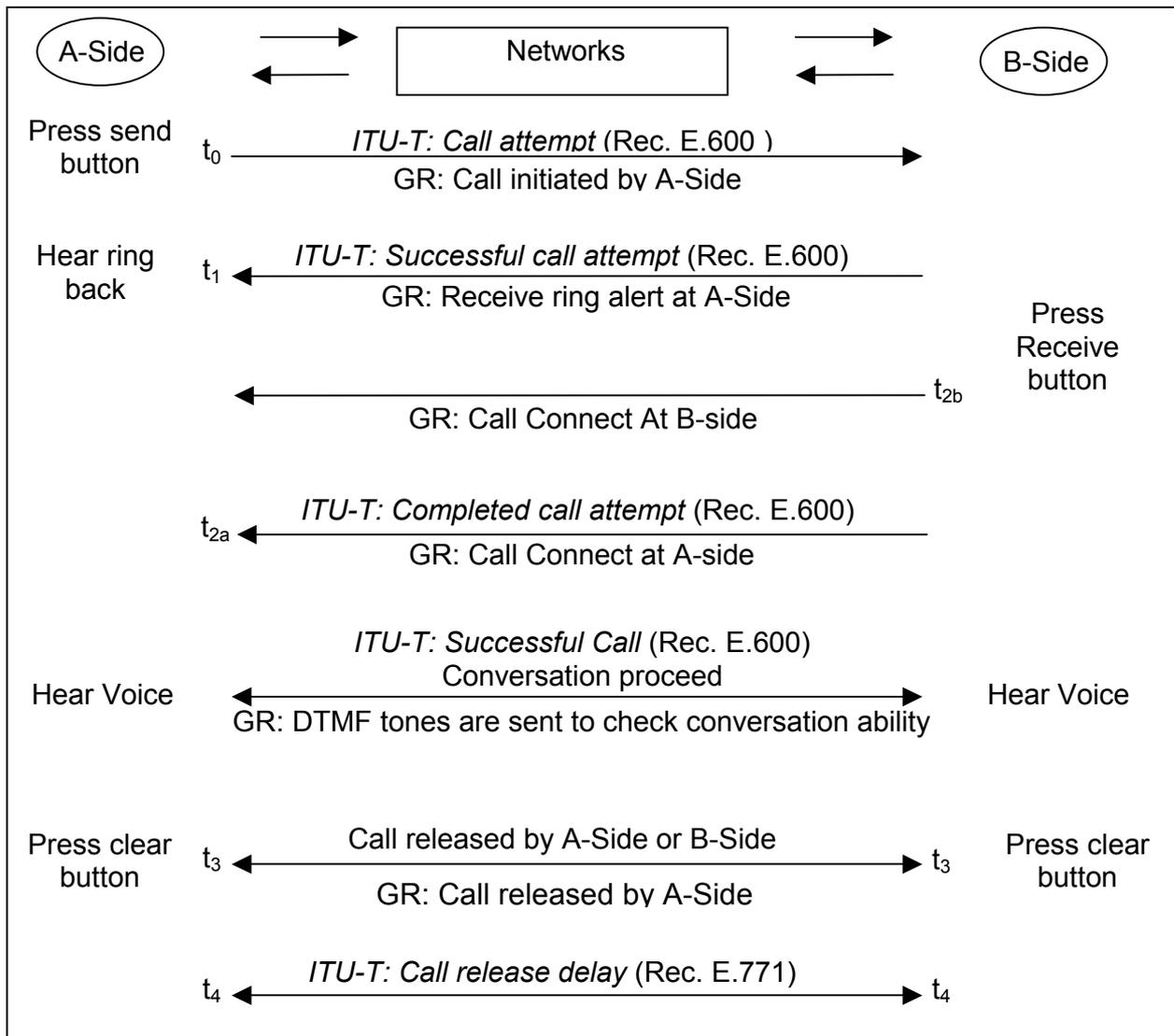
- **Post Selection Delay (ITU-T)** is defined as "The time interval from the instant the first bit of the initial SETUP message containing all the selection digits is passed by the calling terminal to the access signaling system until the last bit of the first message indicating call disposition is received by the calling terminal (ALERTING message in case of successful call).

ETSI defines it as “Telephony Setup Time” which is the time between sending of complete address information and receipt of call set-up notification while GSM Association defines it as “Setup Time Telephony” which is the time between sending of complete address information and receipt of call set-up notification.

- **Answer Signal Delay (ITU-T)** is defined as the time interval from the instant that the B-side passes the first bit of the connect message to its access signalling system until the last bit of the connect message is received by the A-side.
- **Call Establish Duration** is defined as ‘the time difference between call initiate and call connect on calling side” and it is defined by GR which is addition of ITU-T post selection delay and answer signal delay..
- **Call release delay (ITU-T):** The time interval from the instant the DISCONNECT message is passed by the user terminal which terminated the call to the access signalling system, until the RELEASE message is received by the same terminal (indicating that the terminals can initiate/receive a new call).
- **Chargeable Call Duration (ITU-T)** is as follows chargeable duration should begin from the receipt of the answer signal from the called station. The chargeable duration ends when the caller gives the clear-forward signal or as a result of a clearing signal from the called party when an exchange clears the connection. In the latter case, the chargeable duration ends with some slight delay following receipt of the clearing signal from the called party.
ETSI defines chargeable call duration as the difference between the CONNECT message sent to the calling party to the release of the resources (traffic channel).

The flow of GSM call with respect to time is illustrated step by step in Figure 3. Each step is further elaborated with definition from standard bodies. The ITU-T and GR nomenclature for each event is also mentioned in the Figure 3.

Figure 3: Flow of GSM Call with Respect to Time



The KPI's related to time domain are post selection delay and chargeable call duration. From a users perspective **PSD** is a useful network accessibility KPI while **chargeable call duration** is an important KPI from the point of view of billing accuracy. Monitoring of both KPI's is recommended. GlobalRoamer measures both of these KPI's in the Basic Call test with millisecond precision. **ITU specifies a maximum mean value of PSD as 16.5 seconds. We recommend the same maximum mean value as ITU. ETSI specify upper limit of 20 sec for setup time telephony in TS 102 250-5 V1.3.1. Setup time telephony is equivalent term of PSD. However, we are recommending**

an upper limit of 25 seconds which is an industry practice. The Australian 'end-to-end network performance for the standard telephone service' code ACIF C519:2004 specifies a similar upper limit of 25 seconds for post dialing delay which is same as PSD. This code do not specifically applies to international roaming but 25 sec is upper limit of international call as there is no significant difference between international roaming call and international call. The Australian codes have been proposed by the Australian Communications Industry Forum rather than the regulator [8]. It may be reasonable for PTA to adopt this code.

As far as call duration is concerned, the critical parameter is the allowed call release delay or the tolerance in chargeable call duration. For call release delay ITU-T recommends mean value of 1 sec. Overall chargeable call duration tolerance as defined by the ACIF is (-2.5 to +1.5) seconds [2] and as defined by Ofcom of UK is (-1 to +0.5) seconds[9]. The Australian 'call charging and billing accuracy' code ACIF C518:2006 is applicable on local call. However call release delay is the major factor in the tolerance chargeable call duration so it may not vary with local or international call as it is related to air interface of the mobile network. We are also recommending a call duration tolerance of -2.5 to + 1.5 seconds.

Definitions related to the timing domain are summarized in the Table 4 below while timings are illustrated in Figure 3.

Table 4: Timing Definitions of Basic Call

Term	Standard Body	Definition
Post Selection Delay	ITU-T	$t_1 - t_0$
	ETSI	$t_1 - t_0$
	GSM Assoc.	$t_1 - t_0$
Answer Signal Delay	ITU-T	$t_{2a} - t_{2b}$
Call Establish Duration		$t_{2a} - t_0$
Call Release Delay	ITU-T	$t_4 - t_3$
Chargeable Call Duration	ITU-T	$t_4 - t_{2a}$
	ETSI	$t_4 - t_{2a}$

We summarize our recommended KPI's and their reference values in the following Table 5.

Table 5: QoS Parameters for Basic Call and their Reference Values

QoS Parameter	Reference Value
Call Success Ratio (CSR)	85%
Received CLI	90%
Post Selection Delay (PSD)	Mean Value: 16.5 sec Upper limit: 25 sec
Chargeable Call Duration (CCD)	Call duration tolerance: -2.5 to 1.5 sec

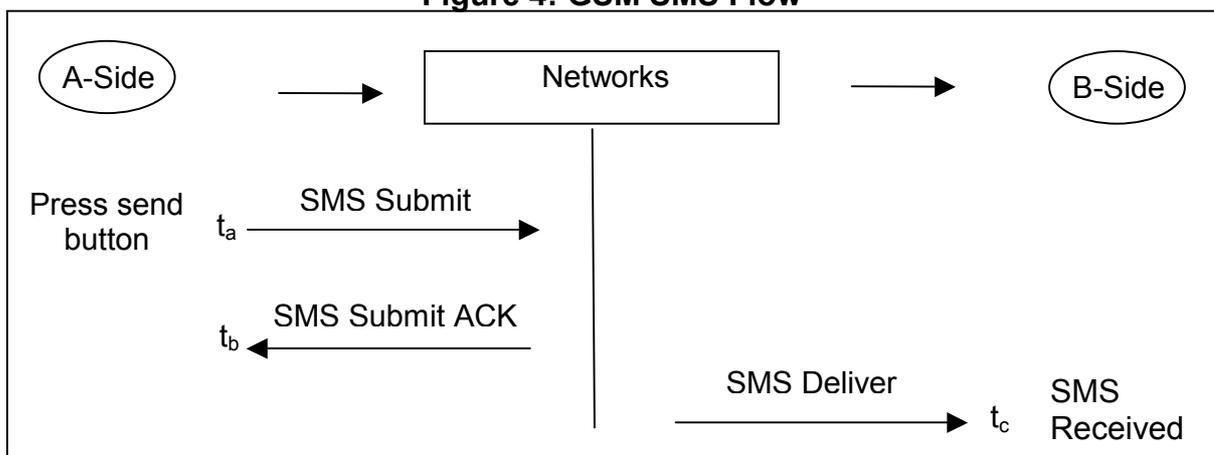
4.3 SMS

Two parameters are adequate to define QoS of SMS. These two parameters are:

- SMS Success Rate
- SMS End to End Duration

The first parameter encompasses both delivery and accurate reproduction of the original message. An SMS is successful only if all the contents of the received message match the contents of the sent message. A reference value of SMS success rate available in the GlobalRoamer for IR is 96%. Portuguese regulator [10], Anacom conducted a quality of service survey of SMS at national level in 2005 using 51,538 test SMS's, the delivery rate (SMS success rate) of SMS was 99.7% in this survey. Since we are focusing on a reference value for IR, we recommend a reference value of 95%.

Figure 4: GSM SMS Flow



SMS send Duration is defined as ‘time from SMS Submit to SMS Submit acknowledgement SMS’ as shown in figure 4.

$$\text{SMS send Duration} = t_b - t_a$$

SMS End-to-End Duration is defined as ‘Time from SMS Submit to SMS Delivery’ as shown in figure 4.

$$\text{SMS End-to-End Duration} = t_c - t_a$$

SMS end to end duration is used to measure end to end delivery time (sender to recipient) of SMS, which is critical parameter from user’s perspective. Sender and recipient always like an immediate response of network, so that both can exchange their views through SMS quickly. The upper limit for it is set at 90 sec by GlobalRoamer while ETSI suggest upper limit of 175 sec for end to end delivery time SMS in TS 102 250-5 V1.3.1. End to end delivery time SMS is equivalent term of SMS end to end duration. As Global Roamer is being used extensively by the industry and its prescribed limits are being generally met successfully, so we recommend upper limit of 90 sec for Pakistan.

The recommended KPI’s and their reference values are in the following Table 6.

Table 6: QoS Parameters for SMS and their Reference Values

QoS Parameter	Reference Value
SMS Success Rate	95%
SMS End to End Duration	Upper limit 90 sec

5 TEST PLAN

Test plan plays a pivotal role in monitoring of QoS. The test plan has to be properly designed to achieve the desired objectives. The objectives of this test plan were:

- Demonstrate the methodology for QoS monitoring proposed in Section 3
- Measure the KPIs defined in Section for basic call and SMS
- Compare the results of the two operators

It is pointed out that the limited sample size contracted can yield indicative rather than conclusive data.

5.1 Scope of Test Plan

Scope of test plan was limited to:

- Testing of two Pakistani GSM operators.
- Testing in three roaming countries namely Malaysia, South Africa and USA with a single roaming partner in each country.
- Basic call and SMS KPI's listed in Table 3 and Table 4
- Total of 240 test calls and 240 test SMS.

The test plan was especially designed to allow comparison between the two operators, comparison between calls originating from roaming country and terminating in Pakistan and calls originating from Pakistan and terminating in roaming country, however measurement of diurnal, weekly, or seasonal variations in QoS were beyond the scope of this test plan.

5.2 Test Plan

Selection of roaming partners and testing times were mutually agreed between PTA and OWT. These selections were made to retain consonance of view for both the local operators' i-e same roaming partner in each country is chosen and tests for both the operators were scheduled at same time. The scheduling times for basic call were taken on the basis of peak voice traffic times to and from Pakistan and roaming country as given in Table 7. Call 1 in Table 11 originates during the peak outgoing traffic hour. Call 2 in originates during peak incoming traffic hour. Similarly, SMS 1 is scheduled to overlap with peak business hours of the originating country, SMS 2 overlaps off- peak business hours of the originating country.

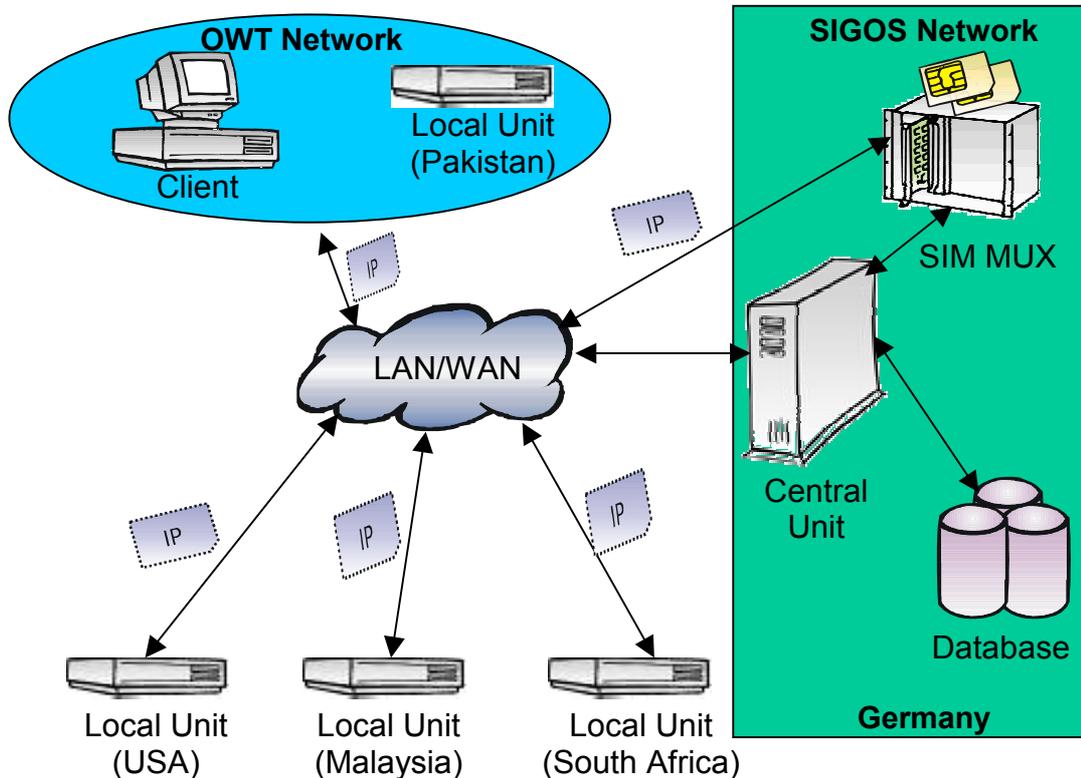
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Table 7: Roaming Detail

Roaming Country	Location	Roaming Partner	Peak traffic times (PST) 24Hrs	
			From Roaming Country to Pakistan	From Pakistan to Roaming Country
Malaysia	Petaling Jaya	Maxis	20:00 - 21:00	19:00 - 20:00
South Africa	West Park	MTN	21:00 - 22:00	12:00 - 13:00
USA	Los-Angeles	T-Mob	21:00 - 22:00	22:00 - 23:00

Figure 5 shows GlobalRoamer network according to the test scenario. Tests were defined and scheduled from Pakistan. SIM's were multiplexed at the desired location for execution of testcases. Results were stored in database, which were than accessed by OWT for reporting.

Figure 5: GlobalRoamer Network



5.3 Testcases

In order to measure the KPIs for basic call and SMS as listed in Tables 5 and 6 respectively, GlobalRoamer testcases T_BasicCall and T_SMS_MO_MT were performed. The details of these testcases are given in Table 6 and 7 respectively.

Table 8: Basic Call Testcase

Testcase: T_BasicCall	
Description	Perform a Basic call establishment.
Test Purpose	Check whether a subscriber can successfully establish and release a call between the selected SIM card at A-location and the selected SIM card at B-location. The B-Channel will be checked by sending and receiving of DTMF tones on both sides. In other words ability of conversation between two sides is checked in this module. Importantly B-Channel should not be taken as B-Side channel.
Test Procedure	A-side: perform the location update procedure B-side: perform the location update procedure A-side: initiate a call to the B-Side B-side: receive the call from A-Side. A-side: send a tone over the B-Channel B-side: recognize a tone B-side: send a tone over the B-Channel A-side: recognize a tone A-side: initiate the call release procedure B-side: release the call
GlobalRoamer Pass Criteria	Testcase will pass when all the following procedures will be completed successfully <ol style="list-style-type: none"> 1. A-Side initiates the Call. 2. B-Side receives the Call. 3. A-Side sends DTMF tones and B-Side receives and recognizes them. 4. B-Side sends DTMF tones and A-Side receives and recognizes them(step 3 and 4 continues until call duration time is reached). 5. A-Side releases the Call.

KPI's	Call Success Rate Endpoints Service Availability CallSetupAlertDuration. ReceivedCLI. CallDuration.
Event Times	CallSetup: Time of call initiation. CallAlert: Time of ring alert on B-side. CallConnect: Time of call connect message on B-side. CallAConnect: Time of call connect message on A-side. CallRelease: Time of call termination from A-side.

Call duration was set to 55 seconds. And timeout for call setup alert is 25 seconds, in accordance with the post selection delay upper limit.

Table 9: SMS Testcase

Testcase: T_SMS_MO_MT	
Description	Send and receive SMS
Test Purpose	Check whether the selected test SIM card at A-location can send an SMS to the selected SIM card at B-location over the Short Message Service Center.
Test Procedure	A-side: perform the location update procedure B-side: perform the location update procedure A-side: send a number of SMS to B-side over SMSC B-side: receive SMS
GlobalRoamer Pass Criteria	Testcase will pass when all the following procedures will be completed successfully <ol style="list-style-type: none"> 1. A-Side sends SMS to B-Side. 2. B-Side receives the SMS with the same contents sent by A-Side.
KPI's	SMS Success Rate SMSEnd2EndDuration. SMSdeliverDuration. SMSsendDuration.

SMS deliver timeout is 90 seconds which is GlobalRoamer default value.

5.4 Tests Scheduling

Tests were scheduled for a period of 10 days for all the roaming countries in which total of 24 test calls and 24 test SMS were generated every day Table 10 gives overall tests distribution. The tests whose results were INCONCLUSIVE were scheduled on the same time after testing period.

Table 10: Tests Distribution

Country	Local Operator	Number of Calls/day	Number of SMS /day	Total Calls	Total SMS
Malaysia	CO1	4	4	40	40
South Africa	CO1	4	4	40	40
USA	CO1	4	4	40	40
Malaysia	CO2	4	4	40	40
South Africa	CO2	4	4	40	40
USA	CO2	4	4	40	40
Total				240	240

5.4.1 Basic Call

Four calls were tested per day per operator for each roaming country. Two of the calls originated from roaming country and terminated in Pakistan while rest of two calls originated from Pakistan and terminated in roaming country. As mentioned earlier that tests scheduling times for basic call were selected on the basis of peak outgoing and incoming traffic hours between Pakistan and roaming country as given in Table 7. These times were taken such that Call originates during peak outgoing traffic hour and Call 2 originates during peak incoming traffic hour. .

Table 11: Basic Call Scheduling

Country	Time of Call Originating from Pakistan (PST)		Time of Call Originating from Roaming Country (PST)	
	Call 1	Call 2	Call 1	Call 2
Malaysia	19:30	20:45	20:30	19:45
South Africa	12:30	21:30	21:15	12:45
USA	22:30	22:00	21:45	22:45

5.4.2 SMS

Four SMS were tested per day per operator for each roaming country. Two of the SMS were sent from roaming country and received in Pakistan while rest of two SMS were sent from Pakistan and received in roaming country. As SMS consumes very little bandwidth for milliseconds, so for this reason scheduling times for SMS were taken on the basis of local peak and off peak timings of Pakistan and roaming country as shown in Table 12. The idea is to check the SMS handling capacity rather than bandwidth/circuit capacity.

Table 12: SMS Scheduling

Country	Time of SMS originating from Pakistan (PST)		Time of SMS Originating from Roaming Country (PST)	
	SMS 1	SMS 2	SMS 1	SMS 2
Malaysia	11:00	23:00	07:00	19:00
South Africa	11:15	23:15	13:00	01:00
USA	11:30	23:30	20:00	08:00

5.5 Details of SIM's

Four postpaid connections were bought (two SIM's for each operator) and posted to "Keynote Sigos" headquarter, Germany for SIM multiplexing. Details of SIM's are given in Annex in Table A-1. As the testing is between Pakistan and roaming country only, so for each operator access level for one SIM is NWD and other is IR activated. All SIM's are billed on per minute basis.

6 TEST RESULTS

The raw data of each test call and SMS is included in the Annex to this report. In this section we focus on macro level trends rather than individual test results. In following sections we present the results for basic call and SMS KPIs. It is important to clarify that the performance for any roaming country is really the performance of the roaming partner in that country and not necessarily the performance of all the GSM networks in that country.

6.1 Call Success Rate (CSR)

We begin by presenting results for CCR, CSR, ESA. Out of a total 240 calls, 184 calls were completed calls, 158 were successful calls, and 155 calls experienced a normal release. Figure 6 illustrates the combined measured CCR, CSR, and ESA values for all three countries. Figure 6 highlights two points. First, neither CO1 nor CO2 met the target values for CCR or CSR. Second, there are a significant number of calls which were completed but the user could not initiate or complete the conversation. These results explain why CSR or ESA are better KPIs for call establishment. Figure 7 further highlights the second point. In the case of Malaysia CCR is more than 70% for CO1 but CSR is less than 50%. Although detailed results of CCR and ESA are available, our future discussion will be restricted to CSR only.

Figure 6: Overall CCR, CSR, and ESA

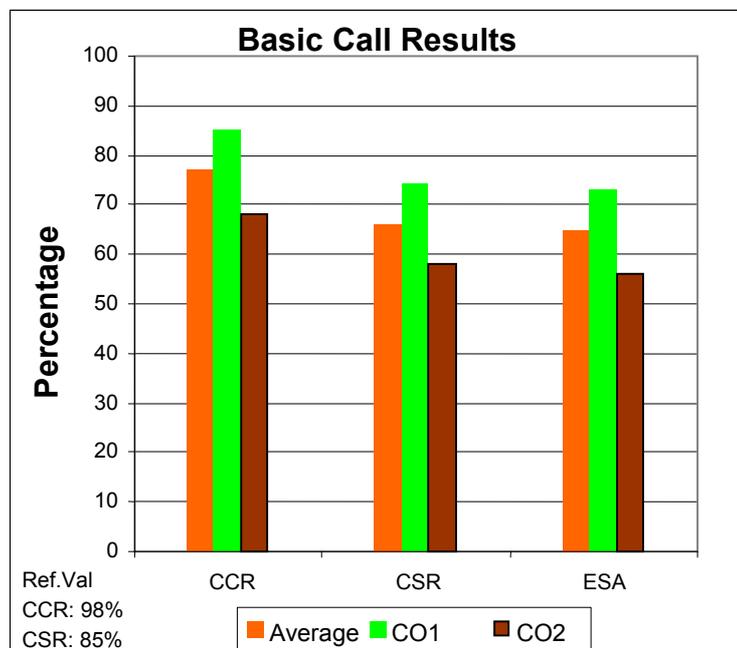
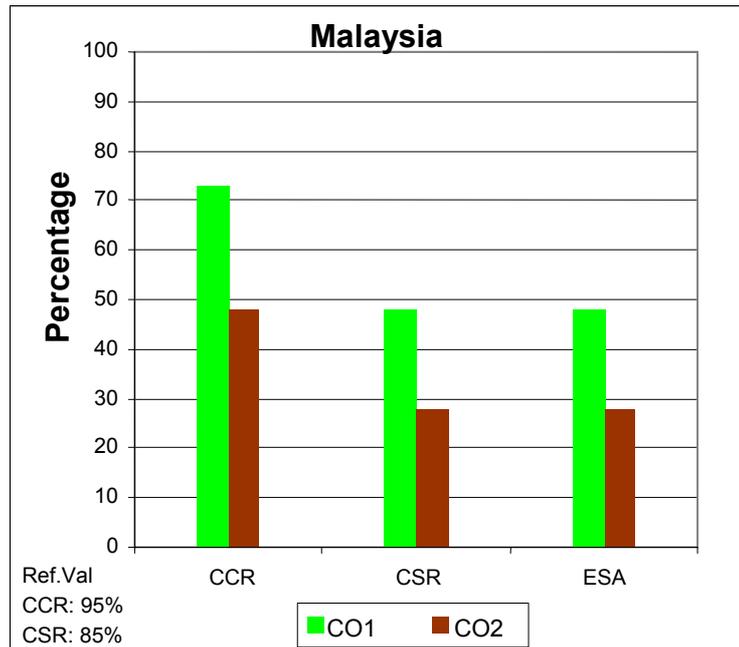
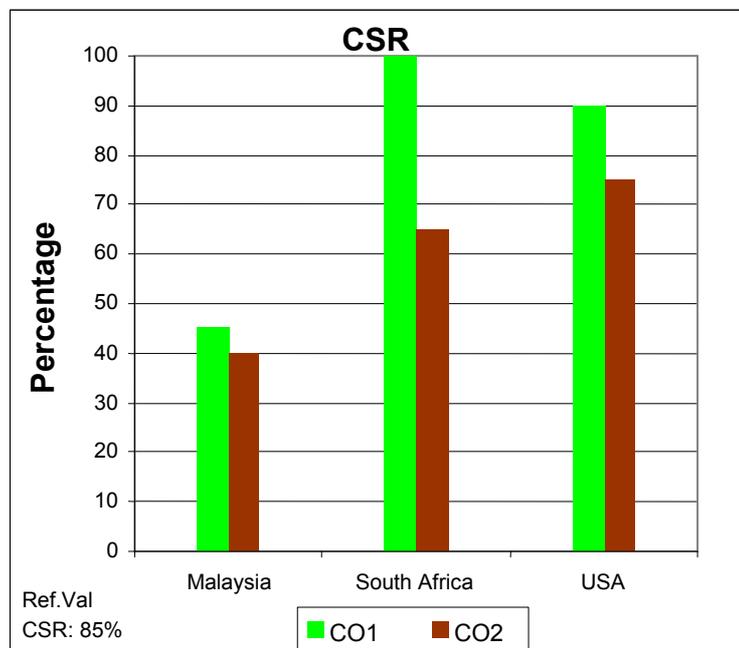


Figure 7: CCR, CSR, and ESA for Malaysia



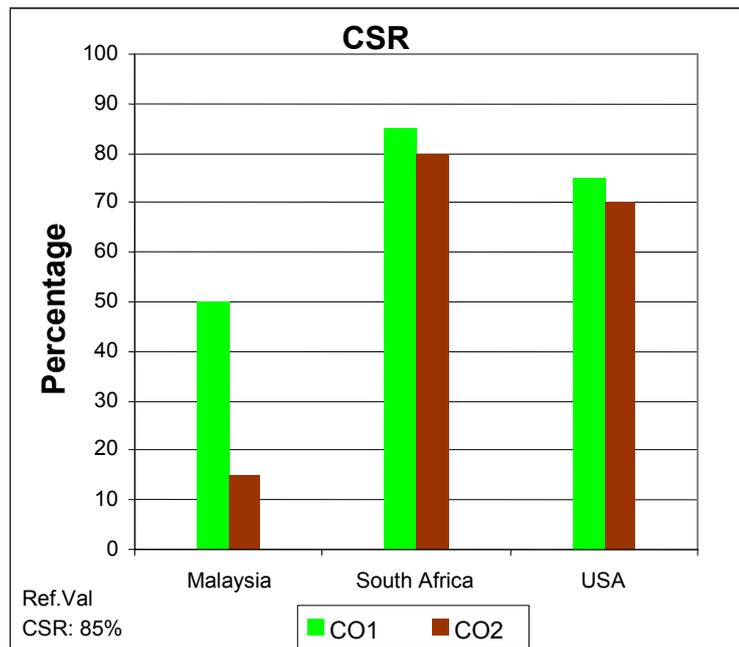
Figures 8 and 9 display country-wise measured values of CSR for calls originating from roaming country and calls originating from Pakistan respectively.

Figure 8: Country Wise CSR for Calls Originating From Roaming Country



Both graphs show a similar trend. CSR values for South Africa and US were not very far from the reference value. In fact, CO1 was able to achieve the reference value for calls originating and terminating in South Africa. However, both operators performance for Malaysia was quite poor. This could be due an **interconnection issue with Maxis network** in Malaysia. It may be worth mentioning that for CO1 only one successful call dropped prematurely; whereas for CO2, two successful calls dropped prematurely, hence CSR values for both operators are quite close to ESA values. Also there is no significant difference between the results of calls originating during peak outgoing and peak incoming traffic hours.

Figure 9: Country Wise CSR for Calls Originating from Pakistan



6.2 Post Selection Delay (PSD)

The average value of PSD for all 184 completed calls is 10.29 seconds, which is within the reference value of 16.5 seconds. The average value of PSD for CO1 and CO2 is almost the same. Time spread of PSD (Post Selection Delay) of CO1 calls originating from roaming country and terminating in Pakistan and vice versa is captured in Figures 10 and 11. Figures 12 and 13 display the same data for CO2. It is quite clear from Figures 10-13 that calls originating or terminating in South Africa have the most stable PSD of around 10 seconds. On the other hands calls originating from Malaysia have the most erratic behavior.

Figure 10: PSD of CO1 Calls Originated from Roaming Country

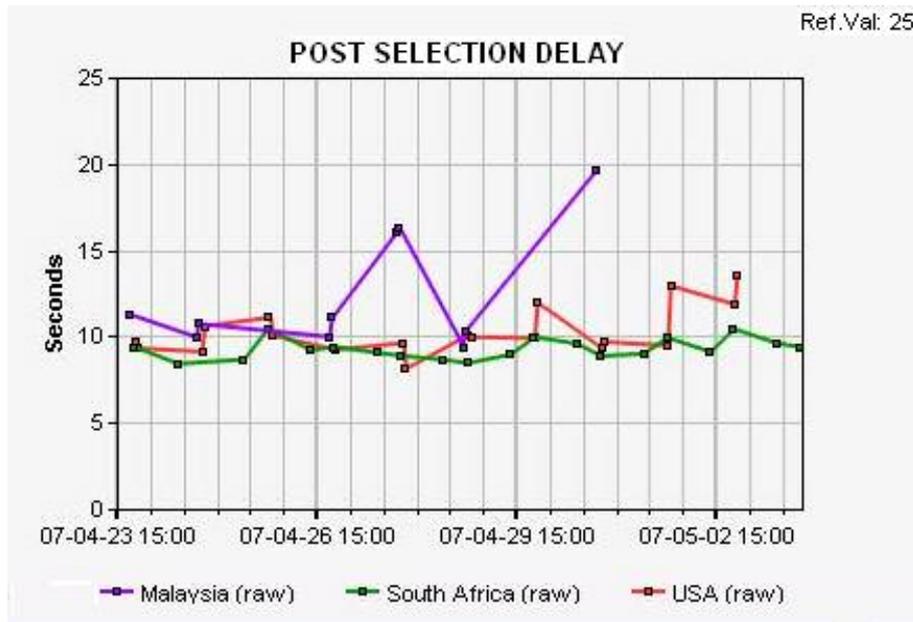


Figure 11: PSD of CO1 Calls Originated from Pakistan

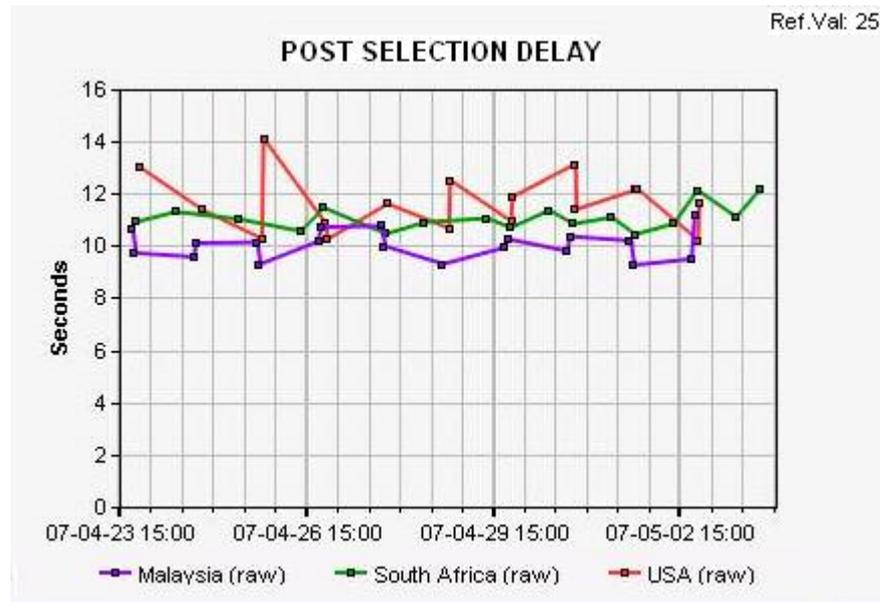


Figure 12: PSD of CO2 Calls Originating from Roaming Country

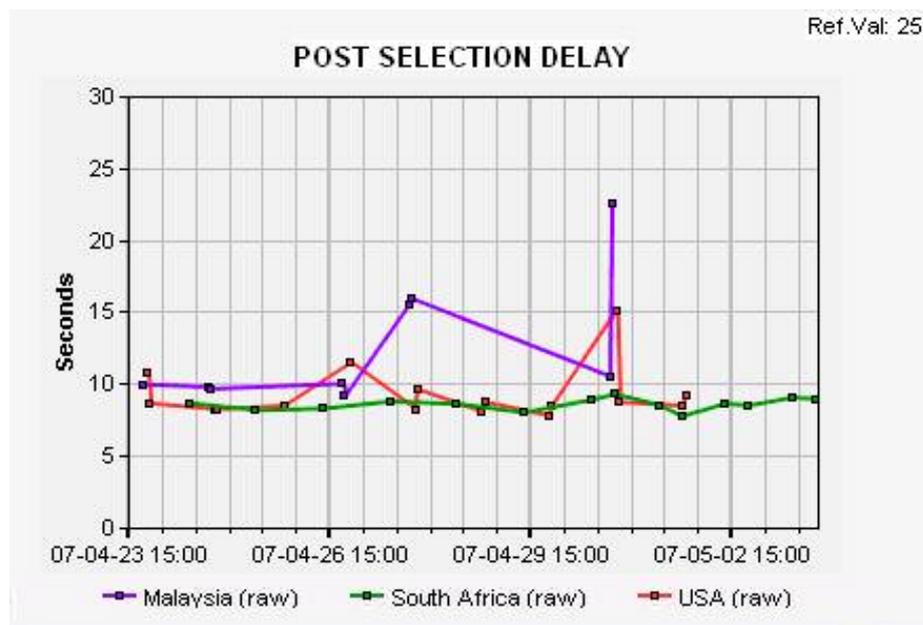
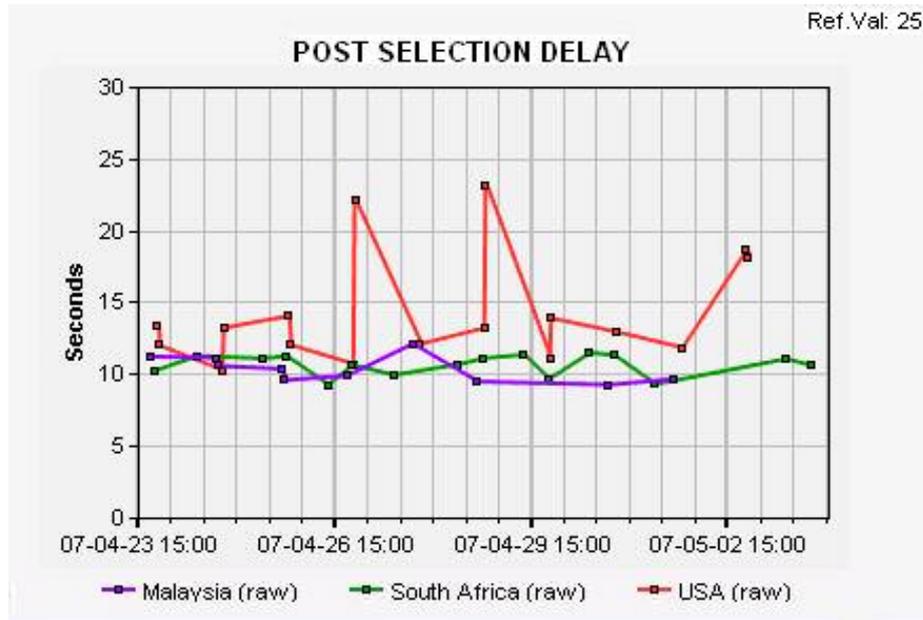


Figure 13: PSD of CO2 Calls Originating from Pakistan



6.3 Received CLI

The Received CLI was correct for 71% of all completed calls (131 calls out of a total number of 184 completed calls), against a reference value of 90%. For calls originating from the roaming country and received in Pakistan, the Received CLI was 68% (60 out of 88 completed calls). For calls originating from Pakistan and received in the roaming country, the Received CLI was 74% (71 out of 96 completed calls). From a roamers perspective the second case is the important case. Figure’s 14 and 15 show the same data for Received CLI with respect to roaming country for both CO1 and CO2. Figure14 indicates that none of the calls originating from Malaysia show the correct CLI. CO2 recorded 100% correct CLI for completed calls originating from South Africa and US. For calls terminating in South Africa both CO1 and CO2 had received CLI of 100%.

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Figure 14: Correct Received CLI of Calls Originating from Roaming Country

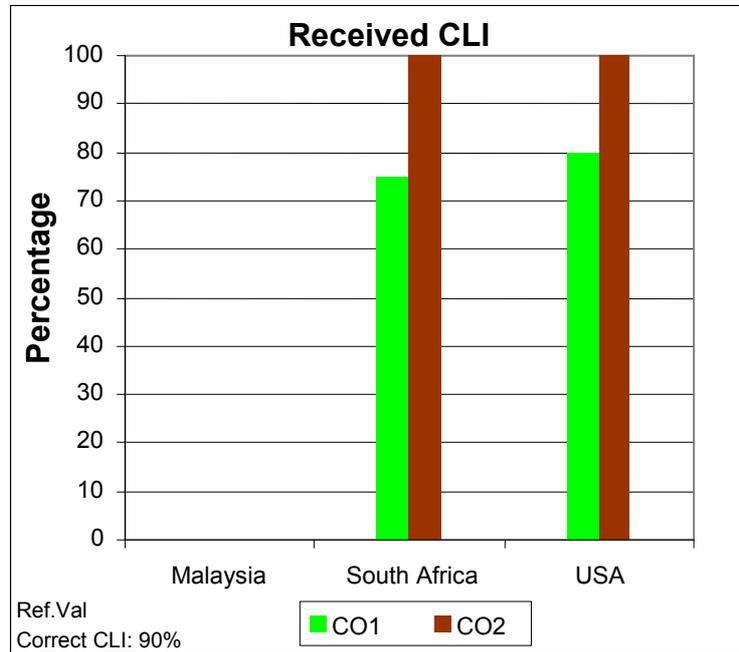
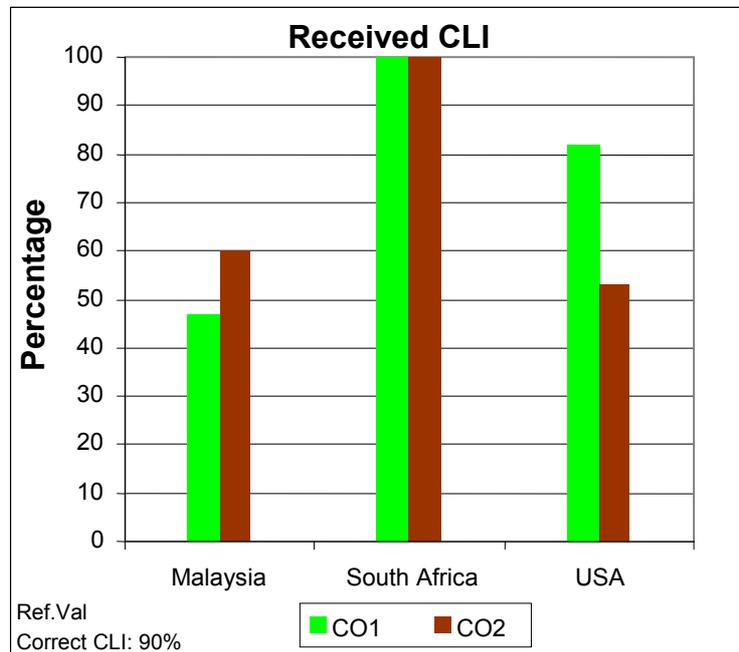


Figure 15: Received CLI of Calls Originating from Pakistan



6.4 SMS Success Rate (SSR)

The overall SSR for all destinations and operators was 86% compared to the reference value of 95%. For SMS originating from the roaming country the SSR was 97% exceeding the reference value; whereas for SMS sent from Pakistan SSR dropped to 76%. Country-wise performance for both CO1 and CO2 is depicted in Figures 16 and 17. Figure 16 demonstrates that SSR for CO1 for SMSs sent from all three roaming countries is 100%. The SSR recorded for CO2 is also meeting the reference value or close to the reference value. In the case of SMS's sent from Pakistan to roaming country, the performance is again 100% for Malaysia and USA for CO1. There appears to be a problem for SMS sent to South Africa from both networks in Pakistan. In the case of SMS too, there is not a significant difference between the results during peak outgoing and peak incoming traffic hours.

Figure 16: SSR of SMS Sent from Roaming Country

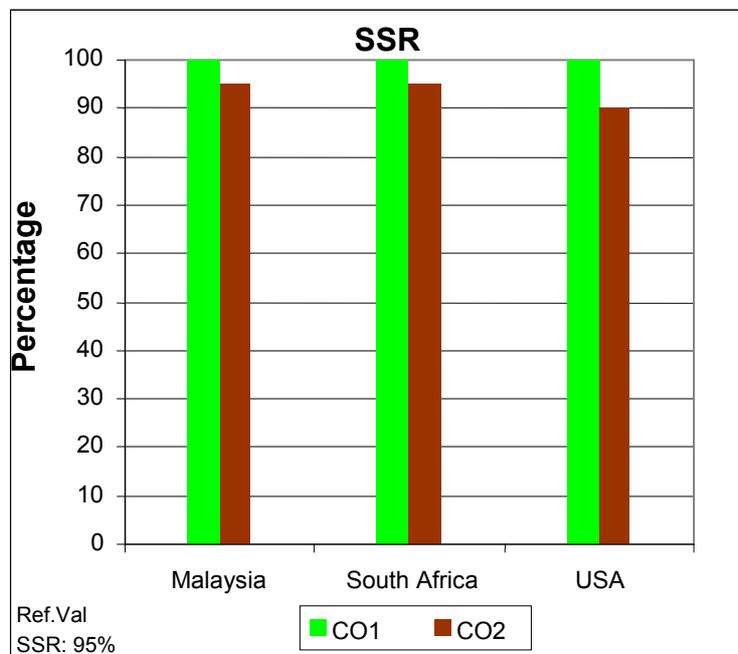
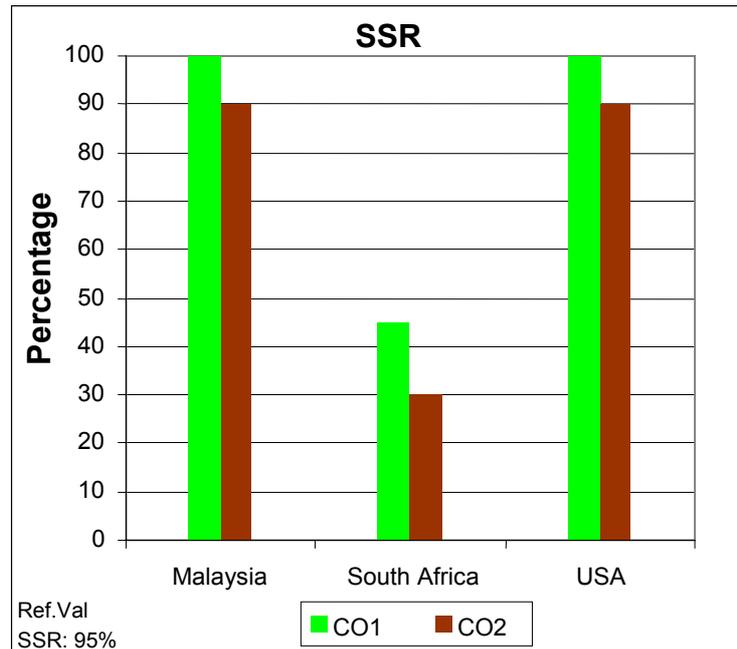


Figure 17: SSR of SMS Sent from Pakistan



6.5 SMS End To End Duration

The average SMS End-to-End duration for all the successful SMS was 12.2 seconds, well within the upper limit of 90 seconds. For SMS sent from roaming countries this number was 11.84 seconds whereas for SMS sent from Pakistan it increased to 12.4 seconds. Figures 18-21 present a country wise performance for End-to-End duration for both operators. In the case of CO1 the average value of SMS End to End duration is relatively same for all the roaming countries, while only 1 SMS from USA took 58 seconds to reach Pakistan. For SMS sent from Pakistan using CO1's network there is one SMS taking 20 seconds but there is a slight increase in the average SMS end-to-end duration time as well as the overall scatter. Results for CO2 are quite similar.

Figure 18: SMS End to End Duration of CO1 SMS Sent from Roaming Country

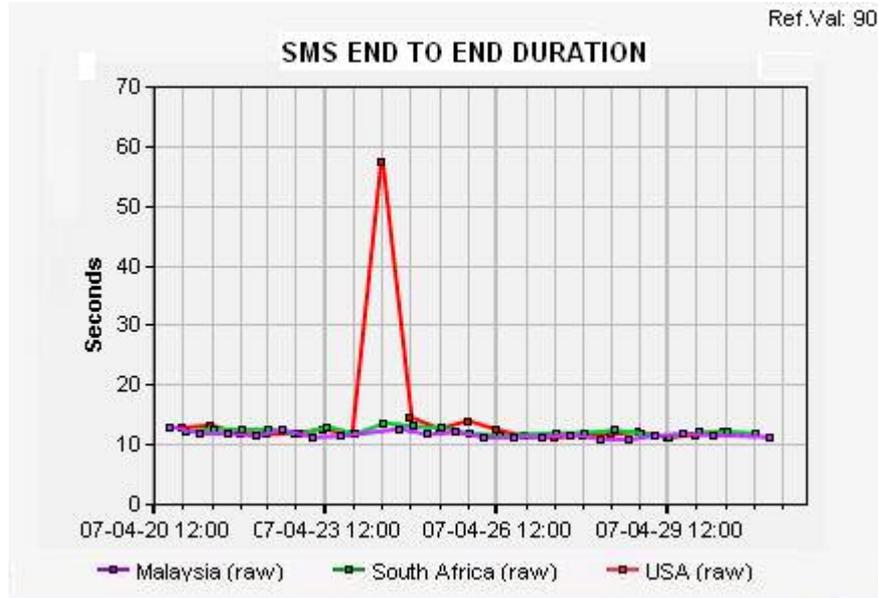


Figure 19: SMS End to End Duration of CO1 SMS Sent from Pakistan

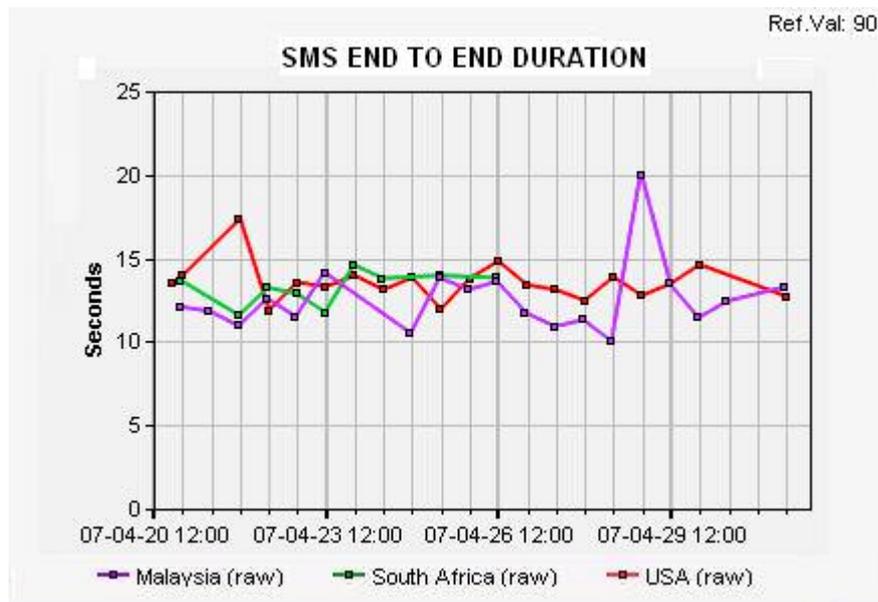


Figure 20: SMS End to End Duration of CO2 SMS Sent from Roaming Country

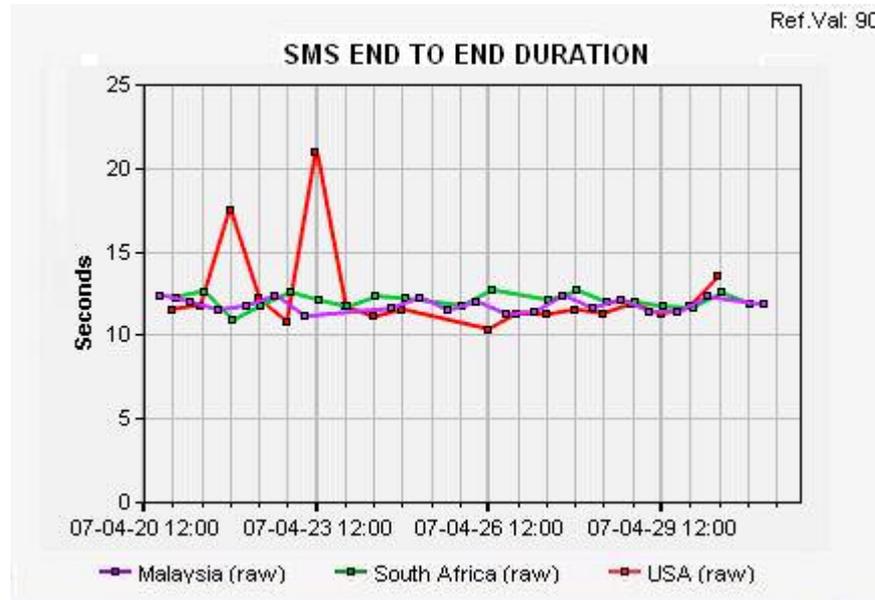
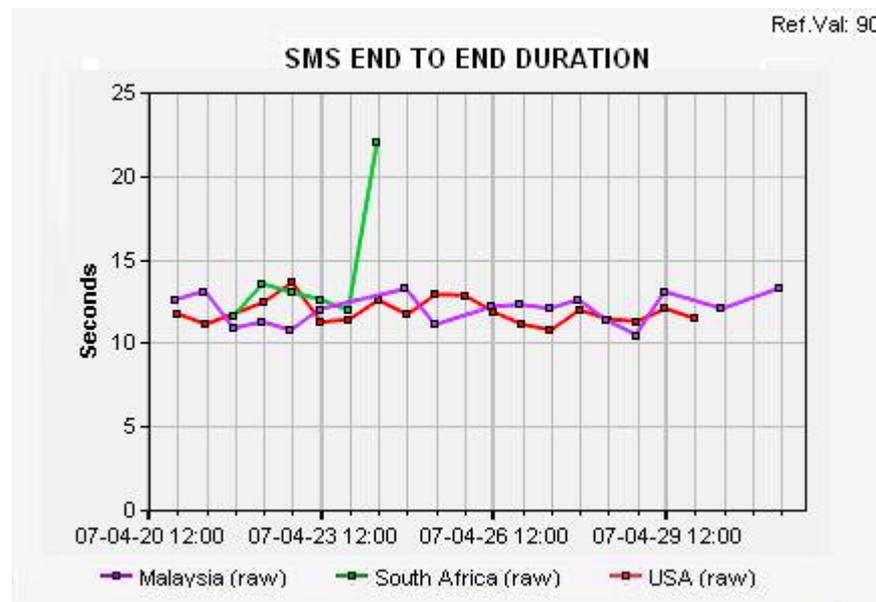


Figure 21: SMS End to End Duration of CO2 SMS Sent from Pakistan



6.6 Billing Accuracy

As far as billing accuracy is concerned we were primarily concerned with call duration and tariffs. To identify the errors in the bills we compared, the bills provided by CO1 and CO2 with GlobalRoamer data. Copies of the bills are included in the Annex. As mentioned in the test plan, all calls were of 55 second duration. This number was

specially chosen to ensure that chargeable call duration does not exceed one minute even after adding the permitted call duration tolerance of 1.5 seconds. Table 13 summarizes the billing accuracy results for basic calls. The first column lists the completed calls. Completed calls are billable calls. For an accurate bill, all billed calls should not exceed one minute duration. Both CO1 and CO2 charge on a per minute basis. However, in the case of CO2 the call duration in the bill was available to the nearest second. CO1's bill provided the call duration in minutes. The difference between billed calls and successful calls quantifies the direct financial impact of QoS on the user.

The advertised tariffs were taken from the official website of each operator. The advertised tariffs were in USD. They were converted to Pak Rs. for comparison with the billed charges by assuming an exchange rate of Rs 60.80. It is perhaps pertinent to mention that CO1 regularly updates its IR tariff so relevant tariff covering the testing period was taken for CO1. However, CO2's website did not provide IR tariffs for April, May and June. The available IR tariff was applicable from March to April 2007.

The comparison of billing reveals that 31% of the completed calls were billed for 2 minute duration; instead, of one minute duration. Figure 22, which displays a country wise distribution of 2 minute calls, highlights that this problem is primarily for US. 80% of all the completed calls originating or terminating in USA were billed for 2 minutes. For calls originating from US this number is 77% and 82% for calls terminating in US. Other than USA two CO2 calls terminating in South Africa were billed for 2 minutes. If we compare CO1 and CO2 results for USA, we find that 89% of billed calls were for 2 minute duration for CO1 and 70% of billed calls were of 2 minute duration. Moreover, there is a slight increase in billed tariff for 2 minute calls.

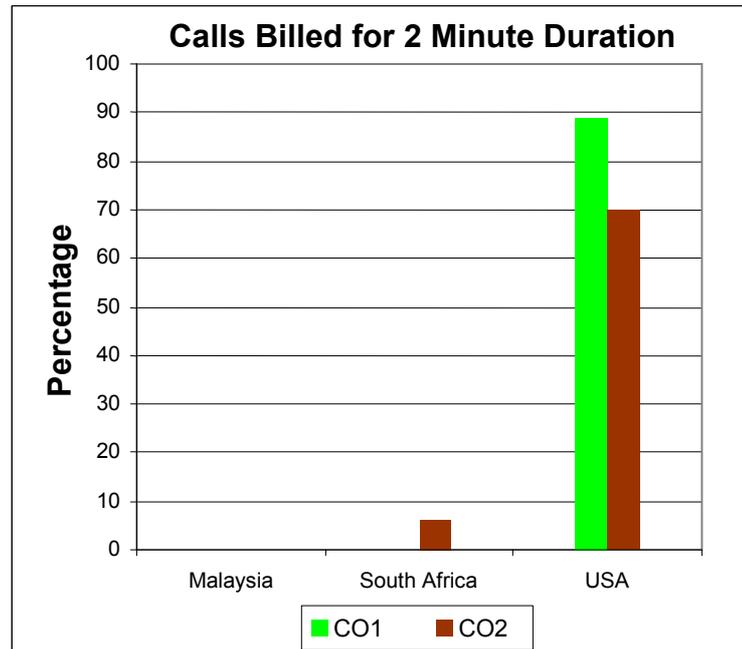
Another aspect which is quite clear from Table 13 is the fact, that the billed tariffs were consistently lower than the tariffs advertised on the website for both CO1 and CO2.

Table 14 summarizes billing accuracy results for SMS. In the case of SMS there is no question of duration. The number of billed SMS matched the number of delivered SMSs. A delivered SMS may not be successful but it is billable. Again the billed or applied tariff was lower than the advertised tariff. CO1 has advertised tariff for SMS received in USA but did not billed; whereas CO2 had advertised free of charge incoming SMS in US.

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Table 13: Billing Accuracy for Basic Call

	Completed Calls	Successful Calls	Billed Calls		Tariff(PKR)	
			1 min	2 min	Advertised Rates/min	Billed Rates/min
Total Calls (240)	184	158	127	57	N/A	N/A
RC to Pak (120 Calls)	88	83	60	28	N/A	N/A
Pak to RC (120 Calls)	96	75	66	30	N/A	N/A
CO1 (120 Calls)	102	89	70	32	N/A	N/A
CO1 Mal to Pak	10	9	10	0	304.608	173.99
CO1 Pak to Mal	19	10	19	0	49.248	49.99
CO1 SA to Pak	20	20	20	0	99.1(April) 102.1(May)	65.76 67.13
CO1 Pak to SA	17	17	17	0	31.008	30.99
CO1 USA to Pak	19	18	1	18	198.208	183.58(1 min) 369.9(2 min)
CO1 Pak to USA	17	15	3	14	81.472(April) 80.864(May)	77.99(1 min) 157.98(2 min)
CO2 (120 Calls)	82	69	57	25	N/A	N/A
CO2 Mal to Pak	9	8	9	0	218.272	173.88
CO2 Pak to Mal	10	3	10	0	45.6	47.09
CO2 SA to Pak	14	13	14	0	64.448	65.33
CO2 Pak to SA	16	16	14	2	27.968	28
CO2 USA to Pak	16	16	7	9	226.176	183.79(1 min) 369.32(2 min)
CO2 Pak to USA	17	14	3	14	102.752	75.26(1 min) 151.98(2 min)

Figure 22: Country wise Distribution of Calls Billed for 2 Minutes**Table 14: Billing Accuracy for SMS**

	Delivered SMS	Successful SMS	Tariff(PKR)	
			Advertised Rates/SMS	Billed Rates/SMS
Total SMS (240)	216	207	N/A	N/A
RC to Pak (120 SMS)	116	116	N/A	N/A
Pak to RC (120 SMS)	100	91	N/A	N/A
CO1 (120 SMS)	117	109	N/A	N/A
CO1 Mal to Pak	20	20	29.184	28.77
CO1 Pak to Mal	28	20	9.728	10
CO1 SA to Pak	20	20	18.24	17.81
CO1 Pak to SA	9	9	9.728	Not Billed
CO1 USA to Pak	20	20	20.064	16.44
CO1 Pak to USA	20	20	9.728	Not Billed

CO2 (120 SMS)	99	98	N/A	N/A
CO2 Mal to Pak	19	19	30.4	28.9
CO2 Pak to Mal	19	18	9.6	10
CO2 SA to Pak	19	19	9.728	18.26
CO2 Pak to SA	6	6	9.728	Not Billed
CO2 USA to Pak	18	18	31.008	16.61
CO2 Pak to USA	18	18	Free of Charge	Free of Charge

7 ROADMAP FOR FUTURE

The scope of this consultancy was limited to two GSM operators, and a limited number of KPIs for basic call and SMS. Any future testing should consider the following recommendations.

7.1 GSM Operators

Any future testing should include all five GSM operators of Pakistan. To ensure complete market equivalence and competence, it is recommended that all GSM operators must be included in testing scheme. A representative picture of the QoS service can only emerge with measurements for all GSM operators. In addition the test plan should be designed to allow benchmarking.

7.2 Speech Quality

For basic all service, speech quality is an important KPI of connection quality. Although connection integrity is being checked in CSR, it is not a complete connection quality check. Since IR calls are an expensive premium service, it is not unreasonable to expect a good voice quality. We recommend that this KPI should be monitored.

7.3 Billing Error Ratio

In this consultancy billing accuracy was limited to call duration and tariffs. Moreover only two bills of each operator were examined. Billing accuracy also includes additional calls in the bill, routing of correct called number, timely delivery of bill, and finally presentation of bill or ease of reading the bill. A number of these issues were observed in this consultancy as well. For example, CO1's bill was delivered at least three weeks late. There is a need to develop a definition of Billing error ratio encompassing the issues mentioned above. We recommend that bill error ratio should be monitored regularly to improve billing accuracy. Monitoring of billing error ratio should be based on a minimum of 20 bills per operator. In Hong Kong [11] and Malaysia [7] 50 bills per operator are examined to ascertain billing error ratio.

7.4 Services

Other services that may be considered are prepaid services. Pakistani GSM operators are providing IR facility to prepaid subscribers in a limited number of countries. Since prepaid services affect a wider user base, monitoring of prepaid basic call and SMS during IR may be beneficial. Some postpaid services such as GPRS, and WAP are quite useful during traveling. They may be considered for countries where there is flow of high-end roaming subscribers like US, UK, Canada etc.

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7.5 Locations

Pakistani local operators are offering international roaming in large number of countries worldwide with mostly more than one roaming partner. There is certainly a need to include some Middle Eastern and European countries. If regular testing on quarterly or six monthly basis is adopted, a new set of countries could be tested in each round of testing for that year. It may be relevant to point out that QoS of a particular roaming partner or country does not represent the QoS for the entire region. Selection of roaming countries should be on the basis of number of Pakistani roaming subscribers and by events or occasions.

7.6 Testing Frequency

Testing frequency depends on roaming country, periodic testing is required for the countries where there is continuous movement of roaming subscribers. It is recommended that for these countries QoS data should be collected and calculated on a quarterly basis starting on 1 January, 1 April, 1 July and 1 October as suggested by ETSI in EG 202 057-3 V1.1.1. For most QoS parameters a data collection period on a quarterly basis is suitable, and will provide adequate up-to-date information. On the other hand, ad hoc testing is required to cover the events like Hajj, games etc.

7.7 Test Times

Test times are generally dependent on type of services. Measurements should be scheduled so as to reflect accurate traffic variations over the hours of a day, the days of the week including public holidays and the months of the year.

7.8 Sample Size

Tests should be conducted in such a way that can reflect accurate QoS perceived by customers. Sample size is chosen in such a way that required measurement precision can be achieved. Increase in sample size will give more accurate picture of QoS perceived by the customers. Sample size varies with test service type and roaming country.

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